Instal : Jurnal Komputer

E-ISSN: 2808-683X
Edisi : Volume 16 Nomor 05 | Desember 2024

Available online at https://journalinstal.cattleyadf.org/index.php/Instal/index

Implementation of BLE and LoRa Communication Channels on monitoring system Fish Pond Water Level in Rural areas Based Internet of Things

Morlan Pardede[1], Regina Sirait[2], Elferida Hutajulu[3], Waldemar Banurea[4]
[1,2,3,4]Politeknik Negeri Medan

ARTICLE INFO

Keywords:

ESP 32, Bluetooth BLE, LoRa SX1276, JSN-SR04T sensor

Corresponding Author:
Morlan Pardede
Politeknik Negeri Medan
Email: morlanpardede@gmail.com

ABSTRACT

This study designs and develops a water level monitoring system for fish ponds based on the Internet of Things (IoT) using wireless communication channels Bluetooth low energy (BLE) and Lo-Ra The system consists of a Sensor Node, Repeater, Gateway, and the Blynk Cloud application. The Sensor Node detects the water level and pump condition, processes the data, and transmits it to the Repeater via BLE signals. The Repeater receives information from the Sensor Node and sends it to the Gateway using Lo-Ra signals. The Gateway receives the data and send it to the Blynk Cloud via WiFi and cellular networks. To conserve battery usage on the Repeater, the transmission process is scheduled periodically, where after sending information to the Gateway, the ESP-32 enters deep sleep mode for 60 seconds before resuming operation. Based on testing, the JSN-SR04T ultrasonic sensor can measure pond water levels ranging from 20 cm to 200 cm with a maximum error of 3% and an average error of 1%. The communication range of BLE in LOS (Line of Sight) areas with a 7dBi antenna can reach up to 40 meters, while the communication range of LoRa can reach up to 700 meters. By utilizing deep sleep mode on the Repeater to delay delivery battery usage is significantly more efficient compared to using the delay function, where a delivery delay of 60 seconds saves 143% and the longer the delay, the more economical the use of deep sleep. The water level and pump condition messages from the Sensor Node to the operator via Blynk vary between 8 to 25 seconds, depending on the internet signal.

INTRODUCTION

The water level in a pond affects both temperature and oxygen content. Shallow ponds tend to heat up more easily, which can reduce dissolved oxygen levels. Additionally, water depth influences the risk of fish jumping out of the pond, especially for active fish like koi [1] . The ideal water depth of the pond depends on the type of fish being kept. For Koi fish, the recommended depth is between 1 and 1.5 meters, and the water temperature should be around 20ºC to 30ºC. By using the Internet of Things, the water quality of Koi fish ponds can be monitored in real-time [2]. To monitor pond water levels in rural areas without internet signals, a wireless network is required to transmit information from a sensor node in a rural location to a gateway in an area with internet access. To overcome signal obstructions caused by hills or trees, a repeater is needed to relay information until it reaches the gateway. The repeater must be strategically positioned to ensure the signal is unobstructed between the sensor node and the gateway. In locations without a power source, the repeater must rely on batteries. To conserve battery power, the system must use components with low energy consumption and implement effective power management strategies. Low-energy communication channels such as BLE and LoRa are viable options. BLE communication ranges are limited to 100 meters, while LoRa can reach up to 15 kilometers, although BLE consumes significantly less power than LoRa. One of the ultrasonic sensors available in the market is the JSN-SR04T, which is designed with waterproof capability and high measurement accuracy. It offers a reading range from 20 cm to 100 cm with an error rate of 1.28% [3].

The ESP32 is a microcontroller chip equipped with WiFi and Bluetooth 4.2. The ESP32 board includes a strip antenna and a low-noise amplifier, making it suitable for IoT applications. One of its advantages is its low power consumption, which can be managed using sleep modes. The ESP32 features five power modes: Active Mode, Modem Sleep Mode, Light Sleep Mode, Deep Sleep Mode, and Hibernation Mode. Each mode determines which hardware components (CPU, WiFi/BT, RTC, Co-Processor) are inactive or in sleep mode. The highest power consumption occurs in Active Mode, while the lowest consumption occurs in Deep Sleep Mode and Hibernation Mode [4]. When transmitting via BLE, the ESP32 consumes approximately 130mA, and while the BLE module is listening, it consumes about 95mA. In Modem Sleep Mode, the CPU consumes around 25mA, and in Deep Sleep Mode, the ESP32 consumes only about 150µA. Communication via BLE on the ESP32 for a distance of 15 meters resulted in a round trip time of 0.01018 ms [5].

One wireless communication technology widely applied in IoT is LoRa (Long Range). LoRa offers long-range communication with low power consumption, resulting in extended battery life. It supports two-way communication, is secure and efficient, and resists interference. The LoRa SX1276 is a Radio Frequency transceiver module designed by Semtech, utilizing Chirp Spread Spectrum (CSS) modulation. It offers a range of up to 15 kilometers and features low power characteristics[6]. The SX1276 can achieve a sensitivity of more than -137 dBm. The output power of the SX1276 can be configured up to +20 dBm (100 mW). LoRa can be used for environmental monitoring in rural areas with a communication range of over 800 meters and a packet loss rate of 20% [7]. LoRa has the potential to be applied in rural development, such as IoT networks, to explore resources like agriculture, environment, and soil [8]. One of the platforms available, both free and paid, is Cloud Blynk. Using the Blynk application, the pH and turbidity levels of koi fish ponds can be automatically transmitted to smartphones [9].

METHODS
The block diagram of the water level monitoring system is shown in Figure 1, and the circuit diagram is shown in Figure 2.

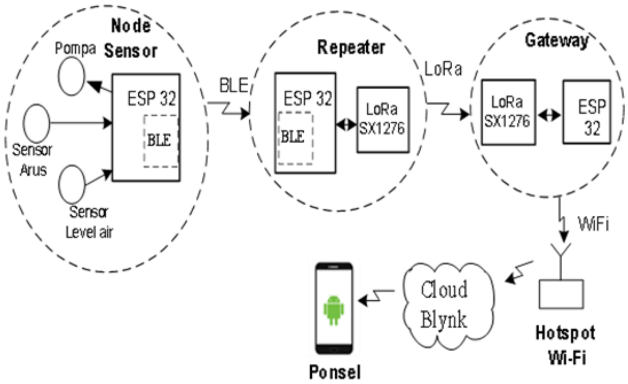

Figure 1. Block Diagram of the Fish Pond Water Level Monitoring System.

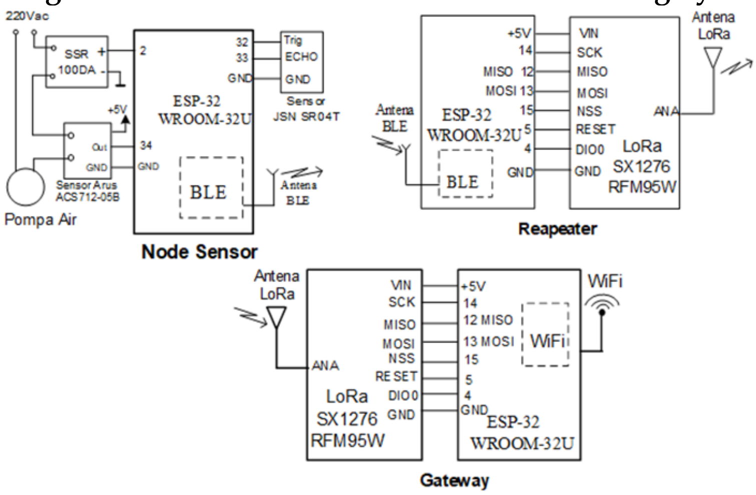

Figure 2. Circuit Diagram of the Fish Pond Water Level Monitoring System.

The sensor node consists of an ultrasonic sensor JSN-SR04T to detect water level, a Solid State Relay (SSR) to turn the pump ON/OFF, an ACS 712 current sensor to detect whether the pump is ON or OFF, and an ESP-32 WROOM-32U microcontroller (equipped with a Wi-Fi and Bluetooth modem) as the processor and BLE antenna with 7dBi gain. The ultrasonic sensor is placed 200 cm above the pool floor, so the pool water depth is:

Pool Water Depth = 200 - Distance from sensor measurement ……………………(1)

In this study, the water level is maintained between 100 cm and 110 cm. If the water level is below 100 cm, the pump will turn ON, and if the water level is above 120 cm, the pump will turn OFF. If the water level is between 100 cm and 120 cm, the pump condition remains unchanged. Turning the pump ON is done by sending a logic "1" to the positive input of the Solid State Relay SSR100DA, and logic "0" to turn off the pump. When logic "1" is given to the SSR, but the output voltage of the ACS712 current sensor is below 2.5 volts, it means the pump is not working or is damaged.

The flow diagram of the program on the sensor node is shown in Figure 3, starting from port initialization and setting BLE parameters. The BLE on the sensor node is set as a server with the UUID service "af0f1e46-3b4d-4914-81c0-9a82928e13cc" and the UUID characteristics "5cb760b6-a6ab-4778-8107-15fbf5dcd6a5". If the BLE signal from the sensor node is connected to the BLE Repeater, the sensor node sends the water level and pump status to the Repeater via the BLE channel.

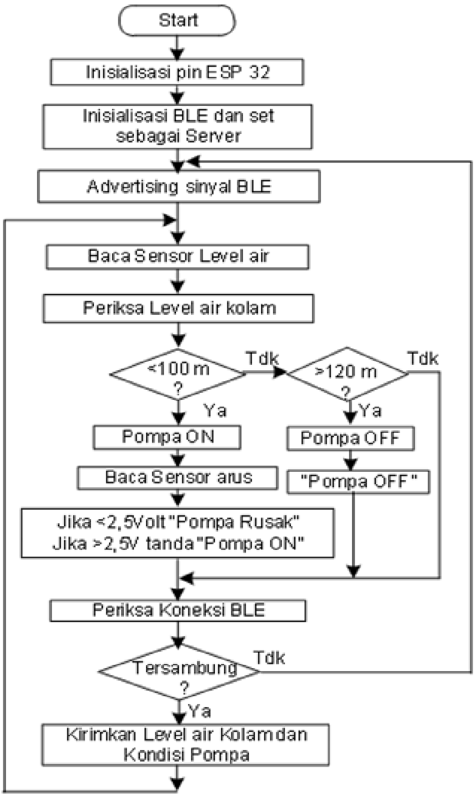

Figure 3. Flow Diagram of the Sensor Node Program

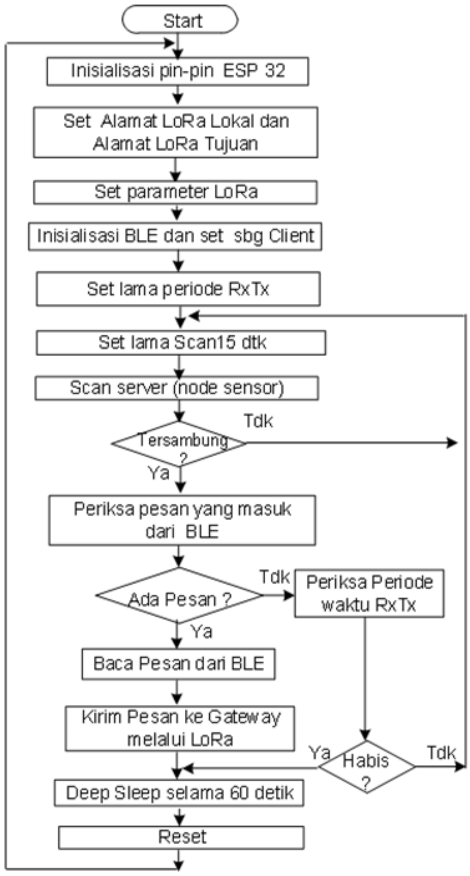

Figure 4. Flow Diagram of the Repeater Program

The Repeater consists of an ESP-32 WROOM-32U as the processor, a BLE antenna with 7dBi gain to receive signals from the sensor node, and a LoRa SX1276 with a 5dBi antenna to send information to the Gateway. The BLE on the Repeater acts as a client with the same UUID services and UUID characteristics as the BLE on the sensor node.

The flow diagram of the program on the Repeater is shown in Figure 4, starting from the initialization of the ESP32 pins, setting the BLE parameters, setting the LoRa parameters, activating BLE as a client, setting the reception and transmission message periods, and scanning the server for 15 seconds. Once connected, it will receive the pool water level message from the sensor node via the BLE channel and send the pool water level message to the gateway via the LoRa channel. The ESP32 then enters deep sleep mode for 60 seconds before resetting.

The format of the message packet frame sent by the Repeater to the Gateway via LoRa is shown in Figure 5, where the message consists of the water level and pump condition.

Figure 5. Message Frame Sent by the Repeater via LoRa

The Gateway consists of a LoRa SX1276 with a 5dBi antenna to receive information from the Repeater, an ESP32 with a 3dBi WiFi antenna to send the data to a WiFi hotspot, and then to the Blynk Cloud via the internet network.

The flow diagram of the Gateway program is shown in Figure 6, starting with the initialization of the ESP32 pins, setting up the LoRa and WiFi parameters, activating WiFi as a client, connecting to the WiFi hotspot, and Blynk. It detects whether a message has been received via LoRa, and if the message is from the Repeater, it is read. If there are no errors, the data of the pool water level and pump condition are checked to determine if they are normal or not. If the received water level is below 90 cm, above 130 cm, or if the pump condition is damaged, an alarm will be triggered, and the event log "Danger, Please Check the Pool Immediately" will be sent. The pool water level data is then sent to the Blynk Cloud through the Virtual Terminal.

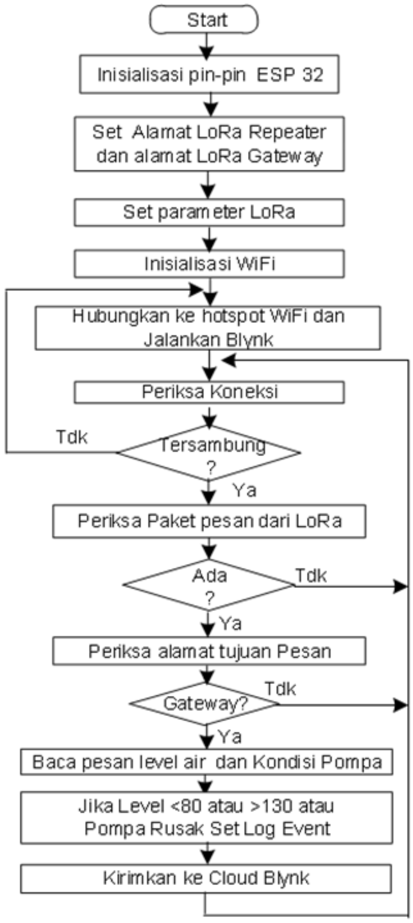

Figure 6. Flow Diagram of the Gateway Program

Blynk Cloud Dashboard In the Blynk Cloud, a data stream is created so that information about the pool water level can be displayed on the dashboard in the form of a gauge and a chart. This allows the current and previous pool water level values to be shown. The template also includes an event mode where, if the pool water level is abnormal or the pump is damaged, Blynk will send a notification to the operator, allowing them to respond promptly.

RESEARCH RESULTS

The results of the pool water depth measurements compared to the measurements with a tape measure are shown in Table 1. From the table, the maximum error is found to be 3%, and the average error is 1.0%.

Table 1. Results of Surface Water Level Sensor Testing

No.	Fish Pond Water Depth (cm)	JSN-SR04T Sensor Measurement	Error (cm)	Error (%)
1	30	30,9	-0,9	3,00
2	50	51,1	-1,1	2,20
3	70	71,3	-1,3	1,86
4	80	80,8	-0,8	1,00
5	90	90,6	-0,6	0,67
6	95	95,4	-0,4	0,42
7	100	100,5	-0,5	0,50
8	105	105,2	-0,2	0,19
9	110	109,6	0,4	0,36
10	115	114,2	0,8	0,70
11	120	119,2	0,8	0,67
12	125	124,1	0,9	0,72
13	130	128,8	1,2	0,92
14	135	133,6	1,4	1,04
15	150	148,2	1,8	1,2
Rata-rata Error				**1,0 %**

The BLE signal range measurement was conducted from a distance of 5m to the range where the message can still be received in a line-of-sight (LOS) area. The measurement results are shown in Table 2.

Table 2. BLE Communication Range Test Results

No	Distance (m)	Message sent	Message Received	RSSI (dBm)	Information
1	5	>105&OFF#	>105&OFF#	-76.	Accepted
2	10	>90&ON#	>90&ON#	-88	Accepted
3	15	>112&OFF#	>112&OFF#	-90	Accepted

4	20	>115&OFF#	>115&OFF#	-94	Accepted
5	25	>120&OFF#	>120&OFF#	-86	Accepted
6	30	>98&ON#	>98&ON#	-90	Accepted
7	35	>110&ON#	>110&ON#	-95	Accepted
8	38	>140&OFF#	>140&OFF#	-97	Accepted
9	40	>80&ON#	>80&ON#	-99	Accepted
10	44	>85&ON#	---	--	Not accepted

The LoRa communication range test between the Repeater and the Gateway was conducted by measuring the reception level at the Gateway, namely RSSI and SNR, starting from 50m until the Gateway can no longer receive messages from the Repeater. The measurement was performed in a line-of-sight (LOS) area. The measurement results are shown in Table 3.

Table 3. LoRa Communication Range Test Results

No	**Distance (m)**	**Message sent**	**Message Received**	**RSSI (dBm)**	**SNR**	**Information**
1	50	>90&ON#	>90&ON#	-89	10.81	Message Received
2	100	>101&ON#	>101&ON#	-95	9.25	Message Received
3	200	>118&ON#	>118&ON#	-103	9.02	Message Received
4	400	.>130&OFF#	.>130&OFF#	-109	8.18	Message Received
5	550	>128&OFF#	>128&OFF#	-112	7.48	Message Received
6	700	>119&OFF#	>119&OFF#	-119	5.94	Message Received
7	720	>112&OFF#	--	--	--	Message Not Received

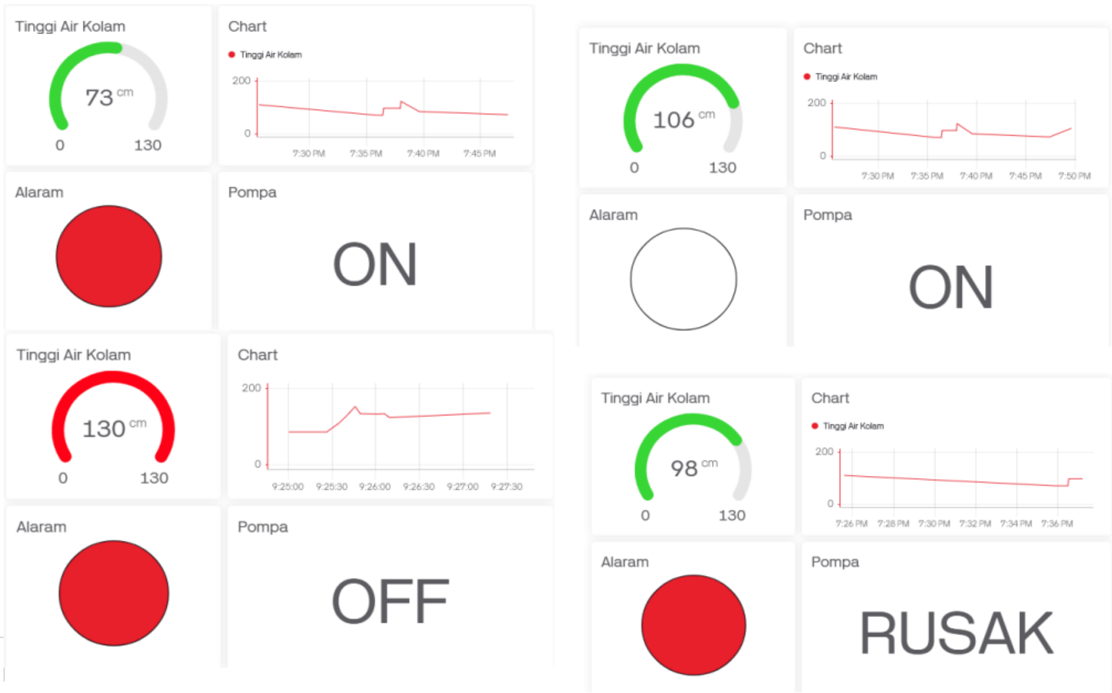

Figure 8. Observation Results on the Blynk Dashboard

Message Delivery Delay

The measurement results of the delay in water level information displayed on the Blynk dashboard and the delay of warning messages received by personnel via email are shown in Table 4.

Table 4. Communication Range Testing Results Energy Consumption of Repeater

No	Delivery Time	Fish Pond Water Depth (cm)	Receive Time	Received on Dash-board	Delay Duration (seconds)	Email received by Officer	Receive Time
1	14:48:21	70	14:48:31	70	10	Danger Pool	14:49:01
2	14:50:34	90	14:50:49	90	15	----	
3	14:52:58	103	14:53:24	100	26	----	
4	14:55:01	120	14:55:12	120	12	Pump Malfunction	14:56:05
5	14:57:15	110	-----	--		---	--
6	14:59:35	104	14:59:55	104	20	----	--
7	15:05:40	108	15:05:59	108	19	----	
8	15:09:55	131	15:10:16	131	21	Danger Pool	15:11:03
9	15:16:01	108	15:16:47	108	46	----	--
10	14:19:12	106	15:19:57	106	45	----	--

Repeater Energy Consumption

The process sequence carried out by the Repeater repeatedly includes initializing and connecting to the sensor Node and receiving messages, which takes approximately 16 seconds with a current consumption of around 30.06 mA. Receiving messages from the sensor node and sending them to the Gateway via LoRa takes approximately 1.5 seconds with a current consumption of around 150.2 mA. Entering deep sleep mode as a delay mechanism for 60 seconds consumes around 2.98 mA, and the system then resets. The measured current consumption of the Repeater module during a 60-second deep sleep delay is shown in Figure 9.

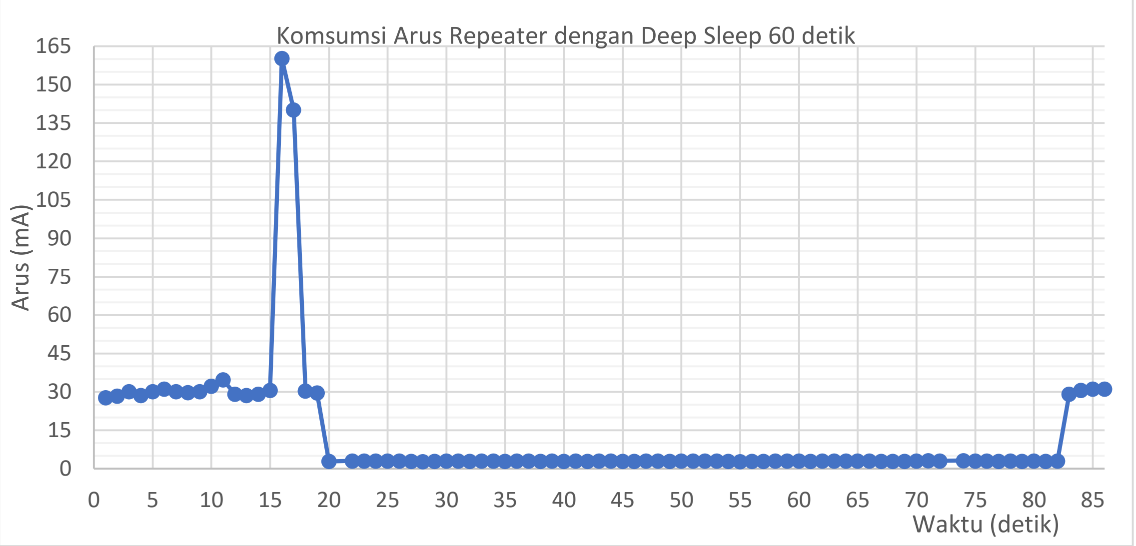

Figure 9. Current Consumption Graph of the Repeater with 60-second Deep Sleep

The total current consumption of the Repeater during 77.5 seconds using a 60-second deep sleep is:

ITot Repeater_Sleep=16×30.06mA+1.5×150.2mA+60×2.98mA=885.06mA

Average current:

$$I_{\text{avg}} = \frac{885.06\,\text{mA}}{77.5\,\text{s}} = 11.42\,\text{mA}$$

Using a battery with a capacity of 3000 mAh, the battery can supply power for:

$$\frac{3000\,\text{mAh}}{11.42\,\text{mA}} = 262.69\,\text{hours}$$

If a 60-second deep sleep delay is replaced with a delay function (delay(60000)), the Repeater will pause for 60 seconds. During this delay, the measured current is 24.85 mA. The total current consumption during 77.5 seconds using the delay function is:

16×30.07mA+1.5×153.1mA+60×24.85mA=2,278.32mA

Average current:

$$I_{\text{avg}} = \frac{2,278.32\,\text{mA}}{77.5\,\text{s}} = 29.40\,\text{mA}$$

With a 3000 mAh battery, the Repeater can be powered for approximately:

$$\frac{3000\,\text{mAh}}{29.40\,\text{mA}} = 102.05\,\text{hours}$$

Energy savings using a 60-second deep sleep compared to a 60-second delay function is 157%

CONCLUSION

After the design, development, and testing process, the following conclusions were obtained: The JSN-SR04T sensor can detect water surface levels from 20 cm to 200 cm with a maximum error of 3% and an average error of 1%. The maximum signal range of the BLE ESP32 sensor Node to the Repeater with a 7 dBi antenna is 40 meters with an RSSI of -99 dBm. By setting the LoRa power to 20 dBm (100 mW), the communication range for a line-of-sight area and a 5 dBi antenna between the Repeater and Gateway can reach 700 meters. Using deep sleep to delay message transmission in the Repeater saves more battery compared to using the delay function. By connecting the Gateway to the Blynk cloud, water surface level monitoring can be performed from anywhere with internet access, with a delay time of approximately 10 to 25 seconds depending on the internet signal condition. When the water level is abnormal or the pump is not functioning, the Blynk cloud can immediately send notifications to personnel, enabling prompt inspection of the fish pond, thereby preventing significant losses. By using low energy BLE and LoRa wireless networks, the condition of fish ponds in rural areas can be monitored from the Internet (Cloud Blynk).

REFERENCES

[1] A. Kusnandi, Hamid, L.G Sumahiradewi, "Pengaruh Ketinggian Air Terhadap Perumbuhan dan Kelangsungan Hidup Benih Ikan Koi (Cyprinus Carpio)," Al-Aqlu: Jurnal Matematika, Teknik dan Sains https://jurnal.yalamqa.com/index.php/aqlu. e-ISSN : 2985-4369 Vol. 2 , No. 1, Januari 2024.

[2] S. Y. Damayanti, dkk, "Sistem Monitoring Kualitas Air Tambak Ikan Koi (Cyprinus Carpio) Berbasis Teknologi Internet Of Things (IOT)", Seminar Nasional Inovasi Teknologi, UN PGRI Kediri, 24 Juli 2021, e-ISSN: 2549-7952 ; p-ISSN: 2580-3336.

[3] H. Purwanto, M. Riyadi, Destiana, I. Wayan,"Komparasi Sensor Ultrasonik HC-SR04 dan JSN-SR04T untuk Aplikasi Sistem Deteksi Ketinggian Air", Jurnal Teknik Industri, Mesin,Elektro dan Ilmu Komputer (Simetris), 2019, https://jurnal.umk.ac.id/index.php/simet/article/view/3529/1907.

[4] Yani Prabowo, "Analisa Power Mode ESP32 Untuk Catu Daya Pada Sistem Berbasis IoT", 2022, https://seminar.iaii.or.id/index.php/SISFOTEK/article/view/351.

[5] B. S. Mahendra, Agung, "Perancangan Sistem Monitoring Konsumsi Listrik Dan On/Off StopKontak Pada Smarthome Dengan Media Komunikasi Bluetooth Low Energy", Jurnal Pengembangan Teknologi Informasi dan Ilmu Komputer, Vol. 5, No. 2, Februari 2021, hlm. 779-788, e-ISSN: 2548-964X, http://j-ptiik.ub.ac.id

[6] Santini, *"Integration and evaluation of LoRa sensors in GreenIoT"*, http://www.teknat.uu.se/student.

[7] M. S. Hidayat, A. P. Nugroho, L. Sutiarso, and T. Okayasu, "Development of environmental monitoring systems based on LoRa with cloud integration for rural area", *IOP Conference Series: Earth and Environmental Science*, *355*(1), 2019, https://doi.org/10.1088/1755-1315/355/1/012010.

[8] E. Murdyantoro, dkk,"A review of LoRa technology and its potential use for rural development in Indonesia", *AIP Conference Proceedings* 2094, 020011, 2019, https://doi.org/10.1063/1.5097480.

[9] A.Taufik, A.Fadlil,"Sistem Monitoring pH dan Kekeruhan Kolam Ikan Koi Berbasis Internet of Things Menggunakan Aplikasi Blynk", Jurnal Jurnal Teknik Elektro Vol. 14. No. 01, Januari. 2023: 56-61. p-ISSN: 2086- 9479 e-ISSN: 2621-8534. http://publikasi.mercubuana.ac.id/index.php/jte.