Jurnal Ilmiah Teknik Elektro Komputer dan Informatika (JITEKI)
Vol. 9, No. 3, September 2023, pp. 810-820
ISSN: 2338-3070, DOI: 10.26555/jiteki.v9i3.26729

Design and Implementation of IoT-Based Monitoring Battery and Solar Panel Temperature in Hydroponic System

Rizky Rahmatullah[1], Trie Maya Kadarina[2], Bagus Bhakti Irawan[1], Reza Septiawan[1], Arief Rufiyanto[1], Budi Sulistya[1], Arief Budi Santiko[1], Puput Dani Prasetyo Adi[1], Nicco Plamonia[1,3], Ravindra Kumar Shabajee[4], Suhardi Atmoko[1], Dendy Mahabror[1], Yudi Prastiyono[1]
[1]National Research and Innovation Agency, Indonesia
[2]Faculty of Engineering, Mercubuana University, Jakarta, Indonesia
[3]Centre for Studies in Technology and Sustainable Development, University of Twente, Netherland
[4]The Automation Training Unit of the School of Information Technology, Mauritius Institute of training and development, Mauritius

ARTICLE INFO

Article history:

Received July 22, 2023
Revised August 04, 2023
Published September 05, 2023

Keywords:

Arduino;
Accuracy;
Grafana;
Internet of Things;
MIT App Inventor;
Monitoring

ABSTRACT

Hydroponics is currently widely used for the effectiveness of farming in narrow areas and increasing the supply of food, especially vegetables. This hydroponic technology grew until it collaborated with the internet of things technology, allowing users to monitor hydroponic conditions such as temperature and humidity in the surrounding environment. This technology requires electronic systems to obtain cost-effective power coverage and have independent charging systems, such as power systems using solar panels, where the power received by solar panels from the sun is stored in batteries. It must ensure that the condition of the battery and solar panels are in good condition. The research contribution is to create a solar panel temperature monitoring system and battery power using Grafana and Android Application. Apart from several studies, solar panels are greatly affected by temperature, which can cause damage to the panels. If the temperature is too high, the battery and panel temperature monitoring system can help monitor the condition of the device at Grafana and Android application with sensor data such as voltage, current, temperature and humidity that have been tested for accuracy. Accuracy test by comparing AM2302 sensor with Thermohygrometer and INA219 sensor with multimeter and clampmeter, both of which have been calibrated. The sensor data gets good accuracy results up to 98% and the Quality-of-Service value on the internet of things network is categorized as both conform to ITU G.1010 QOS data based on network readings on the wireshark application. QOS results are 0% Packet loss with very good category, 14ms delay with very good category and Throughput 71.85 bytes/s. With the results of sensor accuracy and QOS, the system can be relied upon with a high level of sensor accuracy so that environmental conditions are monitored accurately and good QOS values so data transmission to the server runs smoothly.

Corresponding Author:

Arief Budi Santiko, Research Center for Telecommunication, National Research and Innovation Agency, Bandung, Indonesia
Email: puput.danny@gmail.com

1. INTRODUCTION

The conversion of agricultural land into residential and industrial areas in agrarian country are quite high. However. the increase in the transfer of agricultural land is not followed by people's need for food, where it continues to increase every year. This encourages an innovation in agriculture by changing conventional agriculture into modern one for the effectiveness of agriculture on narrow space. A Hydroponic systems based on the internet of things are currently developing with the aim of improving the quality of hydroponic plants and farmers can monitor hydroponic environmental conditions such as [1]-[3]. The hydroponic system uses a battery connected to a solar panel or can be called a Solar Power Plant as in research [4], so that the system can run independently without relying on resources from grid and can charge itself by using solar energy. Monitoring the power source integrated with hydroponics is needed to monitor the battery's condition for 24 hours, so that farmers can find out the condition of the battery and can determine the appropriate action if the battery runs out or is damaged. Previous research, as in [5]-[6], describes the method and application of monitoring the Solar Power Plant Battery Power System that could be used in hydroponics. The novelty in this research is battery monitoring through the Grafana IoT platform and also the Android application. The potential that can be improved on this novelty is to make an early warning system that is immediately delivered to the user when the battery is about to run out. Another problem related to solar panels is if the panels operate at high-temperature conditions for a long time, the panel cells can be damaged due to overheating, as was the result of research in [7]. Therefore the solar panel temperature needs to be monitored to prevent the panel from being damaged due to overheating. Monitoring battery power and solar panel temperature can be combined with the internet of the things-based hydroponic system for monitoring or controling as in research [8]-[12] by monitoring using the web and Android applications. Monitoring data will be stored and become big data [13]-[17] which can be used to improve the system. The primary sensor used to monitor solar panel battery power at a low cost is the INA219 sensor which has been used in [18], [19]. This sensor can monitor the voltage and current values on DC batteries used in hydroponic power systems with good accuracy. Accuracy test by comparing AM2302 sensor with Thermohygrometer and INA219 sensor with multimeter and clampmeter, both of which have been calibrated. the current has an accuracy rate of 96.5%, and the voltage is 99.5%, as in research [20]. Then the sensor used in monitoring the temperature on the panel is the AM2302 sensor, as in [21]-[23]. This sensor has two outputs, temperature and humidity, with humidity accuracy range of 2-5% and ±5◦C for temperature values as in [24]. In terms of accuracy, accuracy needs to be retested to ensure that the sensors used are in good condition with high accuracy so that the data generated can be used to analyze problems that occur in solar panel batteries.

The system created makes it possible to monitor the voltage, current, temperature and humidity needed to monitor the condition of the battery and solar panels installed based on IoT via Grafana, a Web-based IoT Platform used [25], as well as to facilitate monitoring anywhere and anytime. Whenever an Android application is created, that can monitor these data. To create an IoT system for realtime monitoring, QOS testing based on ITU G.1010 is needed to ensure the network used has a good QOS level so that data is sent smoothly from device to server. So, The research contribution is to create a solar panel temperature monitoring system and battery power.

2. METHODS

On the system that has been created, the correct IoT architecture is a 4-layer architecture consisting of the Perception layer, Networks and Gateways, Middleware, and Applications as in [26], with the arrangement shown as shown in Fig. 1. The figure shows the four main layers with the following explanation, The perception layer functions to collect all kinds of information according to the function of the sensor. The network layer receives information from the perception layer and forwards the received data to remote application interfaces using the Internet or other communication technologies. Middleware Layer is responsible for processing raw data received from the previous layer. Through this layer, data can be accumulated, grouped, stored, and processed according to needs. And The application layer is tasked with presenting data that has been processed to users in meeting their needs.

2.1. IOT Preparation

The perception layer is input as a data provider consisting of sensors, actuators and controllers. Networks and Gateways are transmission media for sending data with certain protocols such as UDP, STP, HTTP, and MQTT. Middleware is responsible for processing the raw data received from the previous layer. Through this layer, data can be accumulated, grouped, stored, and processed according to needs. and application, which is tasked with presenting processed data to users in meeting their needs. Presentation of data can be in the form of text, visualization, analysis results, etc. Fig. 2 shows the tasks and functions of each device, along with an explanation:

1) Arduino Mega: Arduino Mega, as a microcontroller, will read data from the AM2302 sensor, which has temperature and humidity data and INA219 data, which has voltage and current data from the battery. Then all data is made into one package and sent to Raspberry Pi 4.

2) Raspberry Pi 4: Raspberry Pi 4 will receive data from Arduino Mega, then the received data packets will be parsed, then prepared to be sent to the database using Python-programming.
3) MySQL XAMPP: In this section, the data sent by the Raspberry Pi 4 will be received, then stored in the database and the data is ready to be retrieved by the IoT platform and Android Application.
4) Android App: Android applications designed using MIT App Inventor 2. It will get data from the database and display it on the dashboard.
5) Grafana: Grafana is an open-source platform that can be used for monitoring with attractive data visualization and has an alarm management system. The advantage of Grafana is that it can export data in CSV form for analytics [27], compared to other open-source platforms such as Thingsboard Community Edition you cannot export data so you have to upgrade to Thingsboard Professional Edition as described in 6.2 in [28].

The operation flow of Fig. 2 is starting from the Arduino Mega 2560 which will receive input data from the AM2302 sensor with temperature and humidity data and the INA219 sensor with voltage and current data, then the data is put together in the form of a string, then sent to the Raspberry pi. The Raspberry pi will receive data from the Arduino Mega 2560, then parse the data and send it to the MySQL database. on MySQL Xampp receives data sent from the Raspberry pi then saves the data then the data will be read by the android and grafana applications or can be exported directly to the MySQL database on the Android application, the initial display will have a login menu, after entering the correct username and password, you will be directed to the dashboard menu to see the data display. on Grafana, it will read data from MySQL then it will be displayed in graphical form, then there is a menu to export data in .csv form.

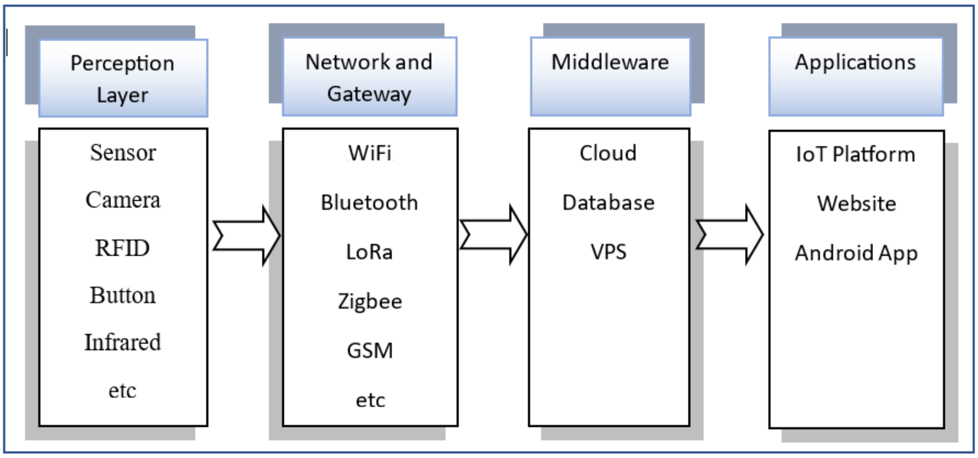


Fig. 1. Layer IoT Architecture

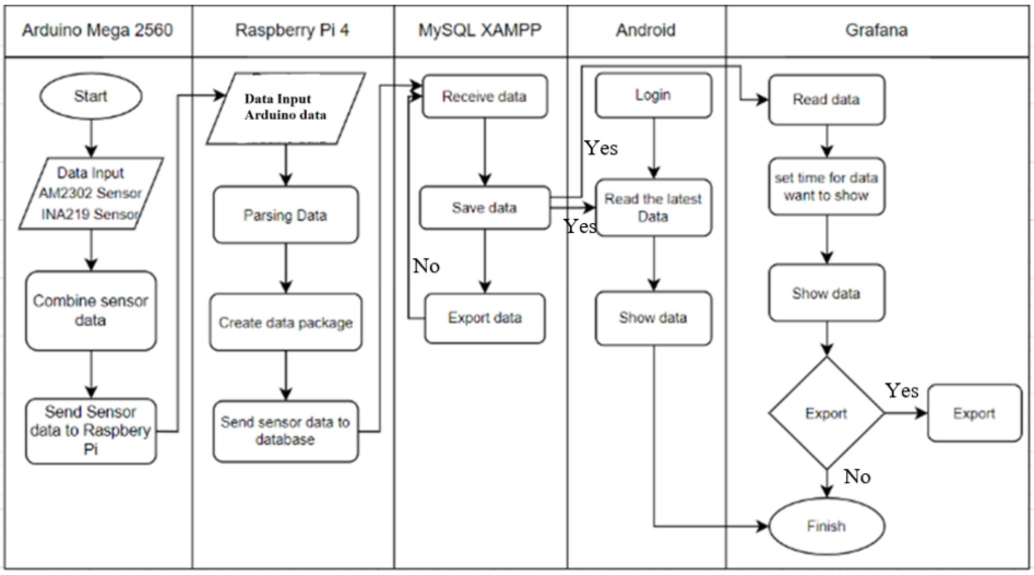


Fig. 2. Flowchart System

2.2. Hardware Design

This hardware consists of a solar charge system as in [1]-[3] and an electronic device to read the AM2302 sensor [21]-[23], which has temperature and humidity data and reads the INA219 sensor [18], [19], which has voltage and current data. Each device is integrated like the design in Fig. 3 and the final result of the electronic device is integrated into a box like in Fig. 4.

The following table shows the connection between the sensor device and the Arduino Mega 2560 in Table 1. This hardware can still be optimized by making a box that is rainproof and has better air circulation.

Table 1. Arduino Mega 2560 Connection With Sensors

Pin Arduino Mega 2560	AM2302 sensor
5V	Positive (Red Wire)
GND	Negative (Black Wire)
D2	Data (Yellow Wire)
	Sensor INA219
5V	VCC
GND	GND
SCL	SCL
SDA	SDA

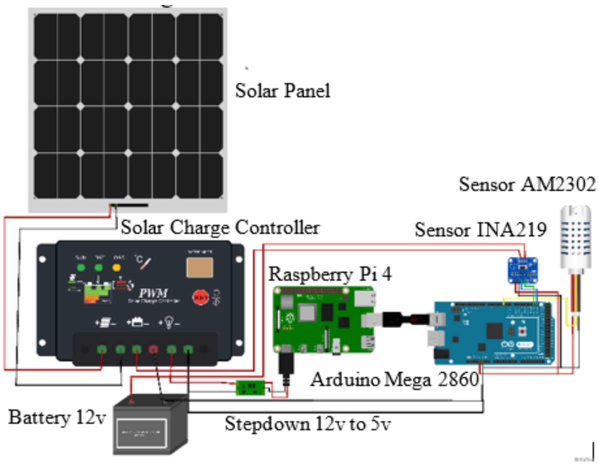


Fig. 3. Hardware Design

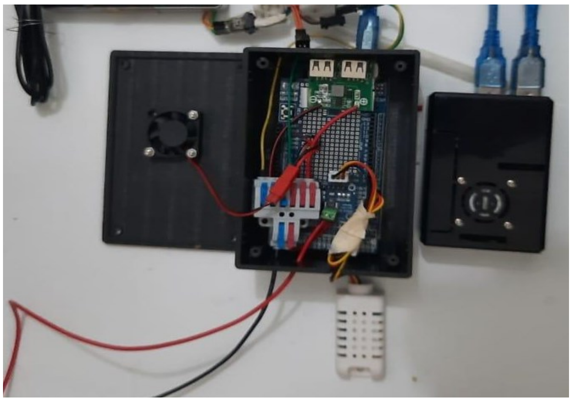


Fig. 4. Electronic Device Design Results

Connections between INA219 Sensors, Batteries, Controllers, Solar Panels. Vin+ INA219 sensor is connected to the positive (+) part of the battery, while the Vin- sensor is connected to the part that has a positive (+) picture of the battery on the controller, then negative (-) battery with the part that has a minus (-) battery image on the controller, then the Input (+) controller is connected to the positive (+) solar panel, then the input (-) controller is connected to the negative (-) solar panel, then the Load (+) Controller part is connected to Input (+) Stepdown 12v to 5v and Load (-) the controller is connected to Input (-) stepdown 12v to 5v, then output

(+) and output (-) are connected with a cable connected to the Raspberry Pi power port and finally Arduino Mega is connected to Raspberry Pi uses a USB cable.

Electronic devices are tested to see whether the system is running well with a test scheme. Namely, the device is run with a power supply of 220 VAC and an output adapter of 5VDC 2A for several days. Electronic devices have succeeded in obtaining temperature, humidity, voltage and current data as in [18]–[23], then these data are sent to the database via a stable wifi network and the network is read by Wireshark to view QoS data, test results are of good value with reference to the results of the QoS test.

2.3. Sensor Accuracy Testing Methods

Accuracy testing is carried out by comparing sensors and tools as data comparisons as in [13], [17]. accuracy testing is taken 10 samples with each sample taken data every 1 minute, while the sensors to be tested for accuracy are:

1) Temperature and Humidity sensors: The sensor is AM2302 which will be compared with a calibrated thermohygrometer. Thermohygrometer tool is calibrated by an official calibration institution.
2) Voltage and Current Sensors: The sensor INA219 will be compared with a calibrated multimeter and clamp meter. The tool is calibrated by an official calibration institution.

2.4. Quality of Service (QOS) Test Method

QoS, according to the International Telecommunication Union (ITU) is the collective effect of service performance that determines the degree of satisfaction of a user with a service [29]-[34]. This test aims to see whether the service or network connection is good. The parameters that become a reference for this situation are throughput, delay, and packet loss. QoS performance refers to ITU-T G.1010. The delay and packet loss categories are shown in Table 2 and Table 3. In these tables, quality is categorized into four categories: Very good, good, medium, and bad.

QoS testing will use Wireshark as in [29] to obtain the required values. QOS testing using wireshark is carried out 24 hours, so that it can calculate the values of throughput, delay and packet loss, following the (1)-(3). The device will send data over a stable WiFi network. Raspberry pi runs the wireshark application to record every data transmission for 24 hours.

$$Packet\ loss = \frac{(Packet\ transmitte - Packet\ received)}{Packet\ transmitted} x100\% \quad (1)$$

$$Delay = \frac{Total\ delay}{Total\ packets\ received} \quad (2)$$

$$Throughput = \frac{Packet\ received}{Time\ transmitted} \quad (3)$$

Table 2. Itu Delay Category G.1010 [35]

Latency Category	Delay
Very Good	<150 ms
Good	150 – 300 ms
Medium	300 – 450 ms
Bad	>450 ms

Table 3. Packet Loss Category Itu G.1010 [35]

Degradation Category	Packet loss
Very Good	0%
Good	5%
Medium	15%
Bad	25%

3. RESULTS AND DISCUSSION

3.1. Website Monitoring Design Results

The Grafana Dashboard functions to monitor temperature, humidity, voltage and current in a graphical form that can be read by setting the time according to the desired setup, as shown in Fig. 5. In this grafana, you have to log in by entering your username and password before you can access the dashboard.

In the dashboard Grafana, each data from sensor are displayed in real time with good QOS like show in Table 6. The graph can be set the time of the data you want to display, so user can monitor the condition of the remaining battery power by looking at the accu voltage (battery voltage) and current accu (battery current) graphs so that the user can ensure that the battery condition is good or not at any time so that the battery can provide power to the hydroponics system as in [1]-[3]. In addition, the user can see the ambient temperature conditions to ensure that the temperature will not harm the panel, as explained in [7].

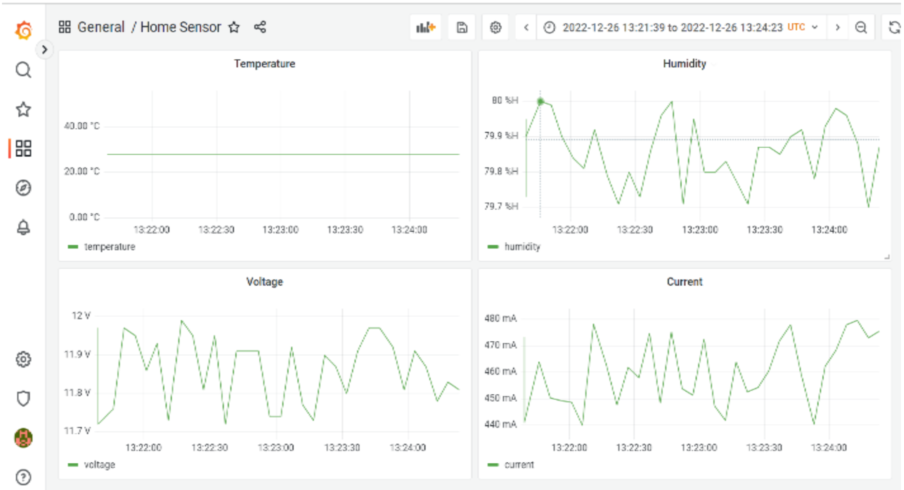
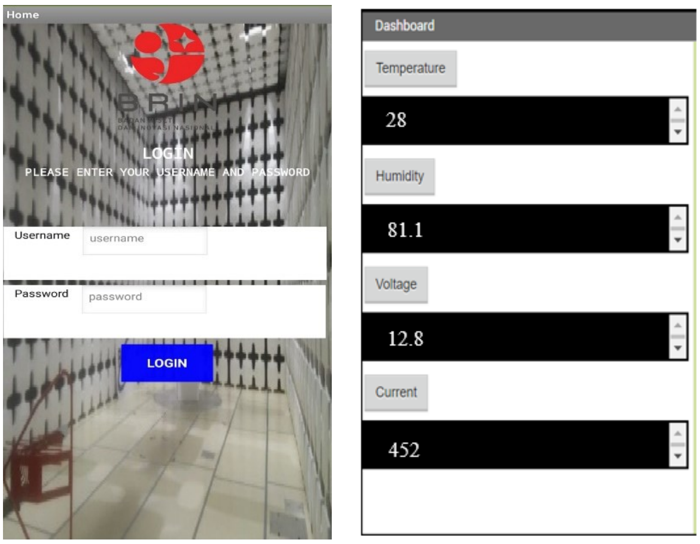


Fig. 5. Grafana Dashboard Application

3.2. Android App Design Result

The Android application functions as a monitoring of temperature, humidity, voltage and current. This application has two views. namely the first display or home is the login menu and the second display or dashboard is a display of the latest data values obtained from the database, along with the Android application design as shown in Fig. 6. This android application was created using the MIT App Inventor website. This website is easy to use because to make the display and each function just drag and drop the available blocks. In the home display design, the login menu is created by entering the username and password in the compare text block which functions to compare the username and password entered by the user. So only users who know the username and password can access the dashboard. Then the Dashboard menu is connected to the MySQL database to get temperature, humidity, voltage and current data, then displayed on the dashboard in the form of numbers. The Android application has the same function as Grafana but in a mobile version that can be installed on a mobile phone so that users can view data anywhere and anytime.



(a) (b)

Fig. 6. Mobile Version (a) Home (b) Dashboard

3.3. Sensor Accuracy Testing

Testing sensor accuracy is part of the validation and verification activities for each sensor's data issued by looking at the difference in data against a calibrated measuring instrument. The AM2302 sensor (temperature and humidity) will be compared with a thermohygrometer that has been tested. Calibrated and INA219 sensors (voltage and current) will be compared with multimeters and clamp meters like the test method in [13], [17]. The results of each comparison of sensor data with a calibrated device will be a reference that can be entered into the programming to adjust the sensor value output results

1) INA219 Sensor Test Results

In testing the accuracy of the INA219 sensor [13], a multimeter will be used for the accuracy of voltage readings and a clamp meter for the accuracy of current readings, as follows in Table 4.

Table 4. The Results of Testing the Accuracy of The Ina219 Sensor

Test No.	INA219 Sensor		*Multimeter*	*Clamp Meter*	*Difference*	
	Voltage (V)	Current (mA)	Voltage (V)	Current (mA)	Voltage (V)	Current (mA)
1	11.78	590.3	12	567	-0.22	23.3
2	11.79	535	12	560	-0.21	-25
3	11.8	537.9	12	556	-0.2	-18.1
4	11.81	543.3	12	581	-0.19	-37.7
5	11.78	535.9	12	571	-0.22	-35.1
6	11.74	611.8	12	554	-0.26	57.8
7	11.79	557.4	12	511	-0.21	46.4
8	11.8	534.6	12	512	-0.2	22.6
9	11.8	546.1	12	505	-0.2	41.1
10	11.8	540.8	12	521	-0.2	19.8
Average	**11.789**	**553.31**	**12**	**543.8**	**-0.211**	**9.51**
Max	**11.81**	**611.8**	**12**	**581**	**-0.19**	**57.8**
Min	**11.74**	**534.6**	**12**	**505**	**-0.26**	**-37.7**

From the results above, subtract the average, maximum and minimum values of the INA219 sensor with a multimeter and clamp meter to see the difference in the data. The results of testing the accuracy of the INA219 sensor for voltage and current data are that the voltage has an accuracy in the value range of -0.26 V to -0.19 V and the current accuracy is in the range of 9.51 mA to 57.8 mA. These results show the accuracy of the voltage in the percentage of 98.4%, and the current results are 99.2%. These results are almost similar to the test on [18]. Perfomance Analysis of INA 219 as in Table 8.

2) AM2302 Sensor Test Results

The AM2302 sensor is a sensor for reading temperature and humidity. Accuracy testing will use a Thermohygrometer as AE (Auxiliary Equipment) [39]-[40], along with the test results shown in Table 5 and Fig. 8. Perfomance Analysis of INA 219 as in Table 7. Results of testing the accuracy of the INA219 sensor and results of testing the accuracy of the INA219 sensor show in Fig. 7. Wireshark reading result show in Fig. 9.

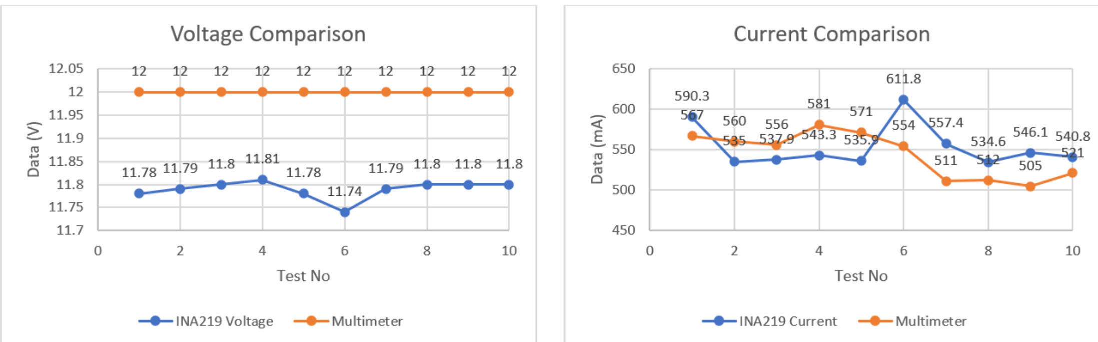


Fig. 7. Measurement comparison chart (a). Voltage (b). Current against the test number

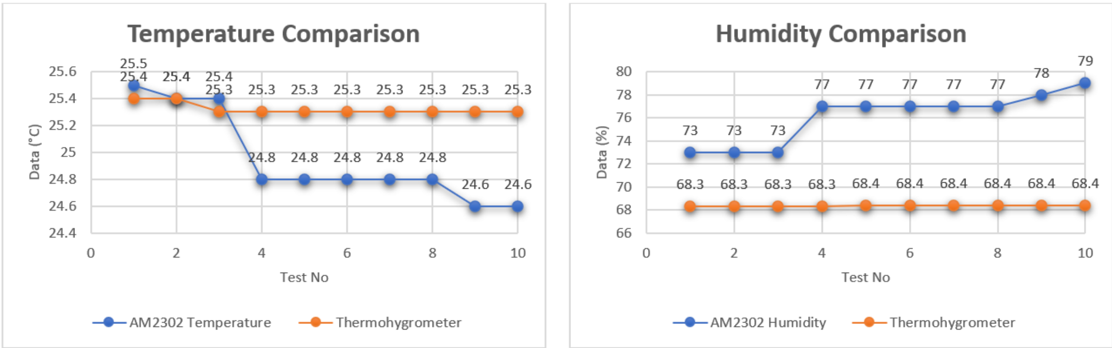


Fig. 8. Measurement comparison chart (a). Temperature (b). Humidity against the test number

Table 5. AM2302 Sensor Accuracy Test Results

Test No.	AM2302 Sensor		Thermohygrometer		*Difference*	
	Temperature	Humidity	Temperature	Humidity	Temperature	Humidity
1	25.5	73	25.4	68.3	0.1	4.7
2	25.4	73	25.4	68.3	0	4.7
3	25.4	73	25.3	68.3	0.1	4.7
4	24.8	77	25.3	68.3	-0.5	8.7
5	24.8	77	25.3	68.4	-0.5	8.6
6	24.8	77	25.3	68.4	-0.5	8.6
7	24.8	77	25.3	68.4	-0.5	8.6
8	24.8	77	25.3	68.4	-0.5	8.6
9	24.6	78	25.3	68.4	-0.7	9.6
10	24.6	79	25.3	68.4	-0.7	10.6
Average	**24.95**	**76.1**	**25.32**	**68.36**	**-0.37**	**7.74**
Max	**24.6**	**73**	**25.3**	**68.3**	**-0.7**	**4.7**
Min	**25.5**	**79**	**25.4**	**68.4**	**0.1**	**10.6**

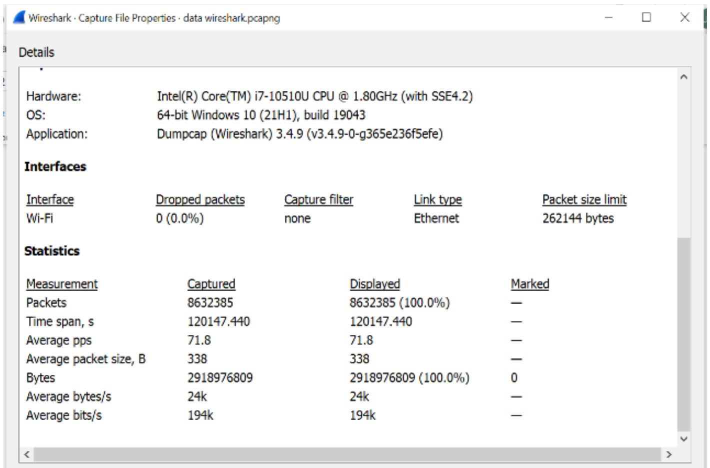


Fig. 9. Wireshark Reading Result

From the results, subtract the average, maximum and minimum values of the AM2302 sensor with a Thermohygrometer to see the difference in the data. The accuracy of the AM2302 sensor is that the temperature is within the value range of -0.7°C to 0.1°C and the humidity is within the value range of 4.7%RH to 10.6%RH. If you look at the sensor specifications and test results in [17], the temperature value has very good accuracy compared to other sensors as in Table 5, while the humidity value is quite good and requires adjustment of the resulting value.

3) Quality of Service (QOS) testing

QoS testing aims to see which connections are in good condition and ensure electronic devices work properly. The results of this test refer to Table 1 and Table 2. To get the required value in calculating (1)–(3), use Wireshark with the following results in Fig. 9.

From the Wireshark reading results, the throughput, delay, and packet loss values can be calculated using formulas (1)–(3). The calculation results and categories, according to Table 2 and Table 3, are shown in Table 4. QOS testing with the results stated that network performance is acceptable because it has a very good value. So that data can be sent to the server without losing data with minimal delay, and can be displayed on the Graphana dashboard and Android applications in real time. Value and category for throughput, delay, and packet loss show in Table 6. Perfomance analysis of the Am2302 sensor and some reviewed literature show in Table 7. Perfomance analysis of the Ina219 sensor and some reviewed literature show in Table 8.

Table 6. Value and Category for Throughput, Delay, and Packet Loss

	Packet loss	Delay	Throughput
Value	0%	14ms	71.85 byte/s
Category	Very Good	Very Good	

Table 7. Perfomance Analysis of the Am2302 Sensor and Some Reviewed Literature

Ref	Temperature	Humidity	Sensor Type
[17]	±5◦C	2-5%	DHT 22
[36]	±4◦C	11%	DHT 11
This Work	**-0.7°C to 0.1°C**	**4.7%RH to 10.6%RH**	**AM2302**

Table 8. Perfomance Analysis of the Ina219 Sensor and Some Reviewed Literature

Ref	Voltage	Current	Sensor Type
[37]	99.31 %	99.1 %	INA219
[38]	97.64 %	98,44 %	INA219
This Work	**98.4 %**	**99.2 %.**	INA219

4. CONCLUSION

The system that is made works well with sensors that have high accuracy so that the system can be used in monitoring the state of the battery and the temperature of the panels to avoid damaged or discharged batteries and damaged panels due to heat which causes the hydroponic system not to work and the plants to lay or fail to harvest. Further work includes an early warning system if the battery is low and the panel is overheating.

Acknowledgments

The authors wish to thank the Head of the BPPT EMC Laboratory, all of his staff and Mercubuana University and the Indonesian Endowment Fund for Education (LPDP) – Ministry of the Finance Republic of Indonesia for funding this research through the funding program named the Research and Innovation for Advanced Indonesia (RIIM) - National Research and Innovation Agency (BRIN) with grant number B-1468/II.7/FR/10/2022.

REFERENCES

[1] Z. Hu *et al.*, "Application of Non-Orthogonal Multiple Access in Wireless Sensor Networks for Smart Agriculture," in *IEEE Access*, vol. 7, pp. 87582-87592, 2019, https://doi.org/10.1109/ACCESS.2019.2924917.

[2] B. Edwin *et al.*, "Smart agriculture monitoring system for outdoor and hydroponic environments," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 25, no. 3, pp. 1679–1687, 2022, https://doi.org/10.11591/ijeecs.v25.i3.pp1679-1687.

[3] D. Xue and W. Huang, "Smart Agriculture Wireless Sensor Routing Protocol and Node Location Algorithm Based on Internet of Things Technology," in *IEEE Sensors Journal*, vol. 21, no. 22, pp. 24967-24973, 2021, https://doi.org/10.1109/JSEN.2020.3035651.

[4] R. K. Chauhan, K. Chauhan, "Battery Monitoring and Control System for Photovoltaic based DC Microgrid," *International Journal of Emerging Electric Power Systems*, vol. 20, no. 6, 2019, https://doi.org/10.1515/ijeeps-2019-0133.

[5] R. Alfita, K. Joni, and F. D. Darmawan, "Design of Monitoring Battery Solar Power Plant and Load Control System based Internet of Things," *Teknik*, vol. 42, no. 1, pp. 35-44, 2021, https://doi.org/10.14710/teknik.v42i1.29687.

[6] S. Siregar, M. Ike Sari, and R. Jauhari, "Automation System Hydroponic Using Smart Solar Power Plant Unit," *Jurnal Teknologi*, vol. 78, no. 5-7, 2016, https://doi.org/10.11113/jt.v78.8713.

[7] A. K. Tripathi, S. Ray and M. Aruna, "Analysis on Photovoltaic Panel Temperature under the Influence of Solar Radiation and Ambient Temperature," *International Conference on Advances in Electrical, Computing, Communication and Sustainable Technologies (ICAECT)*, pp. 1-5, 2021, https://doi.org/10.1109/ICAECT49130.2021.9392619.

[8] K. Tatas *et al*., "Reliable IoT-Based Monitoring and Control of Hydroponic Systems," *Technologies*, vol. 10, no. 1, p. 26, 2022, https://doi.org/10.3390/technologies10010026.
[9] U. Nurhasan *et al*., "Implementation IoT in System Monitoring Hydroponic Plant Water Circulation and Control," *International Journal of Engineering & Technology*, vol. 7, no. 4.44, p. 122, 2018, https://doi.org/10.14419/ijet.v7i4.44.26965.
[10] B. Almadani and S. M. Mostafa, "IIoT Based Multimodal Communication Model for Agriculture and Agro-Industries," in *IEEE Access*, vol. 9, pp. 10070-10088, 2021, https://doi.org/10.1109/ACCESS.2021.3050391.
[11] S. Puengsungwan and K. Jirasereeamornkul, "Internet of Things (IoTs) based hydroponic lettuce farming with solar panels," *International Conference on Power, Energy and Innovations (ICPEI)*, pp. 86-89, 2019, https://doi.org/10.1109/ICPEI47862.2019.8944986.
[12] D. R. A. Tambogon and A. N. Yumang, "Growth of Garlic in Hydroponic System with IoT-Based Monitoring," *14th International Conference on Computer and Automation Engineering (ICCAE)*, pp. 184-189, 2022, https://doi.org/10.1109/ICCAE55086.2022.9762436.
[13] L. Lambrinos, "Internet of Things in Agriculture: A Decision Support System for Precision Farming," *IEEE Intl Conf on Dependable, Autonomic and Secure Computing, Intl Conf on Pervasive Intelligence and Computing, Intl Conf on Cloud and Big Data Computing, Intl Conf on Cyber Science and Technology Congress (DASC/PiCom/CBDCom/CyberSciTech)*, pp. 889-892, 2019, https://doi.org/10.1109/DASC/PiCom/CBDCom/CyberSciTech.2019.00163.
[14] C. Mi, X. Peng, L. Peng, C. Zhao and X. Deng, "Research on Crop Disaster Stress Risk Mapping System Based on Agriculture Big Data," *International Conference on Electronic Information Technology and Smart Agriculture (ICEITSA)*, pp. 525-530, 2021, https://doi.org/10.1109/ICEITSA54226.2021.00105.
[15] S. A. Bhat and N. -F. Huang, "Big Data and AI Revolution in Precision Agriculture: Survey and Challenges," in *IEEE Access*, vol. 9, pp. 110209-110222, 2021, https://doi.org/10.1109/ACCESS.2021.3102227.
[16] N. N. Misra, Y. Dixit, A. Al-Mallahi, M. S. Bhullar, R. Upadhyay and A. Martynenko, "IoT, Big Data, and Artificial Intelligence in Agriculture and Food Industry," in *IEEE Internet of Things Journal*, vol. 9, no. 9, pp. 6305-6324, , 2022, https://doi.org/10.1109/JIOT.2020.2998584.
[17] F. -H. Tseng, H. -H. Cho and H. -T. Wu, "Applying Big Data for Intelligent Agriculture-Based Crop Selection Analysis," in *IEEE Access*, vol. 7, pp. 116965-116974, 2019, https://doi.org/10.1109/ACCESS.2019.2935564.
[18] M. Gopal, T. C. Prakash, N. V. Ramakrishna, B. P. Yadav, "IoT Based Solar Power Monitoring System," *IOP Conference Series: Materials Science and Engineering*, vol. 981, no. 3, 2020, https://doi.org/10.1088/1757-899X/981/3/032037.
[19] N. Nuryanti, W. Purnomo and A. Supriyanto, "Development of Virtual Multimeter in Determining Diode Characteristics Based on LabVIEW," *3rd International Symposium on Material and Electrical Engineering Conference (ISMEE),* pp. 283-289, 2021, https://doi.org/10.1109/ISMEE54273.2021.9774227.
[20] B. Dezfouli, I. Amirtharaj, C. C. C. Li, "EMPIOT: An energy measurement platform for wireless IoT devices," *Journal of Network and Computer Applications*, vol. 121, pp. 135–148, 2018, https://doi.org/10.1016/j.jnca.2018.07.016.
[21] W. Adhiwibowo, A. F. Daru, A. M. Hirzan, "Temperature and Humidity Monitoring Using DHT22 Sensor and Cayenne API," *Transformtika*, vol. 17, no. 2, pp. 209–214, 2020, Https://doi.org/http://dx.doi.org/10.26623/transformatika.v17i2.1820.
[22] A. Arisudin, M. Yahya, and D. Erwanto, "Tea Aroma Classification Using Arduino Uno-Based Gas Sensors," *J. Appl. Sci. Electr. Eng*., vol. 2, no. 2, pp. 115–127, 2021, https://doi.org/10.31328/jasee.v2i02.198.
[23] I. G. M. N. Desnanjaya, A. A. G. B. Ariana, I. M. A. Nugraha, I. K. A. G. Wiguna, and I. M. U. Sumaharja, "Room Monitoring Uses ESP-12E Based DHT22 and BH1750 Sensors," *J. Robot. Control*, vol. 3, no. 2, pp. 205–211, 2022. https://doi.org/10.18196/jrc.v3i2.11023.
[24] T. P. Satya, U.Y. Oktiawati, I. Fahrurrozi, H. Prisyanti, "Analisis Akurasi Sistem Sensor DHT22berbasis Arduino terhadap Thermohygrometer Standar," *Jurnal Fisika Dan Aplikasinya*, vol. 15, no. 1, pp. 40-45. 2020, http://dx.doi.org/10.12962/j24604682.v16i1.5776.
[25] M. Cicioğlu and A. Çalhan, "Internet of Things-Based Firefighters for Disaster Case Management," in *IEEE Sensors Journal*, vol. 21, no. 1, pp. 612-619, 2021, https://doi.org/10.1109/JSEN.2020.3013333.
[26] K. Chen *et al*., "Internet-of-Things Security and Vulnerabilities: Taxonomy, Challenges, and Practice," *Journal of Hardware and Systems Security*, vol. 2, no. 2, pp. 97–110, 2018, https://doi.org/10.1007/s41635-017-0029-7.
[27] D. Huynh, and S. Nguyen-Ky, "Engaging Building Automation Data Visualisation Using Building Information Modelling and Progressive Web Application," *Open Engineering*, vol. 10, no. 1, pp. 434-442, 2020, https://doi.org/10.1515/eng-2020-0054.
[28] S.-H. Ga, H.-J. Cha, and C.-J. Kim, "Adapting Internet of Things to Arduino-based Devices for Low-Cost Remote Sensing in School Science Learning Environments," *Int. J. Onl. Eng*., vol. 17, no. 02, pp. pp. 4–18, 2021, https://doi.org/10.3991/ijoe.v17i02.20089.
[29] M. Asad, S. Qaisar and A. Basit, "Client-Centric Access Device Selection for Heterogeneous QoS Requirements in Beyond 5G IoT Networks," in *IEEE Access*, vol. 8, pp. 219820-219836, 2020, https://doi.org/10.1109/ACCESS.2020.3042522.
[30] P. S. Basappa, S. Gangadhar, T. C. Thanuja, "Energy-efficient data-aggregation for optimizing quality of service using mobile agents in wireless sensor network," *International Journal of Electrical and Computer Engineering*, vol. 12, no. 4, pp. 3891–3899, 2022, https://doi.org/10.11591/ijece.v12i4.pp3891-3899.

[31] A. Charisma, A. D. Setiawan, G. M. Rahmatullah and M. R. Hidayat, "Analysis Quality of Service (QoS) on 4G Telkomsel Networks In Soreang," *IEEE 13th International Conference on Telecommunication Systems, Services, and Applications (TSSA)*, pp. 145-148, 2019, https://doi.org/10.1109/TSSA48701.2019.8985489.

[32] E. Tong, L. Chen and H. Li, "Energy-Aware Service Selection and Adaptation in Wireless Sensor Networks with QoS Guarantee," in *IEEE Transactions on Services Computing*, vol. 13, no. 5, pp. 829-842, 2020, https://doi.org/10.1109/TSC.2017.2749227.

[33] R. Kumar, V. U. and V. Tiwari, "QuOTE: A Quality of Service Aware Optimized Traffic Engineering Approach for Efficient Flow Management in SDWS-IoT Networks," in *IEEE Communications Letters*, vol. 25, no. 12, pp. 3863-3867, 2021, https://doi.org/10.1109/LCOMM.2021.3119549.

[34] R. Kumar, V. U. and V. Tiwari, "QuOTE: A Quality of Service Aware Optimized Traffic Engineering Approach for Efficient Flow Management in SDWS-IoT Networks," in *IEEE Communications Letters*, vol. 25, no. 12, pp. 3863-3867, 2021, https://doi.org/10.1109/LCOMM.2021.3119549.

[35] S. Astiti and N. Iryani, "Implementasi dan Analisis Performansi QoS pada Aplikasi English Competency Test," *JTERA (Jurnal Teknol. Rekayasa)*, vol. 5, no. 2, p. 267, 2020, http://dx.doi.org/10.31544/jtera.v5.i2.2020.267-274.

[36] A. Sujiwa and M. Ubaydillah, "Arduino Based Temperature And Humidity Monitoring Control System for Day Old Chicken (DOC) Cage," *BEST J. Appl. Electr. Sci. Technol*., vol. 3, no. 1, pp. 22–25, 2021, https://doi.org/10.36456/best.vol3.no1.3538.

[37] Y. Y. Leow, C.A. Ooi, and M. N. Hamidi, "Performance evaluation of grid-connected power conversion systems integrated with real-time battery monitoring in a battery energy storage system," *Electr Eng,* vol. 102, pp. 245–258 , 2020, https://doi.org/10.1007/s00202-019-00865-y.

[38] C. C. Li and B. Dezfouli, "Excalibur: An Accurate, Scalable, and Low-Cost Calibration Tool for Sensing Devices," *IEEE Sens. J*., vol. 19, no. 23, pp. 11323–11336, 2019, https://doi.org/10.1109/JSEN.2019.2934137.

[39] C. -R. Li *et al*., "Integrating temperature, humidity, and optical aerosol sensors for a wireless module for three-dimensional space monitoring," *IEEE Sensors Applications Symposium (SAS)*, pp. 1-4, 2018, https://doi.org/10.1109/SAS.2018.8336731.

[40] C. Sugimoto and R. Kohno, "Development of wireless sensing system monitoring physiological information for healthcare in daily life," *Fifth International Conference on Sensing Technology*, pp. 488-493, 2011, https://doi.org/10.1109/ICSensT.2011.6137028.