LouPe LoRa Performance Measurement Tool-(24).pdf

by

Submission date: 18-Jun-2023 09:17PM (UTC+0700)
Submission ID: 2118231424
File name: LouPe LoRa Performance Measurement Tool-(24).pdf (966.35K)
Word count: 3056
Character count: 16097

LouPe: LoRa Performance Measurement Tool

Muhammad Rizky Eka Arlin
Department of Informatics
Universitas Hasanuddin
Makassar, Indonesia
arlinmre14d@student.unhas.ac.id

Muhammad Niswar
Department of Informatics
Universitas Hasanuddin
Makassar, Indonesia
niswar@unhas.ac.id

Adnan Adnan
Department of Informatics
Universitas Hasanuddin
Makassar, Indonesia
adnan@unhas.ac.id

Shigeru Kashihara
Graduate School of Science and Technology
Nara Institute of Science and Technology
Nara, Japan
shigeru@is.naist.jp

Doudou Fall
Graduate School of Science and Technology
Nara Institute of Science and Technology
Nara, Japan
doudou-f@is.naist.jp

***Abstract*— With the popularity and the high demand of Internet of Things (IoT), company and university are striving to deliver innovations every day. LoRa is one of the trending technologies in the IoT field, and it can build Low-Power Wide Area Network (LPWAN). However, the network performance of LoRa strongly depends on an environment where LoRa is installed. Therefore, before deploying a network with LoRa, we need to evaluate network performance. At present, researchers or developers evaluate it manually. In this paper, we provide a design of a measurement tool for evaluating network performance with LoRa to support for deploying a LoRa network. We also show experimental results by using our measurement tool, and we then discussed installing the LoRa network in our crab park environment.**

Keywords—LoRa, performance evaluation, measurement tool

I. Introduction

Various services and applications based on Internet of Things (IoT) are appearing; smart city, smart agriculture/aquaculture, smart healthcare, and so on. With numerous demands and a wide array of use cases, new IoT technologies invented with the short amount of time, from physical module to fully integrated cloud-service for IoT. As the number of IoT market grows significantly [2], the demand of technology like Low-Power Wide Area Network (LPWAN) also increases to open up opportunities due to its characteristics of long-range connectivity, low power, low deployment and operational cost, reliability, robustness, and potential to scale [3]. However, those characteristics still in its early phase, there are still many improvements that should be made to draw its full potential.

At present, there are several LPWAN technologies such as LoRa, Sigfox, NB-IoT, EC-GSM-IoT, Nwave's, Ingenus's, Telensa, Weightless, and WAVIoT's NB-Fi [4]. LoRa is a popular physical module in the IoT field. LoRa Alliance in their End of Year Report 2017 [1] announced that there are more than 500 companies, organization, and university joining their alliance in supporting and implementing LoRaWAN. One of LoRa Alliance's members is managing data from 200,000 sensors [5].

LoRa is PHY layer implementation, and LoRaWAN is a protocol specification for LoRa in the MAC layer. LoRaWAN implements star topology, and there are three classes in LoRaWAN protocol to satisfy different needs of various use cases. Class A – Lowest power, end-devices open downlink communication for a short time right after an uplink transmission, Class B – end-devices open downlink communication with the scheduled time, and Class C – end-devices never close the downlink communication [6]. LoRaWAN class A is an ALOHA-like protocol. The only difference is LoRaWAN class A doesn't use a fixed frame size.

On the other hand, LoRa allows us to configure its PHY Parameters that directly affect the LoRa Performance. Each parameter has a trade-off for the LoRa performance [7]. For instance, the parameters are as follows: spreading factor (SF), bandwidth (BW), coding rate (CR), transmission power (TP). The ratio of LoRa's symbol rate and chip rate is called Spreading Factor. Signal to Noise Ratio (SNR) will be directly affected by SF in a way that higher SF will increase the SNR. Hence, the range and sensitivity will also be increased. The trade-off is in the Time on Air. A packet transmitted with high SF will take a longer time. Available option for spreading factor start from 6 to 12. Each increment in SF will make the transmission duration two times longer. Thus the energy consumption will also become higher.

Bandwidth is the width of frequencies used in a transmission band. The data rate can be increased by using higher Bandwidth, which also makes shorter ToA. The trade-off is lower sensitivity because more noise integrated from its more extensive use of frequencies. A lower bandwidth increases the ToA but gives lower sensitivity. Data in LoRa is sent at a chip rate of the same level to the bandwidth; 250kHz of bandwidth corresponding with a chip rate of 250 kbps. Mostly, LoRa network operates at either 125 kHz, 250 kHz, 500 kHz. Even though LoRa can operate in a range of 7.8 kHz to 500 kHz.

LoRa utilizes forward coding error correction (FEC) that can be configured as CR. The FEC rate used by the LoRa device to protect the transmission from bursts of interference. This CR offers four options: 4/5, 4/6, 4/7, and 4/8. Increasing the CR will give make LoRa more resistant against error. However, increasing the CR will also increases the ToA. Modules with different CR can still communicate one another if the modules implement explicit header. High TP increases the Signal to Noise Ratio but also increases the energy consumption. TP can be chosen from -4 dBm to 20 dBm, but the range is often limited to 2 dBm to 20 dBm because of limitation in the hardware implementation.

Frame size or packet size also plays an essential role in LoRa performance. There are some regulations regarding the maximum payload size of LoRa [8]. With the highest data rate

978-1-5386-8050-6/18/$31.00 ©2018 IEEE

and without a repeater, the maximum payload size is 250 KB. In several countries, there is no regulation about the limit of LoRa frame size. The time needed by the packet from the transmitter to the receiver is called ToA. ToA is directly affected by the PHY Parameters and the frame size. Some of the regulations regarding LoRa specify the duty cycle of nodes in the network. The duty cycle is the limit of the amount of time a device can use a channel. The duty cycle came in a percentage of the time unit. We can use the LoRa airtime calculator [9]. For example, EU has the <1% duty cycle [8], which means the nodes cannot occupy the channel 1% of the time or above.

As described above, to design a LoRa Network, we need to investigate the communication performance while changing the parameters. In the paper, to support a design and deployment of the LoRa network, in this paper, we propose a design of a measurement tool for evaluating network performance with LoRa. Also, we show the performance evaluation result, and then design a LoRa network based on the evaluation results for our crab farming park as a practical lesson.

II. RELATED WORK

There are several studies on LoRa performance evaluation using theoretical and simulation method. For instance, reference [10] provided a simulation-based study to investigate how the number of nodes affects the number of received packet per hour. Reference [11] investigated a LoRaWAN network through a mathematical model to find out the occurrences of packet loss and collision. Also, reference [12] studied the impact of the network load to the Packet Error Rate (PER) and Packet Loss Ratio (PLR) through simulation experiments with the different number of nodes. However, the three studies do not show any experimental performance evaluation in an actual environment.

In the studies for an actual environment, reference [7] investigated the impact of LoRa PHY parameters to the RSSI and energy consumption. Reference [13] showed the impact of Spreading Factor to the RSSI and the throughput and the impact of the distance between the gateway and the nodes to the Packet Delivery Ratio (PDR). Also, reference [14] conducted a performance evaluation at a tree farm. They investigated the impact of PHY parameters, distance, and antenna height to RSSI and PDR. However, these experimental performance evaluations have to calculate all of the metrics after all transmissions are done. They set the total packets that a LoRa network will transmit and log all the received packets. Then, they calculate the Packet Delivery Ratio (PDR) or Packet Error Rate (PER) based on that. Therefore, when we want to rerun the experiment with or without changing the factors and the scenarios, e.g., PHY parameters, distance, number of packets to be transmitted, number of nodes, and so on, they have to recalculate the result to present the metrics in a meaningful way. Moreover, when we want to present the result in charts, we have to reinput the calculation result.

III. LOUPE – MEASUREMENT TOOL

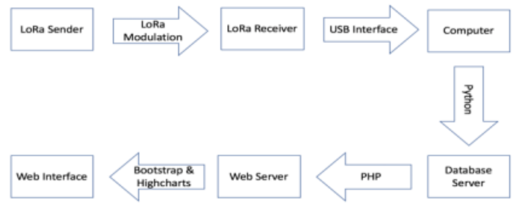

Fig. 1. LouPe system diagram

Fig. 1 depicts the design of the measurement tool, LouPe. In the figure, the rectangles are entities, and the arrows are technology or interface that connect the entities. LoRa Sender is a LoRa module that will broadcast data with the LoRa modulation. For the payload, we use an array of bytes. In order for this measurement tool to work, several data need to be specified in the payload. The packet structure is as follows:

Table I. Packet Structure

Index	Data
0	Node ID
1	
2	
3	Experiment Number
4	Interval
5	Packet Number
6	

The first three bytes are the node id, using three bytes allows us to categorize and identify the nodes that act as LoRa Sender in the network. The next byte is the experiment number. The default is 0; when we want to rerun the scenario without changing any parameters, we increment the value by 1. Specifying the experiment number will help us to distinguish experiments with same scenario and different experiment time. The fifth byte is the interval between transmissions in the particular node. The last two bytes are the packet number. It is important to specify the transmission interval and the packet number because the gateway is unable to identify them by itself.

Next, LoRa Receiver (sometimes, a gateway) will receive data from LoRa Sender, and print it to the serial interface along with the PHY parameters, packet number, RSSI, and SNR in a key-value String format.

<key:value,key:value…..>

The LoRa Receiver is connected to a computer via USB Serial Interface. In the computer, we make a python script that will listen to the USB interface and parse the string. Using PyMySQL library, the parsed data is sent to the Database Server.

We stored all the transmission record in a database server with fields as follow: id, frame_size, interval, experiment, node_id, packet_num, SF, CR, BW, TP, RSSI, SNR, and timestamp.

We use Laravel for the server-side scripting in the web server. Laravel is the most popular PHP framework. We chose Laravel because its Eloquent allows us to work with the database easily and in an Object-Oriented approach.

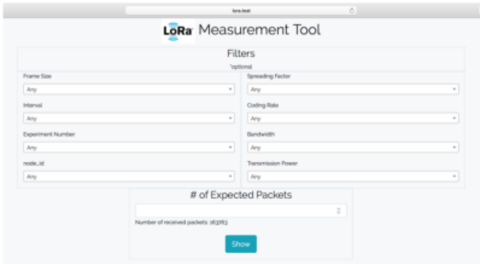

Fig. 2. LouPe Web Interface

The web interface was built with Bootstrap Framework, a Front-end grid system framework for a website. What we have in the web interface are filters and the number of expected packets input field.

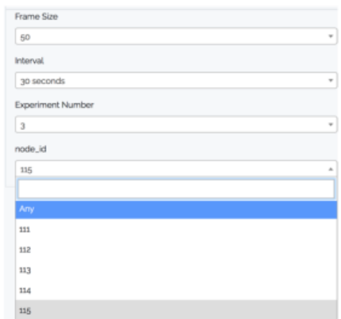

Fig. 3. LouPe filter options

The filter section is giving us the ability to look into the performance with a particular scenario. We used the drop-down menu for the filters with the options are generated from existing database records. In Fig. 3, the options for the node_id filter are 111 to 115, that is those are the only node_id exists in our database.

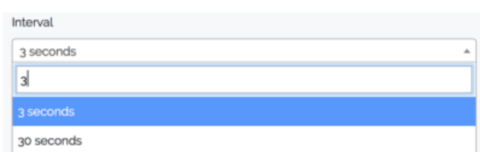

Fig. 4. The implementation of select2.js in LouPe

We also make use of select2.js to make the dropdown options searchable. Select2.js is javascript library to help manipulate a dropdown list in a webpage. With select2.js, the user can easily search all through the options by using keyword.

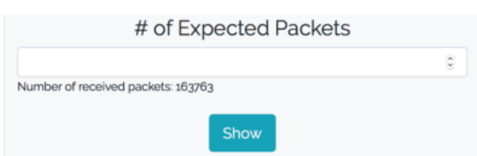

Fig. 5. The number of expected packets input field

Below the number of the expected packets input field, we show the preview of how many records or received packets existing in the database.

When we click the show button, we will get the result of the performance evaluation in the pie chart and table. We use highcharts for generating the pie chart. Highcharts is an interactive javascript chart library.

IV. Basic Performance Evaluation

We perform a basic performance evaluation with our Measurement Tool in Laboratory for Cyber Resilience, Graduate School of Information Science, Nara Institute of Science & Technology.

A. Network Design

PHY parameters that we used is the default parameters from RadioHead library, which is SF7, BW125, CR4/5, & Tx13. We used Dragino LoRa mini dev for the nodes and the gateway. We experimented with three and five nodes. All of these nodes are placed a meter away from the gateway.

In this performance evaluation, we used three factors; frame size, transmission interval, and the number of nodes. Frame size that we used is 10, 50, 100, 200 bytes. For the transmission interval, we used 1, 2, 3, 5, 7, 10, 15, 30 seconds. As we mentioned before, we used three nodes. We ran every frame size, interval, and the number of nodes scenario for five times. With this full factorial experiment, we undergo 320 tests. Every node sent 150 packets for every test, which means we are expecting 72000 packets to be received.

B. Result

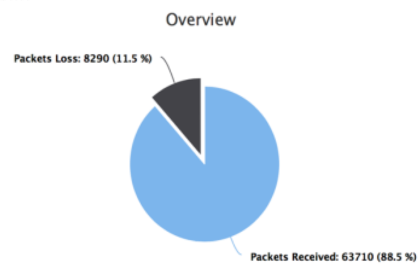

Fig. 6. PDR Pie chart

Fig. 6. shows the comparison between the number of Packets Loss and Packets Received with their percentage.

# of Expected Packets	: 72000
# of Received Packets	: 63710 (88.48611111111%)
# of Packet Loss	: 8290 (11.51388888889%)
Average RSSI	: -25.1531
Average SNR	: 38.4177

Fig. 7. More detailed result

Below the pie chart you will find the details of the performance evaluation, including the Average RSSI and SNR from all transmissions as shown in the Fig. 7. With the presented data, we can easily conclude the performance of LoRa Network without doing any manual calculation.

The python script listens to logged data from the gateway via USB Serial Interface and then send the data to database server. The python script and the database server are in the same host. This scenario ensures high result accuracy, since there is only low to zero possibility the logged data from the python script is not received by the database server. However, this is not the case when the database server is on another host where the network connection between the hosts is crucial.

C. Discussion about LoRa network deployment for crab farming

Our university, Hasanuddin University, owns a soft-shell crab farming park in Barru Regency, South Sulawesi, Indonesia. One of the challenges that we face is soft-shell crab high mortality rate. In our pond, 30% of the crabs died because of dirty water and unsuitable water temperature, and so on.

To tackle this problem, we are planning to deploy a sensor network using LoRa technology to monitor several parameters. Those parameters are temperature, salinity, pH, and dissolved oxygen. For these parameters, we need at least 18 bytes of frame size.

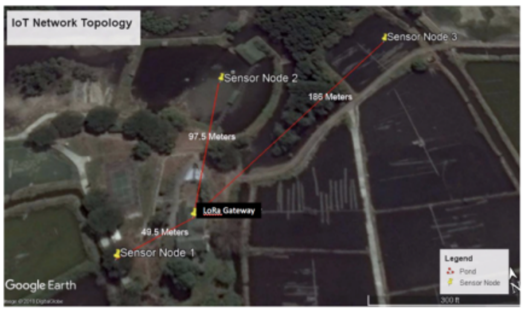

Fig. 8. Distance between the gateway and the ponds

To tackle this problem, we here design a sensor network with LoRa technology to monitor several parameters. The observed parameters are temperature, salinity, pH, and dissolved oxygen. These parameters consist of an 18-byte frame. For the design of the network, we first chose three ponds which are closest to the gateway. The distances are 49.5 meters, 97.5 meters, and 186 meters. The frame will be transmitted every 30 seconds. By using the frame size and interval filter of LouPe in our basic performance evaluation, we can estimate that with 50 bytes frame size and 30 seconds interval, 99.4% PDR is obtainable. However, in the planning, as the network performance does not include the impact of the errors by distance, the network may not be able to obtain the estimated performance. For the problem, our proposed measurement tool is also useful for continuous measurement in an actual environment.

V. CONCLUSION

LoRa is one of the essential technologies in the IoT era. To deploy a LoRa network, we need to investigate the network performance of LoRa. So far, there are several studies on LoRa network performance, but none of them are using or developing a measurement tool. In the paper, we designed and implemented a measurement tool for LoRa, LouPe. The LouPe provides the easy settings and visualized results. The paper also provided the experimental results using LouPe and discussed the network planning for our crab farming park based on the experimental results.

ACKNOWLEDGEMENT

This work was supported by JICA C-BEST Grant, Heiwa Nakajima Foundation, NAIST Global Collaboration Program, and SBK Riset Dasar Grant, Ministry of Research, Technology, and Higher Education, Indonesia.

REFERENCES

[1] LoRa Alliance, "2017 End of Year Report," 2018. [Online]. Available: https://lora-alliance.org/sites/default/files/2018-04/LoRa-Alliance-Annual-Report.pdf. [Accessed 28 June 2018].

[2] L. Columbus, "2017 Roundup Of Internet Of Things Forecasts," Forbes, 10-12-2017. [Online]. Available: https://www.forbes.com/sites/louiscolumbus/2017/12/10/2017-roundup-of-internet-of-things-forecasts/#4270c33a1480. [Accessed 29 July 2018].

[3] D. Ismail, M. Rahman, and A. Saifullah, "Low-power wide-area networks: opportunities, challenges, and directions," In Proceedings of the Workshop Program of the 19th International Conference on Distributed Computing and Networking (Workshops ICDCN '18). Article 8, 6 pages. January 2018.

[4] J. Finnegan and S. Brown, "A Comparative Survey of LPWA Networking.," arXiv:1802.04222v1 [cs.NI], 2018.

[5] Semtech, "AN 1200.22 LoRa™ Modulation Basics," May 2015. [Online].Available: https://www.semtech.com/uploads/documents/an1200.22.pdf. [Accessed July 2018].

[6] LoRa Alliance ™, "About LoRaWAN™," LoRa Alliance ™, [Online]. Available: https://lora-alliance.org/about-lorawan. [Accessed 11 July 2018].

[7] M. Bor and U. Roedig, "LoRa Transmission Parameter Selection," 2017 13th International Conference on Distributed Computing in Sensor Systems (DCOSS), pp. 27-34, June 2017.

[8] LoRa Alliance, "LoRa Regional Parameters v1.1rB," January 2018. [Online]. Available: https://lora-alliance.org/resource-hub/lorawantm-regional-parameters-v11rb. [Accessed 5 September 2018].

[9] M. Kooijman, "Spreadsheet for LoRa airtime calculation," The Things Network, 4 February 2016. [Online]. Available: https://www.thethingsnetwork.org/forum/t/spreadsheet-for-lora-airtime-calculation/1190. [Accessed 10 August 2018].

[10] F. Adelantado, X. Vilajosana, P. Tuset-Peiro, B. Martinez, J. Melia-Segui and T. Watteyne, "Understanding the Limits of LoRaWAN," in IEEE Communications Magazine, vol. 55, no. 9, pp. 34-40, September 2017.

[11] G. Ferre, "Collision and packet loss analysis in a LoRaWAN network," 2017 25th European Signal Processing Conference (EUSIPCO), pp. 2586-2590, October 2017.

[12] D. Bankov, E. Khorov and A. Lyakhov, "On the Limits of LoRaWAN Channel Access," 2016 International Conference on Engineering and Telecommunication (EnT), pp. 10-14. November 2016.

[13] A. Augustin, J. Yi, T. H. Claus, n and W. M. Townsley, "A Study of LoRa: Long Range & Low Power Networks for the Internet of Things," Sensors, Volume 16, Issue 9, September 2016.

[14] D. Yim et al., "An experimental LoRa performance evaluation in tree farm," 2018 IEEE Sensors Applications Symposium (SAS), pp. 1-6, March 2018.

LouPe LoRa Performance Measurement Tool-(24).pdf

ORIGINALITY REPORT

11%	5%	10%	2%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Martin Bor, Utz Roedig. "LoRa Transmission Parameter Selection", 2017 13th International Conference on Distributed Computing in Sensor Systems (DCOSS), 2017 Publication	2%
2	Shigeru Kashihara, Muh. Arief Wicaksono, Doudou Fall, Muhammad Niswar. "Supportive Information to Find Victims from Aerial Video in Search and Rescue Operation", 2019 IEEE International Conference on Internet of Things and Intelligence System (IoTaIS), 2019 Publication	1%
3	Ashirwad Gupta, Makoto Fujinami. "Battery Optimal Configuration of Transmission Settings in LoRa Moving Nodes", 2019 16th IEEE Annual Consumer Communications & Networking Conference (CCNC), 2019 Publication	1%
4	Nappaphol Siriphun, Shigeru Kashihara, Doudou Fall, Assadarat Khurat. "Distinguishing Drone Types Based on	1%

Acoustic Wave by IoT Device", 2018 22nd International Computer Science and Engineering Conference (ICSEC), 2018
Publication

5	Novi Nurlaela, Muhammad Niswar, Ingrid Nurtanio, Yushinta Fujaya, Shigeru Kashihara, Doudou Fall. "Detection of Megalopa Phase Crab Larvae Using Digital Image Processing", 2019 International Seminar on Research of Information Technology and Intelligent Systems (ISRITI), 2019 Publication	1 %
6	link.springer.com Internet Source	<1 %
7	Runal Rezkiawan Baharuddin, Muhammad Niswar, Amil Ahmad Ilham, Shigeru Kashihara. "Crab Molting Identification using Machine Learning Classifiers", 2021 International Seminar on Machine Learning, Optimization, and Data Science (ISMODE), 2022 Publication	<1 %
8	Submitted to University of Leeds Student Paper	<1 %
9	Submitted to University of Queensland Student Paper	<1 %
10	naist.repo.nii.ac.jp Internet Source	<1 %

11	www.jstage.jst.go.jp Internet Source	<1 %
12	Sugianto Sugianto, Azwar Al Anhar, Ruki Harwahyu, Riri Fitri Sari. "Simulation of Mobile LoRa Gateway for Smart Electricity Meter", 2018 5th International Conference on Electrical Engineering, Computer Science and Informatics (EECSI), 2018 Publication	<1 %
13	livrepository.liverpool.ac.uk Internet Source	<1 %
14	Muhammad Niswar, Sonny Wainalang, Amil A. Ilham, Zahir Zainuddin et al. "IoT-based Water Quality Monitoring System for Soft-Shell Crab Farming", 2018 IEEE International Conference on Internet of Things and Intelligence System (IOTAIS), 2018 Publication	<1 %
15	Noushin Poursafar, Md Eshrat E Alahi, Subhas Mukhopadhyay. "Long-range wireless technologies for IoT applications: A review", 2017 Eleventh International Conference on Sensing Technology (ICST), 2017 Publication	<1 %
16	docs.ansible.com Internet Source	<1 %
	mafiadoc.com	

17	Internet Source		<1 %
18	www.researchgate.net Internet Source		<1 %
19	Dhaval Patel, Myounggyu Won. "Experimental Study on Low Power Wide Area Networks (LPWAN) for Mobile Internet of Things", 2017 IEEE 85th Vehicular Technology Conference (VTC Spring), 2017 Publication		<1 %
20	Ferran Adelantado, Xavier Vilajosana, Pere Tuset-Peiro, Borja Martinez, Joan Melia-Segui, Thomas Watteyne. "Understanding the Limits of LoRaWAN", IEEE Communications Magazine, 2017 Publication		<1 %

Exclude quotes	On	Exclude matches	< 5 words
Exclude bibliography	On		