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Implementation of multi-hop lora network for centralized remote display of running text message based on IoT

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ABSTRACT

Running text is a promotional and information billboard made by LED. It can be programmed by using a computer to display text, images, and animations. Running text makes people interested to read some message because a color of the lights and animation. For wide location such as campuses, airports and many more place, several running texts are needed. It's difficult to change some message manually one by one. It will spend energy and time. To solve the problem, this research was conducted to create a system to display of messages on three running texts centrally using a multihop LoRa wireless network. Each running text board consists of four P10 panel boards, an ESP 32 as a microcontroller, and a LoRa SX1276 as a sender and receiver. Message setting is done from a computer connected to the Gateway or from an android phone via Telegram bot. The results are LoRa power 10 dBm, distance between nodes can be reached 110 m. The amount of round-trip time (RTT) for point to point is 103 ms and for two hops of 1221 ms. The length of the message that can be sent 256 characters with the character patterns available in the DMD 32 library. This system is very suitable to support areas where internet is not available. The signal emitted by LoRa is Line of sight for achieve maximum coverage. The antenna between the nodes must be installed facing without obstruction.

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1. INTRODUCTION

Running text is an electronic media consisting of an array of LED lights. It can be displayed some texts and animation (Ericsson, 2023; Hadi & Lestari, 2021). Running text will attract the attention of many people to see and read the message because running text is very suitable to be used to convey information to the audience. Some running text

has been able to change the appearance of message through wireless networks such as Wi-Fi or Bluetooth. It has been able to be managed the messages from one running text to another one via Wi-Fi signal (multi hop)(Nataprawira, Rizal, & Wibowo, 2020; Sulistianingsih, Suherman, & Pane, 2019; Triwahyuni & Beta, 2022). For location has a lot of running text, it will be difficult and require a lot of time to change the message one by one. It needs an internet network. If there is no internet available, it will not be able to be managed (Ericsson, 2023; Johri et al., 2021).

One way to overcome the blind spot internet is to use LoRa wireless network. LoRa has the advantage of long range and low power consumption. LoRa can cover rural areas as far as 20 km and about 8km for urban areas (Chalacan, 2020; Gallardo, Ahmed, & Jara, 2021; Li, Yang, Han, Wang, & Wang, 2018). According to the data sheet of LoRa Ra-02 module, the range of LoRa can reach 15 km with 1 mW power. In accordance with the data sheet that LoRa is a star and line of sight (LOS) type wireless network (Alves et al., 2020; Kerkouche, Alami, Féraud, Varsier, & Maillé, 2018; Kim, Lee, & Jeon, 2020). To be able to reach nodes (Running Text) that are far from the controller and to overcome obstacles due to buildings, a multihop LoRa network can be formed where messages for distant nodes are relayed to the Subscribe to DeepL Pro to edit this document. Visit www.DeepL.com/pro for more information destination node. According to Centells, using multi hop will expand the range of the LoRa gateway (Centelles, Freitag, Meseguer, & Navarro, 2021; Lavric & Popa, 2017). By a multi hop network, it can expand coverage even in areas that are difficult to access (Cotrim & Kleinschmidt, 2020; Raza, Kulkarni, & Sooriyabandara, 2017). This research aims to build a multi hop LoRa communication network as a communication network to manage the Running Text by centrally based on IoT. It make easier for officers to set the message to be announced (Lundell, Hedberg, Nyberg, & Fitzgerald, 2018; Sartori, Thielemans, Bezunartea, Braeken, & Steenhaut, 2017).

2. RESEARCH METHOD

This research was conducted using the research and development model and experimental method. The data collection process was carried out by testing the design results, while data analysis was carried out using simple statistical methods. The stages of this research consist of information gathering, needs analysis, design, testing, data analysis andconclusion. This research was conducted at the Telecommunication Engineering Laboratory of POLMED.

2.1 System Block Diagram

This research will control the display on 3 (three) Running Text Panel P10 boards with each size 128cm x 16cm with a distance between pixels 10mm. Each Running Text panel controlled by ESP32 with LoRa SNX1276 MRV- RFM95 communication has been equipped with a logic level converter so that it can be supplied with a +5V voltage source (Babiuch, Foltýnek, & Smutný, 2019; Yusri, 2020). The display on each Running Text board can be changed from the Gateway using the LoRa communication network, and can also be changed from a cell phone via the internet network as shown in Figure 1 (Setya & Rizaldi, 2023).

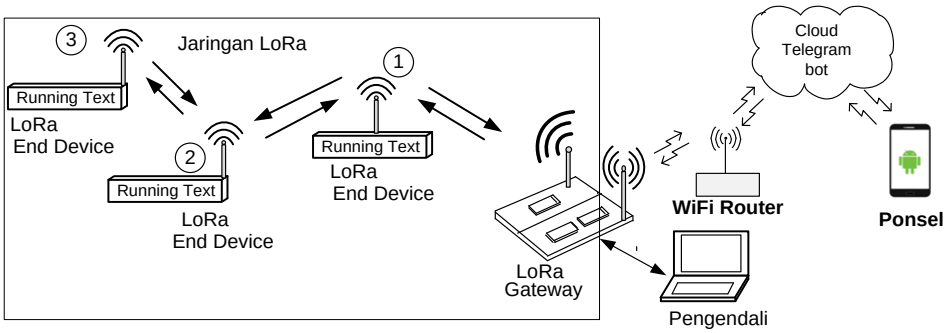

Figure 1. Block diagram of Running Text Display Setting System

a. Gateway circuit

The Gateway circuit consists of an ESP-32 and a LoRa SNX1276 MRV- RFM95 module (Margolis, Jepson, & Weldin, 2020). The connection between the ESP-32 and LoRa is done through the SPI serial communication channel as shown in Figure 2.

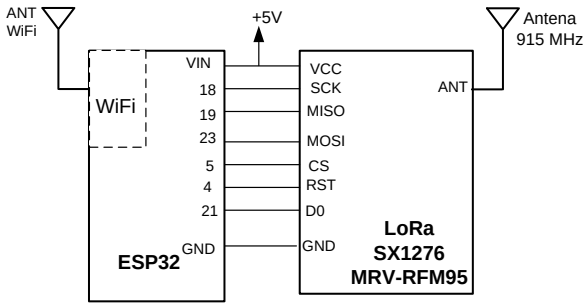

Figure 2. Gateway circuit

The gateway is connected to the Telegram platform (internet) via Wi-Fi communication (Saban, Aghzout, & Rosado-Muñoz, 2022). The LoRa MRV-RFM95 module has a voltage converter from 5V to 3.3V to supply the LoRa SX1276 which works with a voltage of 3.3V.

b. Running Text Module Set

Running Text circuit consists of 4(four) P10 panels and LoRa communication module. The ESP32 interface to the P10 panel is done through the SPI0 (VSPI) channel while the interface to the LoRa module is through SPI1 (HSPI) as shown in Figure 3 (Corns et al., 2018; Xiong, Liang, Zhang, Xu, & Luo, 2023).

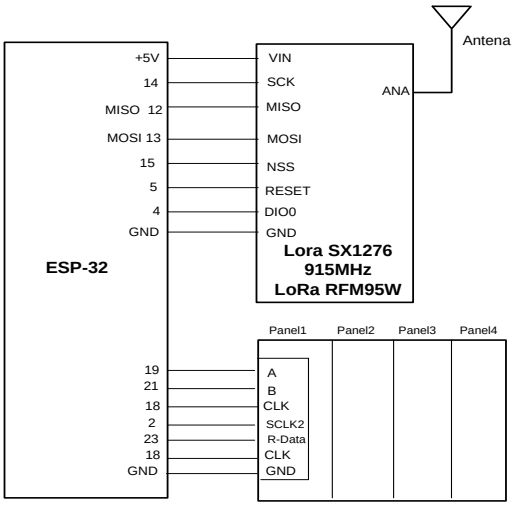

Figure 3 Running text circuit

Initialization with the LoRa module is done with the following SPI Class spiLoRa (HSPI);

```
#define SCK_LORA 14
#define MISO_LORA 12
#define MOSI_LORA 13
#define SS_LORA 15
#define FREQ_LORA 915E6
#define RESETPin5
#define IRQPin 4
```

Before use LoRa parameters need to be set, where in this study LoRa is set with a power of 15 dBm (maximum 20 dBm or 100 mW), bandwidth 125kHz, Spreading Factor 12 and synchronous character between LoRa and A5H with the following command (Techavijit et al., 2018):

```
LoRa.setTxPower(15);
LoRa.setSignalBandwitdth(125e3);
LoRa.setSyncWord(0xA5);
LoRa.setSpreadingFactor(12);
```

The pin definition for the P10 panel is done in the DMD32 library as follows:

```
Define PIN_DMD_n0E22//D22 active low Output
Enable,
#definePIN_DMD_A                19//D19
#definePIN_DMD_B                19//D21
#definePIN_DMD_CLK18//          D18_SCK
Is SPI Clock if SPI is used
#definePIN_DMD_SLCK             2//D02
#definePIN_DMD_R_DATA           23//D23_MOSI
#definePIN_OTHER_SPI_Ncs SS
```

The program to manage the P10 panel display is Done through the DMD 32H and DMD.CPP Libraries.

c. Program Design

In order for the ESP32 to work as desired, the ESP on the gateway and on the Running text must be programmed (Alsammak & Mohammed, 2022). The gateway receives the message and the destination address of the Running Text where the message will be displayed, then the Gateway sends the message along with the destination Running Text address to node 1 (Nasser & Hussain, 2022; Singanamalla et al., 2020). If the message destination is 1 then the message is retrieved and displayed to the Running Text, but if the message destination is not address 1 then the message continues node 1 to node 2. At node 2 the message is checked again, if the message address is node 2 then the message will be displayed on the Running Text but if the destination address is not node 2 the message will continue 2 to node 3. As shown in Figure 4. In this research the Gateway address is set at 0xCC, node 1 address 0xBB, node2 address 0xAA.

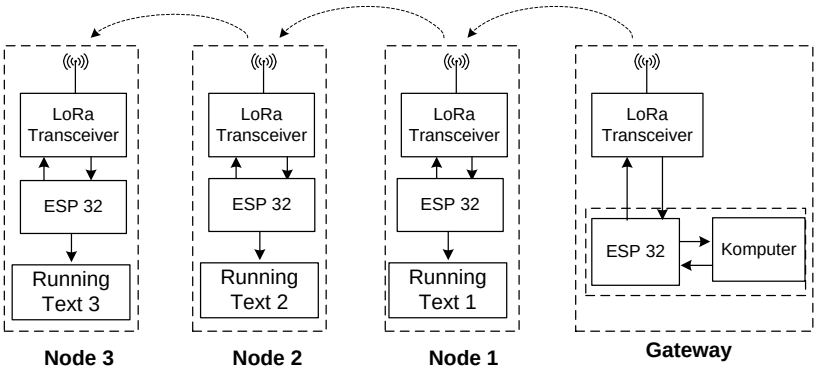

Figure 4 Message Delivery Process

d. Gateway Program Design

The gateway will wait for incoming messages via Wi-Fi and also via serial input (Fortino, Guerrieri, Russo, & Savaglio, 2014). Messages sent by users via Wi-Fi or via computers are preceded by the destination Running Text address then a colon (:), message and enter as shown in Figure 5.

Destination Address:	Pesan	Enter

Figure 5. Gateway input message format

If there is an incoming message ESP 32 will read the message then retrieve the destination address, and the contents of the message that will be sent to running Text. Furthermore, the gateway adds the marker character '>' at the beginning of the message and the '#' character at the end of the message. Furthermore, the Gateway sends a message to LoRa which begins with sending the next address (0xCC), sender address (0xDD), message destination address, message length and finally the message that has been added to the beginning and end characters as shown in Figure 6.

Next Addr.	Local Addr.	Destination Addr.	Panjang Pesan	> Pesan #

Figure 6. Gateway sent message format.

The delivery is written with the following command:

```
LoRa.beginPacket():    //start packet
LoRa.write(nextAddress):       //add destination address
LoRa.write(localAdrdress):     //add sender address
LoRa.write(destinationAddress):        //add sender address
LoRa.write(outgoing.length())://add payload length
LoRa.print(outgoing):  //add payload
LoRa.endPacked():      //finish packet and send
```

e. Program Running Text

The message sent by the Gateway is received by the Running Text address with address 0xCC. At first the ESP32 displays the preset message. If there is an incoming message from LoRa ESP32 will read the message starting by reading the following address of the message (next Address) then the address of the sender of the message, the destination address of the message (message address displayed), the length of the message sent by the sender and the message. The Running Text program flowchart is shown in Figure 7. This reading is done with the length of the message is checked if it matches the length of the received message, if it is not the same then the message is not retrieved. Furthermore, the next address sent by the Gateway is checked, if it is not the same as the Local Address then the message is ignored and then the Address destination (message destination) if it is the same as the local address then the message is retrieved and displayed in Running Text and if it is not the same then the message and destination address are continued to be sent to the next node address (node 2 with address 0XBB). The same process is also carried out on node 2 and subsequent nodes.

```
Receiver = LoRa.read();       //recipient address
Sender = LoRa.read();         //sender address
Destination – LoRa.read();   //sender address
byte incomingLength = LoRa.read();          //incoming msg length
if(receipient != localAddress) {
      Serial.printIn("This message is not for me.");
        return;        //skip rest of function
        }

            Char buff[incomingLength+1]={}; //read the payload
            //adjustsize if needed
            Uint8_t ix = 0;
            While(LoRa.available()) {
                  Buff[ix++] = LoRa.read();
                  }
                  Incoming= String(buff);
```

3. RESULTS AND DISCUSSIONS

3.1 Running Text Circuit Testing

Running Text circuit was tested first. After the program displays "WELCOME TO POLITEKNIK NEGERI MEDAN" to be uploaded on the ESP32, it is obtained that the message on the Running Text displays the message "WELCOME TO POLITEKNIK NEGERI MEDAN" in motion. The test results of the three Running Texts are shown in.

Figure 8. Testing the Running Text circuit

3.2 Message Reception Testing on the Gateway

Testing the reception of messages from the serial monitor and from the mobile phone is done by uploading the Gateway program on the ESP 32 at the Gateway, and the Running_CCprogram on node 1, Running_BB program on node2, Running_AA program on node 3. The message to be delivered to the selected Running text is typed from the computer and provided Serially to the Gateway. Messages can also be given from Telegram bots on cellphones via Wi-fi to the Gateway. Testing was done by typing a message on a computer connected to the Gateway. When BB is typed: WELCOME TO

POLITEKNIK NEGERI MEDAN, the ESP 32 retrieves the destination address of the message (BB) and then sends the message to the destination address as displayed on the serial monitor in Figure 9.

Figure 9. Serial monitor display on the Gateway when sending a message.

3.3 LoRa Network Testing

The tests carried out are point to point communication tests, namely between the Gateway and node 1 address 0xCC and multi hope testing between the Gateway with node 2 address 0xBB and node 3 address 0xAA. In this point-to-point test, the Gateway is made the next address is 0xCC and the Destination address is also set 0xCC.

Table 1. Point to Point Testing

	Distance (m)	Message typed on the Gateway	Message Received Node 1	Round trip time
1	5 m	Welcome	Welcome	102ms
2	10 m	Good morning	Good morning	103 ms
3	20 m	Good afternoon	Good afternoon	105 ms
4	30 m	Good afternoon	Good afternoon	100 ms
5	40m	Welcome	Welcome	108 ms
6	50m	Please be orderly	Please be orderly	105 ms
7	60m	Take a rest	Take a rest	103 ms
8	70m	Keep clean	Not accepted	---
			Avarage	103,7 ms

So that the LoRa range is not too far, the LoRa power is set at 10 dBm. The distance between the Gateway and the sensor node (Running Text) is made different by moving the Gateway away from the Running Text. The test results are shown in table 1 where information from the Gateway can be received and displayed on Running Text node 1 (address 0xCC) with an average round trip time of 103 ms (0.103 seconds) and a maximum distance where messages are still received up to 60m. RTT of 100 ms transmission delay of only 0.05 seconds. Some views of Running Text on node 1 (address 0xCC) during point-to-point testing are shown in Figure 10.

Figure 10. Running Text display of node 1 during point-to-point testing.

Multi hop testing is done with the Gateway set Address 0xCC, the destination address of node 2 (address 0xBB), at node 1 is set Address Next 0xBB, the destination address corresponds to the address received from the Gateway, namely address 0xBB. In this test node 1 is placed 3 m away from the Gateway, node 2 is made to move from node 1 starting from distance of 5 m to 70 m. The results of the two-hop test are shown in Table 2.

Table 2. The two-hop test

NO	Distance (m)	Message on the gateway	Message Received at node 1	Round trip time (ms)
1.	5m	Good morning	Good morning	1202
2.	10m	Good afternoon	Good afternoon	1230
3.	20m	Good afternoon	Good afternoon	1215
4.	30m	Take a rest	Take a rest	1220
5.	40m	Welcome	Welcome	1232
6.	50m	No smoking	No smoking	1228
7.	60m	Please be orderly	Please be orderly	1214
8.	70m	Keep clean	Not accepted	---
		Average		1221,8 ms

3.4 Telegram Bot Communication Testing

To be able to send messages from Telegram (cellphone), a Token and Telegram bot ID are required. In this research, the connection between ESP32 and the internet (Telegram) is done through a Wi-Fi channel, for that it must first be connected to a Wi=Fi server after that it can only be sent via Telegram. Testing is done by typing the destination address of the message and continuing the message to be displayed. To display "SAFETY FIRST" in the running text of node 2, type "BB: SAFETY FIRST ". The display of the cell phone (Telegram Bot) when setting the message on the Running text display is shown in Figure 11. Test results of the Running Text display settings are shown in Table 3.

Figure 11. Telegram bot display during Running Text Message setup.

In accordance with the test results, when the Gateway sends a message to node 1, node 1 can receive a message and node 2 can also receive a message this is indicated by the information "This message is not for me." on the serial monitor of node 2. In this study, to save power, the LoRa power is set at 10 (10 mW) where with this much power it can reach the destination (the maximum distance between buildings is 30 m). The round trip time of the message when multi point is much greater than point to point, this is because the routing execution time requires a much larger time compared to data transmission, where when point to point is not routing. Running Text that can be controlled can be more than three pieces, where the more Running text the greater the delay in the arrival of the message at the end Running Text. The length of the message that can be sent is sufficient for Running Text as a notice board. The length of the message sent from Telegram (cellphone) is also affected by the internet network.

Table 3: Testing Message Delivery from Telegram (Cell Phone)

No.	Message from Telegram	Receiving Node	Display Running Text	Replies On Mobile
1	CC: Welcome to the Electronics Laboratory, Electrical Engineering Department	1	Welcome to the Electronics Laboratory, Electrical Engineering Department	Ok
2	BB: Welcome to the Electrical Laboratory, Department of Electrical Engineering	2	BB: Welcome to the Electrical Laboratory, Department of Electrical Engineering	Ok
3	AA: Welcome to the Telecommunication Laboratory, Department of Electrical Engineering	3	Welcome to the Telecommunication Laboratory, Department of Electrical Engineering	Ok
4	BB: Safety first	2	Safety first	Ok
5	AA: You are in an quite learning location	3	You are in an quite learning location	Ok
6	CC: It's time to rest, please take a rest	1	It's time to rest, please take a rest	Ok

4. CONCLUSION

Running Text is one of the information media that is mostly used today, with the many things needed for the development of Running Text, the author conducted this research, as for the results of the achievements made, namely the successful control of the Running Text display centrally using the IoT-based multi hop LoRa network. Which is where the message is typed from a computer connected to the Gateway or from a Telegram bot on a cellphone. This system is very suitable to support areas where internet is not available. The signal emitted by LoRa is Line of sight for achieve maximum coverage. The antenna between the nodes must be installed facing without obstruction.

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