Telecontrolling Catfish Breeding Ponds Based on Wireless Sensor Networks with Solar Energy Implementation (Case Study: Catfish Breeding Berkah Maju Bersama Malang)

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***Abstract*— Catfish Breeding Farmer Group Berkah Maju Bersama is a farmer group that focuses on catfish breeding activities. This group has an address in Plaosan Village, Wonosari District, Malang Regency. Challenges in maintaining optimal pond conditions and effective monitoring are often faced by these farmer groups. In an attempt to address this problem, the study proposes a telecontrol system of catfish breeding ponds using wireless sensors with the implementation of solar energy. This study aims to create and design a catfish breeding pond telecontrol system by implementing solar energy. This research uses ESP32 as microcontroller, temperature sensor (DS18B20), pH sensor Module 4502C, LoRa type E220-400T30D. The results of the study in the form of temperature sensors have a percentage of sensor reading accuracy of 99.99%, pH sensors have a percentage of sensor reading accuracy of 99.99%. The maximum distance of data transmission by LoRa is 1213 meters, charging by solar panels for 7 hours 4.375 Ah (31.25% of the total battery capacity), and battery discharge is 0.356 Ah (abterai lasts for 98 hours). The calibration of the pH sensor module 4502C reads the pH value according to the reading of the pH meter analyzer. Overall, the system can run well. The lights and solenoid valve can be active with two modes, namely manual mode and auto mode contained in website features.**

Keywords*— *Catfish, DS18B20, LoRa, Microcontroller, pH Sensor, Solar Panel.

I. INTRODUCTION

Catfish Breeding Farmer Group Berkah Maju Bersama is a farmer group that focuses on catfish breeding activities. This group has an address in Plaosan Village, Wonosari District, Malang Regency. Catfish farming has been carried out traditionally by the fish farmers. Therefore, efficiency and productivity in catfish breeding are important to meet the demand for catfish breeds.

Often, environmental monitoring and control of catfish breeding ponds is done manually or limited by current technological limitations. Manual monitoring presents several problems, such as inaccurate data, slow responses, and high operational costs. Therefore, monitoring and controlling the environment of catfish breeding ponds is crucial [1].

Solar energy is an abundant and environmentally friendly natural resource [2]. In recent years, solar energy technology has become more popular in many industries, such as agriculture and fishing. To support the operation of the device required to

Telecontrolling catfish breeding ponds, the use of solar energy can be an interesting solution. The use of solar energy will reduce operational costs and provide wider access to locations previously unreachable by conventional power sources. The application of wireless sensor networks is more flexible and advantageous because it allows automation services and long-distance communication without the use of wires [3] to environmental parameters such as water temperature, and water pH. These sensors can be connected to a wireless sensor network, allowing the control center to receive data directly from the sensors. By using a wireless sensor network, fish farmers can monitor and control the environmental conditions of nursery ponds precisely and efficiently. In this final project, a control and monitoring system will be created to maintain the temperature and pH of the water contained in the catfish nursery pond using wireless sensor network technology. A wireless sensor network is a network of small components called sensor nodes. Sensor nodes in this network are distributed and work together to communicate information that is monitored in a timely manner. nirkabel. The data collected by the sensor node is sent to the coordinator who uses the data locally or connected to another network [4].

Literature review is carried out to help understand and find out previous research gaps, to get development potential in the field of knowledge and technology. Research also provides research methodologies and techniques to improve the validity and reliability of research. The first research was conducted by Arif Supriyanto, Fathurrahmani et al. (2019) with the title

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"Prototype of Water Quality Monitoring System in Freshwater Fish Ponds Based on Mobile Web Applications". A tool was made to monitor the water quality of freshwater fish ponds with parameters of temperature, pH, and turbidity of water using Arduino as a microcontroller. With the results displaying sensor measurement results through the LCD screen and website that can be accessed in real-time using a smartphone connected to the internet [5].

The next research was conducted by Dian Ariyanto and medulla Kusriyanto (2023) with the title "IoT-Based Koi Fish Pond Water Quality Monitoring System". A koi pond water quality monitoring device was made with temperature, pH, and solute parameters or TDS (Total Disolved Solid) using ESP32 as its microcontroller. The results of IoT-based koi pond water quality monitoring were able to display sensor readings on smartphones through the Blynk application, making it easier to monitor pond water quality parameters consisting of water pH, water temperature and water TDS. [6].

The next research was conducted by Riksa suta Adji and Heru Nurwasito (2022) with the title "Development of a Data Delivery System using LoRa Multipoint using Simple LoRa Protocol as Chicken Coop Fire Control. With the results of the sensor node is able to take temperature and smoke data that has been designed by implementing the LM35 sensor module and MQ-2 sensor module with the NodeMCU intermediary, In the process of sending data packets using the LoRa communication module, it is able to run well by running two nodes as multipoints in the process of sending data from the sensor node to the gateway. In the performance of sending data packets with packet loss, delay and jitter parameters, it was found that the delivery using variations in distance between the sensor node and the gateway was very influential [7].

Based on a review of previous studies, this study will focus on how wireless sensor network technology can be optimized to monitor and control the water quality of catfish nursery ponds. This research is expected to provide strategic recommendations for farmers in managing catfish breeding ponds more efficiently and practically.

II. METHOD

A. Type of Research

The type of research that will be carried out is research and development (R&D) on catfish breeding ponds in the Berkah Maju Bersama Malang catfish seed farmer group to address the challenges faced. This study focuses on identifying conditions in catfish fry pond water including water temperature conditions and water pH The research process begins with research design to analysis of research results.

B. Research Stages

The stages of research are made to detail each stage of making tools until testing is carried out so that the results obtained are sequential. The design of the research to be carried out in the manufacture of the system is shown in the Figure:

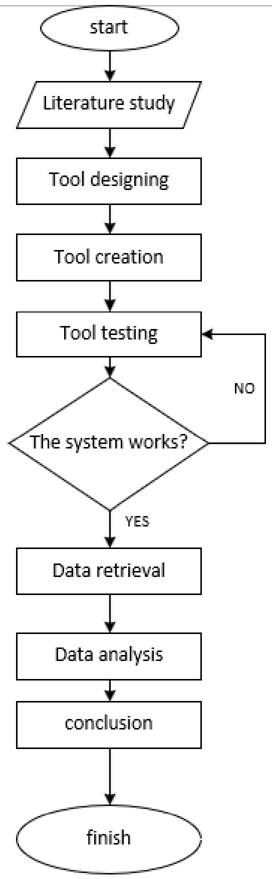

Figure 1. Research Flow Chart

The research process begins with a literature study, namely conducting literature studies in reference journals, articles and theses that have been published by various sources regarding the monitoring and control system of IoT-based catfish breeding ponds, sensors used in the system. The second stage of device design, the design of this system includes a control system connected to the internet, then the design of a series of tools and the design of the position of the temperature and pH sensors of water. The stage of making tools is to make tools, making this tool implements the system on the tool according to the system design that has been made, namely the implementation of tools and control systems using the website. Furthermore, the manufacture of tools according to the design that has been made to be able to carry out functional testing of the system. The tool testing stage is by seeing whether the system on the tool can be used and in accordance with the parameters to be tested. The data retrieval stage is carried out after the tool testing process is successful, data retrieval in the form of parameter readings and website software. When the tool is working properly, Furthermore, data is taken for analysis. Data analysis, involves data collected from the beginning of tool design to tool implementation. Conclusion, This stage aims to make conclusions based on the data analysis carried out.

C. System Design

1. Block System Diagram

The system will be depicted in the following block diagram consisting of two nodes and one server, which will store data on the database and can control it through the website.

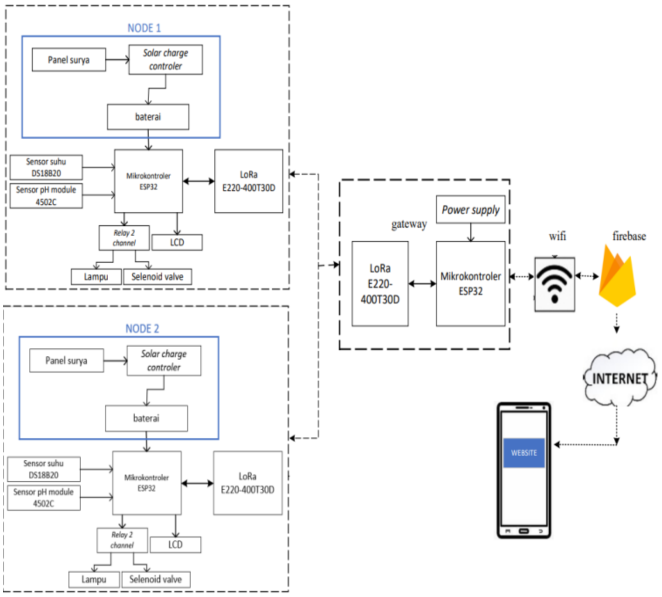

Figure 2. Block System Diagram

The power supply system is given to a microcontroller at 5V generated from the battery. In the charger section using a 50 wp solar panel, then the energy generated is flowed to the solar charge controller device so that the battery does not experience over charge, then flowed to the battery as a temporary storage of energy before being flowed to the microcontroller. Power from the battery will enter the stepdown module to lower the voltage from 12 volts to 5 volts as a power source for the Arduino microcontroller.

The microcontroller device used in this circuit is ESP 32 VWROM which serves as the brain of the data processing system [8]. DS18B20 temperature sensor is used as a temperature detector for pool water, pH sensor is used as a detection of acid/alkaline levels in pool water. LoRa modules are used to transmit data from sensor nodes to base stations [9] Which will then be sent to Firebase to be displayed in the form of a website that can be accessed by farmers via smartphones. So that farmers can control and also monitor fish pond water to keep it sTable.

2. System Flowchart

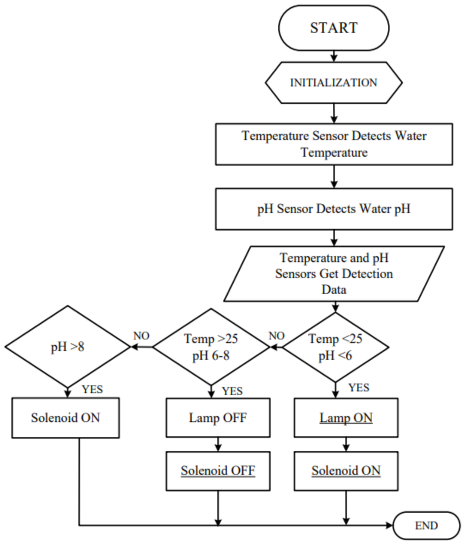

Figure 3. System flowchart

The system will start with initialization, then the temperature sensor will detect the temperature of the pool water and the pH sensor will also detect the pH of the pool water. These sensors will get detection results. If it meets the condition of the pool water, that is, if the temperature sensor detects a temperature 25°C, a decrease in pool water temperature is detected, the dc lamp will turn on. then If the pH sensor detects a pH value of water 6, an acidic pool water condition is detected. Then the Solenoid valve will turn on. If the pH sensor detects a pH value of water 8, an alkaline pool water condition is detected. Then the solenoid valve will turn on. Finish.

3. System Circuit Schematic

The schematic of the system circuit is used to plan the manufacture of a series of systems for Telecontrolling Catfish Breeding Based on Wireless Sensor Networks with Solar energy Implementation shown in Figure 5:

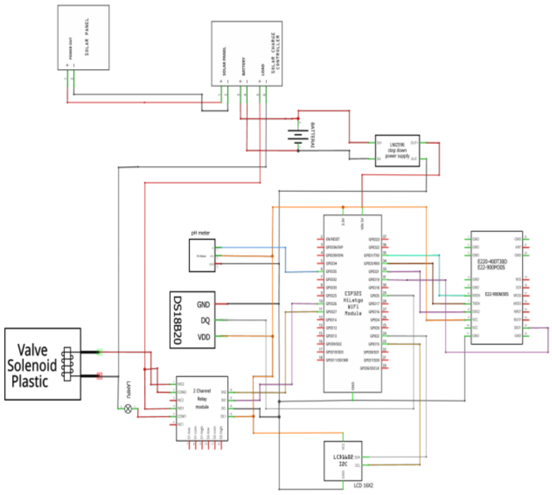

Figure 3. System-Wide Range

The schematic wiring description of the system circuit in Figure 5 is addressed in the following Tables 1, 2, 3, 4:

TABLE I
32 PIN ESP WIRING

Device	ESP32 Pin
Temp Sensor (DS18S20)	GPIO 5
pH Sensor (odule 4502C)	GPIO 35
Relay 1	GPIO 26
Relay 2	GPIO 27
LCD 16x2 (SDA, SLC)	GPIO 02, 15
LoRa E220-400T30D	GPIO 01/TXD,03/RXD, GPIO 21

TABLE II
WIRING RELAY PIN

RELAY 1	
NC	Dc Lamp
COM	12V
RELAY 2	
NO	Selenoid valve
COM	12V

TABLE III
WIRING RESOURCE CLASSIFICATION

Devide	Resources
Temp sensor (DS18S20)	3.3V
pH Sensor (module 4502C)	3.3V
Relay 1	3.3V
Relay 2	3.3V
LCD 16x2 (SDA, SLC)	3.3V
LoRa E220-400T30D	3.3V
Dc coverter (stepdown 5v)	12 V

TABLE IV
SOLAR WIRING

Solar Panel	Solar charger controller	Battery
Pin +	Solar Panel Pin +	
Pin -	Solar Panel Pin -	
	Battery pin +	Pin +
	Battery pin -	Pin -

4. Program Design

In making a Telecontrolling system for Catfish Breeding Ponds Based on Wireless Sensor Network Case study: Berkah Maju Bersama Catfish Nursery was carried out system program design as follows:

```
#include <ArduinoJson.h>
#include <OneWire.h>
#include <DallasTemperature.h>
#include <LiquidCrystal_I2C.h>
#include "LoRa_E220.h"
LoRa_E220 e220ttl(&Serial2, 18, 21, 19);
LiquidCrystal_I2C lcd(0x27,16,2);
int modeAuto = 1;
int R1_VAL = 0;
int R2_VAL = 0;
const int oneWireBus = 5;
StaticJsonDocument<300> doc;
#define PH_PIN 34
#define R1_PIN 25
#define R2_PIN 26
}
```

5. Website Program Design

In the design of the website program Telecontrolling Catfish Breeding Pond Based on Wireless Sensor Network Case Study : Catfish Nursery Berkah Maju Bersama was designed the website program as follows:

```
<!doctype html>
<html lang="en" data-bs-theme="auto">
<link rel="canonical"
href="https://getbootstrap.com/docs/5.3/examples/pricing/">
<link href="assets/dist/css/bootstrap.min.css" rel="stylesheet">
<link href=https:gh/gitbrent/bootstrap4-toggle@3.6.1/css/bootstrap4-
toggle.com
rel="stylesheet">
<style>
@media (min-width: 768px)
```

6. System Calibration

Telecontrol system calibration of catfish breeding ponds is an important process that aims to ensure that all devices and sensors in the system work with accuracy and consistency. At this stage, the author uses a thermometer measuring instrument as a reference to compare the value of temperature sensor readings, and a pH meter measuring instrument as a reference to compare the value of water pH sensor readings.

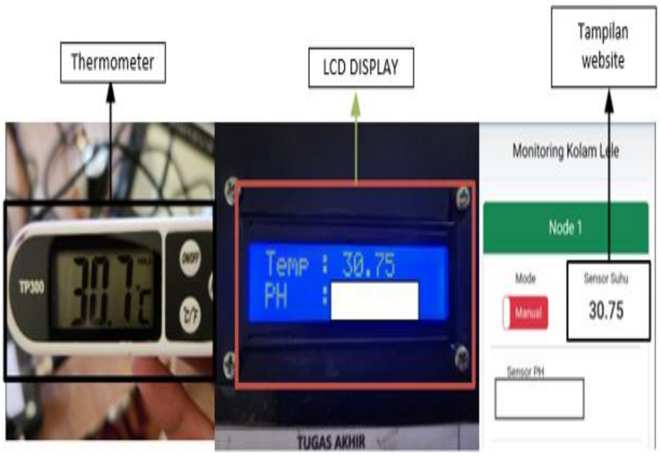

Figure 6. Temperature Sensor Calibration

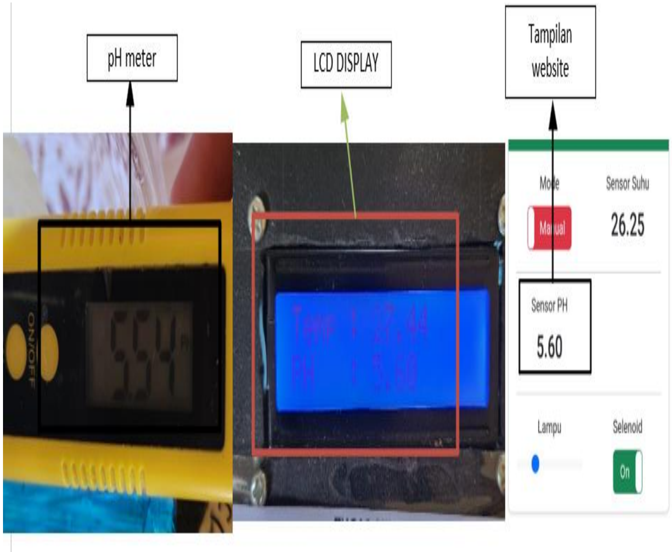

Figure 7.Water Ph Sensor Calibration

During and after calibration document all changes that occur to the system, the following documentation Table of system calibration results:

TABLE V
TEMPERATURE SENSOR CALIBRATION

No	Nilai Ukur Thermometer	Nilai Ukur Sensor Suhu	Tampilan LCD Display	Tampilan di Website
1	30.7	30.75	30.75	30.75
2	30.7	30.75	30.75	30.75
3	30.7	30.75	30.75	30.75
4	29.1	29.10	29.10	29.10
5	29.1	29.10	29.10	29.10
6	29.1	29.10	29.10	29.10
7	27.5	27.55	27.55	27.55
8	27.5	27.55	27.55	27.55
9	27.5	27.55	27.55	27.55
10	24.6	24.62	24.62	24.62
11	24.6	24.62	24.62	24.62
12	24.6	24.62	24.62	24.62
13	31.5	31.58	31.58	31.58
14	31.5	31.58	31.58	31.58
15	31.5	31.58	31.58	31.58

TABLE VI
PH SENSOR CALIBRATION

No	Nilai Ukur Thermometer	Nilai Ukur Sensor Suhu	Tampilan LCD Display	Tampilan di Website
1	5.59	5.60	5.60	5.60
2	5.59	5.60	5.60	5.60
3	5.59	5.60	5.60	5.60
4	7.14	7.15	7.15	7.15
5	7.14	7.15	7.15	7.15
6	7.14	7.15	7.15	7.15
7	6.39	6.40	6.40	6.40
8	6.39	6.40	6.40	6.40
9	6.39	6.40	6.40	6.40
10	8.24	8.25	8.25	8.25
11	8.24	8.25	8.25	8.25
12	8.24	8.25	8.25	8.25
13	5.89	5.90	5.90	5.90
14	5.89	5.90	5.90	5.90
15	5.89	5.90	5.90	5.90

After calibration is carried out on both sensors, it can be seen that the sensor reading value is almost close to the reading value by the manufacturer's measuring instrument. The error presenter of sensor readings reached 99.99%.

III. RESULTS AND DISCUSSION

A. Results of the Overall System Design

The results of component planning for telecontrolling catfish breeding ponds which include the results of making hardware, software. The results of making hardware in the form of microconductors that have been connected to sensors, sensors and other devices and the results of making software are used to monitor and control the condition of pool water connected to Firebase in realtime.

Figure 8. Hardware Design Results

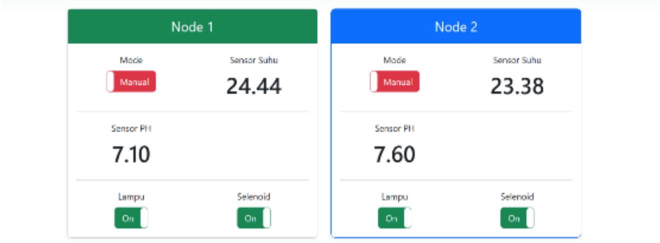

Figure 9. Website Design Results

1. Solar Power Plant Testing

The test results on PLTS as a power supply for all microcontroller devices are obtained with charging data on the battery and battery discharge as a supplier for all microcontroller devices. In this study, solar panels function as a source of electrical energy [10]. Charging testing is carried out by connecting the solar panel to the solar charger controlling as a battery charging controller as shown by Figure 8, Solar panel efficiency is a measure of the amount of solar energy (irradiation) that falls on the surface of the panel and is converted into electricity. Due to many recent advances in solar cell technology, the average panel conversion efficiency has increased from 15% to 20%[16]. Next, connect the solar charger controlling with a battery with a capacity of 35 Amperes. Monitoring time for 7 hours charging time.

Figure 10. Charging By Solar Panels

$$\text{Battery Capacy} = \frac{\text{total energy Wh}}{\text{Battery voltage}}$$

$$\text{Battery Capacy} = \frac{52.5\ \text{Wh}}{12\ \text{V}} = 4.375\ \text{Ah}$$

So, a 50 Wp solar panel can charge a 35 Ah battery for 7 hours in sunny weather conditions by optimally charging around 4,375 Ah (or about 31.25% of the total battery capacity). In Figure 10 the indicator in the solar charger controller displays the battery discharge mode. In this test, we will discuss battery discharge with a frequency of every 1 hour, with a battery capacity of 35 Amperes (A) and a total load for 24 hours of 8,558 A.

Figure 11. Power Discharge Indicator

$$\text{Discharging} = \frac{\text{Total load}}{\text{time}}$$

$$\text{Discharging} = \frac{8.558\ A}{24\ jam} = 0{,}35658\ \text{A/Hour}$$

So, the average energy discharged from the battery every hour is about 0.35658 Amperes/hour. Furthermore, based on an average usage of 0.35658 A/hour, we can calculate an estimate of how long the battery will last before it must be recharged:

$$\text{Survival time} = \frac{\text{Battery capacity}}{\text{Hourly discharge}}$$

$$= \frac{35\ \text{A}}{0{,}35658\ /\text{hour}} = 98{,}15\ \text{Hour}$$

So, with a discharge of 0.35658 A/hour, the battery will last about 98.18 hours without recharging.

2. Temperature Sensor Testing

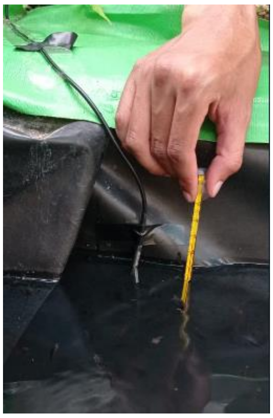
Figure 12. Temperature Sensor Testing

Test results on the DS18B20 Temperature sensor (sensor 1 as the position at Node 1 and sensor 2 as the position at Node 2) are obtained with data read by the system with a measuring instrument (thermometer). DS18B20 is a digital temperature sensor that follows a 1-wire protocol and can measure temperatures from -55 o C to +125 o C (-67 o F to +257 o F) with an accuracy of +-5%[17]. The test was conducted 15 times. The following is a Table of temperature sensor test results:

TABLE VII
TEMPERATURE SENSOR TEST RESULTS

Testing To	Measuring Instrument Results (C)	Measurable Results of DS18B20 Sensor (C)	Error (%)	Status
1	26.8 C	26.81 C	0	Lamp Off
2	26.8 C	26.81 C	0	Lamp Off
3	26.8 C	26.81 C	0	Lamp Off
4	26.8 C	26.81 C	0	Lamp Off

Testing To	Measuring Instrument Results (C)	Measurable Results of DS18B20 Sensor (C)	Error (%)	Status
5	25.5 C	25.55 C	0.001	Lamp Off
6	25.5 C	25.55 C	0.001	Lamp Off
7	25.5 C	25.55 C	0.001	Lamp Off
8	25.5 C	25.55 C	0.001	Lamp Off
9	25.2 C	25.26 C	0.001	Lamp Off
10	25.0 C	25.06 C	0.001	Lamp Off
11	24.8 C	24.88 C	0.001	Lamp On
12	24.8 C	24.88 C	0.001	Lamp On
13	24.8 C	24.88 C	0.001	Lamp On
14	24.8 C	24.84 C	0	Lamp On
15	24.8 C	24.84 C	0	Lamp On

The results of the calculations that have been done, it can be seen that the percentage of success of sensor 1 in retrieving and sending data is 0.999%. On the other hand, from the calculation results it can also be seen that the percentage of sensor 2 in carrying out the same function reaches 0.999%. It also shows excellent performance. Overall results indicate that both sensors are well capable of performing their duties.

3. pH Sensor Testing

Figure 13. pH Sensor Testing

Test results on the pH sensor module pH-4502C (sensor 1 as the position in Node 1 and sensor 2 as the position in Node 2) are obtained with data read by the system with a measuring instrument (pH meter). The pH sensor system consists of an indium tin oxide (ITO) electrode, an Ag/AgCl reference electrode, a computing enhancer, and a wireless communication module. The operational amplifier addition circuit increases the overall potential signal collected by the pH electrode and sends it to the wireless reader from the sensor tag[18]. The test was conducted 15 times. The following is a Table of pH sensor test results:

TABLE VIII
PH SENSOR TESTING

Testing To	pH Meter Results	pH Sensor Measured Results	Error (%)	Status
1	7.92	7.95	0.003	Selenoid Off
2	7.92	7.95	0.003	Selenoid Off
3	7.92	7.95	0.003	Selenoid Off
4	7.92	7.95	0.003	Selenoid Off
5	7.48	7.50	0.002	Selenoid Off
6	7.48	7.50	0.002	Selenoid Off
7	7.48	7.50	0.002	Selenoid Off
8	6.83	6.85	0.002	Selenoid Off
9	6.83	6.85	0.002	Selenoid Off
10	6.83	6.85	0.002	Selenoid Off
11	6.83	6.85	0.002	Selenoid Off
12	6.46	6.50	0.004	Selenoid Off
13	6.46	6.50	0.004	Selenoid Off
14	6.46	6.50	0.004	Selenoid Off
15	6.46	6.50	0.004	Selenoid Off

From the results of calculations that have been done, it is found that the percentage of availability or accuracy of sensor 1 is 0.999%, while sensor 2 has a percentage of availability or accuracy of 0.99%. This performance percentage reflects the sensor's success rate in collecting accurate and reliable data.

4. LoRa Testing

LoRa testing with Serial Monitor aims to verify whether data transmitted from one LoRa device is successfully received by the destination device [11].the test scenario aims to see the effect of distance on the transmission of data sent from the sending device to the receiving device. This test is carried out directly in the field by changing the distance of the end-node to the LoRa gateway to get accurate data. The deployment factor should be allocated according to the sensor placement distance from the gateway[19]. Test location selected deliberately, Testers perform test distance point mapping in Google Earth software. Testing was carried out in urban areas or urban areas, Testing was carried out as many as 15 times sending data at several locations with test points as follows:

The testing center point is at the tester's house in Sumberpasir village.

1. In front of Indomaret Sumberpasir
2. Along Sumberpasir highway Sukoanyar highway

Figure 14. Test Point Location Map

The following are the results of testing the accuracy of the LoRa range distance by taking samples of location points as shown in the Table:

TABLE IX
LORA DISTANCE TESTING

No	Base station		Data input points		Distance (m)	Status
	lat	long	lat	long		
1	-7.97315	112.740756	-7.973658	112.740678	57	Message received
2	-7.97315	112.740756	-7.973886	112.7413	102	Message received
3	-7.97315	112.740756	-7.974078	112.741769	153	Message received
4	-7.97315	112.740756	-7.97985	112.749322	1213	Message received
5	-7.97315	112.740756	-7.980714	112.750369	1365	Message bounced

The results of the LoRa test can successfully transmit data up to a distance of 1213 meters, the distance can be known from the indicator on the serial monitor. In the test distance of 1300 m – 1800 m, the signal sent by the sending device cannot be detected by the receiving device. This can be caused by a variety of factors, such as too long a distance, signal interference, interference, or other technical problems.

5. Quality of Service Testing

The following is a test of the functionality of the website which is used as a feature to monitor and control the condition of catfish fry pond water by farmers. This testing is carried out using the Quality of Service (QoS) method. is the process of testing and evaluating the quality of service of a system, application, or network. QoS refers to the ability of a system or service to meet certain requirements and expectations regarding performance, availability, reliability, and responsiveness [12]. In this process, network devices are monitored for the smallest data movements and peaks allocated radio resources that undermine stagnation[20].

The following is a Table of test results:

TABLE X
QOS TESTING

No	Time	Total Parcel	Throughput (Kb/s)	Packet Loss (%)	Average Delay
1	Morning	1250	213	2,8	0,103011
2	Morning	1312	425	3,963	0,087919
3	Morning	1342	136	2,60	0,187448
4	Noon	1178	470	2,122	0,365756
5	Noon	1084	247	0,992	0,546081
6	Noon	1032	204	1,162	0,634192
7	Noon	1084	666	2,398	0,34672
8	Night	1115	236	0,179	0,769897
9	Night	1260	175	1,269	0,123015
10	Night	1116	229	0.627	0,56211

In the Table, there is information about QoS calculations including throughput, packet loss, and average delay. Let's do a calculation to illustrate how Througput, packet loss, and average delay can provide quality of service information:

Througput

$$\text{Throughput} = \frac{number\ of\ Bytes}{Time\ Span} \text{ x } 8$$

It can be known the number of bytes in the details of network information, which is as much as 332835 and time span as much as 322,639, then the Throughput value can be calculated, namely:

$$\text{Throughput} = \frac{number\ of\ bytes}{Time\ Span} \text{x8}$$
$$= \frac{332835}{322.639} \text{x8} = 825.2815 \text{ KB/s} = 825 \text{ Kb/s}$$

Based on the results of calculations that have been done, it is obtained that the throughput value is 825 Kb / s. the results of this value can be matched with detailed network information in the Average bits / s section which shows the same result value of 825 K. From the calculation results it can be concluded that the quality of the network used includes in category Throughput is good with a percentage of 82.5%. This throughput category follows the standardization of TIPHON where the very good category is 100%, the Good category is 75%, the Medium category is 50% and the Bad category is 25% [13].

Packet loss

To find out the percentage value of packet loss, you can use the following calculation:

$$\text{Packet Loss} = \frac{\textit{Packets sent} - \textit{packets received}}{\textit{paket dikirim}} \text{ x } 100\%$$
$$= \frac{1248-1243}{1248}\, x\, 100\%$$
$$= 0.004 \text{ x } 100 = 100 - 0{,}004 = 0.996\%$$

The results of the calculation of package loss obtained package loss results of 0.996% where these results are included in the TIPHON standardization, namely the value of 0% including the Very Good category, 1-3% in the Good category, 4-15% in the Medium category, and if the value is more than 25% then it is included in the bad category [14].

Average delay

To get the total delay value use the following calculation.

$$\text{Delay} = \text{Second time} - \text{First time}$$

To get the delay value, namely by subtracting at both times, in the picture a subtraction is made with the excel formula '=I1-J2' then the delay result of the two times will be 72966s. Then if you have got the total delay value, then next find the average delay value using the calculation formula as.

$$\text{Average delay} = \frac{\textit{Total delay}}{\textit{Packet received} - 1}$$
$$= \frac{72966}{1247} = 0.5851543 \text{ s}$$

An average delay of 0.5851543 seconds indicates that the system is able to respond in a relatively short time. This is a positive factor in the quality of service, as users can expect sending and receiving data in a fast time.

IV. CONCLUSION

Through the process of testing and data collection that has been carried out, conclusions can be drawn, as follows: At the level of sensor reading accuracy in detecting pool water temperature The temperature sensor has a reading accuracy percentage of up to 99.97%. While the accuracy of the pH sensor reading when detecting the pH of pool water is 99.92%. In testing the distance of sending data by LoRa, the maximum distance of the data receiver is up to 1213 m, the test location is in a residential area with obstacles in the form of high-rise buildings and tall trees. Solar panel with a capacity of 50 wp is capable of charging the battery up to 4,375 Ah (or about 31.25% of the total battery capacity) for 7 hours in weather sunny conditions. While in discharge by a battery with a power load of 0.35658 A / hour, the battery will last about 98.18 hours without recharging. Overall the system can run well. DC lights and solenoid valves can be controlled in two ways through the website, namely auto mode and manual mode, besides that the system can also detect the condition of the pool water when 25 ° C, the pH of the pond water with a value of 6 – 8 where the value is the standard pH of pond water found in catfish breeding ponds.

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