LoRa

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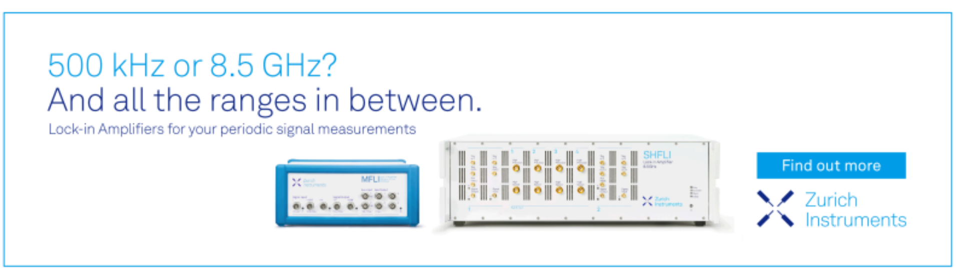

Design and Evaluation of LoRa-based Mesh Network for Water Metering Infrastructure

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Abstract. The demand for water meter monitoring has become urgent nowadays. For this reason, this research aims to develop a LoRa network for water meter infrastructure applications. We have designed a low-power measurement node using an 8-bit microprocessor and LoRa transceiver by connecting software for monitoring water consumption and remote data transmission. In this study, several schemes were made to measure Lora data transmission performance for point to point and mesh networks. The results showed that the LoRa value and the TX power and spread factor (SF) value, which was higher, could increase the data transmission range for point-to-point network schemes. SF 8 provides the most optimal data transmission performance in a mesh network scheme, both in direct transmission and multiple hops. The packet delivery rate is measured at 100%, with an average ping time of 582 ms for each hop. This design increases the time interval and reduces transmission failures in times of data congestion. Implementing a LoRa-based mesh network in residential areas automatically builds data transmission lines and connects with surrounding nodes to build a mesh network. Percentage of PDR measured for each node in the network above 97%.
Keywords: LoRa, Mesh, Packet delivery ratio, Spreading factor.

INTRODUCTION

Wireless mesh network (WMN) is the potential data communication network for metering applications. In a mesh network, each node is interconnected, either directly or through an intermediate node. When one of the network nodes dies, the surrounding nodes' communication does not get affected. Another advantage of WMN implementation is that it can increase the transmission range. WMN is also resistant to interferences, such as weather, radio frequency interferences, and fading. Due to these reasons, it is very suitable for metering applications that consist of a large number of nodes and have a large scope of distribution [1].

A digital meter reading system using WMN has been previously designed [2]. The system uses RF as a basis of meter data transmission to the utilities. RF is a data transmission technology that works using the principle of single-channel frequency modulation. In general, the RF is designed to have low power consumption, and it is usually used for small data transmissions. However, RF has the disadvantage that the data transmission range cannot be more than 100 m [3]. The WMN can also be developed on street lights controllers [4]. The controllers in the system work by turning on and turning off the street lights and adjusting the light's intensity, and they are connected in the WMN using WiFi. WiFi is an internet protocol (IP)-based technology that has been widely used for many applications, such as personal computers, game consoles, smartphones, etc. WiFi has a data transmission speed of more than 50 Mbps and can serve voice, image, and video communications [3]. However, this technology is not suitable to be applied as a basis of meter data transmission because of its relatively high-power consumption [5].

In this paper, we propose applying LoRa technology in WMN as the basis for communication in water meter infrastructure. LoRa is a data communication technology that uses tweet modulation to transmit data. LoRa

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allows transmission over long distances with low power consumption. It has high sensitivity and a high tolerance for the mismatch between sender and receiver [6]–[10]. The state of the art of this research is that we have designed a low power measurement node using an 8-bit microprocessor and a LoRa transceiver by connecting software to monitor water consumption and remote data transmission. In this study, several schemes were made to measure Lora data transmission performance for point to point and mesh networks.

DESIGN OF THE SYSTEM

The metering infrastructure design scheme applied to the water meter monitoring system in this study is shown in figure 1. The system consists of a LoRa-based digital water meter (LDWM) device connected to build a mesh network connected to a gateway. The measured meter data will be sent to the gateway via a mesh network. When the data arrives at the gateway, it will be sent to the cloud server via the internet network. Cloud servers are containers on the internet that can hold large amounts of data, which can then be managed and analyzed remotely. Also, data stored on cloud servers can be monitored via devices connected to the internet, such as internet computers, cell phones, etc.

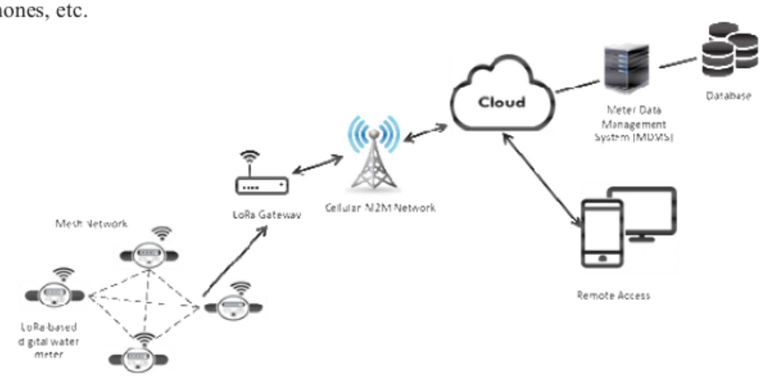

FIGURE 1. Scheme for designing a water meter infrastructure system

The LDWM function of the wireless mesh network node is to read data from the meter digitally and send it to the LoRa transceiver gateway. The meter node consists of five main parts: power supply, microcontroller, counter, real-time clock (RTC), and LoRa transceiver. It works at a voltage of 3.3 Volts and a small current of 150 mA. In this study, the Arduino Pro Mini microcontroller module based on ATMega328 was used. It is a type of 8-bit microcontroller that usually works at a voltage of 3.3 volts and a current of 0.2 mA processing mode for later integration with other devices (I2C, SPI, UART, Serial, GPIO) [11]. The microcontroller's function is to receive data from the counter, build the network communication process's logic, and send data to the target node using the LoRa transceiver. The process keeps repeating, as shown in figure 3. If a processing error occurs, the last data received from the counter will be stored in the EEPROM, then the microcontroller will start the process again.

This research starts with a channel set, performs data rate, and transmits data from RF fower. To do this, LoRa is used as a wireless communication module that is developed to transmit data over long distances based on tweet modulation. We use a LoRa module with type SX1278 (LoRa RA-02) from Semtech. LoRa works at a frequency of 433 MHz with a supply voltage of 3.3 volts and a maximum current of 120 mA in transmit mode [5]. We chose LoRa because it has low power consumption, has a wide data transmission range, and can build a mesh topology network through software development. LoRa uses the SPI interface to communicate with the microcontroller [2], [9], [11].

The next step is that the embedded node with the mesh program automatically initializes itself and its environment. Other adjacent nodes are identified as neighboring nodes (next hop) and entered in the routing table. When a node sends a message to the target node, it will check whether there is a route to the target node or not. If there is no route, the node will re-initialize (route discovery). Route discovery is the node's action to find a route to another node by broadcasting a route request message on the network. Each node that receives the message will check its routing table, whether the target node's address is in the routing table or not. If not, the node will re-broadcast the request after adding its own address to the list of nodes the request has visited so far. This will continue until the node finds a route to the target node. When the target node has been found, the source node's request message will be answered along with the built node's route information. There are many routes built into the network discovery scheme. However, once the source node receives the reply message, it will determine which route to choose. The selection criterion for the route is the least number of jumps to the target node. The source node will forget routes other than the selected route[12].

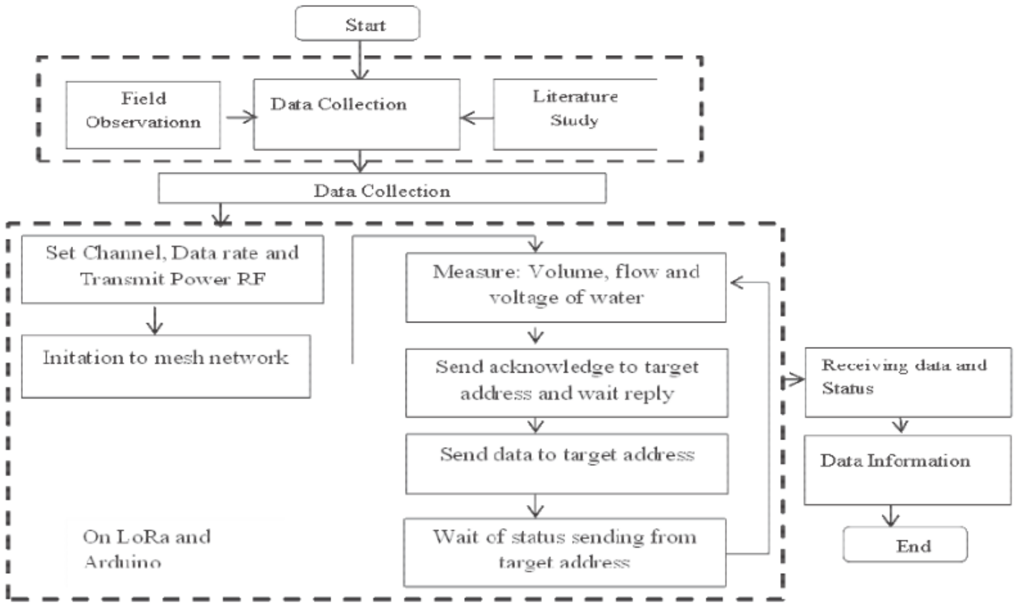

FIGURE 2. Research Flow Chart to Make a Programming flow on the microcontroller

When a data transmission route has been found, the node will first send an acknowledged message (ACK) to the target node. Its purpose is to determine the target node's status, whether it is available to receive messages or not. If available, the target node sends an ACK response to the source node. If there is no available or no reply, the source node sends another ACK. The maximum repetition of an ACK transmission is three times. When the source node has received an ACK response, it will send data to the target node[13].

RESULT AND DISCUSSION

LoRa Based Metering Node

We have successfully designed a LoRa-based node for water meter infrastructure in this study. The node has been specifically designed for experiments and performance evaluations of LoRa transceiver in the mesh network. The node consists of a meter reading device, a microcontroller, a LoRa transceiver with an antenna, and a 3-volt battery, as seen in figure 3. The antenna that we use for the LoRa transceiver is a 17 cm long jumper cable. We chose the antenna because it is simpler and easier to install in the circuit. The LoRa-based node was placed in a waterproof box with a thickness of 4 mm. The box serves to keep the node in good condition from the weather during the evaluation.

FIGURE 3. LoRa-based metering node

The Effect of SF Set on the Performance of LoRa-based Metering Node

Theoretically, by increasing the node's SF, the transmission range of the node will also increase. Therefore, we have created an experimental design to measure the performance of our Lora-based nodes. The measurement was taken in Batununggal Indah Residence, Bandung, Indonesia, at 02.00-04.00 PM (WIB), as shown in figure. 4. The experiment was designed to measure packet error rate (PER) and received signal strength indicator (RSSI) under different SF settings. PER is a size or percentage of the number of incorrectly received data relative to the total number of packets sent in a transmission. The PER and RSSI testing program algorithms can be seen in Figure 5.

FIGURE 4. Location of LoRa-based metering node data transmission measurement using point to point scheme

```
include Mesh library
include LoRa library
define SOURCE_ADDRESS
define DESTINATION_ADDRESS
Integer data = 1
Integer Size of data();

void setup()
{ Intiation mesh
 LoRa.setTxPower
 LoRa.setSpreadingFactor
}

void loop()
{ Set of transmitter time
 Send data
 Wait reply data
 int tunggu;

 if (reply data == true)
 received reply data
   } else
   { Serial.println ("No reply") } }
 Delay (2000)
 data = data+1;
 if (data == 101)
 { data=1 }
```

```
include Mesh library
include LoRa library
define SOURCE_ADDRESS
define DESTINATION_ADDRESS

Integer reply data
Integer Size of reply data();

void setup()
{
 Intiation mesh
 LoRa.setTxPower;
 LoRa.setSpreadingFactor
}

void loop()
{
   Received data
   Reply data = data
   Sending reply data
   print(LoRa.packetRssi());

}
```

FIGURE 5. Right: LoRa Transmitter program and left: LoRa receiver

To measure PER, we set the Tx power value to 17 dB and used three SF settings (SF 8, SF 10, and SF 12). We used a transmission time interval of 2 second. The results of the measurement are presented as a graph, as shown in figure 6.

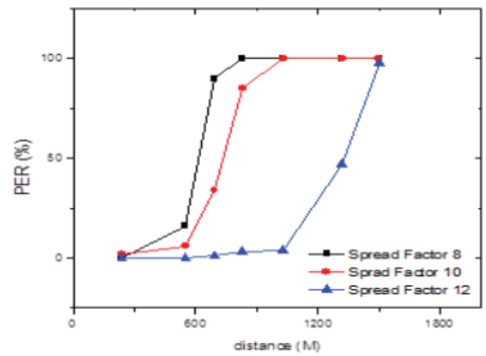

FIGURE 6. Graph of PER measurement on the LoRa-based metering node

Based on figure 6 above, it is found that the effect of the data transmission distance on the measured PER. The greater the SF value used, the smaller the PER measured; this condition can be seen at a distance of 550 m. These results also prove that increasing the SF will extend the transmission range. The farthest transmission distance is about 1.5 km using SF 12. Under the same conditions, we also measure the RSSI by the same method as in section b, as shown in figure 7.

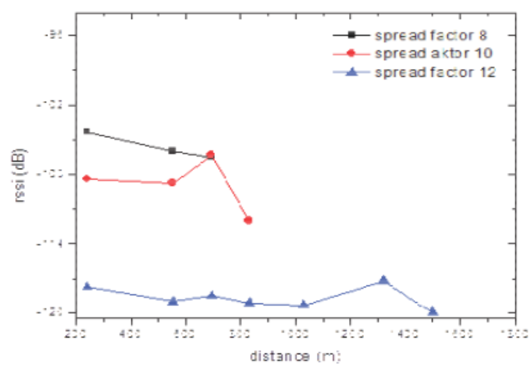

FIGURE 7. Graph of RSSI measurements on the LoRa-based metering node

The measurement results in figure 7 show the effect of different SF settings on the measured RSSI. Increasing the SF value will result in a negative RSSI value. At 550 m, it can be seen if the RSSI value is the most negative with the largest SF value (12) around -122 dB at a distance of 1.5 km. This condition indicates that SF's increase will result in a negative power value received by the receiving node, but the transmission range will be further away.

Measurement of Multi-hop Ping Time in LoRa Mesh Network

The measurement aims to determine the ability of LoRa in transmitting data in the mesh network. The built network consists of several hops, where each hop is represented as a node. For example, hop 0 is represented as node 1, hop one is represented as node 2, etc., as shown in figure 8. A node (M in figure 8) was set to transmit data to each node in the network. All five nodes in the network were configured using SF 8 and a Tx power of 2 dBm. We chose a configuration of SF 8 due to the limited area we used for the measurement. The nodes that were set as target nodes (1, 2, 3, and 4 in figure 8) were set to send the received data back to M. The time needed for a data to be transmitted from M to one of the target nodes and to return to M is measured as ping time. Ping time is the required time for data to travel to the target node and back again to the source node. The ping time can describe the transmission speed between the nodes in a network. The larger the measured ping time, the higher the level of obstacles or the process during data transmission is. Ping time is usually expressed in millisecond (ms).

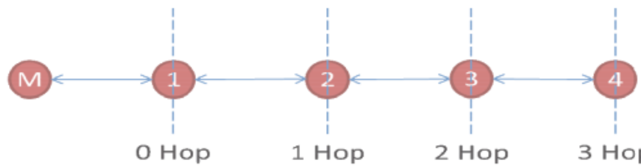

FIGURE 8. Scheme of ping time measurement in LoRa mesh network

The measurement results at a different number of hops in the network are presented in figure 9. The measured ping time at 0 hop was 582 ms. At one hop, two hops, and three hops, the measured ping time was 1171 ms, 1758 ms, and 2341 ms, respectively. The graph in figure 9 shows that the more hops passed in a transmission, the higher the measured ping time is.

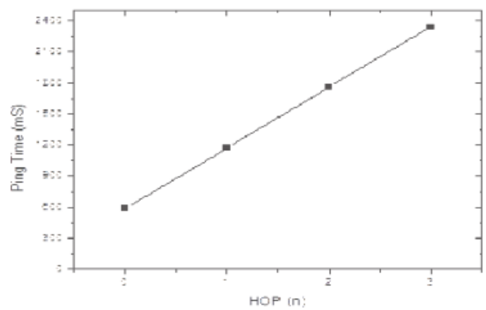

FIGURE 9. Scheme of ping time measurement in LoRa mesh network

LoRa-based Metering Node Performance in a Mesh Topology

We have successfully developed a mesh network in a residential area. To test its performance, some measurements on PDR and ping time were taken. The measurements aim to determine the ability of the LoRa-based nodes to transmit data through multiple hops. The measurements were taken in Jl. Konstitusi (UNPAD Residence), Cigadung, Bandung, at 02.00-04.00 PM as shown in figure 10.

An illustration of the Lora-based node deployment mechanism in residential areas is in figure 10. Each node that is deployed has been programmed to transmit data using a mesh topology. The nodes are installed randomly and placed at the height of about 1.5 m from the road surface. Node M is set to send 100 data to each target node on the network (Nodes 1 - 8 in figure 8), and each target node is also set to send received data back to node M. Then, we measure the ping time and packet delivery ratio (PDR) for each transmission data. PDR is the percentage of the number of packets that has been successfully received by the transceiver to the total number of packets sent by the transmitter. Actually, PDR is the opposite of PER. When PER is measured by 0% in a data transmission, it will be equal to a PDR percentage of 100%. The use of the term "PER" and "PDR" usually depends on the pleasure of choosing the term. All nodes in the network are configured using a Tx power of 17 dB and SF 8. The time interval between data transmissions is set to 1 second. The two measurement results for each target node address can be seen in figure 11.

FIGURE 10. Location of Lora-based nodes data transmission measurements using mesh topology

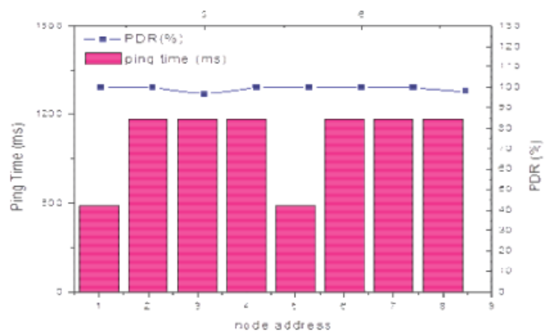

FIGURE 11. Graph of ping time and PDR measurement results using mesh topology

The ping time and PDR measurements on the developed LoRa mesh network are shown in figure 9. The measured ping times for nodes 1 and 5 are approximately 582 ms, and for nodes other than 1 and 5, about 1171 ms. While the measured PDR percentages for nodes 3 and 8 are 97% and 98%, respectively.

CONCLUSION

In this paper, the design and implementation of a prototype LoRa-based metering node using mesh topology were presented, and its performance in actual experiments was evaluated. The maximum range achieved by the Lora-based nodes in data transmission is about 1.5 km. We have also proved that the LoRa technology is also implementable in a network with a mesh topology. The LoRa transceiver can transmit data through multiple hops in a mesh network. However, increasing the data traffic density will degrade the performance of data transmissions. Using a much longer transmission time interval will be a solution to overcome the problem. The prototype of the developed metering node was also tested on an actual state. From the performance evaluation of LoRa-based nodes in the mesh network, we can conclude that the nodes can automatically and efficiently build a transmission route. The more hops occur in the network, the transmission time to the destination node will also increase, resulting in a transmission success rate above 98%. It has shown that the LoRa mesh network has been developed successfully. In the future, this system can be adapted for electricity meter reading system and LPG gas meter.

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