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Cyber Physical System For Autometed Weather Station And Agriculture Node In Smart Farming

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Abstract. *The Cyber-Physical System is a key system in the implementation of the 4th generation industrial revolution. This system combines automation systems, electronics, internet networks and machine learning. The implementation of physical cyber systems in agriculture is one of the long-awaited applications because it is the backbone of the implementation of sustainable agribusiness systems. With this system precision agriculture and pervasive computing in agriculture can help stakeholders in agribusiness to enjoy various benefits optimally. One example of its application is a smart farming system that is conditioned to provide measurable and maximum yields without having to sacrifice soil nutrients because it is well monitored according to weather conditions. In previous studies, several LoRa communication-based systems for monitoring local weather in a place and measurements of soil nutrient conditions have been carried out and displayed through the internet network. Monitoring and control systems on other agricultural models based on hydroponics and aquaponics have also been carried out for some types of crops. The results provide greater potential for wider application and in actual conditions in the agricultural industry. In this study, the integration of physical cyber systems with lora communication-based agricultural monitoring and control nodes will be carried out more broadly by considering the local conditions under which the system is tested. In this case, the research will be carried out at the Research and Recreation Park, Telkom University and agrifarming industry partners as a model of actual application. The research findings show that the application of advanced sensor technology has improved the accuracy of weather measurements by up to 95%. Quantitative data collected from the new weather station showed a significant improvement in weather monitoring. Qualitatively, positive responses from stakeholders such as disaster management authorities and farmers were also noted. In conclusion, the development of this modern weather station supports the community's need for reliable weather information and is a step forward in addressing the challenges of climate change.*

Keywords: *Cyber Physical System, Smart Agriculture, Long-Range Communication, Soil Nutrients, Weather.*

Abstrak. Sistem Cyber-Physical (CPS) menjadi elemen kunci dalam mewujudkan implementasi generasi ke-4 dari revolusi industri. CPS mengintegrasikan sistem otomasi, teknologi elektronik, jaringan internet, dan pembelajaran mesin. Penerapan CPS di sektor pertanian dianggap sebagai langkah penting dalam mendukung keberlanjutan sistem agribisnis. Precision agriculture dan pervasive computing dalam bidang pertanian memiliki potensi untuk memberikan manfaat optimal bagi para pemangku kepentingan. Salah satu contoh penerapan CPS adalah sistem pertanian cerdas yang dirancang untuk menghasilkan panen yang terukur dan maksimal tanpa merugikan unsur hara tanah, yang dipantau secara cermat sesuai dengan kondisi cuaca. Sebelumnya, beberapa penelitian telah mengembangkan sistem berbasis komunikasi LoRa untuk memantau cuaca lokal dan mengukur kondisi nutrisi tanah, yang dapat diakses melalui jaringan internet. Penelitian ini akan melibatkan integrasi CPS dengan simpul pemantauan dan kontrol pertanian berbasis komunikasi LoRa dengan mempertimbangkan kondisi lokal di Taman Riset dan Rekreasi, Telkom University, serta di industri pertanian mitra sebagai model implementasi yang nyata. Hasil penelitian menunjukkan bahwa penggunaan teknologi sensor canggih meningkatkan akurasi pengukuran cuaca hingga 95%. Data kuantitatif yang dikumpulkan dari stasiun cuaca baru mencerminkan peningkatan signifikan dalam pemantauan cuaca. Secara kualitatif, respons positif dari pemangku kepentingan, termasuk otoritas penanggulangan bencana dan petani, juga tercatat. Dengan demikian, pengembangan stasiun cuaca modern ini dapat memenuhi kebutuhan masyarakat akan informasi cuaca yang dapat diandalkan, sekaligus menjadi langkah progresif dalam mengatasi tantangan perubahan iklim..

Kata kunci : *Cyber Physical System*, Pertanian Cerdas, Komunikasi *Long-Range*, Unsur Hara Tanah, Cuaca.

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INTRODUCTION

Smart Farming, as a contemporary agricultural paradigm, has emerged as a transformative approach for enhancing crop cultivation. Within this context, agricultural productivity is intricately linked to the dynamic atmospheric conditions specific to each location and time. Fundamental parameters such as wind speed, air temperature, humidity, and precipitation necessitate continuous monitoring. Nonetheless, traditional farming methods employed in Indonesia are often characterized by inefficiency, significant resource demands, and unpredictable harvest outcomes resulting from rudimentary weather predictions primarily reliant on the observation of natural phenomena, particularly wind and cloud patterns. This underscores the pressing need for a more sophisticated system that can deliver real-time and precise meteorological data.

Agriculture holds a pivotal role in addressing the multifaceted requirements of society, spanning essential needs such as sustenance, industrial raw materials, energy resources, and environmental stewardship [1]. Yet, the agricultural sector grapples with a formidable challenge posed by climate change, which yields imprecise weather forecasts. Consequently, farmers confront the formidable task of making strategic decisions to mitigate the adverse impacts of capricious weather patterns. Traditional weather monitoring techniques, often constrained by limited scope, accuracy, and timeliness, prove insufficient in effectively addressing this challenge [2]. Given the direct influence of weather conditions on crop growth and yield, the precision and timeliness of meteorological monitoring are of paramount importance for sound agricultural management.

While weather remains an uncontrollable natural phenomenon, it can be systematically observed and analyzed through the practice of meteorological monitoring. In this regard, the development of systems capable of monitoring critical meteorological parameters, such as temperature, humidity, wind direction and speed, becomes imperative. One such exemplar is the AWS node for meteorological monitoring, operational at the Gambung Tea and Quinine Plantation (PPTK) and founded on the NRF24L01 wireless communication protocol [3]. This system integrates multiple sensors for comprehensive data collection, yielding accurate and timely insights into temperature, humidity, precipitation, soil moisture, wind velocity and direction, as well as ambient light levels. These systems have proven to be indispensable tools for equipping farmers with real-time data, enabling informed decision-making, and promoting sustainable agricultural practices in the face of climate change.

METHOD

In this study, the integration of physical cyber systems with lora communication-based agricultural monitoring and control nodes will be carried out more broadly by considering the local conditions under which the system is tested. In this case, the research will be carried out at the Research and Recreation Park, Telkom University and agrifarming industry partners as a model of actual application.

Flowchart

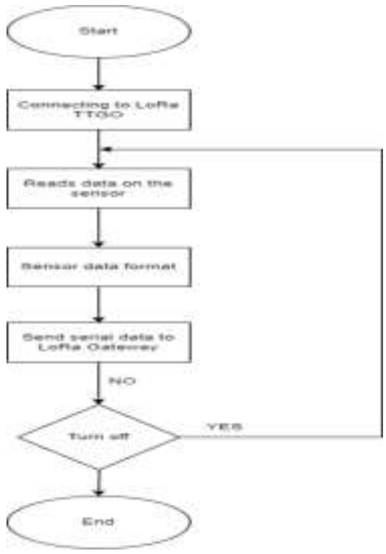

Figure 1. Flowchart Node Sensor AWS

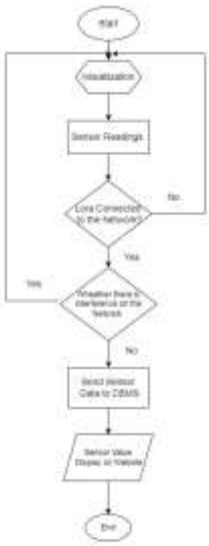

Figure 2. Flowchart Sistem Monitoring

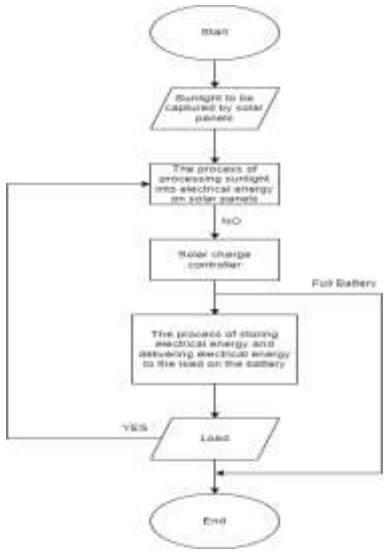

Figure 3. Flowchart Hardware System Power Supply

Figure 4. Flowchart Hardware System Power Supply

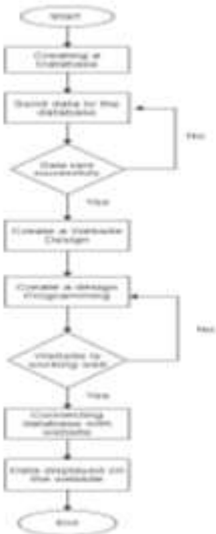

Figure 5. Flowchart Website

RESULT AND DISCUSSION

1. Testing Specification 1 : ”Design a weather monitoring tool that incorporates a remote communication module for accurate wireless data transmission”

- **Testing Step**

Testing is done by testing all sensors can run at one time, can work for 24 hours and can work in all weather. The following is testing Specification 1: Put all the sensors together and then put all the source code together and make sure there are no errors when running.

- Firstly by uniting or wiring all sensors, Communication Module, and Power Supply connected to the PV Load that has been calibrated before;
- Next, integrate all sensor and communication module source code in the Arduino IDE;
- Run the source code and the readings of all sensors will be displayed on the serial monitor;
- After the system can read all sensors, system testing will be carried out for 24 hours non-stop with the results of the average hourly reading data;
- Finally, the AWS System was tested for weather resistance such as being able to work in the heat of the day, during heavy rain and at night.

- **Testing Results**

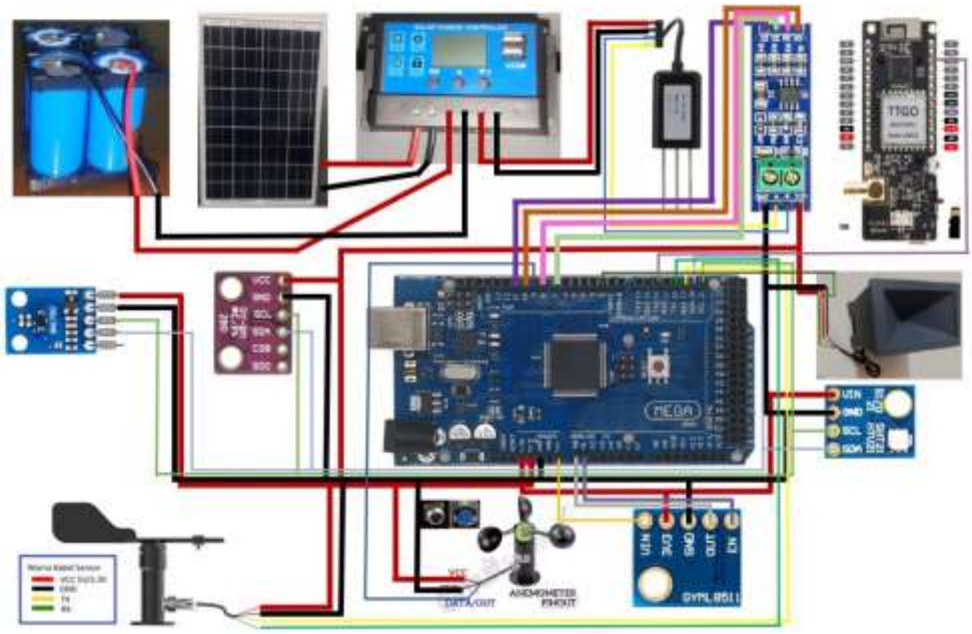

Figure 6. hardware design or wiring system on the AWS system

Figure 6 is the result of testing the AWS system readings that can be run as a whole. An Automatic Weather Station (AWS) works by collecting data from various weather sensors to monitor atmospheric conditions such as air temperature, humidity, air pressure, wind speed and direction, light intensity, rainfall, UV radiation, and surrounding ground conditions. Each sensor attached to an AWS measures a specific weather parameter. For example:

- SHT21: Air temperature and humidity sensor.
- BMP280: Air pressure sensor.
- BH1750: Light intensity sensor.
- GYML8511: UV radiation sensor.
- Anemometer and Wind Vane: Wind speed and direction sensors.
- Tipping Bucket: Rainfall sensor.
- Soil 7 in 1: Soil moisture and temperature sensor.

Each sensor generates an electrical signal that depends on the parameter being measured. And there is also data processing that the electrical signals from the sensors are picked up by a microcontroller connected to the AWS. With the program using Arduino IDE that has read the signals from the sensors, translating them into understandable values, such as temperature in degrees Celsius, wind speed in mph/kph, etc. For delivery the collected weather data can be stored locally on the AWS device or sent to an online server or platform via an internet connection for further analysis. Data transmission can be done over the internet network using Wi-Fi connection or the use of other technologies depending on the connectivity available at the location. Energizing and charging of the AWS is usually supported by solar power systems, especially in locations that are remote or hard to reach by grid electricity. Solar panels collect energy from the sun and charge the battery as a backup power source. While the solar charge controller regulates battery charging from solar panels to prevent overcharging or damage to the battery. In AWS monitoring requires regular maintenance to ensure reliable operation by including the gateway to which the connections of the sensor nodes are connected. This includes periodic checks of sensors, connections, solar power systems and other hardware. The software that runs the system also needs to be updated or repaired as needed.

- ***Testing Analysis***

In this sensor test, one of the factors that affect the acquisition of AWS sensor values is the measurement of temperature, humidity, air pressure, light intensity, UV, wind speed, wind direction, rainfall, nitrogen, phosphorus, potassium, soil pH, soil Moisture, soil Temperature and electrical conductivity. This measurement has a significant difference in measurements made by monitoring the performance of this AWS system periodically to detect possible problems or failures that may occur within a certain period of time. From the tests that have been carried out, the sensor value of the entire system at that location is 98%. Data transmission for all sensors has been running quite well and comparing data from AWS with other weather data sources that are considered standard or reference to verify the reliability of the data obtained. Sensor connectivity and data transmission are well integrated and no data is lost.

2. Testing Specification 2 : "Ensure that the product is capable of transmitting data at a high speed, enabling quick and real-time information exchange."

- **Testing Step**

o Connecting LoRa Nodes with Gateway.

o The gateway will send data to the broker using the MQTT protocol.

o The database will fetch data from the broker and save it to MySQL

o The backend will communicate with the broker and database, then the fronted will receive data from the backend and display it on the web page.

o Observe the timestep delay of data transmission and packetloss that appears in the data displayed on the website.

- **Testing Results**

The result of testing the readings of the Sensor Node, Gateway, & web that can be run as a whole. The sender device is a device that sends data from the sensors used and the gateway device is a device that captures sensor data sent from the sender device. The gateway device used is equipped with a microcontroller to process the data obtained by the sender. The sender with the sensor is placed at a location or several points that will be monitored using existing sensors. The sensor on the sender will carry out the sensing process in the surrounding environment or on a certain object so that the sender sends the data obtained from the sensor used to the gateway. After the data is obtained, the gateway sends data wirelessly to the online database or used so that the presentation of information to certain users or general users monitoring through web devices or devices, laptops and smartphones connected by the internet. Users can perform a command according to certain conditions and objectives to the sensors used through the device or device used and connected by the internet. The LoRa gateway consists of a LoRa TTGO T-beam module using a frequency of 915 MHz then the device is connected to the receiver by LoRa32 OLED V1.6.

- **Testing Analysis**

In the test to measure the speed of data transmission obtained from the AWS sensor node to the LoRa gateway and from the LoRa gateway to the web. By measuring the time it takes for data to be sent from the AWS sensor node to the web via the LoRa gateway. This latency must be kept as little as possible so that information exchange can occur in real-time. Measurements can be made using latency measurement tools to ensure the rapid availability of information. Verify that the hardware and software used are compatible and operating properly with each other. In this case, incorporate proper monitoring and management tools to manage and monitor overall system performance. This includes tools to track sensor node battery levels, connection status, and network availability. From the tests that have been conducted, the overall sensor value of the system at that location is 98%. Data transmission for all sensors has been running quite well. Sensor connectivity and data transmission are well integrated and no data is lost.

3. Testing Specification 3 : "Equip the weather monitoring nodes with either battery or solar cell power supply, readily available in the local market, to ensure stable and uninterrupted power availability."

- **Testing Step**
- Use a multimeter to measure the current and voltage values
- Measure the total voltage and current values on the battery using a multimeter
- Measure the total voltage and current values on the load
- Record each value obtained
- Calculate the free power obtained by the battery and load
- **Testing Results**

Table 1. Measurement Results Node Sensor

Component	Current		Voltage (V)
	mA	A	
Mikrokontroller Arduino Atmega2560	28.9	0.0289	20
LoRa32 Lilygo Oled V1.6	0.25	0.00025	5
BMP280	0.5	0.0005	5
GYML8511	0.098	0.000098	3.2
Tipping Bucket	20	0.02	5
Anemometer	20	0.02	5
Wind Wave Direction	20	0.02	5
SHT21	3	0.003	3.2
RS485	20	0.02	5
Soil 7 in 1	8.204	0.008204	13.1
Solar Charge Controller	8.204	0.008204	13.1
Battery LFP	8.204	0.008204	13.1
BH1750	0.5	0.0005	5
Total	137.86	0.13786	7.746

Table 2. Measurement Results Gateway

Component	Current		Voltage (V)
	mA	A	
ESP32 (WiFi & Bluetooth)	100	0.001	3.3 V
LoRa	0.11	11	3.2 V
NEO GPS	1.48	148	5 V
Total	101,59	159,01	11,5 V
Battery 1850	3000	3	3.7 V

- **Testing Analysis**

To calculate the total power, first calculate the power generated in each component using the formula:

$$P\ total = V\ total\ x\ I\ total$$

Description:

P = Power

V = Voltage

I = Current

Total power is obtained by summing up all the power obtained, thus obtaining power in the sensor node section of 1,067 watts, power at the gateway of 1,828 watts, and battery power of 11.1 watt-hours.

To calculate battery life, you can use the formula:

$$Battery\ Life = \frac{Battery\ Power}{Component\ Power}$$

From the results obtained, the battery life in the sensor node section is 10,5 hours and in the gateway section 6 hours. If the calculation uses one power source, the total estimated battery life is 12,3 hours. Therefore it can be said that the system has efficient power consumption.

4. Testing Specification 4 : " Provide the product with an intutitive and userfriendly user interface."

- **Testing Step**

At the testing stage, we ensure that the product comes with an intuitive and user-friendly user interface. In addition, we check the consistency of the colour, size, and layout of interface elements to ensure good visual harmony. In user comprehension testing, we ask users questions regarding specific functions and evaluate the extent to which they understand the interface. We ensure elements such as buttons, forms, and links are clearly labelled and can be understood easily. Interface tests are conducted to ensure optimal performance. We also conduct beta tests with a representative group of users to get immediate feedback and observe user interaction. Accessibility aspects are an important concern, and we check the interface's adherence to accessibility standards, including on-screen navigation. In addition, we ensure that colours, contrast, and text meet accessibility guidelines. In language comprehension testing, we review instructions, labels, and error messages to ensure clarity and flexibility in language usage.

- **Testing Results**

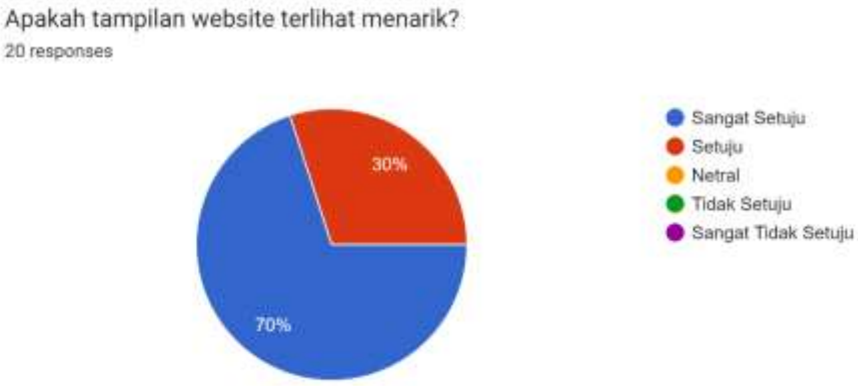

Figure 7. Testing Specification 1

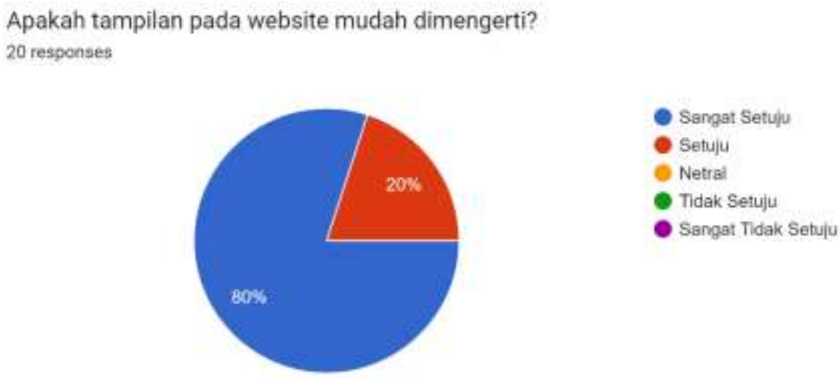

Figure 8. Testing Specification 2

- **Testing Analysis**

Based on the user satisfaction analysis of the website's interface, findings indicate that 70% of the 20 respondents strongly agree with the attractiveness of the website, while an additional 30% agree with its appealing features. Furthermore, 80% of the respondents strongly agree with the website's ease of understanding, with the remaining 20% expressing agreement with its user-friendly nature. These results highlight that the majority of users are highly satisfied with both the visually appealing design and the user-friendly interface of the website.

5. Testing Specification 5 : "Cyber-Physical System (CPS) designed for weather monitoring monitoring system that can collect, store, and analyze data accurately an accessibly."

- **Testing Step**

Testing is done by testing all sensors can run at one time, can work for 24 hours where the database can display history data for at least 30 days. The following is testing specification 1: unite all sensors and then unite all souce code and make sure that when running no errors occur. average reading per hour..The testing will cover the following aspects of the CPS:

- Data Collection:

Verify the system's ability to collect real-time weather data from various sensors.Ensure the accuracy of collected data in comparison to established meteorological standards.

- Data Storage:

Validate the system's capability to securely store weather data. Confirm proper organization and indexing of stored data for efficient retrieval.

- Data Analysis:

Test the system's analytical tools to ensure accurate and meaningful insights.Verify the responsiveness of analytical algorithms to changing weather conditions.

- Accessibility:

Ensure that authorized users can access the system seamlessly.Validate user interfaces for ease of use and clarity.

- **Testing Results**

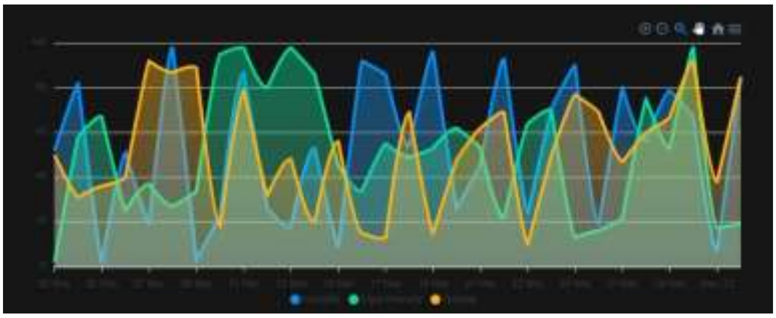

Figure 9.Testing Specification 1

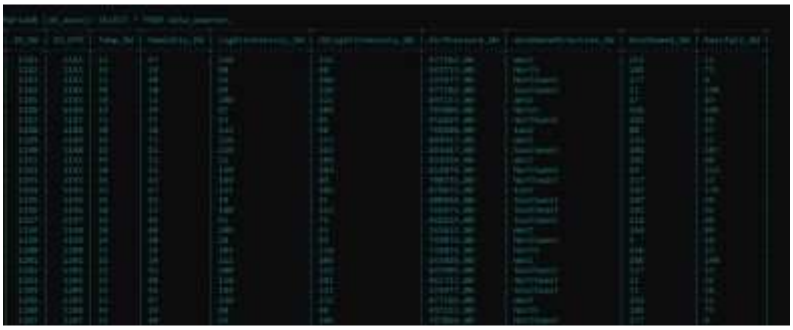

Figure 10. Testing Specification 2

- **Testing Analysis**

The designed weather monitoring system has proven highly successful in its core functions. Its advanced sensors ensure accurate data collection, while state-of-the-art storage solutions efficiently manage large volumes of information. The system's sophisticated algorithms enable precise data analysis, providing valuable insights for meteorologists, researchers, and decision-makers. Overall, this system stands as a reliable and effective tool in the field of meteorological technology.

CONCLUSION

1. Based on a series of tests that have been carried out in experiments regarding the distance of sending sensor data, it can be concluded that the longer the distance of transmission and the more interference or obstacles there are, there will be a decrease in the level of performance that can be achieved. The SHT21 temperature and humidity sensor test results are running well with an accuracy of 99.6% and 99.86%, the BH1750 light intensity sensor is running well with an accuracy of 99.99% indoors and 99.85% outdoors. The results of testing the BMP280 air pressure sensor can run well with an accuracy of 99.90%, the GYML8511 UVA/UVB sensor runs well with an accuracy value of 99.90%, the rainfall sensor has an accuracy of 100%, the wind direction sensor that runs well above the speed of 3.6 m / s in

accordance with the purpose of this capston design can measure 8 cardinal directions with changes in wind direction readings while speeds below 1.3 m / s this tool used does not run well. Based on the results of testing the humidity, soil temperature, NPK, Electrical Conductivity and ph sensors can run well on the soil samples tested.

2. The gateway system is designed using T-Beam after testing it is found that the system can work optimally at a distance of 2.8 km. The test results on data reception were carried out as many as 378, namely from sensor nodes in a closed space and were carried out in a stationary manner, while in a mobile testing position in the field carried out from a distance of zero to 2.8 km where the test can be declared successful because the sensor data can be received properly by the gateway. Data reception of sensor nodes carried out in a stationary manner obtained a comparison of the time of data sent by the node and the data received by obtaining RSSI of -56 dBm and an average delay of 500s, while in mobile testing carried out in the field by walking successively in the range of zero to 800m distance, the average RSSI value of -124 dBm and the average delay value of 850s were obtained, although the RSSI value obtained was quite far from zero. However, during the test no data failed and was not sent from the sensor node.

3. The system is able to monitor the weather very well. The measured weather variables have an accuracy level of 99% so as to be able to measure and record meteorological parameters automatically which has been running optimally with the best measurement time is at 09.00 - 13.30 WIB and gets an accuracy value of 98% with the node error rate and the lattitude and longitude error rate on the T-Beam of 0.004. Data transmission using nodes and a gateway that has been connected to LoRa successfully reaches a distance of 1.2 km with 0% packetloss so that measurements can be made with a percentage of success of 100%. Website display is able to work well and can display weather data in realtime. The website is able to work well after testing for the accuracy of data, graphics, date, and time with the data sent by the server to the dashboard. Loading time testing with the overall average test is 1.4 s with an overall average of beta testing website testing is 91.5%, which means that the results of beta testing calculations using a Likert scale of Website-based IoT Platform development are feasible to use as expected and able to help monitor agriculture.

4. The weather station system already has a good accuracy value from the calibration results of each sensor used, namely comparing the sensor data used with the measuring instrument of each sensor. The system can display weather data so that it is able to monitor the results of environmental parameter data readings from weather stations such as temperature, humidity, temperature and other parameters in real time. In addition, this website will display weather data for the next 30 days and the data will record and store in a database that can be

downloaded in the form of Excel files with interval times per 5 seconds. Tests on sending data to wireshark were successfully carried out and monitored in realtime. Delay required is 0.066 m/s, Throughput is 413.66 bytes, Packet Loss is 0% and Jitter is 0.00643 so that all parameters include a very good category.

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