LoRa and IoT Based Monitoring System for Detecting Ganoderma Disease Attacks on Oil Palm Plants

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ABSTRACT

This research develops a monitoring system based on LoRa and IoT to detect ganoderma disease attacks on oil palm plants, aiming to detect ganoderma disease early. The method used involves the use of MQ-138 and TGS 2611 sensors to detect the level of volatile organic compounds gas emitted by palm trunks affected by ganoderma disease. The research results show that this system is capable of detecting ganoderma disease with a range of increased values on healthy palm plant samples: 0 - 5 values; moderate oil palm plants: 8 - 22 values; and on sick oil palm plants: 28 - 32 values. The system can also transmit data up to a range of 757.92 meters with an RSSI value of -105 dBm in conditions with minimal obstacles, and send and receive information from LoRa devices to Blynk IoT with an average time difference of 0.695 seconds for LoRa devices and 0.701 seconds for Blynk IoT.

Keywords: Ganoderma, Volatile, LoRa, IoT, Blynk IoT

1. INTRODUCTION

West Kalimantan can produce 5,742,925 tons of palm plantation yields with a planting area of 2,109,890 hectares. However, despite these abundant plantation yields, the productivity of palm plantations in West Kalimantan is still below average, i.e., 3,282 Kg/Ha compared to the national average of 3,339 Kg/Ha [1]. Disease is one of the factors affecting oil palm productivity. Even with good soil nutrient factors, crop productivity will still decrease if it is infected with diseases.

The type of disease that often and most damages oil palm plants is stem rot disease (Ganoderma) caused by the fungus Ganoderma boninense [2]. The mortality rate of plants due to ganoderma disease, which reaches 80%, causes a significant decrease in oil palm productivity by up to 50% per hectare area, with potential losses estimated to exceed USD 250 million [3].

Control of plant diseases is carried out by spraying pesticides, but excessive use of pesticides apart from causing financial losses also has a bad impact on the environment in the form of a buildup of chemical residues which can have a bad impact on the lives of living creatures in the surroundings[4], so information on the risk of plants being attacked by disease is needed so that pesticide use can be carried out wiser and more precise.

The difficulty in detecting infected plants is the cause of the high risk of plant mortality due to disease. Many oil palm plants are only known to have been diseased after it becomes severe, resulting in delayed handling and eventually being cut down [5]. Therefore, an early detection system is needed that can know as early as possible the condition and risk of oil palm plants being infected with diseases. In addition to assisting in decision-making time and target pesticide use, it also assists in the palm plantation process to be more efficient because it can be monitored in real-time on smartphone applications.

The system uses Long Range (LoRa) technology that utilizes radio frequency as signal transmission between the transmitter and receiver devices. The transmitter contains an early ganoderma disease detection sensor, while the receiver serves as a data recipient that has been transmitted by the LoRa transmitter and will be forwarded to the Blynk Apps through the internet network, thus forming an IoT (Internet of Things) system.
2. LITERATURE REVIEW

2.1. Previous Research
This research refers to several previous studies as references. In 2021, Agustin Sri Mulyatni and colleagues from Gadjah Mada University conducted research by testing the electronic nose system in detecting basal stem rot disease in oil palm based on volatile organic compounds (VOC) parameters, using TGS sensors with Arduino Uno as the microcontroller [6].

Muhammad Muzakky Al Maududy, Koko Mardianto, and Agus Susanto, in 2021 discussed sensors that can be used in oil palm plantation management, including temperature sensors as an early warning system for pest attacks of oil palm leaf-eating caterpillars such as fire caterpillars and bag caterpillars. This journal also discusses gas sensors that can be used for early detection of ganoderma disease (basal stem rot) [7].

Mhd Feri Desfri, Minarni, Dewi Laila Sari, Dewi Anjarwati Mahmudah, Ihsan Okta Harmaili, and Irfan Cahyadi, in 2022 conducted a study comparing the sensitivity of several types of TGS sensors in identifying ganoderma disease in oil palm plants. Volatile organic compounds (VOC) emitted by G.Boninensis will be read by 6 different types of TGS sensors, until it was concluded that the TGS 2611 sensor has the highest sensitivity [8].

Moh. Nadhif Muttaqin from Maulana Malik Ibrahim Islamic State University of Malang conducted research on an electronic nose device in the form of a space made of copper pipes to select beef and pork using an LM35 temperature sensor and MQ-138 as a gas sensor sensitive to Volatile Organic Compounds (VOC) gas compounds which were then processed by Arduino Uno as a microcontroller in the system [9].

Siska Wati, Joseph Dedy Irawan, and Yosep Agus Pranoto in 2022 designed a tool for remote monitoring and control of oil palm seedlings in the IoT system. Arduino Uno and NodeMCU ESP8266 are used in series so that sensors and components in the system can connect to the internet and can be monitored and controlled remotely [10].

Hazia Rifka Maulida, Fikra Titan Syifa, and Mas Aly Affandi from the Telkom Institute of Technology conducted research on the creation of a tool for monitoring temperature and humidity of tea plantation land. In the system, two devices were made, a transmitter equipped with a sensor and placed on tea plantation land, and a receiver whose job is to receive data and forward it to the internet network. Both devices are each paired with a LoRa module to be able to communicate with each other [11].

2.2. Arduino Uno
Arduino Uno is one of the types of Arduino microcontroller boards that has an ATmega328P-based chip. This microcontroller is open source, making it suitable for use in the design and construction of research tools. Arduino Uno has 14 digital input/output (I/O) pins (6 of which can provide PWM output), 6 analog input pins, a 16 MHz quartz crystal, USB connection, power jack, ICSP header, and reset button [12].

2.3. ESP32 Dev Kit
This module is a successor to the ESP8266, which has 36 GPIO (General Purpose Input Output) pins that function as analog and digital input and output pins. The similarity of the ESP32 Dev Kit program to Arduino allows this module to be programmed via the Arduino IDE with some additional settings. This module is widely used in IoT applications because it supports Wi-Fi connections [13].

2.4. LoRa RFM95
LoRa is a type of Low Power Wide Area Network (LPWAN) technology that operates at frequencies of 169 MHz, 433 MHz, 868/915 MHz, and 2.4 GHz, where these frequencies are included in unlicensed frequency that can be used freely [14].

2.5. TGS 2611 Sensor
The TGS 2611 sensor is a sensor capable of measuring methane or other natural gas levels, with high sensitivity, low power consumption, and good durability. This sensor also could measure volatile organic compounds (VOCs) and odorous gases emitted by certain biological processes [15].

2.6. MQ-138 Sensor
The MQ-138 sensor is sensitive to Volatile Organic Compounds (VOCs/Aldehyde, Alkanol, Ester, Ether), n-Hexane, benzene, alcohol, and hydrogen. The sensitive material of the MQ-138 gas sensor is SnO2, which has lower conductivity in clean air [16].
2.7 **Blynk IoT**

Blynk is an open-source server service that offers capabilities such as remote device control, reading data storage, and visually displaying data, making it very suitable for use in Internet of Things system applications with Android and iOS operating systems. Blynk has many widgets, each with different functions, ranging from displaying graphic data, numbers, even images, making it very easy to read and use.

3. **RESEARCH METHODOLOGY**

3.1. **Research Procedure**

The flow in the research process on the design of the LoRa and IoT based monitoring system to detect ganoderma disease refers to the flow diagram shown in the Figure 1.

![Figure 1: Research procedure flowchart](image)

3.2. **Research Method**

The research method used in this study is the research and development method. Research and development is a research method used to produce a particular product and test its effectiveness [17]. This research method is commonly used in various fields, including engineering, to produce a particular product using need analysis research and to test the effectiveness of the product.

3.2.1. **Literature Study**

This research began with a case study and literature study by collecting references from books and journals relevant to the research to then formulate the problems to be solved.

3.2.2. **System Design and Programming**

The system design is divided into two, namely hardware design and software design. The hardware design is carried out by creating a system work block diagram and an electronic device schematic circuit. The software design contains program designs and the Blynk IoT application interface. In the hardware design there are two devices, namely a transmitter device containing an Arduino Uno microcontroller, LoRa RFM95 as a data sender, and sensors. Meanwhile, the receiver device contains an ESP32 Dev Kit and LoRa RFM95 microcontroller module as a data receiver from the transmitter.
3.2.3. System Testing

The implementation of the design results is then carried out, if the implementation is successful, testing is performed. However, if the implementation is not successful, an evaluation of the system design is conducted in terms of both hardware and software. System testing was carried out on several non-target samples such as: soil, non-ganoderma dead palm plants and ganoderma fungi. Meanwhile, the target samples include oil palm plants in the categories of healthy, medium, sick, and oil palm trunks infected with ganoderma.

The stages carried out in data collection are sensor stabilization for 20 minutes to 30 minutes to achieve the sensor’s working temperature and stability with the environmental air and optimization of testing time. The test time is set in the system to collect data every 5 seconds. Testing was also carried out to determine the length of delivery time between transmitter and receiver devices as well as the length of delivery time between receiver devices and Blynk IoT.
3.2.4. Data collection and Analysis

Once testing has been conducted, data collection is carried out to then perform analysis and discussion. In this case, the parameters that become the performance benchmark of the system to be analyzed are the ability to read volatile organic compounds for each sensor. In the final stage, conclusions are drawn. The signal response in the form of voltage and analog data from the sensors used for each sample will be displayed in graphic data to see the response between sensors to the sample. Then a comparative analysis of each sensor is carried out to determine the sensor's sensitivity to the given sample.

The results of testing the length of delivery time between the transmitter and receiver devices will be recorded and then the time difference for each data transmission will be looked for to determine the difference in the average time for data transmission.

4. RESULTS AND DISCUSSION

4.1. The Results of System Design and Construction

4.1.1. System Hardware

The hardware transmitter device is used as a device that has components for detecting VOC gas compounds from ganoderma. This device consists of MQ-138 and TGS 2611 sensors, an I2C 2004 LCD, an Arduino Uno, a battery indicator, and a 18650 battery. This device uses clear acrylic as the outer casing that protects the components. The assembled hardware transmitter device is shown in Figure 5.

![Transmitter hardware](image)

Figure 5. Transmitter hardware (a) Front view, (b) Side view, (c) Rear view

The receiver hardware is used as a receiving device for the data sent by the transmitter device via the LoRa communication network. This device consists of a LoRa RFM95 module, ESP32 DevKit, I2C 2004 LCD, battery indicator, and 18650 battery. This device uses a clear acrylic material as an outer casing to protect the components. The assembled receiver hardware is shown in Figure 6.

![Receiver hardware](image)

Figure 6. Receiver hardware (a) Front view, (b) Side view, (c) Rear view
4.1.2. System Software
Making system software interfaces is done on Blynk Apps for smartphone interfaces, and Blynk Web Dashboard on Blynk Console for desktop interfaces. Making the software includes adding widgets, adjusting virtual pins, setting reading formats, and the type of data used. The system software interface images are shown in Figures 7 and 8.

![Figure 7. Blynk web dashboard interface](image1)

![Figure 8. Blynk apps interface](image2)

4.2. The Workings of The Gas Sensor
The workings of the gas sensor for VOC compounds are similar to the human nose, which is to recognize the gas around it, where the gas that enters and hits the sensor will be identified according to the compounds that can be recognized by the sensor and then the results of the readings are sent to the microcontroller so that it can be translated into information that can be easily easy to read by users. Each sensor has a different sensitivity to gas readings according to sensor specifications and configuration.

The transmitter has 2 sensors reading VOC compounds with different specifications to detect 3 target compounds found in oil palm trees identified as ganoderma, namely: 2-Furan-carboxaldehyde, 5-
(hydroxymethyl)-, which is included in the aldehyde group; Thiophene, 2-propyl- with an odor resembling benzene; and other organic compounds namely 4H-Pyran-4-one [18]. Sensors used include:

1. MQ-138 sensor for VOC, Aldehyde, benzene, alcohol, and other gas readings.
2. The TGS2611 sensor is sensitive to VOC gases, methane, and other natural gases.

4.3. Sensor Target Test Results Data

The testing of this sensor was conducted by collecting data from samples of oil palm plants with health condition categories of healthy, moderate, and diseased. Healthy oil palm plants are characterized by green leaf morphology and no spear leaves are found, and there are no Ganoderma fruiting bodies; The condition of oil palm plants with the moderate category is characterized by the morphology of the beginning of spear leaves and being around sick oil palm plants; while the condition of oil palm plants with the diseased category is characterized by the morphology of the beginning of at least 2 spear leaves and the presence of Ganoderma sp fruiting bodies is found. The images of the oil palm plants used as samples are shown in Figures 9 and 10.

![Figure 9. Samples of oil palm plant stems: (a) healthy, (b) moderate, (c) diseased](image1)

![Figure 10. Samples of oil palm plant leaf: (a) healthy, (b) moderate, (c) diseased](image2)

Tests were also conducted on samples of palm trunks known to be infected with ganoderma disease to understand and calibrate the severity level of ganoderma attacks on oil palm trees. The samples were taken from the trunk of the oil palm tree from field tests. Testing was done by taking sensor reading data from the samples placed at a certain distance, then calibration adjustments were made to the palm health category based on ADC sensor data. The recapitulation of the total ADC values of the results of target testing by the sensor at an ideal distance of 1 cm to 4 cm is shown in Table 1.

<table>
<thead>
<tr>
<th>Component</th>
<th>Distance</th>
<th>ADC Total Value in Time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>5 sec</td>
</tr>
<tr>
<td>Healthy Palm</td>
<td>1 cm</td>
<td>110</td>
</tr>
<tr>
<td></td>
<td>2 cm</td>
<td>111</td>
</tr>
</tbody>
</table>

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The increase in sensor values is inversely proportional to the increase in reading distance, which can be seen from the sensor reading graph visualization. The closer the reading distance, the higher the sensor reading value, and the further the reading distance, the lower the sensor reading value. This is because the reading gas does not reach the sensor's sensing element at a far distance, resulting in a reduction in value. Even though there is a decrease in value, at a distance of 1 cm - 4 cm, the sensor can still read the increase in values that occur in oil palm plants. However, when the reading is set 5 cm from the oil palm plant, the reading starts to show a significant decrease and unstable readings, so it can be inferred from this data that the limitation of the sensor is only at a maximum reading distance of 4 cm.

The highest reading value occurred in the sample of sick plants. Besides reading volatile gas at the base of the diseased plant, the emergence of ganoderma sp fruit bodies at the base of the plant increases the sensitivity of the sensor in data reading. In the Ganoderma sp. Sample, were found aliphatic compounds with 8 carbon atoms such as 1-octen-3-ol (69.43%), also known as mushroom alcohol, 3-octanone (10.34%), and 1-octanol and (E)-2-octenal (20.23%) [19]. Thus, with the presence of the ganoderma sp fruit body on the outer part of the palm base, it can increase the reading value of both sensors.

### 4.4. Non-Target Sensor Test Results Data

Non-target sensor testing was conducted to determine the increase in values that occur on the sensor due to other components that occur during sensor readings on oil palm plants. These components are components outside of the VOCs of ganoderma palm disease. Testing components made non-targets for the sensor include soil, non-ganoderma dead palm plants, and ganoderma sp. fungi. Non-target sensor test data is shown in Table 2.

<table>
<thead>
<tr>
<th>Components</th>
<th>Samples</th>
<th>Initial ADC</th>
<th>Final ADC</th>
<th>Difference in ADC Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil</td>
<td>Soil 1</td>
<td>108</td>
<td>109</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Soil 2</td>
<td>109</td>
<td>111</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Soil 3</td>
<td>110</td>
<td>112</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Soil 4</td>
<td>104</td>
<td>105</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Soil 5</td>
<td>108</td>
<td>110</td>
<td>2</td>
</tr>
<tr>
<td>Non-ganoderma dead palm plants</td>
<td>Dead palm 1</td>
<td>111</td>
<td>113</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Dead palm 2</td>
<td>111</td>
<td>112</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Dead palm 3</td>
<td>106</td>
<td>107</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Dead palm 4</td>
<td>105</td>
<td>105</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Dead palm 5</td>
<td>110</td>
<td>112</td>
<td>2</td>
</tr>
<tr>
<td>Ganoderma sp</td>
<td>Ganoderma 1</td>
<td>110</td>
<td>117</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Ganoderma 2</td>
<td>111</td>
<td>122</td>
<td>11</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Components</th>
<th>Samples</th>
<th>Initial ADC</th>
<th>Final ADC</th>
<th>Difference in ADC Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ganoderma 3</td>
<td>111</td>
<td>132</td>
<td></td>
<td>21</td>
</tr>
<tr>
<td>Ganoderma 4</td>
<td>112</td>
<td>135</td>
<td></td>
<td>23</td>
</tr>
<tr>
<td>Ganoderma 5</td>
<td>112</td>
<td>142</td>
<td></td>
<td>30</td>
</tr>
</tbody>
</table>

BPPSDMP data, Ministry of Agriculture states that in the process of soil aeration, the atmosphere above the soil contains 21% O2, 0.03% CO2, and almost 79% N2 [20]. These three compounds are not included in group of compounds in ganoderma and are not included in the target gas sensor reading compounds. Hence the sensor readings on the soil sample did not show a significant increase.

4.5. Testing RFM95 LoRa Connection from Transmitter to Receiver

The testing of the LoRa RFM95 was conducted by placing the transmitter and receiver devices at different distances. This test uses a frequency of 915 MHz and a 5 db Omni LoRa antenna. The LoRa RFM95 communication test was carried out on Sepakat II Street with reading distances between devices starting from 100 meters, 250 meters, 450 meters, 650 meters, and 750 meters. The location was chosen considering minimal obstacles and a sufficiently long straight path to obtain the maximum distance between LoRa. The transmitter will be placed at the 0-meter point with a height of 150cm from the ground, and the receiver will be moved away from the transmitter until the maximum distance is reached for LoRa communication to get the RSSI (Received Signal Strength Indication) value. From the tests that have been carried out, the results of reading LoRa RFM95 communication are as shown in the graph in Figure 11.

![Figure 11. Graph of RSSI Value Against the Distance Between LoRa](image)

Based on the data from the graph in Figure 11, it is known that the further the distance between the LoRa devices, the smaller the RSSI value becomes. The smaller the RSSI value, the worse the signal quality received by the transmission system. The RSSI value at the maximum distance recorded is -105 dBm at a distance of 757.92 meters.

Testing of the LoRa transmitter and receiver was also carried out in the oil palm plantation area on Dermaga Kuala Mandor Street, Central Java Village, Sungai Ambawang Subdistrict, Kubu Raya Regency. From the field testing, the farthest distance between the LoRa transmitter and receiver obtained was 469.13 meters. The maximum distance obtained is not as far as the distance in testing with minimal obstacle conditions because the destination oil palm plantation area has obstacle conditions in the form of oil palm plants and residential buildings, thus affecting the ability of radio signal transmission between the transmitter and receiver.

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4.6. Testing of Transmission and Reception Time of LoRa RFM95 Data from Transmitter to Receiver - Blynk IoT

The data for the transmission and reception times between LoRa RFM95 devices are shown in Table 3.

<table>
<thead>
<tr>
<th>Data Number</th>
<th>LoRa Transmitter Data Transmission Time (hours:minutes:seconds)</th>
<th>LoRa Receiver Data Reception Time (hours:minutes:seconds)</th>
<th>Time Difference (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10:48:31.586</td>
<td>10:48:32.302</td>
<td>0.716</td>
</tr>
<tr>
<td>2</td>
<td>10:48:36.737</td>
<td>10:48:37.465</td>
<td>0.728</td>
</tr>
<tr>
<td>3</td>
<td>10:48:41.935</td>
<td>10:48:42.636</td>
<td>0.701</td>
</tr>
<tr>
<td>4</td>
<td>10:48:47.101</td>
<td>10:48:47.793</td>
<td>0.692</td>
</tr>
<tr>
<td>5</td>
<td>10:48:52.267</td>
<td>10:48:52.984</td>
<td>0.717</td>
</tr>
<tr>
<td>6</td>
<td>10:48:57.433</td>
<td>10:48:58.037</td>
<td>0.604</td>
</tr>
<tr>
<td>7</td>
<td>10:49:02.569</td>
<td>10:49:03.296</td>
<td>0.727</td>
</tr>
<tr>
<td>8</td>
<td>10:49:07.736</td>
<td>10:49:08.493</td>
<td>0.757</td>
</tr>
<tr>
<td>10</td>
<td>10:49:18.086</td>
<td>10:49:18.776</td>
<td>0.690</td>
</tr>
<tr>
<td>11</td>
<td>10:49:23.270</td>
<td>10:49:23.960</td>
<td>0.690</td>
</tr>
<tr>
<td>12</td>
<td>10:49:28.421</td>
<td>10:49:29.074</td>
<td>0.653</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td></td>
<td></td>
<td><strong>0.695</strong></td>
</tr>
</tbody>
</table>

Based on the data in Table 3, it is known that there is a time difference between the transmission and reception of data between LoRa devices. The average time difference is 0.695 seconds. Therefore, with an average time of 0.695 seconds, the RFM95 LoRa module can transmit data between two LoRa transmitter and receiver devices.

<table>
<thead>
<tr>
<th>Data Number</th>
<th>Receiver Data Transmission Time (hours:minutes:seconds)</th>
<th>Blynk IoT Data Reception Time (hours:minutes:seconds)</th>
<th>Time Difference (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10:48:32.968</td>
<td>10:48:34</td>
<td>1.032</td>
</tr>
<tr>
<td>2</td>
<td>10:48:38.154</td>
<td>10:48:39</td>
<td>0.846</td>
</tr>
<tr>
<td>3</td>
<td>10:48:43.213</td>
<td>10:48:44</td>
<td>0.787</td>
</tr>
<tr>
<td>4</td>
<td>10:48:48.461</td>
<td>10:48:49</td>
<td>0.539</td>
</tr>
<tr>
<td>5</td>
<td>10:48:53.526</td>
<td>10:48:54</td>
<td>0.474</td>
</tr>
</tbody>
</table>
Based on the data in Table 4, it is known that there is a difference in precision in the time format between the receiver device and Blynk IoT. The receiver device can obtain data up to an accuracy of 0.000 seconds that can be displayed on the serial monitor, while on Blynk IoT, data can only be obtained up to an accuracy of 0 seconds. The average time difference that occurs in the process of sending and receiving data between the receiver device and Blynk IoT is 0.701 seconds.

**5. CONCLUSION**

Based on the testing results of the LoRa and IoT based monitoring system to detect ganoderma disease attacks on oil palm plants, the following conclusions can be drawn:

The ganoderma disease detection system with MQ-138 sensor and TGS2611 sensor can detect the level of ganoderma volatile organic compounds, with the following results: The optimal sensor reading distance for oil palm plants is in the range of 1 cm to 4 cm. Sensor testing on non-target components such as soil and dead palm not due to ganoderma results in a minimum total ADC difference of 0 - 2 values. Meanwhile, the ganoderma mushroom produces a total ADC difference between 7 - 30 values according to the maturity level of the ganoderma mushroom body.

The LoRa and IoT-based monitoring system for detecting ganoderma disease attacks on oil palm plants can transmit data from the transmitter to the receiver with a range of up to 757.92 meters and an RSSI value of -105 dBm in conditions with minimal obstacles.

The system can send and receive information from LoRa devices to Blynk IoT with the following time differences: The time difference for sending and receiving data between the RFM95 LoRa transmitter and receiver devices averages 0.695 seconds. The time difference for sending and receiving data between the receiver device and Blynk IoT averages 0.701 seconds.

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