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Prototype of Long-Range Radio Communication for e-Nelayan Devices using LoRaWAN

Performance Case Study within City Boundaries

Syifaul Fuada[1], Sinantya Feranti Anindya[2], Febri Dawani[3]*, Aditia Rifai[4], Erick Adinugraha[5], Irfan Gani Purwanda[6], Trio Adiono[7]

[1,2,3,4,5,6] IC Design Laboratory, PAU Building, Tamansari Street No. 126, ITB Campus, Bandung city, West Java, Indonesia (40132)

[7] Electrical Engineering Department, School of Electrical and Engineering, Institut Teknologi Bandung

[1,2,3,4,5,6] University Center of Excellence on Microelectronics, Institut Teknologi Bandung

[7] Ganesha Street No. 10, Bandung city, West Java, Indonesia (40116)

*Corresponding email: febridawani@gmail.com

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Abstract — In this paper, development progress of a long-range radio communication-based fishing assistant system called *e-Nelayan* is reported. The purpose of the system is to increase the productivity, safety, and welfare of fishermen using mobile phone and long-range radio based system that enables them to report maritime violations, access and exchange information regarding weather, fishing area, marketplace, and also communication with mainland using Android-based mobile phone within extended range. We used LoRaWAN as a base technology for long-range communication scheme. In this work, the test conducted to obtain an insight to e-Nelayan device (LoRa-based) received RSSI and its packet loss. The received data collected in a server also includes the GPS tracking data. The test results show that our system reached approximately 5 km of distance between end-node to the LoRa Gateway within urban area (LoS configuration) and about 2 km for NLOS configuration.

Keywords – e-Nelayan, LoRaWAN, Long-range radio communication, RSSI, Urban area

I. INTRODUCTION

Indonesia has second largest capture fisheries production in marine waters in the world, i.e. 5.8 million km^2 which are divided into 11 Fisheries Management Areas of Republic of Indonesia. In 2016, fishery contributes 19 percent to the gross domestic product (GDP) of the country, with average growth of 1.49 percent per year between 2012-2015 [1]. Combined with other potentials such as natural resources and marine tourism, the maritime and fishery sector in Indonesia has strong potential to become the primary driving force behind the economy of the country.

Despite the aforementioned potentials and the seemingly positive growth, maritime and fishery sector in Indonesia remains riddled with numerous challenges those hamper its economic potentials, ranging from resource management to the welfare of citizens working in the sector. In terms of economic welfare, although 15.61 percent of village-level administrative zones are located in coastal areas, only 21.16 percent of said villages have fishery as their primary source of income. Furthermore, in total, only 1.95 percent of Indonesian citizens work as fishermen as their primary job. Although in general the fishermen have better trade value than fish farmers, many of them remain below poverty line with total income below the regional minimum wage. Furthermore, being a fisherman is a high-risk job full of uncertainty such as frequently changing weathers, and many fishermen are not equipped to handle such situation.

In terms of resource management, the problems include environmental damage due to both overfishing and land clearing for fish farming/aquaculture, as well as pollution. If not handled properly, the environmental damage will also negatively impact the economic growth. As such, various policies and development established by the country must also take these risks into consideration, including the technological development.

To address the aforementioned issues, in this research a long-range radio system for assisting fishermen in Indonesia's coastal areas is developed. The aim of the developed product is to enable Indonesian fishermen – particularly the users of small-size vessels (< 5 GT category) and below – to access information system related to their occupation in real time; the accessible information includes (but not limited to): weather forecast, potential fishing spots, real-time global positioning system (GPS) position and price of the various fishes in the nearest market. The system is also equipped with reporting, tracking, and SOS features, which are crucial for the fishermen's safety and for reporting irregularities such as sightings of illegal fishing. The system comprises of three components: an Android-based mobile application, a long-range (LoRa) radio for relaying commands from the mobile phone to the off-shore station, and a back-end web application where related policy makers can manage data received from the fishermen. The system will also be connected to databases from various institutions, such as Meteorological, Climatological, and Geophysical Agency's database for weather forecast. This publication reports the progress and continuation from our previous studies reported in [2] and [3].

Despite the target area of operation of the system (i.e. coastal areas), in this publication the system's deployment will be limited to within boundaries of Bandung city area before moving to the actual testing grounds. The justification behind this limitation is that city area possesses far more obstacles compared to those may hinder the system's performance compared to coastal area; as such, if the system is able to work well within the city boundaries, it is assumed the system will also work well in coastal and sea areas. Therefore, only test result from the city boundaries is conducted and reported in this article, while the result for field test in coastal areas will be detailed further in future article.

This paper consists of five sections: 1) Introduction; 2) Research methods that discusses literature review, overview of LoRaWAN technology, define the system specification, design and implementation of e-Nelayan, testing and scenario); 3) Results; 4) Analysis, and 5) Conclusion.

II. RESEARCH METHOD

A. Literature Review

The information and communication technology (ICT) is generally used in maritime field to streamline various processes concerning marine-related operations. The European Commission's e-Maritime [4] initiative is one such example, where ICT is applied for information exchange concerning shipping and transport-related operations [5], [6], as well as assisting in navigation [7]. Another example is application of Internet of Things (IoT) to support ship maintenance and repair [8]. These systems are generally used for enhancing the process within large scale.

Compared to applications for improving shipping and transportation process as a whole, the application to improve the condition of the ship and livelihood of the fishermen has not been researched as much. Rao *et al* [9] proposed a long-range Wi-Fi mobile infrastructure to enable fishermen to communicate with mainland from afar (45 km+) using smart phone, while Al-Zaidi *et al* [10] proposed a ship ad-hoc network based on VHF radios to support data acquisition and cartography tasks. Another example is the e-navigation service proposed by Kwang in [11] for non-SOLAS ships. The systems proposed in aforementioned studies have strong prospect to enhance the fishermen's well-being particularly in safety aspects; however, given the elaborated background, safety is not the only concern for Indonesian fishermen. Later, Hidayat [12] proposed for 10 – 30 GT vessel monitoring system using LoRa combined with Microcontroller. However, in [12] doesn't discuss about technically implementation yet, it means, the reference [12] still in preliminary study (concept design) step.

To increase the livelihood and trade value of Indonesian fishermen, they also need to be able to access information regarding the market. As such, in this research, the proposed system is equipped not only with safety functions such as SOS and communication with nearest port, but also functions to access and exchange information regarding fishing zone and environmental situation. By providing said functions as contribution, it is hoped the system will be able to increase the effectiveness and efficiency of the fishermen's activities

B. LoRaWAN Technology

This research utilizes LoRa as the primary communication protocol. LoRa or called as LoRaWAN is a communication specification for low-power wide area network (LPWAN) formed using wireless devices, which are generally operated using battery. LoRaWAN is commonly employed for IoT application whether for bidirectional, mobile, or local communications. The LoRaWAN provides seamless interoperability between connected smart devices. Table 2 shows the comparison between LoRa to other wireless technologies.

Table 1. Comparison of LoRa to WiFi, Bluetooth, Zigbee, Cellular Network

Technology	Advantages	Challenges
Local Area Network (Bluetooth 4.0, Zigbee, WiFi)	Well established standards in building	Battery live, provisioning, network cost and dependencies
Cellular network (GSM, 4G, 3G+/H+)	Existing coverage and high data rate	Autonomy and total cost of ownership
LoRa	Low power consumption, low-cost, operating in the	High data rate

Technology	Advantages	Challenges
	license-free spectrum	Emerging standards

The LoRa network is employed for situations those require extended range coverage, low-bitrate, and low-power usage. Some example cases employing LoRa include:

1) IoT for smart city, the performance evaluation of LoRaWAN was reported by [13-14]. An implementation example such as noise urban mapping [15].
2) Smart lighting application [16], an example of this application is to control the lights based on weather condition.
3) Smart parking to enable user to quickly find available parking spaces such as reported by [17].
4) Smart agriculture [18], the application case such as monitoring the soil humidity, air humidity, and for finding ideal plantation condition.
5) Sea water application, such as reported by [19]. In this work, the targeted goal is to implement our system to sea area. However, we first focus on urban area test.

The architecture of a LoRaWAN network is presented in Fig.1. The LoRa is an open standard utilizing sub-GHz frequencies to enable extended range of coverage. Possible frequency ranges for e-Nelayan applications include 868 MHz and 902 – 928 MHz.

The LoRaWAN architecture comprises of three main components: end-node, gateway, and server. The end-node is the part that will be connected to the client, specifically the digital radio of the client. The common specification of LoRaWAN is as follows:

- Optimized for long range, low rate data transfer.
- Transmit power: 70 mW
- TX Peak Current: 122 mA
- RX Peak Current: 10 mA
- 150 bps @ -141dBm to 37.5 kbps @ -112 dBm
- 145 dB total link budget
- 20 dBm output power
- Rated for 100% duty cycle
- Sleep current: <1 µA (regulated/direct), 10 µA (unregulated)
- 0.75” x 0.9” of dimension
- Simple SPI and UART interface
- 64 selectable channels
- Hopping operation allows -140dBm sensitivity @ 150 bps

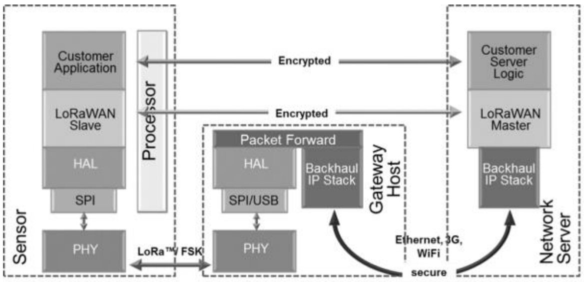


Fig 1. Network Diagram of LoRaWAN [20]

C. System Specification

The system supports multi-gateway infrastructure to the server, similar to cellular network infrastructure. As such, the system can be easily connected to existing wireless infrastructure. In addition, the system can also support multiple users through allocation of different frequencies. The scheme of the data communication system of e-Nelayan is depicted in Fig.2, with the description of each section as follows:

1) Fishermen communication module is used by fishermen’s device when no signal or cellular service is available. This module is a client-side module comprises of two devices, namely:
   - Smartphone containing graphical user interface/application of e-Nelayan. The user can engage in conversation, send SOS signal, and send their location data using the application.
   - Radio module serves to enable data exchange using data modulation.
2) Tower communication module is installed in a tower in the port and connected to the server and the Internet.
3) Server application serves as command center for monitoring and data gathering based on the information reported by active fishermen.

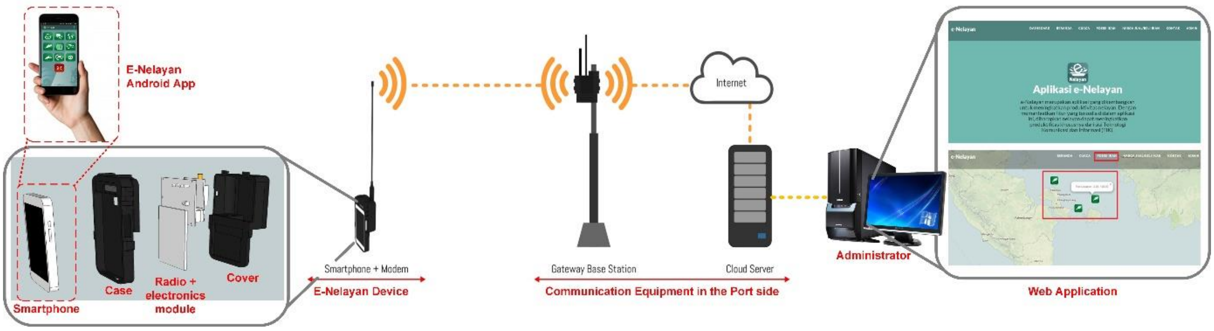


Fig.2. System Architecture

The radio module is the most important part of the system that enables communication between the fisherman and the mainland/port. The radio module comprises of several components, namely:

1) Microcontroller unit that serves as the motherboard of the radio module as a whole.
2) LoRa radio module for data exchange through air.
3) Bluetooth module for exchanging data with the user interface/smartphone.
4) DC regulator for supplying power to the radio module.
5) LiPo charger for recharging and storing power within the battery installed into the system.

D. Design and Implementation

Once the specification is defined, the next step is to design and implement the system. In this research, only the end-node and server network will be covered, while the gateway part is implemented by utilizing the LoRaWAN's innate module. The system prototype reported in this article comprises of one unit of Android-based smartphone equipped with one radio module.

The server application is designed to store tracking data captured by the end-node device. In this research, the monitoring/data storage system is implemented using Python programming language without graphical user interface; instead, it contains log of entries written in the format as presented in Eq. (1). The node ID is assigned using reference number "2". The counter tx indicates the amount of data transmitted.

YYYY-MM-DD hh:mm, node id, RSSI, latitude, longitude, tx counter (1)

E. Testing Procedure

As previously described in the introduction section, for this phase of research, the prototype is tested within city area (Bandung) instead of sea area. The aim of the test is to obtain data related to coverage area from the server gateway and evaluate the performance of the prototype before it is deployed to the field; the Bandung area is deemed suitable for testing against the possible obstacles those may hinder the system's performance. The testing data includes position of the end-node and received signal strength indicator (RSSI), the latter of which is presented in dBm.

The testing is conducted using simultaneously transmission scenario, where the transmitter (end-node) sends the data to the receiver (Gateway) via LoRaWAN continuously. We set the data packet size sent by the end-node as 20 Byte/second. The RSSI value of e-Nelayan system is then collected and stored in cloud server along with the received packet and GPS tracking data; the packet loss can be identified when the RSSI is within certain level. In this work, we used Eq. (2) to measure packet loss.

$$100\% - \left(\frac{\text{Received packet data}}{\text{Transmitted packet data}} \times 100\%\right) \quad (2)$$

While for the e-Nelayan testing, we utilized several components, namely:

1) End-node prototype consisting hardware and software with LoRaWAN configuration.
2) Android-based smartphone containing application for receiving data during test. The smartphone is connected to the end-node using Bluetooth type HC-05. In this work, we used 4G smartphone made by Indonesian, namely *Digicoop* (https://koperasidigital.id/).
3) Server gateway (Fig.3) located in the rooftop of PAU building of ITB (GPS coordinate located at -6.888190, 107.609689). The gateway was installed at ±50 meters height.
4) Server tracking application, in this work we used a PC connected directly to ITB cloud server.

Fig.3. Server Gateway Installation

The test is conducted according to the following steps: first, both the end-node (radio) prototype and smartphone application dubbed as "LoRa Test" are activated. Then, the smartphone and the end-node are paired using Bluetooth. The distance between the tower and the end-node is gradually increased while the test is performed, while the data is observed using Android application to check whether the data packet received is the same as the packet sent. The tracking scenario includes non-line-of-sight (NLOS) because we tested in urban area where there are many obstacles (buildings) and the trees. Moreover, the Bandung city's contour tends (almost) to climb. Therefore, the difference between LOS and NLOS is in "field test condition". Fig.4 illustrates the testing scenario, we employed Institut Teknologi Bandung server as a cloud server to store the data logger as expressed in Eq. (1).

The tracking data is displayed in both Android application and the server-side application. The first and last tracking entries are then retrieved and plotted using online Map Maker application (https://www.darrinward.com/lat-long), while the contour is mapped using the application in http://www.heywhatsthat.com/.

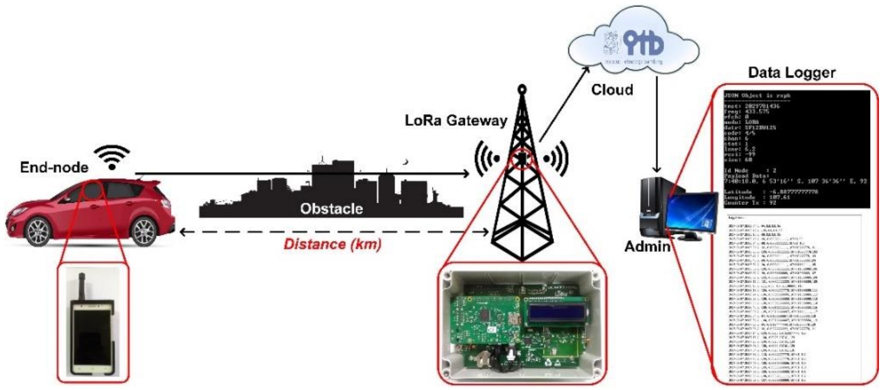


Fig.4. Testing Scenario for e-Nelayan End-Node in The Urban Area Including Lora Gateway, End-Node, ITB Cloud Server and PC Admin

III. RESULTS

A. Hardware Implementation

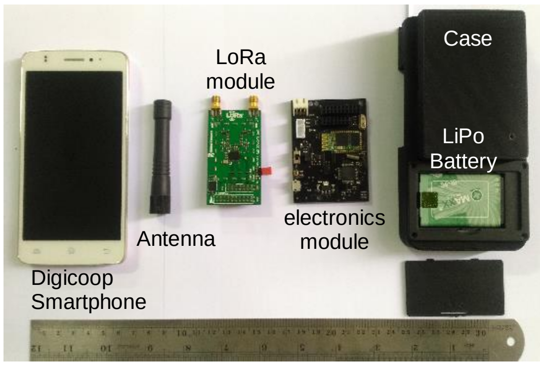
The end-node of e-Nelayan system is depicted in Fig.4, while its components is depicted in Fig.5(a). The end-node consists Digicoop Android smartphone, LoRa radio module, electronics module, RF mini antenna, 12 V_{DC} LiPo battery and e-Nelayan case. Then, we zoomed-out the electronics module to show the part of circuit that includes (a) MCU using STM32 chip from ST Microelectronics; (b) Bluetooth module HC-05; (c) DC regulator on-chip; and (d) LiPo battery charger circuit as shown in Fig.5(b).

Fig.4. Prototype of e-Nelayan End-Node

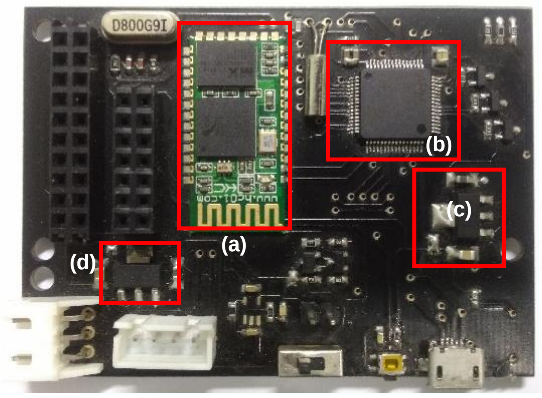
B. Coverage tracking of LoRa

The test was conducted in August 7-9, 2017 starting from 8 AM. The first five data and last five data for August 7 is depicted in Table 2. In accordance to the data format previously elaborated in Eq. (1), the data is presented as date (2017-08-07), time (20:05:04), end-node ID (“2”), and RSSI value (-90 dBm), latitude and longitude (6.88861111111 and 107.61), and packet counter.

The plotting result for the first day’s test is depicted in Fig.6 and Fig.7. Fig.8 shows the contour condition between Gateway (*x*) location to the last point of end-node position (*y*) using Heywhatsthat feature. While the data recording, distance, and contour map are depicted in Fig. 9(a), 9(b), and 9(c) respectively.



(a)



(b)

Fig 5. (a) Anatomy of e-Nelayan Radio System; (b) Electronics Part of e-Nelayan Includes MCU and Bluetooth Module HC-05

Table 2. Data Logging Result For First Day (Point-1)

```
2017-08-07 20:05:20, 2, -90, -6.88861111111, 107.61, 99
2017-08-07 20:05:24, 2, -88, -6.88861111111, 107.61, 100
2017-08-07 20:05:30, 2, -92, -6.88861111111, 107.610277778, 101
2017-08-07 20:05:35, 2, -103, -6.88861111111, 107.610277778, 102
2017-08-07 20:05:41, 2, -94, -6.88861111111, 107.610277778, 103

…

2017-08-07 20:15:48, 2, -111, -6.9075, 107.610555556, 227
2017-08-07 20:25:12, 2, -110, -6.93222222222, 107.625277778, 340
2017-08-07 20:25:17, 2, -111, -6.93222222222, 107.625555556, 341
2017-08-07 20:25:46, 2, -112, -6.93194444444, 107.625277778, 347
2017-08-07 20:25:52, 2, -111, -6.93194444444, 107.625277778, 348
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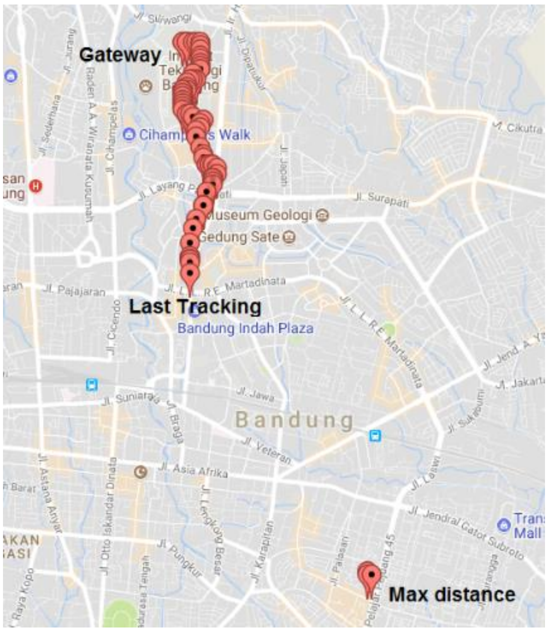
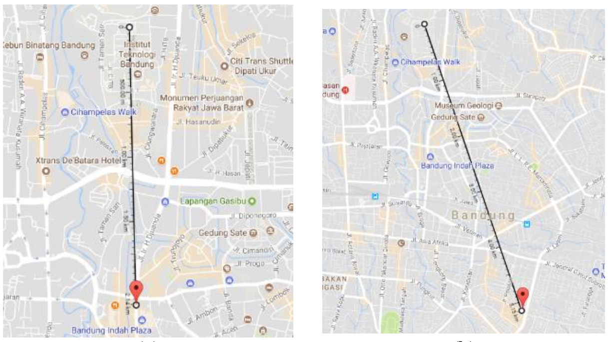


Fig.6. Tracking Data Plot from Google Map, April 7, 2017



(a) (b)

Fig.7. Distance to Final Point in Configurations: (a) Nlos; (b) Los

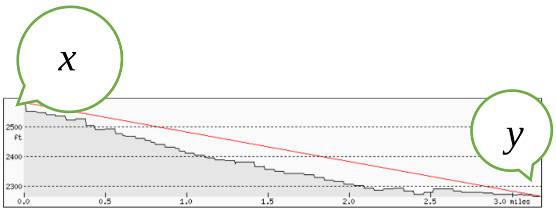
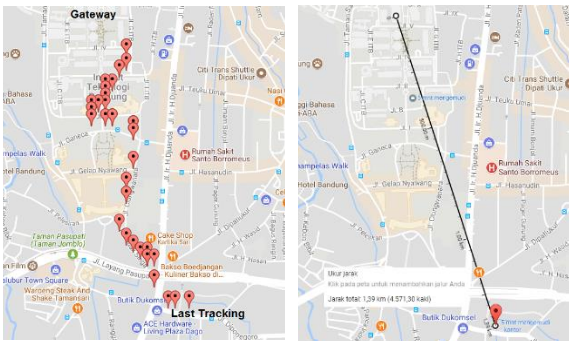
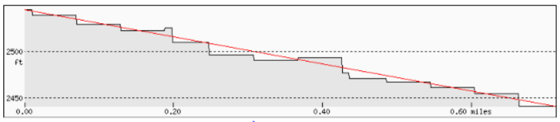


Fig.8. Contour Plot in Day I Test, x Point = Gateway Location & y Point = End-Node Location



(a) (b)



(c)

Fig.9. (a) Tracking Data Plot for Day II, August 8, 2017; (b) Final Point Distance (-6.90027777778, 107.613888889)

The final point in the third day is determined based on three areas in NLoS configuration, namely: (-6.9, 107.601111111), (-6.89888888889, 107.618333333), and (-6.87388888889, 107.619166667) which located around ITB campus as visualized in Fig.10. Table 3 summarizes the maximum distance for each point. The contour map based on the gateway and end-user's positions for all three locations can be observed in Fig.11, which shows that all paths leading into each point tend to have rocky contour/elevation.

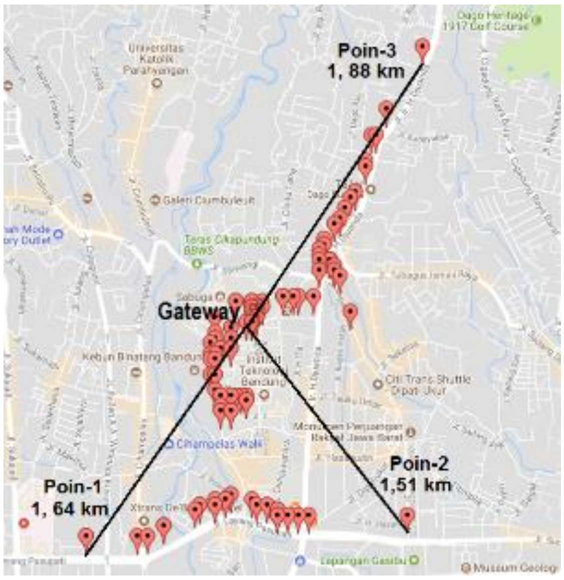
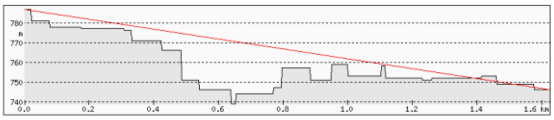


Fig.10. Tracking Data Plot for Day III, August 9, 2017. Gateway is Located in (-6.888190, 107.609689) While End-Node is Located in (-6.92472222222, 107.644166667), With Gateway is Located 53m from Ground

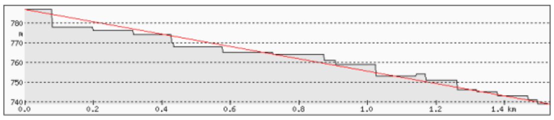
Table 3. Maximum End-Node Distance in NLoS Mode (Day III)

Point	Position (latitude, longitude)	RSSI (dBm)	Distance (Km)
1	-6.9, 107.601111111	-111	1.64

Point	Position (latitude, longitude)	RSSI (dBm)	Distance (Km)
2	-6.89888888889, 107.618333333	-109	1.51
3	-6.87388888889, 107.619166667	-109	1.88



(a)



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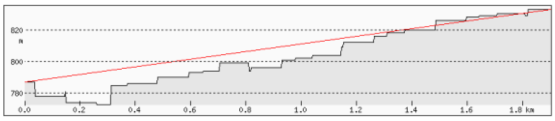

(c)

Fig.11. Gateway position contour to: (a) first point; (b) second point; and (3) third point in Day III, August 9, 2017

IV. DISCUSSION

Based on Table 2, it can be observed that the further the end-node is from the tower, the RSSI value worsens (-90 dBm to -111 dBm). The unstable RSSI values were resulted from obstacles such as buildings. The poorer signal quality is also indicated through the packet loss in the last five entries; for example, from counter 227 the packet counter jumped to 340, then 341 to 347. In total, we sent 348 times of data packet and loss of 148 data packet. It means, the received packet is 200. The percentage of successful received data packet in Day I is 57.47 %. Therefore, refer from Eq. (2), the loss packet is 42.53 %. Based on Fig. 7a and 7b, the distance between first and last point is 2.14 km in NLoS condition and 5.15 km in LoS condition.

In the second day, 114 data packets are transmitted with 16.67% packet loss, hence 95 data packets are received. Based on Fig.9(a), 9(b), and 9(c), it can be concluded that the maximum distance between end-node and gateway is 1.39 km in NLoS configuration.

Based on the maximum distance and RSSI obtained from three different points as visualized in Fig.11 and presented in Table 3, 365 out of 778 data packets sent are not received, thus resulting in 47-53% loss. This shows that the loss is not necessarily influenced by existence of obstacles such as trees and buildings.

V. CONCLUSION

In this paper, progress of long-range radio communication-based system for e-Nelayan is reported, which includes testing of the radio system in urban area. The aim of the test is to gauge the performance of the system before it is tested in the appropriate field and obtain benchmark for later adjustments. The test is conducted in three days to obtain the coverage range of the radio. Based on the test result, the system can reach 5.15 km in LoS condition (field test condition without any obstacles), while in NLoS condition the coverage varies between 1.39 km to 2.12 km, while the data packet loss varies between 16.67% to 57.47% that can be categorized as the minimum travel distance because the transmitted signal affects the condition of Bandung City contour, i.e. NLOS. The NLOS configuration can reduce the transmission signal strength because it has influences such as fading and noise.

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