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Implementation of Multi-Hop Communication in Wireless Sensor Network for Flood Early Warning Monitoring System

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ABSTRACT
A system has been created for a flood early warning monitoring system using LoRa-based multi-hop communication based on several limitations that LoRa has in its implementation of single-hop communication and end devices are located in dark spots or areas that are difficult to reach by the network. The research method starts with creating sensor nodes, relays, and gateways and measuring system performance. The results of system performance measurements are shown by the highest average RSSI value for multi-hop communications being -56.6 dBm at a distance of 20m and the lowest being -85.2 dBm at a distance of 300 m. Meanwhile, the highest average RSSI value for single-hop communication was -79 dBm at a distance of 20 m and 50 m and the lowest was -85.2 dBm at a distance of 150 m. The PDR value in multi-hop communication is 100% up to a distance of 300 m and the PDR value in single-hop communication is 100% up to a distance of 150 m, while in multi-hop communication it is 100% up to a distance of 600 m. The system can monitor data readings from rain sensors and ultrasonic sensors using the NodeMCU ESP8266 on the Thinkspeak web server via a smartphone screen. Overall, the tool can function well

1.0 Introduction

Indonesia is at the meeting point of two continental plates and the equator, which makes Indonesia have a tropical climate with high rainfall. As time goes by and to overcome existing problems, rapid flood prevention is needed. This prevention can take the form of communicating in providing good information at the right time, namely via the Internet. But communicating via the internet can be hampered in sending information to the recipient of the information. The cause is due to various factors. This problem can be solved using Internet of Things (IoT) technology and wireless systems (without cables). Currently, IoT-based wireless systems have developed rapidly in various sectors. IoT is a network in which physical devices, equipment, sensors, and other objects can communicate with each other without human involvement. This system is not confined to technology and engineering applications; it also extends to medical devices, including those used for physiological monitoring (Md Hussin, M.H.F, 2023). Wireless Sensor Network (WSN) is a central component of IoT. WSN is a collection of sensor nodes that form a wireless network spread over a certain area (sensor field). Each sensor node can collect data and communicate with other sensor nodes (Kanakaris et al., 2019). The application of WSN technology requires a minimum of two nodes connected to communicate. Nodes in WSN can be composed of devices that carry out sensing, and then send packets to the gateway node which is useful in receiving data from sensors, and then sending data to the network server (Nandika et al., 2023).

All nodes in the WSN can be connected using communication modules. Several parameters can be tested to determine the performance of a wireless sensor network, such as data transmission delay, communication distance between sensor nodes, Packet Delivery Ratio (PDR), number of installed sensor nodes, or Received Signal Strength Indicator (RSSI). The quality of a system based on a wireless sensor network depends on the communication module. The communication modules used include ZigBee (Desnanjaya et al., 2020), NRF24L01 (Kamaruddin et al., 2019), and LoRa (Liu et al., 2022). ZigBee and LoRa can both be used in the same IoT system. ZigBee can be used for high-data-rate applications. On the other hand, LoRa can be used for low-power applications that require longer distances and lower data rates (Ali & Zorlu Partal, 2022). Apart from having several advantages, there are several limitations, LoRa communication implementation is single-hop; this single-hop characteristic causes problems when applied in densely populated areas. Apart from that, problems also arise when the end device is in a dark spot or an area that is difficult to reach by the network. This allows the gateway node not to reach the furthest end node device (Velde & Lora, n.d.). While Zigbee and NRF24L01 are limited in distance, on average the data sent remains stable from a distance of 10 meters to 300 meters with an average of 80-90% of the data is successfully sent, and the connection will only be lost at a distance of 400 meters (Haque et al., 2022).

Based on these problems in this research, multi-hop Wireless Sensor Network communication was implemented for a LoRa-based Flood Early Warning Monitoring System. The flood monitoring systems currently used in the market are using single-hop communication and are still relatively expensive. A multi-hop communication system is a communication that can be used to expand a wireless network so that the negative impact of signal weakening experienced by wireless channels can be overcome without having to require more network resources so that communication with other nodes that are outside the network reach is still possible (Triwidyastuti et al., 2020). By using this multi-hop communication system, it is hoped that the LoRa coverage distance can be at maximum range and can be effective for monitoring disaster events.

2.0 Research Methodology

The flood early warning monitoring system using LoRa-based multihop communication is divided into sensor nodes which act as data sources, relays which act as data forwarders, and gateways which act as data destinations and sinks. Figure 1 is a block diagram of a flood early warning monitoring system using LoRa-based multi-hop communication.

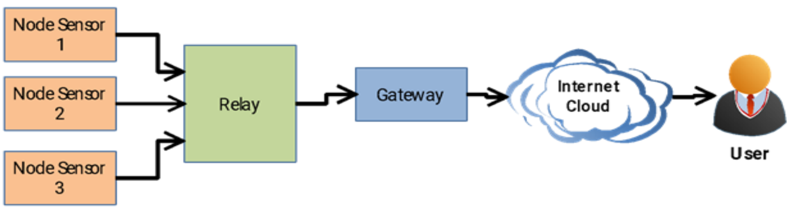

Figure 1: Block diagram Flood early warning monitoring system uses LoRa-based multihop communication

2.1 Node Sensor Section

The sensor node section consists of a microcontroller, rain sensor, and ultrasonic sensor. The rain sensor is used to detect whether it is raining or not. This sensor module means that when rainwater falls and hits the sensor panel, an electrolysis process will occur. The liquid will conduct an electric current (Hussein et al., 2020), while the ultrasonic sensor is used to detect the presence of an object in front of it, the working frequency of this sensor is above sound waves, namely from 40 kHz to 400 kHz (Asha Banu et al., 2021). The data from both sensors is then processed using a microcontroller. Next, the sensor data is sent using LoRa. The sensor node section is shown in Figure 2 and the system design is shown in Table 1.

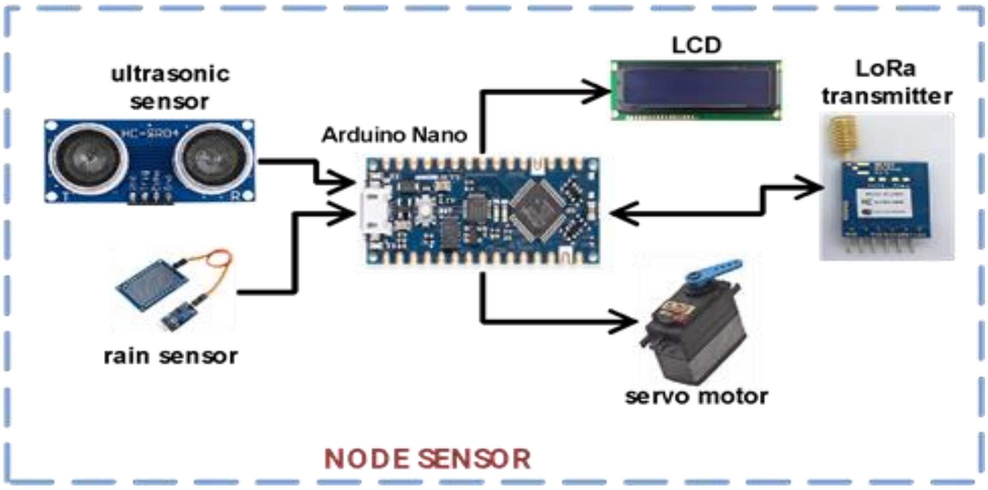

Figure 2: Node Sensor

Table 1: Flood early warning monitoring sensor node system design

Sensor/part	Condition	
Ultrasonic sensor	1 cm	Flood Alert
	2 cm	Siaga Banjir
	>3 cm	Flood Emergency
Rain sensor	High (Logika 1)	Hot
	Low (Logika 0)	Rain
Servo motor	90°	Floodgates Closed
	0°	Floodgates Open
LCD	Ultrasonic sensor > 0 cm	“cuaca hari ini panas”
	Ultrasonic sensor 0 cm	“cuaca hari ini hujan”
	Ultrasonic sensor 1 cm	“Waspada banjir”
	Ultrasonic sensor 2 cm	“siaga banjir”
	Ultrasonic sensor 3 cm	“Darurat banjir”

2.2 Relay Section

The relay hardware only consists of Arduino Nano and LoRa. The relay working system begins with address initialization. In this research, one relay with address FF is used. Then the relay checks whether there has been sensor data received from the sensor node. The relay will send request packets to each sensor node in turn. One sensor node is given 1 second for the data transmission process. The packet sent contains the address of each destination sensor node. If the relay has received sensor data, this data will be forwarded to the gateway. The block diagram of the relay node is shown in Figure 3.

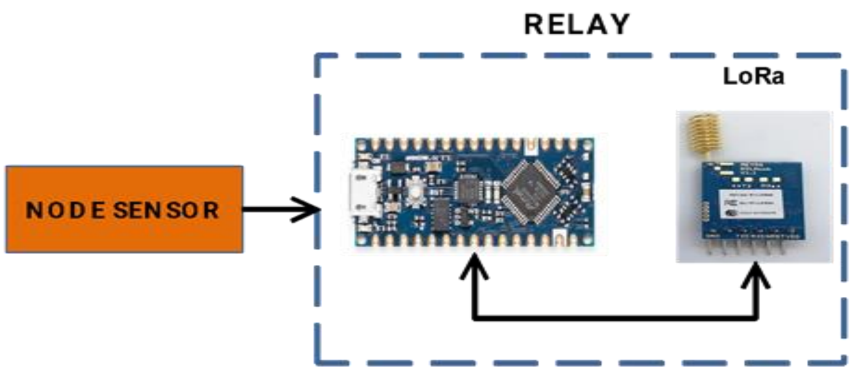

Figure 3: Relay block diagram

2.3 Gateway Section

The data received by the relay is forwarded to the gateway. The gateway is tasked with forwarding the data to the Thingspeak server so that sensor data can be accessed. The gateway consists of Lora, and an ESP32 microcontroller as shown in Figure 4.

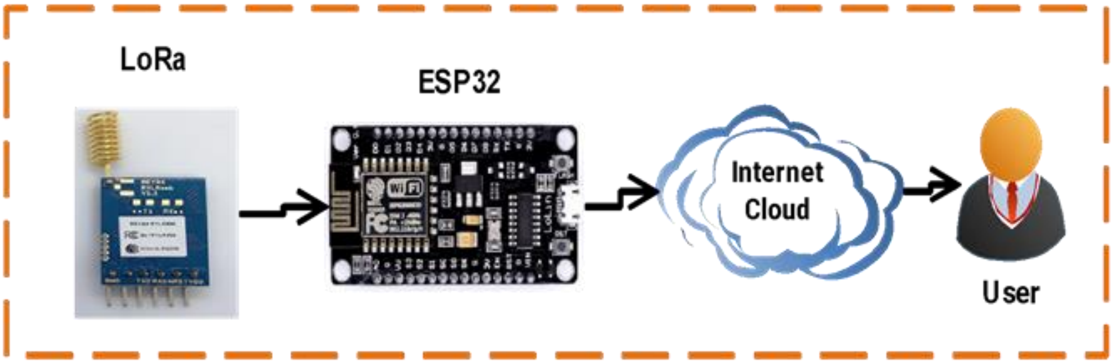

Figure 4: Gateway block diagram

All data is sent to the Thingspeak server with WiFi and Auth which has been set in the Arduino IDE program in the form of ID, Password, and Thingspeak Auth. After that, the data can be monitored and controlled in real-time by the user after everything is connected.

2.4 System Testing

After the flood early warning monitoring system is realized, the next step is to test the system's performance. The tests carried out included RSSI, PDR values, and a mobile application-based flood monitoring display. The testing area was carried out on Jalan Kapalo Koto as shown in Figure 5.

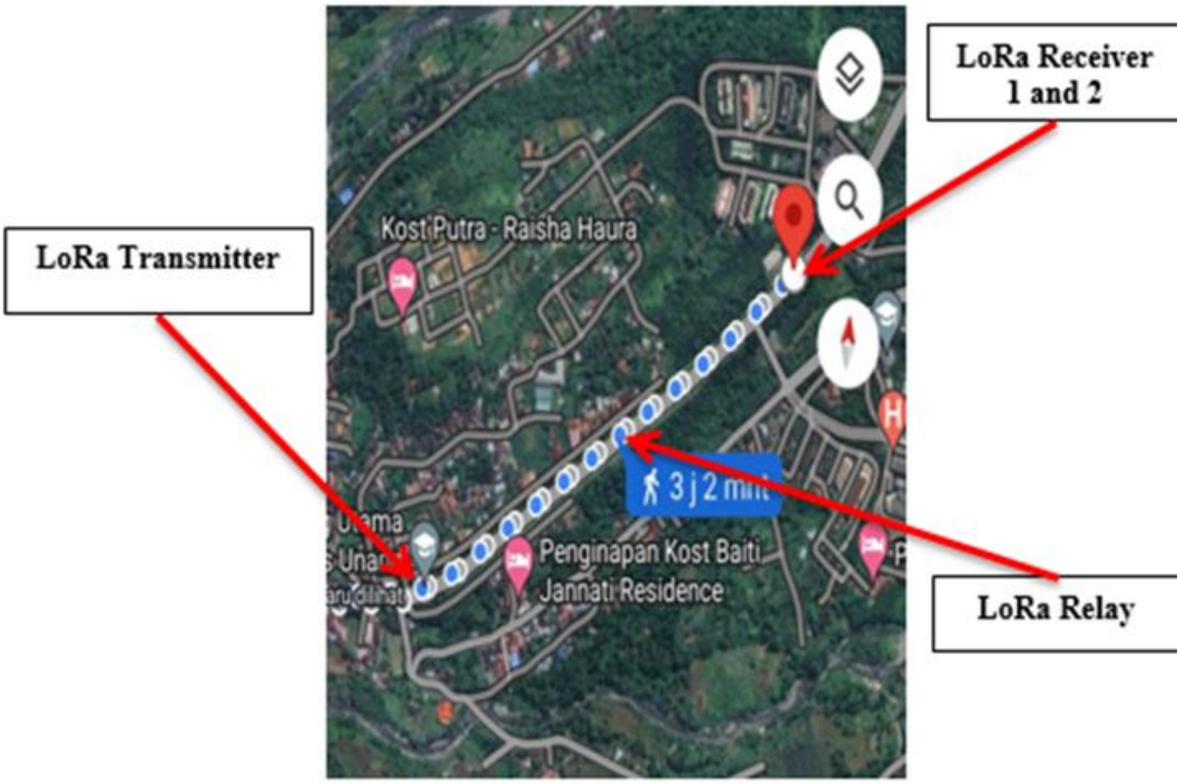

Figure 5: LoRa Multihop Testing location

3.0 Results And Discussion

Testing of this tool is carried out to determine whether the tool made is as expected. The prototype tool is shown in Figure 6.

Figure 6 : (a) Prototype of flood detection tool (b) LoRa Transmitter (c) LoRa Relay (d) LoRa receiver

RSSI (Received Signal Strength Indication) is a measurement parameter used to measure the quality of the signal reception obtained. RSSI is measured on the receiver side while communicating with the sender. The main goal of testing RSSI values on LoRa is to evaluate the quality and reliability of wireless communications between LoRa devices in various environmental conditions and settings. The value of RSSI can be divided into several levels (Models, 2024). The results of testing RSSI values for Multi-Hop and Single Hop Communication are shown in Table 2 and Table 3. A comparison of the two average Multi-Hop and Single Hop RSSI values is shown in Figure 7.

Table 2: Single-Hop RSSI Value Data

Distance (m)	**Average RSSI value (dBm)**	
20	-75	Very good
50	-79,6	Very good
100	-82,7	Very good
150	-93,9	Good
300	-99,5	Good
400	0	Loss Signal
600	0	Loss Signal
700	0	Loss Signal

Tabel 3 : Multi-Hop RSSI Value Data

Distance (m)	Average RSSI value (dBm)	
20	-54,1	Very good
50	-72,1	Very good
100	-74	Very good
150	-79	Very good
300	-85,8	Very good
400	-91,3	Good
600	-101,1	Good
700	0	Loss Signal

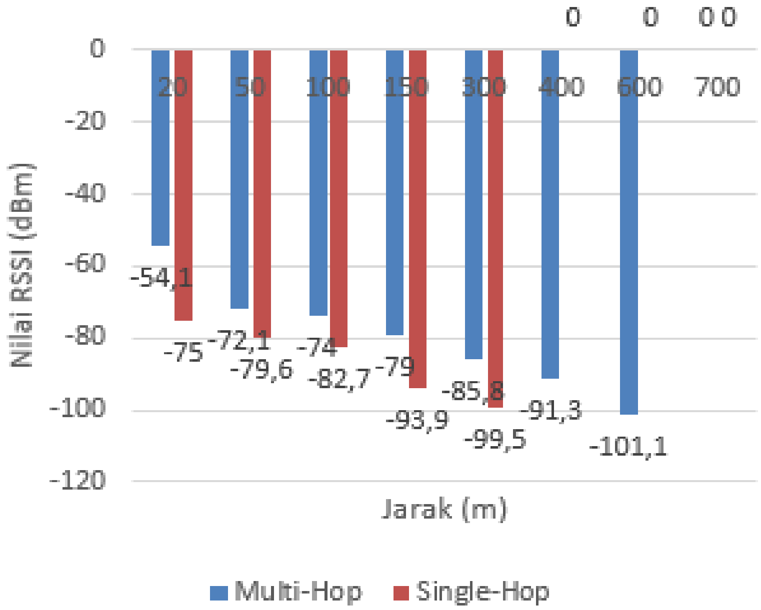

Figure 7: Comparison of Single-hop and Multi-hop RSSI Values

Based on Figure 7, the average RSSI value for multi-hop communication is -56.6 dBm at a distance of 20 m and the lowest is -85.2 dBm at a distance of 300 m. Meanwhile, the highest average RSSI value for single-hop communication was -79 dBm at a distance of 20 m and 50 m and the lowest was -85.2 dBm at a distance of 150 m.

Next, testing and analysis of the PDR value are carried out on multi-hop and single-hop communication Lora. PDR (Packet Delivery Ratio) is a metric that measures the extent to which sent data packets are successfully received by the receiving device without errors or data loss. PDR testing and analysis on LoRa are critical to understanding the reliability and quality of communications between LoRa devices in a given environment (Aimi et al., 2022). To calculate PDR, you can look at the equation:

$$\text{PDR} = \frac{Paket\ Diterima}{Total\ Paket} \times 100\% \quad [1]$$

Tables 4 and 5 show the results of testing PDR values on LoRa for Multi-Hop and Single-hop communications. Figure 8 compares the two average PDR values for Multi-Hop and single-hop.

Table 4: Single-Hop PDR Value Data

Distance (m)	Packages Received	Total Packages	PDR Value (%)
20	12	12	100
50	12	12	100
100	12	12	100
150	12	12	100

300	12	12	100
400	0	12	0
600	0	12	0
700	0	12	0

Table 5: Multi-Hop PDR Value Data

Distance (m)	Packages Received	Total Packages	PDR Value (%)
20	12	12	100
50	12	12	100
100	12	12	100
150	12	12	100
300	12	12	100
400	12	12	100
600	12	12	100
700	0	12	0

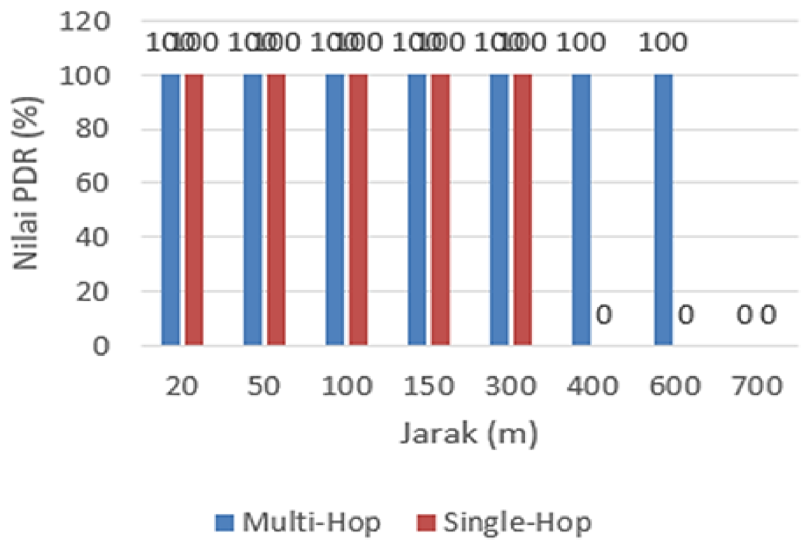

Figure 8: Perbandingan Nilai PDR Single hop dengan Multi hop

Based on Figure 8, the PDR value in multi-hop communication is 100% up to a distance of 300 m and the PDR value in single-hop communication is 100% up to a distance of 150 m, while in multi-hop communication it is 100% up to a distance of 600 m.

After testing the RSSI and PDR values on Multi-hop and Single-hop communications. Next, monitoring testing with the ESP8266 using thingspeak. Testing was carried out to find out that the ESP 8266 which was connected to Wifi could monitor the water level and rainfall that had been used. To access monitoring, the ESP 8266 is connected to the Arduino Uno pin with a voltage of 3.3V. Data transmission monitored on Thingspeak is sent from Arduino to the ESP 8266 by connecting the RX and TX pins on the ESP 8266. The data reading test display with a smartphone is shown in Figure 9.

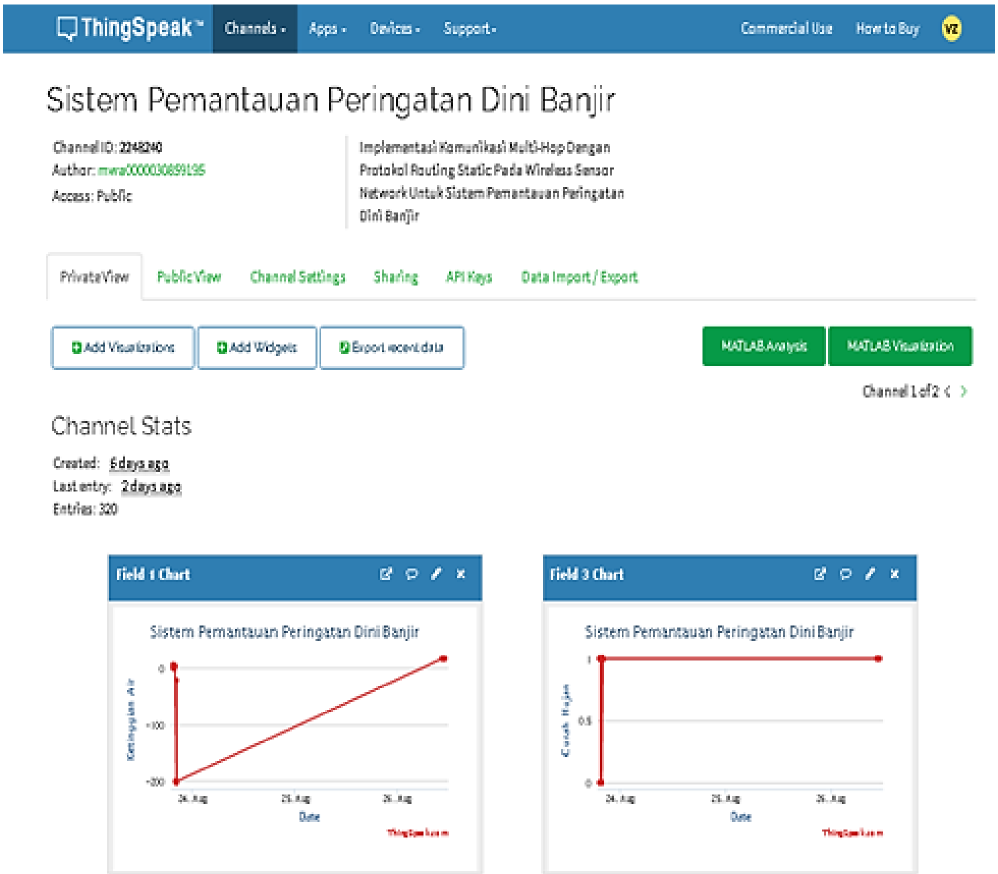

Figure 9: Real-time monitoring testing on the Thingspeak application

4.0 Conclusion

Based on the results and discussion following the research objectives, it can be concluded. The flood early warning monitoring system uses LoRa-based multi-hop communication divided into Relay and Gateway sensor nodes. The tests carried out included RSSI, PDR values, and a mobile application-based flood monitoring display. The implementation of multi-hop communication on a wireless sensor network for a flood early warning monitoring system can function to double the distance compared to single-hop communication. When with obstacles the furthest distance is 300 m and when without obstacles it can reach a distance of 600 m.

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Author Contributions

Yultrisna: Conceptualization, Methodology, Software, Writing- Original Draft Preparation, Writing – Review & Editing; **Vernando Ziandi Putra**: Methodology, Investigation; **Aditya Wardhani**: Methodology, Investigation; **Yulastri**: Supervision, Resources; **Yul Antonisfia**: Supervision, Validation.

Conflicts of Interest

The manuscript has not been published elsewhere and is not being considered by other journals. All authors have approved the review, agree with its Submission, and declare no conflict of interest in the manuscript.

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