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Simulation of Mobile LoRa Gateway for Smart Electricity Meter

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***Abstract*— LoRa is a viable connectivity technology for smart electricity meter. In addition to measuring electricity usage, a smart electricity meter enables many features for smart grid, safety, etc. LoRa is advertised to be capable in very long range transmission and low power consumption. However, LoRa uses sub 1 GHz unlicensed spectrum. In the era of connected smart things, this spectrum is very crowded and will be even more crowded. In this paper we propose the use of mobile LoRa gateway for smart electricity meter. With mobile LoRa gateway, the transmission range can be decreased. Thus, LoRa end devices can save more power and nearby systems can reuse the same band with less interference. We study the performance via simulation using modified LoRaSim. The result shows that the performance of LoRa mobile gateway can be achieved.**

Keywords—LoRa, LoRaSim, Smart Meter

I. INTRODUCTION

Electricity is a very important source of energy in people's lives, whether in the household sector, lighting, communications, industry, and so on. In Indonesia, 43.7 percent of electricity consumers are the household sector. The National Power Utility Company (PLN) is the state-owned enterprise in the electricity sector in Indonesia. Currently PLN has 2 electricity bill payment systems, namely prepaid and postpaid. The number of postpaid users is more than prepaid users. The comparison between postpaid users and prepaid users is 75.7 percent to 24.3 percent [1].

For postpaid customers, PLN needs to conduct periodic checks to verify the accuracy of their electricity meters. This is to ensure that the data counted by the electricity meter is in accordance with the amount of electricity used by the customers. This process is done manually by PLN officer who read directly on the meter located in each house. This reading meter process is less accurate, takes time and costed [2]. In addition, the customer cannot monitor process of recording the electric usage.

The prepaid system was introduced within the last decade to gradually replace the postpaid system. The prepaid system requires newer metering devices which uses GSM/GPRS connectivity to the charging server in PLN's office. It does not need manual work by the officer on-site. To support the upcoming smart grid era [2, 3], where customer can also sell the electricity that they generate (e.g. by solar panel or generator), and to incorporate additional features such as emergency alarm and smart pricing, smarter electricity meter is required. These features can only be achieved when the metering device is more connected. Initially, the idea of power-line communication was studied [4]. However, it faces many implementation hurdles. One of feasible connectivity technology for this case is LoRa [5, 6]. Based on Indonesia regulation, PLN does not need to get license from regulator to use LoRa technology [2].

Long Range (LoRa) [1] is a spread spectrum modulation technique derived from Chirp Spread Spectrum (CSS) with an integrated Forward Error Correction (FEC). Some features of LoRa are low power, robust long-range coverage, low cost, and geolocation. Several interesting studies have been conducted about LoRa. Wibisono and Permata [2] proposed an advanced metering infrastructure based on LoRa WAN, the result is LoRa WAN can be operated in electricity smart meter. Raju et al [7] provides an overview of the LoRa used in collecting data from various air pollution sensors to be analyzed with pollution monitoring systems. Wei Ma and Liang Chen [8] proposed LoRa use to support intelligent agricultural data collection and equipment control. Nugraha et al [9] did the experimental trial using LoRa for monitoring and tracking patients with mental disorder. Bor et al [10] built LoRaSim as the environment to simulate LoRa to find LoRa is Low-Power Wide-Area Network (LPWAN) scale, and the result show that LoRa Network can scale when they use multiple gateways and/or use the parameter selection of dynamic transmission.

LoRa is advertised to be capable in very long range transmission and low power consumption. However, LoRa uses sub 1 GHz unlicensed spectrum. In the era of connected smart things, this spectrum is very crowded and will be even more crowded [11]. The number IoT units installed in 2020 is more than 20 millions [12] and according to a study by Wi-Fi Alliance [13, 14], additional spectrum between 500 MHz and 1 GHz in various regions are needed to support the expected growth by 2020.

Indeed, to anticipate the high demand of IoT connectivity, many IoT networks needs optimization to be able to effectively use their resource [15]. In this paper we propose the use of mobile LoRa gateway for smart electricity meter. With mobile LoRa gateway, the transmission range can be decreased by decreasing its power. The requirement for electricity data meter is not real time, so the data transmitted time from LoRa end devices can be set. Thus, LoRa end devices can save more power and nearby systems can reuse the same band with less interference. Hence, it can use the limited unlicensed spectrum and coexist with other users better.

The performance of mobile LoRa gateway is evaluated via simulation. We perform the simulation using LoRaSim [10] which we modified for several scenarios with mobile gateway. In the next section we introduce about LoRa, LoRaWAN, LoRaSim, and electricity smart meter simulation. Section 3 describes scenario of LoRaSim simulator considered in our simulation. Section 4 presents the results and discussion of our simulation. Section 5 presents the conclusion of this paper.

II. LITERATURE REVIEW

A. *LoRa*

Long Range (LoRa) is patented spread-spectrum radio modulation developed by Cycleo (Grenoble, France) and acquired by Semtech in 2012 [16]. LoRa is not suited for video streaming, it is well fit to serve the Internet of Things (IoT) and Machine to Machine (M2M) applications. Packet size of IoT/M2M generally < 100 kbps and implemented for sensors, or meters, while video streaming > 1 Mbps. The range of frequencies of LoRa that can be used is between 137 MHz to 1020 MHz. A LoRa receiver can decode transmission of 19.5 dB below the noise floor.

Some features of LoRa are low power, robust long-range coverage, low cost, and has geolocation. LoRa uses an asynchronous communication method, the nodes power will on when they send data to the gateway and will return to the power saving mode when no data is sent. LoRa coverage up to 30 miles in rural areas and over 2 miles in densely populated urban areas. LoRa operates in unlicensed spectrum and the LoRa protocol is a free royalty which means LoRa is cost less. LoRa geolocation uses Differential Time of Arrival and other hybrid techniques to determine location. The location of node is estimated by the time packet arrival algorithms from the sensor node to multiple gateways.

LoRa has five configuration parameters that have an influence on energy consumption, transmission duration, resilience to noise, robustness and range [10, 17].

- Transmission Power (TP). TP on LoRa can be set between -4 dBm and 20 dBm in 1 dB steps. A bigger TP increases the energy consumption, the transmission duration (more faster), resilience, robustness and the range (more wider).
- Carrier Frequency (CF). CF can be programmed between 137 MHz to 1020 MHz in steps of 61 Hz. A higher CF increases the energy consumption, the transmission duration (more faster), resilience, robustness and the range (more wider).
- Spreading Factor (SF). SF is the ratio between the symbol rate and chip rate. In each symbol, SF determines how many bits are encoded. SF can be set between 6 and 12. A higher SF increases the energy consumption, resilience, robustness and the range (more wider), while the transmission duration more slower.
- Bandwidth (BW). BW is the width of frequencies in the transmission band. BW can be selected from 7.8 kHz to 500 kHz. A higher BW increases the energy consumption, the transmission duration (more faster), resilience, robustness and the range (more wider).
- Coding Rate (CR). CR is the FEC rate used by the LoRa modem that offers protection against burst interference. CR can be set to either 4/5, 4/6, 4/7 or 4/8. A higher CR increases the energy consumption, resilience, robustness and the range (more wider), while the transmission duration more slower.

B. *LoRaWAN*

LoRaWAN is a communication protocol and system architecture for LoRa network [5, 18]. LoRa nodes are not associated with a specific gateway, but data transmitted from a LoRa node received by multiple gateways. The gateways support bidirectional communication and can process packets sent from LoRa nodes. Fig 1. Shows that each gateway forward the packet to the network server, and the network server forward it to the application server which handles the customer application and presents relevant data. LoRaWAN gateways designed for outdoor or indoor use, and enable for public and private network deployments.

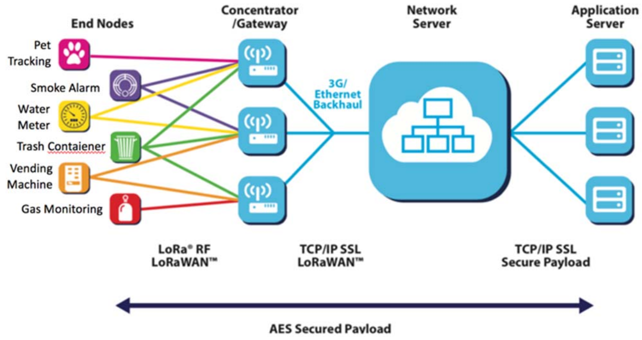


Fig. 1. LoRaWAN Network

C. *LORASIM*

LoRaSim is a discrete-event simulator based on SimPy built by Bor, Roedig, Voight and Alonso [10, 19]. LoRaSim is built to simulate the collision of LoRa networks and to analyse the scalability. There are four Python scripts in LoRaSim: loraDir.py to simulate a single gateway, loraDirMulBS.py to simulate 2 to 24 gateways, directionalLoraIntf to simulate nodes with directional antennae and multiple networks, and oneDirectionalLoarIntf.py to simulate gateways with directional antennae and multiple networks.

D. *Electricity Smart Meter Simulation*

An electricity smart meter simulation that we perform using LoRaSim [10] that we had modified. We modified the placement of nodes and gateway. Nodes in LoRaSim [10] is placed randomly, then gateway is in fixed location. In LoRaSim that we modified, the nodes are in fixed location, and gateway is move from one point to another point. This means that the gateway is mobile.

In this simulation, it is assumed that a residential area consists of 20 houses in each row, if there are 100 houses it will consist of 5 rows of housing and so on as shown in Fig. 2. Each LoRa node will be installed on the electricity meter device in every house. The gateway will be brought by PLN officer using a motorcycle through residential area. Each node will send a packet of electrical data usage (in KWH) to mobile gateway.

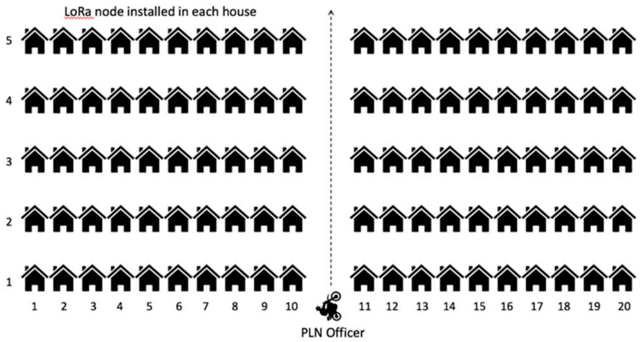


Fig. 2. Residential Area of Simulation

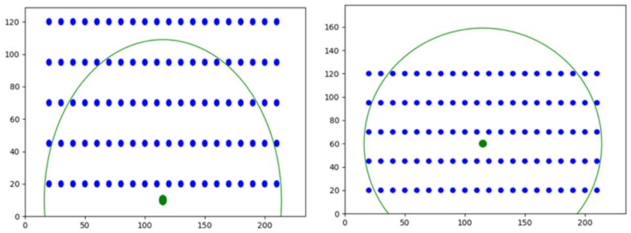
III. SIMULATION SCENARIO

We modified the LoRaSim simulator as follow: first we define the start position of gateway, then we set the movement of mobile gateway. Second we define the start position of first node and create as many nodes that we want for simulation. The nodes is in fix place position forming like Fig. 2 consists of 20 nodes in each row. Mobile gateway will move from the first row until the last row. To run simulation, we use the expression below:

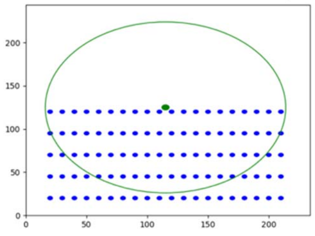
```
./loraDir.py <Nodes> <AvgSend> <Experiment>
<SimTime> [Collision]
```

Nodes parameter is the number of nodes in one simulation. AvgSend parameter is average of sending interval in milliseconds. Experiment parameter is type of radio setting that used for simulation. The value of experiment setting is 0-5 which every value has embedded parameter setting in LoRaSim. Experiment 0 (Exp 0) use the setting with the slowest data rate. Experiment 1 (Exp 1) is similar to Exp 0, but use a random transmit frequencies. Experiment 2 (Exp 2) use the setting with the fastest data rate. Experiment 3 (Exp 3) use optimize setting per node based on the distance to the gateway. Experiment 4 (Exp 4) use the setting as defined in LoRaWan. And Experiment 5 (Exp 5) is similar to Exp 3, but also optimizes the transmit power. SimTime parameter is the total of running time simulation in milliseconds. Collision parameter is the collision check of simulation. To enable full collision check, set 1, and to enable simplified collision check, set 0.

We choose an electricity meter case study in Indonesia with the assumptions outlined in section 2.4. We run the simulation with modified LoRaSim to evaluate scalability and performance of LoRa deployments. Gateway moves right in the middle of residential area. The simulation example can be seen in Fig. 4. Gateway start position in 2(1), 2(2) gateway is right in the middle of trip, and 2(3) gateway at finish position.



(1) Mobile Gateway start moving (2) Mobile Gateway is in the middle of trip



(3) Mobile Gateway stop moving

Fig. 3. Simulation Examples of Gateway and Nodes Position in LoRaSim

We run simulation to find Data Extraction Rate (DER) and Network Energy Consumption (NEC). In [10] DER is the ratio of received messages to sent messages over a certain period of time. DER value is between 0 to 1. LoRa deployment is effective when DER value is near to 1. NEC is the energy consumed by the network so the messages can be successfully extracted. The lower NEC value, the more efficient of LoRa deployment.

$$DER = \frac{\Sigma \text{ packet sent} - \Sigma \text{ collision}}{\Sigma \text{ packet sent}}$$

-packet sent: packet sent of each node
-collision: collision occur during sending packets

$$NEC = \frac{\sum_{i=0}^{n}(t\,packet_i * TxPower_i * V * packet\ sent_i}{1000000}$$

-i: index for node
-n: number of nodes
-t packet: time for packet sent per node
-Tx Power: transmission power
-V: node power
-packet sent: packet sent of each node

The number of nodes in simulation that we use are 100, 120, 140, 160, 180 and 200. We use experiment (Exp) parameter value 3 and 5 which has defined in LoRaSim. As previously explained, in Exp 3 each node has optimized setting based on the distance to the gateway, while in Exp 5 has similar setting to Exp 3 but the transmit power is also optimized. Packet transmission rate (λ) defined as 1 x 10^{-6} ms, and packet payload (B) defined as 20 byte. Parameter setting in Exp 3 and Exp 5 shown in Table 1. For average sending packet by LoRa node is 30 s (30000 ms). Our assumption in this IoT era, there are many interferences which can lead collisions. Therefore in our simulations we set 1 to collision parameter. Then we simulate in several scenario. Gateway movement speed based on SimTime parameter value. In any number of nodes (100, 120, 140, 160, 180, 200), the number of rows of nodes (housing) will also increase, so we add the SimTime in any number of rows that increase.

TABLE I. DEFINED PARAMETER SETTING IN LORASIM

Parameter	Exp 3	Exp 5
TP (dBm)	14	Min (TP)
CF (MHz)	860	860
SF	Best (SF)	Best (SF)
BW (kHz)	Best (BW)	Best (BW)
CR	4/5	4/5
λ (ms)	1 x 10^{-6}	1 x 10^{-6}
B (byte)	20	20

We use 3 scenarios to run simulation. In Scenario Number 1 (SN 1) shown in Table 2, we use 100-200 nodes, the average sending interval is set to 30000ms, the Exp is set to 3, and the collision is set to 1. The SimTime for 100 nodes is 6 minutes (360000 ms), SimTime for 120 nodes is 7.2 minutes (432000 ms), SimTime for 140 nodes is 8.4 minutes (504000 ms), SimTime for 160 nodes is 9.6 minutes (576000 ms), SimTime for 180 minutes is 10.8 minutes (648000 ms), and SimTime for 200 nodes is 12 minutes (720000 ms). In Scenario Number 2 (SN 2), we change the speed of mobile gateway by changing the SimTime. SimTime 1 similar to SimTIme SN 1, SimTime 2 we increase twice from SimTime 1, and SimTime 3 we decrese twice from SimTime 1. Parameter setting for SN 2 shown in Table 3. In Scenario Number 3 (SN 3), similar to SN 2 but we change the experiment with Exp 5 which has optimized transmit power as shown in Table 4.

TABLE II. PARAMETER SETTING FOR SN 1

Parameter	Scenario Number 1 (SN 1)					
Number of Nodes	100	120	140	160	180	200
AvgSend (ms)	30000					
SimTime (ms)	360000	432000	504000	576000	648000	720000
Exp	3					
Collision	1					

TABLE III. PARAMETER SETTING FOR SN 2

Parameter	Scenario Number 2 (SN 2)					
Number of Nodes	100	120	140	160	180	200
AvgSend (ms)	30000					
SimTime 1 (ms)	360000	432000	504000	576000	648000	720000
SimTime 2 (ms)	180000	216000	252000	288000	324000	360000
SimTime 3 (ms)	720000	864000	1008000	1152000	1296000	1440000
Exp	3					
Collision	1					

TABLE IV. PARAMETER SETTING FOR SN 3

Parameter	Scenario Number 3 (SN 3)					
Number of Nodes	100	120	140	160	180	200
AvgSend (ms)	30000					
SimTime 1 (ms)	360000	432000	504000	576000	648000	720000
SimTime 2 (ms)	180000	216000	252000	288000	324000	360000
SimTime 3 (ms)	720000	864000	1008000	1152000	1296000	1440000
Exp	5					
Collision	1					

IV. SIMULATION RESULTS AND EVALUATION

A. Scenario Number 1 (SN 1)

We run simulation in several times. The result show DER value is decreasing in some number of nodes (DER Min). It caused by to many collision that occurs during sending packet from LoRa nodes to mobile gateway at a time. As an example in 140 nodes, there is a time that reach 6012 collisions, while the average of the best performance (DER) is around 1000 collisions. When the number collisions are normal, DER value is about 0.9 (DER Max). Overall, the average of DER value (DER Average) from SN 1 results are still above 0.9, except at 200 nodes. With increasing the number of nodes, the energy used also increases. The results of SN 1 are shown in Fig. 4 and Fig. 5.

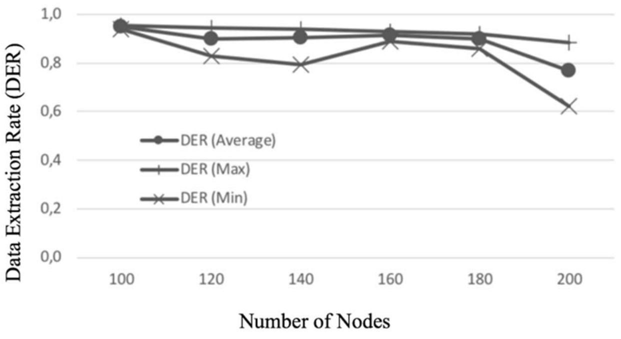


Fig. 4. DER value of SN 1

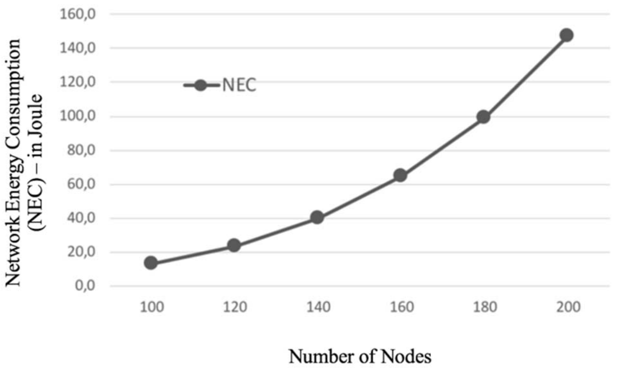


Fig. 5. NEC value of SN 1

B. Scenario Number 2 (SN 2)

We compare SimTime 1 (V1), SimTime 2 (V2) and SimTime 3 (V3). When the SimTime is increase or decrease twice, the performance does not change too much. The result is still influenced by collisions that occur at a time. But for NEC value, when the SimTime is increase, the energy used is lower than before. And when the SimTime is decrease, the energy used is higher. The results for SN 2 are shown in Fig. 6 and 7.

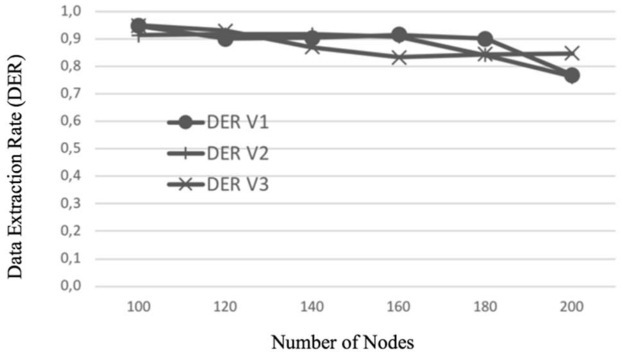


Fig. 6. DER value of SN 2

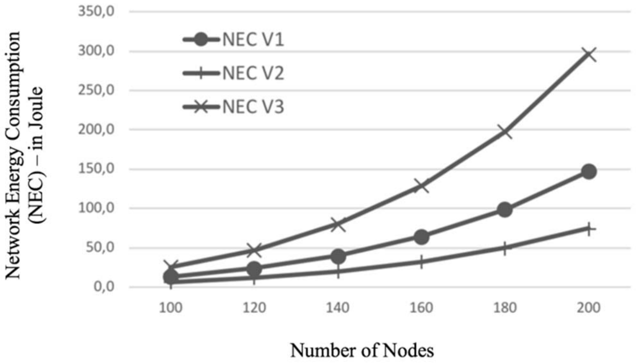


Fig. 7. NEC value of SN 2

C. Scenario Number 3 (SN 3)

Same results for SN 3 which DER value is influenced by collisions that occur. Different results are on the energy used, using Exp 5 can saves 70-80 percent than using Exp 3. The results of SN 3 are shown in Fig. 8 and 9.

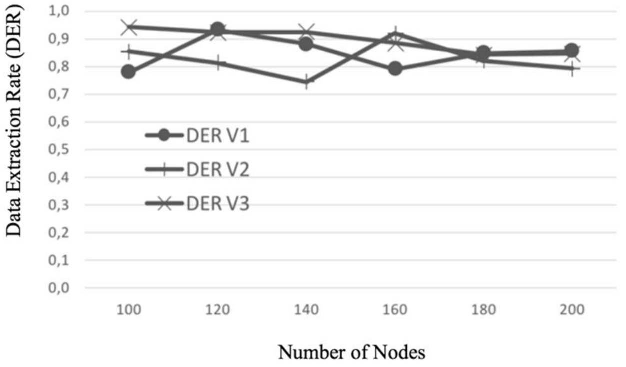


Fig. 8. DER value of SN 3

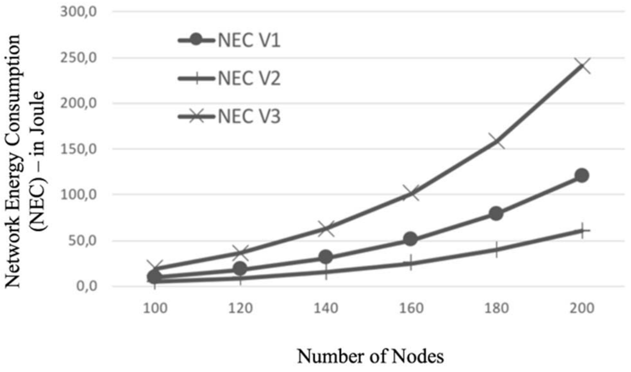


Fig. 9. NEC value of SN 3

V. CONCLUSION

Based on our work in electricity smart meter simulation with LoRaSim, overall the performance of mobile gateway with LoRa can be achieved, even at a time there is a performance could not be achieved when occur to many collisions. The challenge is to choose a time when the number of collisions that occur is not too much.

When the number of nodes is increase, the energy consumption is also increase. When increasing the simulation time speed, the energy consumption is getting smaller. Optimizing the transmitter power can saves the energy consumptions too.

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