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Television Transmitter Relay Performance Monitoring System Based on the Internet of Things and the MQTT Protocol: A Case Study

Leonardus Sandy Ade Putra*[1], Eka Kusumawardhani[1], and Vincentius Abdi Gunawan[2]

[1] Department of Electrical Engineering, Universitas Tanjungpura, Indonesia
[2] Department of Informatics Engineering, Universitas Palangka Raya, Indonesia
Email: {leonardusandy; ekawardhani}@ee.untan.ac.id; abdi.g05@gmail.com

Abstract

Television transmitters (television relays) are important devices in amplifying television signals and are tasked with distributing them to all users in a broader area. Each transmitting device is divided into receiving and sending devices placed on each tower in a specific area. The device's location is under and above the tower, with a height of around 100 meters from the ground. The condition of the location of the equipment that is far from reach, both in terms of the location of the tower and the height of the location of the equipment, needs to be improved in monitoring the performance of the device. The location of the device, which is in an extreme area, often causes the transmitter device to experience internal and external damage. Damage to internal factors is usually caused by the instability of the voltage or current that works on the device. In contrast, external factors can occur due to lightning, scorching weather, and other conditions. This study aims to design a system that can remotely monitor-transmitter devices for various sensor parameters by integrating the monitoring process more efficiently and more easily to overcome the problems of these two factors. The designed system utilizes Long Range (LoRa) technology as a sensor node data transmission from the tower, which is then forwarded using Internet of Things (IoT) communications to send data to the cloud database and utilizes the Message Queuing Telemetry Transport (MQTT) protocol as data transmission security. The designed system reads five device conditions and environmental conditions around the device to find out the real-time conditions of relay performance. The results show that each sensor node can work with a distance of more than 500 meters to communicate via LoRa, which can then be monitored via the website. Environmental temperature and humidity conditions do not significantly affect the device voltage and current and the performance of the sensor node. The device's voltage works at an average value of 4.8V and an average current of 0.34A. Environmental conditions influence data communication systems, with signals reaching -61 dBm in particular weather. Overall, monitoring the RSSI signal value for sending sensor data on average works at a value of -41.57 dBm, which is stated as a good quality signal condition, and sensor data can be displayed in real-time.

Keywords: *Televsion Transmitter, MQTT Protocol, Long Range (LoRa), Internet of Things (IoT), Website Monitoring.*

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1. Introduction

A television relay station or commonly referred to as a TV transmission unit, is a place that is useful for transmitting television broadcasts in its coverage area. Television relay stations are generally placed in the highlands and on the border to forward television broadcast programs from the central television station to all user areas in Indonesia. The importance of continuing television programs is seen from the content of programs that contain formal education programs, such as distance learning or school programs, as well as non-formal education programs, such as educational programs for children or training programs for the community. Television programs also help broaden people's horizons and knowledge on various educational topics, including science, technology, and culture. With a good television program, it is hoped that it can improve access to and quality of education in Indonesia, especially for those who live in remote or hard-to-reach areas.

In order to realize the distribution of television programs, television relays are placed on transmitter towers with an average height of above 100 meters from the ground. The transmitter power for each relay is rated from 0.1 kW to 180 kW [1]. The greater the transmitter's power, the better the broadcast quality and the more comprehensive the broadcast range, and vice versa.

Transmitting devices located above towers have a high risk of damage due to lightning that can strike the tower and provide a very high shock voltage, bad weather, and damage to the device itself which cannot be known directly without direct checking. Difficult geographical conditions, such as tower locations in hilly or border areas, can also complicate the process of monitoring and maintaining equipment. Therefore, a new alternative is needed in monitoring devices that are more efficient and flexible, such as remote monitoring technology, which can enable monitoring to be carried out remotely and provide more accurate and real-time information about the status and reliability of broadcast performance. It can help overcome problems and increase efficiency in maintaining and repairing the transmitting equipment on the tower.

This study aims to design a monitoring system to determine device voltage, current, temperature on the sensor node system and devices, ambient humidity, and power. Each sensor is placed on a transmitter device located on a tower with a height of 100 meters. Two methods, namely, do communication on this system; 1) Using Long Range (LoRa) to send data from the tower to the master system node. 2) Using the Internet of Things, which is used to send data to cloud databases and monitoring websites [2]. By using Internet of Things technology, monitoring of transmitter devices can be done remotely, providing more accurate and real-time information about the status and reliability of broadcast broadcasting performance, making it possible to take action more quickly and effectively in overcoming problems. This technology can also increase efficiency and flexibility in checking and maintaining transmitter equipment on the tower to help overcome the problems encountered.

2. Related Work

Related research using Internet of Things and LoRa technology to monitor a system has been carried out. Research that builds the Structural Health Monitoring (SHM) platform using Internet of Things was carried out by Md Anam et al. Monitoring health by utilizing the Rasberry Pi platform as a master microcontroller for a system designed to perform calculations using a mathematical model has been successfully monitored and applied as a health monitoring tool [3]. On the other hand, Ahmad Roihan et al. utilizes Internet of Things as a communication system for monitoring and controlling server areas. Internet of Things sends messages via SMS Gateway with input from the MQ-02 sensor, DHT22 sensor, and Wemos D1. The data is sent to remotely monitor the condition of the server area in real-time and simultaneously provides a sense of security for the company in maintaining server performance [4].

Padlan A. and Nanang Ismail designed an Internet of Things-based Uninterruptible Power Supply (UPS) monitoring system using the MQTT protocol. An Arduino microcontroller connected to an Ethernet shield helps the UPS monitoring process and displays monitoring results via a web-based application. The results show the difference in data obtained from the sensor compared to the measuring instrument, with each parameter having a difference of 0.20% [5]. The MQTT protocol was also carried out by researcher Ao Huang et al. to monitor sensor nodes in the sea. The designed sensor nodes communicate with each other through the LoRa network, which is then continued through Internet of Things communication. Through this designed system, researchers have succeeded in monitoring sensor nodes far from the mainland in real-time with more than 5 kilometers [6]. The current use of Internet of Things for broadcast monitoring, up to broadcast monitoring of audio transmitter devices carried out by Huang Haocheng, is carried out to determine the conditions and coverage of audio broadcasts emitted by radio transmitters. The designed architecture has a high level of complexity by utilizing several system layers, from the perception layer and the network layer to the application layer as a monitoring system interface [7].

By utilizing various Internet of Things and LoRa technologies for various fields of science [8]–[10], the researchers proposed the idea of designing a new monitoring system for monitoring the transmitting and receiving transmitter devices (relay devices) on television transmitters in the tower and monitoring devices designed to utilize the combination of Internet of Things and LoRa communication technologies in monitoring the system. LoRa in this study is used to receive data monitoring the condition of the equipment located on a tower with a height of 100 meters. The system control master located at the transmitter station receives data which is then sent to the cloud system to be displayed on the website via the Internet of Things communication system. With this design, monitoring the transmitter equipment's condition can be carried out in real-time and can quickly take action when damage occurs.

3. Method

This section describes the system architecture, workflow, sensor node design, and monitoring system interface used in the television transmitter monitoring system. The system architecture includes the design of the transmitter architecture and system communication to the monitoring interface. Meanwhile, the system workflow discusses sending data via the MQTT protocol. Then the sensor node design explains the desired parameters in the monitoring process, and the monitoring interface explains the features contained in the user interface section.

3.1. System Architecture

This section describes the system architecture designed to monitor the transmitting equipment on the tower. The architecture is divided into three main parts: the user side, sensor nodes, and data communication systems that work in an integrated manner in one device monitoring system. Figure 1 provides a clear picture of the monitoring system.

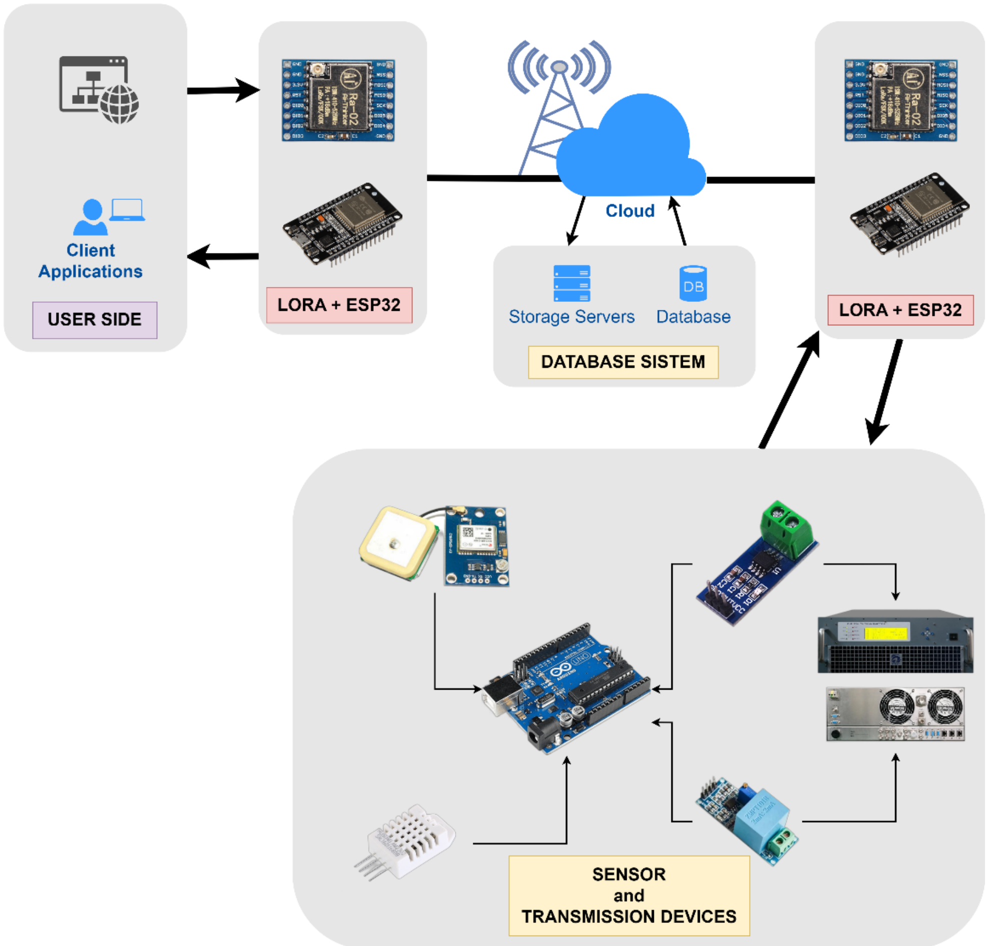

Figure 1. Monitoring System Architecture.

The user side is part of the monitoring system interface that displays the results of sensor node readings on the transmitter device. Utilization of the website as an interface is used to facilitate remote monitoring of measurement results. Users can monitor every parameter in real time through continuous communication between the website and sensor nodes via Internet of Things communication and MQTT Brokers [11]. The sensor node is the most crucial in recognizing the conditions and environment around the transmitter device. The sensor node consists of various sensors and communication modules that are used to read the state of the transmitting device continuously. The obtained sensor data will be sent to the user via LoRa communication and sent via Internet of Things to the MQTT Broker.

Long Range uses the Ra-02 with an antenna added to obtain a farther area coverage. LoRa communication transmits data with a security code provided in the script to protect the observed sensor node data [12].

This system architecture also shows the computing process in the cloud and database storage of sensor reading results. Data processing from sensors uses the Arduino Uno microcontroller as the system computing master and the LoRa module as a communication tool. The communication and sensor node sections are equipped with a power supply module that supplies electrical power to the system. ESP32 is used to assist in sending data to the internet network. Then the data will be processed by publishing and subscribing through the MQTT broker [13]. Each ESP32 module is equipped with a script to continuously publish and subscribe to the broker server to generate real-time readings. With this architecture, the monitoring system can effectively obtain data from sensor nodes regarding the condition of the transmitting device. Users can then access the data through the user side for real-time monitoring through Internet of Things communication and MQTT Brokers.

3.2. System Workflow

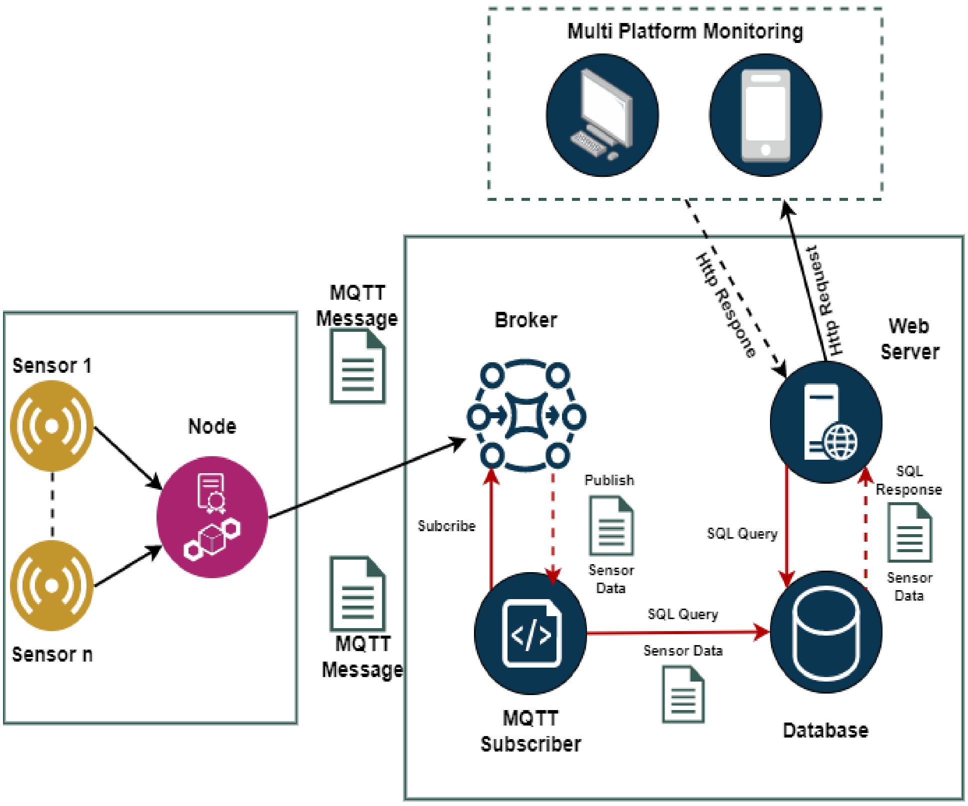

Figure 2. Flow diagram of system data delivery.

The flowchart of the process of transmitting data for the transmitter device monitoring system is shown in detail in Figure 2, which explains the process for data from sensors sent via the MQTT protocol to the interface. The Message Queuing Telemetry Transport (MQTT) protocol is a protocol that is widely used in Internet of Things (IoT) communications because it has a lightweight design, is efficient in bandwidth usage, and can be implemented on various platforms [14]. This protocol is specifically designed to transmit data and messages between devices connected to the Internet of Things network by taking advantage of low bandwidth and unstable network connections [15]. MQTT uses a publish-subscribe model, in which devices or clients connected to an MQTT broker can publish messages or subscribe to specific topics to receive messages published by other devices or brokers. In addition, MQTT also uses QoS (Quality of Service) to regulate the quality of message delivery. There are three QoS levels available, namely QoS 0 (fire and forget), QoS 1 (at least one delivery), and QoS 2 (definitely arrive) [16].

The use of the MQTT protocol in Internet of Things networks has several advantages. First, its ability to transmit data with low bandwidth and unstable network connections. Second, this protocol can optimize power usage on Internet of Things devices. Third, MQTT enables real-time and centralized data transmission with high security [17].

3.3. Sensor Node Design

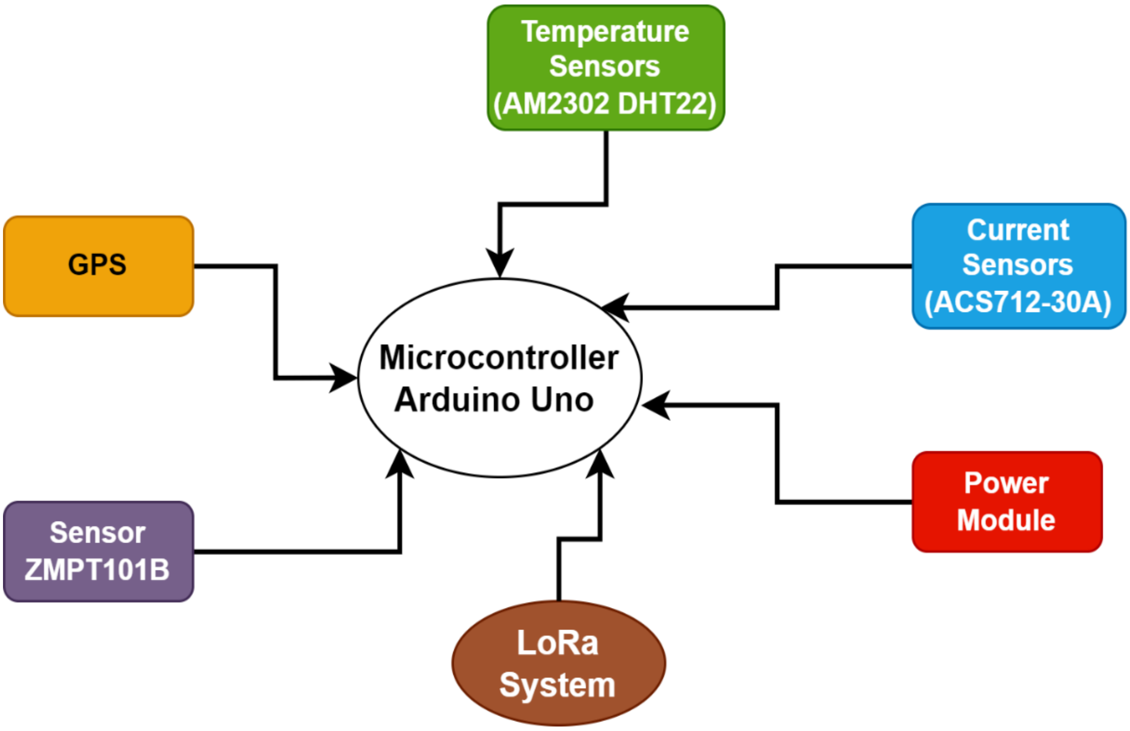

Figure 3. Block diagram of the node system.

The design of transmitter condition monitoring in this study involves the use of 4 sensors, namely temperature sensors, humidity sensors, voltage sensors, and current sensors, as well as power and data communication systems. The designed system node can monitor devices in real-time and be used remotely. This node integrates various components, such as the sensors, the GPS module, the power module, and the LoRa communication system, which communicate via the Arduino Uno microcontroller. The scheme of the system designed for the nodes is shown in

Figure 3. This node system is an essential part of the primary work system depicted in Figure 1, which describes the overall monitoring system architecture [18]. Sensor nodes are placed at several transmitter points that communicate with each other to monitor transmitter devices that are sensitive to weather and internal factors of the device itself.

3.4. Message Formats

Sensor nodes periodically publish sensor values to topics in the MQTT broker. The sensor values are then converted into a string data type of five parts separated by a space character. Parameters sent through the MQTT Broker include Device ID, Device Voltage, Device Current, Device Temperature, and Humidity around the device [14]. For example, the message sent by the sensor node could be "1 4.95 0.23 35.8 84," and as an example, this information can be shown in Table 1.

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Tabel 1. Message Formats.

Message = 1 4.95 0.23 35.8 84	
Parameters	***Value***
Device ID	1
Voltage (V)	4.95
Current (A)	0.23
Onboard Temp (%)	35.8
Humidity (%)	84

3.5. Website Monitoring System

Website Monitoring is a system designed to monitor and control television transmitting equipment at a broadcasting station. This monitoring system uses a website as a user interface that allows users to view and manage information related to television transmitters in real time. The monitoring website allows users to view the status and performance reliability of broadcast broadcasting, such as the temperature, voltage, current, and humidity of transmitter devices. This information is obtained through sensors connected to the transmitting device and integrated into the system. The display of the monitoring system is shown in Figure 4, which presents the real-time sensor readings.

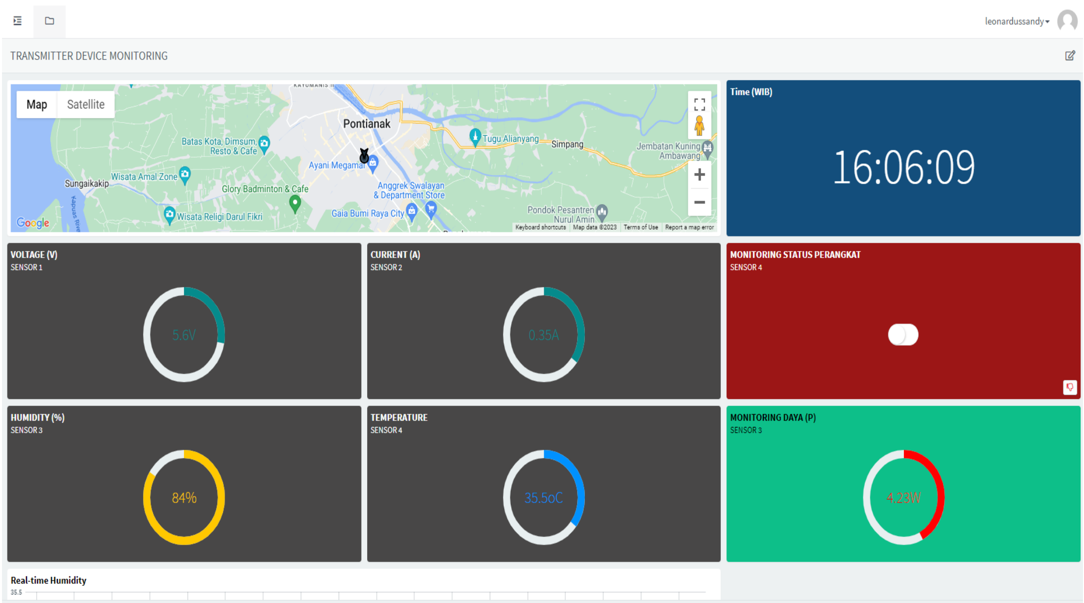

Figure 4. Display of the Monitoring System on the website interface.

Users can monitor the condition of the transmitter device, make device settings and configurations, and get reports and notifications regarding the transmitter's status. Users can also monitor and control devices remotely without having to be at the physical location of the transmitting device. Use Internet of Things technology and MQTT protocol-based communication to send and receive data between transmitter devices and backend servers. This enables efficient data transmission with low bandwidth usage. With a website monitoring system for transmitters, the operation and maintenance of television transmitters can be done more efficiently and flexibly [15]. Users can easily monitor and manage transmitting devices in real-time through the website [16], thereby minimizing the risk of damage and ensuring optimal broadcast quality.

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4. Experimental Results and Discussion

This study tested three aspects: device sensor testing, data communication testing through the MQTT Broker, and software testing as an interface monitoring system. The sending of data through the MQTT Broker is tested by running commands in script form to publish messages to topics appropriate to system performance. The script created contains sensor data accompanied by a device ID to make detecting the device being monitored easier. From all the data obtained from the sensors, the main observations were made on environmental influences in the form of temperature and humidity, which affect the value and performance conditions of the sensor nodes on television relay devices.

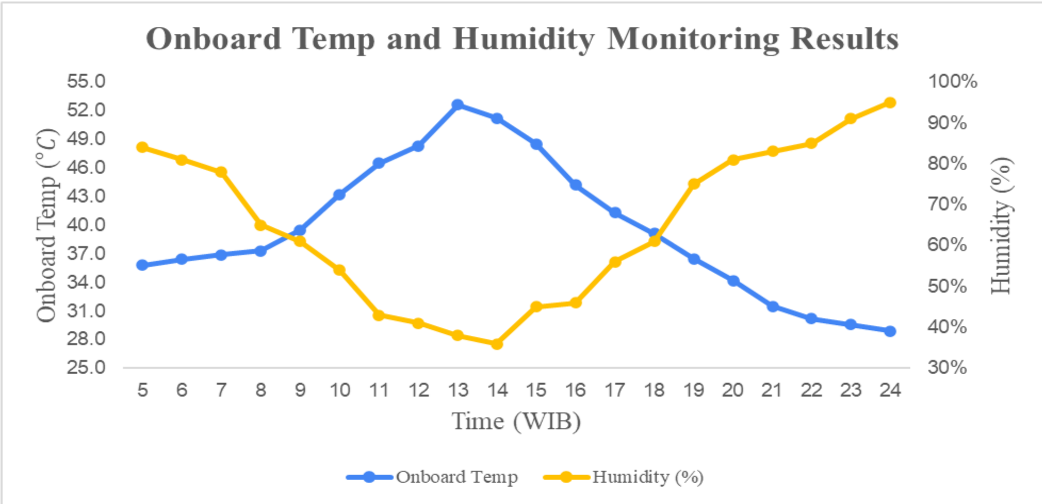

Figure 5. The results of measuring the temperature value of the sensor device against environmental humidity.

This research monitors the temperature and humidity in the area of the transmitter device as an initial process in maintaining the performance of the sensor node and the transmitter device. These two parameters are essential because they are related to the long-term robustness of the device sensor. Temperature and humidity readings are carried out using sensors, and the results are shown in Figure 5. The data presented includes the data collection process every hour from 05.00 WIB to 24.00 WIB.

From the sensor measurements, it can be seen that temperature and humidity have different patterns. During the 20 hours of monitoring, morning temperatures were relatively normal to moderate (between 34°C and 40°C). However, the temperature experienced a significant increase during the day, reaching its peak at 13.00 WIB with temperatures reaching 53°C. The temperature then drops in the afternoon, reaching below 31°C at night. This extreme and scorching temperature is caused by hot weather conditions around the device and low humidity values, which are factors that increase the temperature of the sensor device.

Humidity monitoring values show that humidity rises above 70% in the early morning and evening. From the results of monitoring these two parameters, it can be concluded that the temperature of the device is affected by the weather and humidity factors around it. One of the factors that can increase the temperature of the device is the performance process of the sensor node, which continuously reads. Therefore, monitoring to prevent extreme conditions that can damage the sensor node hardware devices and communication modules located on the transmitter tower is necessary.

To increase the resistance of sensor node performance, this research adds a cooler to cool the device and sensor nodes if the temperature exceeds 50°C or low humidity below 20%. It is expected to maintain the device's temperature within a safe range and prevent damage.

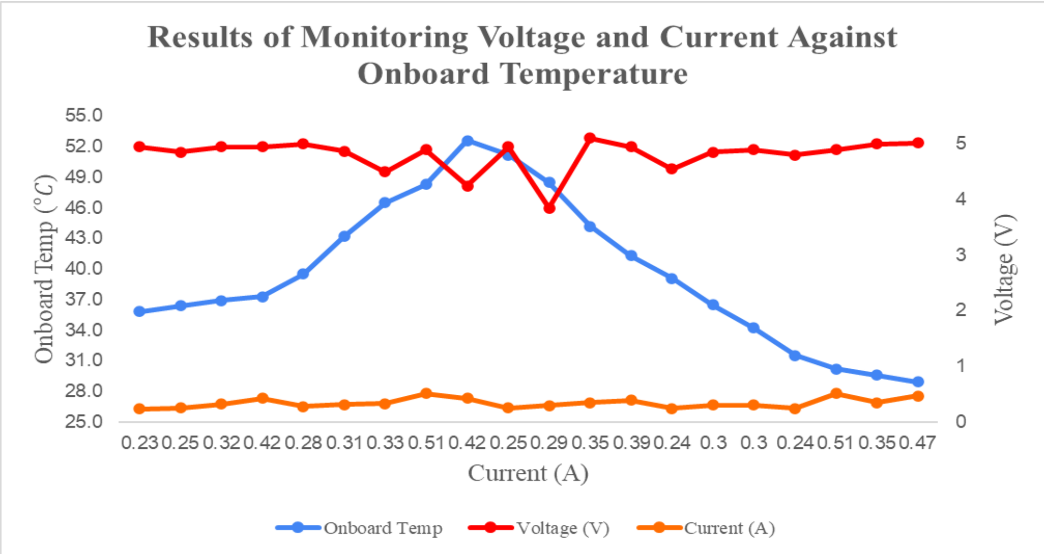

Figure 6. Results of monitoring the voltage and temperature values on the transmitting device.

Monitoring on the device prioritizes voltage and current as monitoring parameters generated by the transmitter device. Figure 6 shows the three parameters displayed, namely device temperature, voltage, and current of the transmitter device. From the data that has been obtained, the temperature does not significantly affect the performance of the device voltage. However, data anomalies occur during the day, showing that the voltage becomes less stable. The less stable voltage also affects the less stable current simultaneously. It is found that the sensor readings in the figure above are readings for one day which are illustrated for the next day with the same monitoring and reading system.

Table 2. The results of the sensor node readings on the transmitter device.

No	Time (WIB)	Voltage (V)	Current (A)	Onboard Temp (°C)	Humidity (%)	RSSI (dBm)
1	05.00	4.95	0.23	35.8	84%	-48
2	06.00	4.85	0.25	36.4	81%	-38
3	07.00	4.95	0.32	36.9	78%	-40
4	08.00	4.95	0.42	37.3	65%	-45
5	09.00	5	0.28	39.5	61%	-45
6	10.00	4.87	0.31	43.2	54%	-48
7	11.00	4.5	0.33	46.5	43%	-51
8	12.00	4.9	0.51	48.3	41%	-38
9	13.00	4.25	0.42	52.6	38%	-35

10	14.00	4.95	0.25	51.2	36%	-44
11	15.00	3.85	0.29	48.5	45%	-34
12	16.00	5.1	0.35	44.2	46%	-30
13	17.00	4.95	0.39	41.3	56%	-45
14	18.00	4.55	0.24	39.1	61%	-61
15	19.00	4.85	0.3	36.5	75%	-56
16	20.00	4.9	0.3	34.2	81%	-35
17	21.00	4.8	0.24	31.5	83%	-35
18	22.00	4.9	0.51	30.2	85%	-36
19	23.00	5	0.35	29.6	91%	-39
20	24.00	5.02	0.47	28.9	95%	-33

The sensor node device on the transmitter has obtained data continuously and is stored in the cloud database. Table 2 shows the sensor readings in one day for 20 hours. The sensor reading results presented have a period of 1 hour with five main parameters of sensor node condition, transmitter device, and quality of data transmission. The temperature reading on the sensor node device is carried out to determine the condition of the sensor so that it does not work at too hot temperatures, which causes damage to the sensor node and a decrease in the sensor system. Voltage and current readings on the transmitting device are carried out in real-time, which are then sent via LoRa communication. From the results of the voltage sensor readings, an average of 4.8V is obtained and an average current of 0.34A. In reading the temperature, the average temperature that works on the sensor node in one day is 39.58°C, and the lowest humidity increase reaches 36%.

After the sensor reading process from several parameters, the data will be sent via LoRa, which is then forwarded to the Internet of Things system to be processed and displayed on the monitoring website. Researchers observe the RSSI value to measure the relative quality of the signal received by the device, but it does not have an absolute value. The results of the observation of the signal quality obtained the best quality, which reached -30 dBm in the afternoon conditions. While the quality is quite good, the signal quality value is -61 dBm. The observation is that the unstable temperature on the sensor device and humidity conditions that are pretty extreme and work at 36% to 95% do not significantly affect the performance of sending data via the LoRa network.

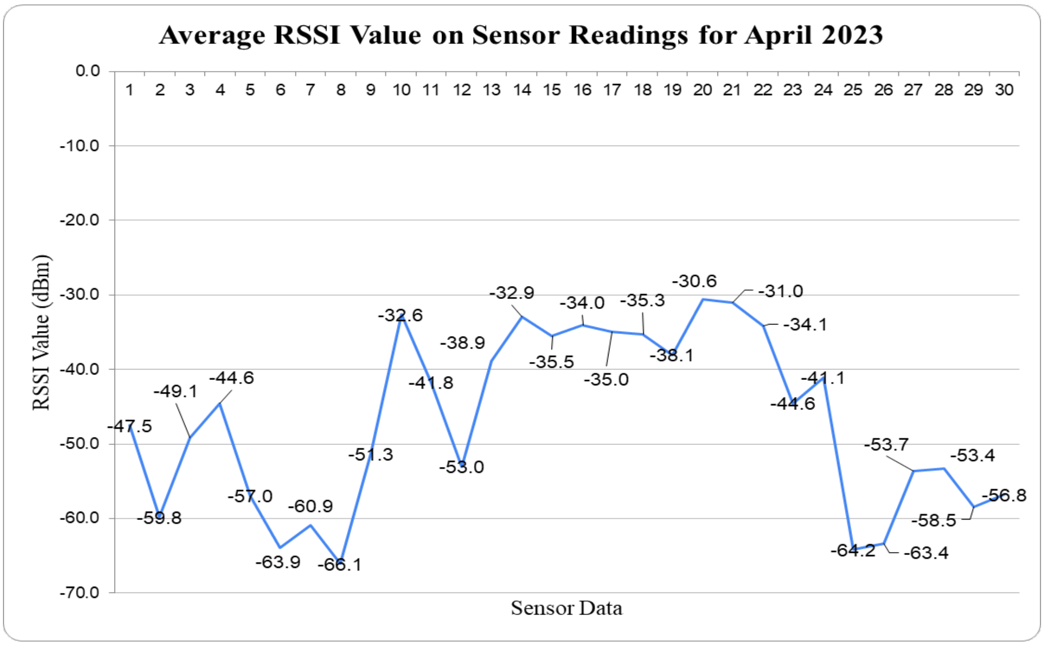

Figure 7. The average result of the RSSI value for data transmission.

Researchers made specific data observations in April for one month on the performance of sending data communication systems from sensor nodes to monitoring websites. From the data shown in Figure 7, the RSSI value has a fluctuating average. The changing RSSI value is obtained from data communication via the LoRa module to the Internet of Things module, which has a transmission distance from tower to tower of up to 500 meters. The change in the RSSI value in the data above can be grouped into three groups representing the chart area on a specific date.

Some of the RSSI values on April 1 - 9 stated that the values obtained for data transmission ranged from -66.1 dBm to -44.6 dBm. At the beginning of April, the quality of data transmission was quite good. Then on the following data delivery, April 10 – 24, the data transmission performance has an excellent index. It is because data transmission works and produces RSSI values between -30.6 dBm to -44.6 dBm. Furthermore, on April 25-30, the RSSI value decreased drastically from -64.2 dBm to -53.7 dBm.

The analysis of changes in the RSSI value resulted from several factors, namely the reliability factor of the sensor node device, the LoRa module as communication, and the weather factor from the surrounding environment. The performance factor of sensor nodes and communication systems has previously been tested and has excellent working values in reading the condition of transmitter devices and sending data. The next factor, the change in the weather for that month, is also the main factor in the change in the RSSI value obtained. The research area in April has extreme climate change and high rainfall. At the beginning and end of the month, the research location has rainy weather conditions, while in the middle of the month, the rainfall rate decreases, and there is no rain. From the weather factor, climate change and weather and rain conditions influence the RSSI value in the data transmission process. The weather factor causes the signal strength to decrease to a reasonably good level, but it can still transmit sensor reading data to the transmitting device.

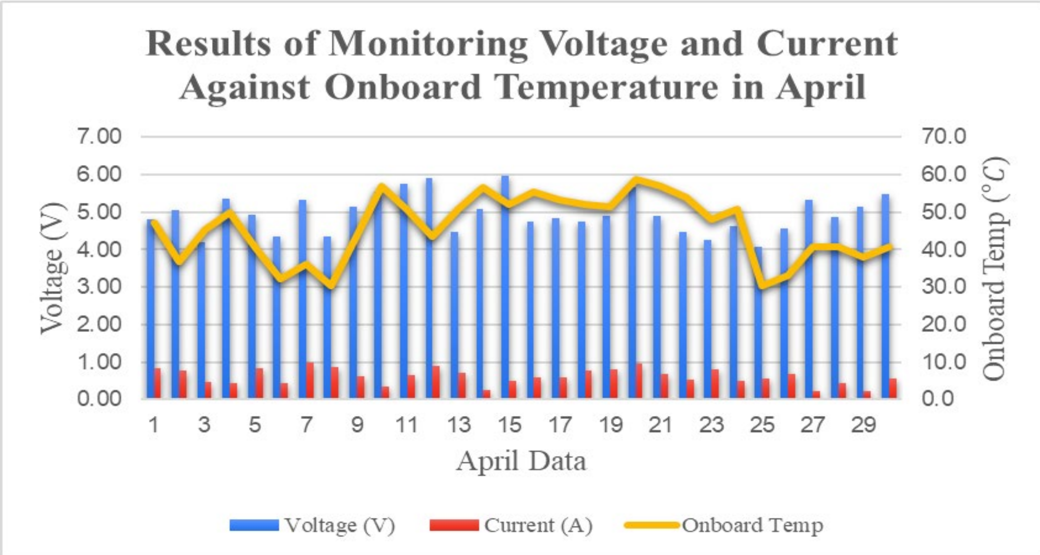

Figure 8. Results of monitoring the performance of transmitter equipment within 1 month.

The monitoring results during April have been presented in Figure 8, which states the three parameters between voltage, current, and device temperature. It is shown that changes in each of these parameters result from the average daily value and are outlined in the graph above to make it easier for data analysis. It can be seen that the voltage changes up to above 5.5 V occur when the current and temperature of the device increase.

Suppose it is described from the results of monitoring the RSSI value in Figure 7. In that case, it is found that the temperature of the device is affected by the weather in the surrounding environment. It can be seen from the increase in temperature that occurs in the middle of the month and the decrease in temperature that occurs at the beginning and end of April.

5. Conclusion

This research produces a monitoring system for television transmitters on towers that monitors several sensor parameters in real time via a monitoring website. The monitoring system using the MQTT protocol and LoRa communication can work very well by promoting efficient and low-cost results to reach tower locations that are difficult to reach, starting from the location and height perspective. The designed system can anticipate and handle damage from internal factors through sensor monitoring processes with parameters including voltage and current to determine the stability of the power on the transmitting device. Monitoring device temperature and humidity parameters is also carried out to overcome damage problems from external factors in extreme weather. The use of the parameter value of the RSSI signal is observed to determine the performance of LoRa communication on the data transmission system. The research showed that the value of environmental conditions in the form of temperature and humidity did not significantly affect device performance. In weather that causes the temperature to rise, placing the fan as an automatic cooler dramatically affects the stability of the performance of the relay device. However, environmental conditions impact data communication performance using LoRa, as evidenced by the RSSI signal value. The best value in sending data produces a signal value of -30 dBm, and the worst is obtained at -61 dBm, with the average value of the RSSI signal working at a value of -41.57 dBm. This value is excellent in data transmission conditions at remote locations and extreme weather areas. With the ability and performance of the system, it is possible to take action more quickly and effectively in overcoming problems that occur.

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