Faculty of Computer Science and Information Technology

AN EXPERIMENTAL PERFORMANCE EVALUATION OF LORA NETWORK

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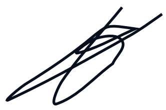

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Abstract

Internet of Things (IoT) is rapidly becoming a part of our life and several company. We are expected to see several IoT device to grow in the future. The verticals within IoT paradigm such as smart cities, smart farming or goods monitoring remand a string requirement to the Radio Access Network (RAN). Recently, LoRaWAn has emerged as a promising technology for IoT, claiming its ability to have a high coverage for transmission data while consume low energy. In this report, the experimental performance (time required to sent certain amount of packet) evaluation of LoRa device over real-life scenario will be carried out. In the end of Final Year Project 1, the idea and method to carry out the experiment have been identified. The significance of this project can assist UNIMAS or any other sector that going to apply IoT able to identify and understand the performance of LoRa device and increase the productivity.

Abstrak

Internet of Things (IoT) semakinpantasmenjadisebahagiandaripadakehidupankita dan beberapasyarikat.Kami dijangkamelihatbeberapaperanti IoT akanberkembang pada masa hadapan.Penegak dalam paradigma IoT seperti bandar pintar, pertanianpintaratаupemantauanbaranganmemerlukanrentetankeperluan kepada Rangkaian Akses Radio (RAN).Baru-baru ini, LoRaWAntelahmunculsebagaiteknologi yang menjanjikan untuk IoT, mendakwakeupayaannya untuk mempunyailiputan yang tinggi untuk data penghantaransambilmenggunakantenaga yang rendah.Dalam laporan ini, penilaianprestasipercubaanperanti LoRa berbandingsenariokehidupansebenarakandijalankan.Pada akhirProjekTahun Akhir 1, idea dan kaedah untuk menjalankaneksperimentelahdikenalpasti.Kepentinganprojek ini boleh membantu UNIMAS atau mana-mana sektor lain yang akanmenggunakan IoT dapatmengenalpasti dan memahamiprestasiperanti LoRa dan meningkatkanproduktiviti.

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CHAPTER 1: INTRODUCTION

1.1 An experimental Performance evaluation of LoRa Network

The Internet of Thing (IoT), mainly refer to the network of interconnected things, that is the device such as sensors and actuators, equipped with a telecommunication interface and processing and storage unit. This telecommunication interface should enable seamless integration of potentially any object with the internet and forming a new form of interaction between human and devices.

In general, the communication needs of such scenarios differ from the classic high throughput and low delay requirement that is mainly design of traditional communication system. For example, monitoring of solar panels, smart panel can be installed on the roofs of several buildings to optimize their collective efficiency. As the number of sensors in the IoT system grow, comes the issue on how to transfer data among those devices become extremely complex, and the data transmit needed to be balanced with operating considerations and infrastructure costs. LoRa is one of the technologies proposed to be embedded in those IoT sensor, due to its long-range transmission and low energy consumption. Some experiment had shown that a LoRa devices can transmit data over 15km in an open area, which is suffice for most of the data transferring IoT sensors. However, LoRa device is unable to communicate wirelessly with nearby GW while used indoor, due to obstacle between sensors, which will affect the wireless signal strength and results in package losses and communication errors.

In this research, we will need to investigate the percentage of packages losses in different scenario, be in indoor or outdoor. For urban area, there might be some obstacle between sensors and the frequency might be disrupted by different kind of signal existing in the urban area. Rural area on the other hand, will experience shown that the data transmission range can hit over 15km, we can’t make sure that there is no package loss during the process of transmitting data.

1.2 Research Problem

In this industry revolution era, IoT device plays an important role in connecting human being and sensory device. But, due to the immature yet technologies, a lot of error is found during implementing the IoT device. For example, heat sensor device, which is used in industry to detect the temperature of the machine, confirming in condition, either working normally or overheating. Due to IoT device immatureness, some incorrect or missing data might be sent to the received end and wrong measurement, or decision might be made. Theres a lot of IoT device on the market, we have to identify the benefit and flaws of them, so we can implement them in different type of situations.

1.3 Project aim

The project aim is to evaluate the network coverage of LoRa Device in real deployment scenario and evaluate the energy consumption of LoRa Device under different transmission rates and network coverage, and to determine the reliability and robustness of LoRa device.

1.4 Scope

The scope of this project is focusing on:

LoRa device:

1. LoRa is a proprietary modulation scheme derived from the Chirp Spread Spectrum modulation (CSS).
2. The LoRa device is to improve the sensitivity at the cost of a reduction in the data rate for a given bandwidth.

1.5 Objective

1. To design and develop Arduino for Liligo LoRa32 T3 v1.6.1 board.

2. To evaluate the network coverage of LoRa Device in real deployment scenario

3.To determine the reliability and robustness of LoRa device

1.6 Methodology

LoRa performance will be tested in different scenario, such as urban area, rural area on data transmission distance and data transmission efficiency.

1.6.1 Phase 1: Problem statement and analysis

In this phase, collecting and analysis the problem that is faced by LoRa device user through online. The data is collected through article and some feedback from the user. During observing the article, the performance, and the data of LoRa device efficiency will be recorded.

1.6.2 Phase 2: LoRa design

In this phase, the system design of the application will be developed using data flow diagram, entity relationship diagram. Data flow diagram will include and illustrate the flow of the data transmission from sending end to received end of the LoRa device. The requirements that collected in previous phase will be referred in this phase for parameter purposes.

1.6.3 Phase 3: Implementation and testing of LoRa device.

After the development of the device, the prototype will be implemented and deployed into different scenario for testing purposes. The proposed scenario will be including the data transmission rate of LoRa device in urban area, rural area, and open space. The energy consumption of LoRa device will be recorded in the meantime.

1.6.4 Phase 4: Documentation

For the data recorded from the previous phase, data will be processed and plotted into graphs. Graph such as packet loss for each measurement location, SNR value for each point with spreading factor, PDR evolution with the distance for each DR for each scenario.

1.7 Significant of the Project

The significance of this project is to design and testing a device that is suitable to be deployed into IoT section. The proposed experiment will be able to assist industries or user in choosing which type of data transmission device that is suitable for the sensory device. Through this experiment, user will increase the understanding of the importance of data transmission in IoT sector.

1.8 Expected Outcome

At the end of this project, we are expected to determine and identify on the efficiency of the LoRa device and determine which IoT situation is suitable for LoRa device.

The output of this project will benefit those industry that is transforming into Industry 4.0 direction. Instead of trial and error, management team can decide on the data provided, and choose the suitable data transmission device for their machine. Furthermore, the huge coverage of the data transmission will benefit those control unit such as streetlight, they might just be able to control and adjusted the reading or those devices.

CHAPTER 2: BACKGROUND & LITERATURE REVIEW

This chapter presents the current available article regarding LoRa device and the literature review for this project. In order to carry out the proposed experiment, which to determine the performance of the LoRa device, a research have to be carried out on the existing article and understand the manipulating factor of this experiment (Ana E et al., 2020; Christos B et al., 2022; Nuttakit et al., 2017)

In the end of this chapter, the strength and weakness of LoRa device will be discussed to support the result of the experimental phase of LoRa device.

2.1 Current ecosystem of IoT

The ecosystem for IoT is broad, containing several devices with data rates ranging from a few bps to Mbps. Coverage also variable from a few centimetres to several kilometres. LPWAN is responsible for covering the new application that arise daily. Even though these network must cover different needs, there are common requirement in designing a LPWAN network. The main characteristics of an LPWAN network is:

1. Require minimum energy consumption during operation.
2. Low-cost compared to another device.
3. The network infrastructure is easy to assemble.
4. The transferred information between the node and final user must be safe.

Currently, LoRaWAN is one of the most deployed LPWAN access networks for IoT. Signal propagation is important in IoT as this will affects the network performance in terms of coverage, reliability and data-rate. LoRa is a proprietary modulation scheme derived from the Chirp Spread Spectrum modulation (CSS). The main goal of LoRa is to improve the sensitivity of the device at the cost of reduction in the data rate for a given bandwidth. LoRa is physical layer implementation and does not depend on higher layer implementation. This make LoRa device able to coexist with different network architectures.

2.2 Study of the performance of LoRa device in different scenario

In this section, a study of three reviewed system will be conducted in detail and used as reference purpose for the proposed experiment. The first reviewed is the study of the LoRa signal propagation in forest, urban, and suburban environments by Ana Elise Ferreira, Fernando M. Ortiz, Luis Henrique M. K. Costa, et al. This review will be analysed based on the performance and the reading recorded. The experiment carried out in the forest using short-term static scenario and long-term static scenario is being reviewed.

2.2.1 A study of the LoRa signal propagation in forest, urban, and suburban environments

The study regarding the signal propagation in the forest, urban, and suburban environment is being proposed by Ana Elise Ferreira, Fernando M. Ortiz, Luis Henrique M. K. Costa, et al. The study included 4 kind of scenario which is conducted in the forest, which is short-term static scenario, long-term static scenario, one-mobile node scenario and two-mobile scenario. The metrics used to evaluate the LoRa technology are radio range, RSSI, SNR, PDR, PIR time and mobility. The experiment in forest is carried out using the prototypes as shown below.

Figure 2.1. Pole-mounted nodes

Figure 2.2. Tree-mounted node

Short-term static scenario is to measure the maximum coverage in the forest and trace the behaviour of the signal by analysing the main parameters concerning the distance as shown in Figure 2.1. For each experiment, 200 packets are transmitted and ten run are performed for each distance.

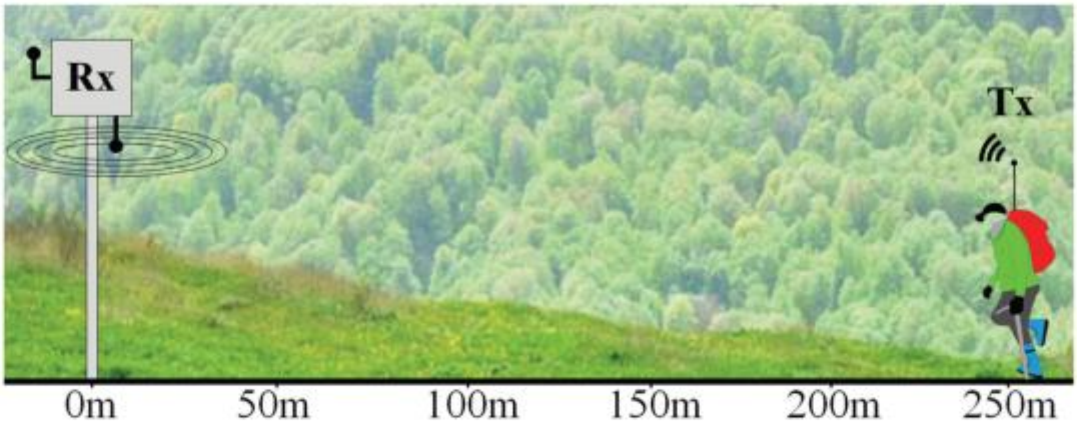

Figure 2.3. short-term static scenario

Long-term static scenario on the other hand Is to analyse the behaviour of the signal over a longer measurement interval and to identify recurring variations and disruptions. The finding indicates that connectivity in the forest environment may behave inconstantly, leading to intermittent connection and opportunistic communication.

2.2.1.1 Result finding

In this section discussed about the finding regarding the 4 methods used in the experiment. RSSI, SNR, PDR and PIR is observed and record.

Short-term static scenario

The scenario is mainly used to identify the range of the LoRa device in the forest. PDR, RSSI and SNR are evaluated as the distance increases.

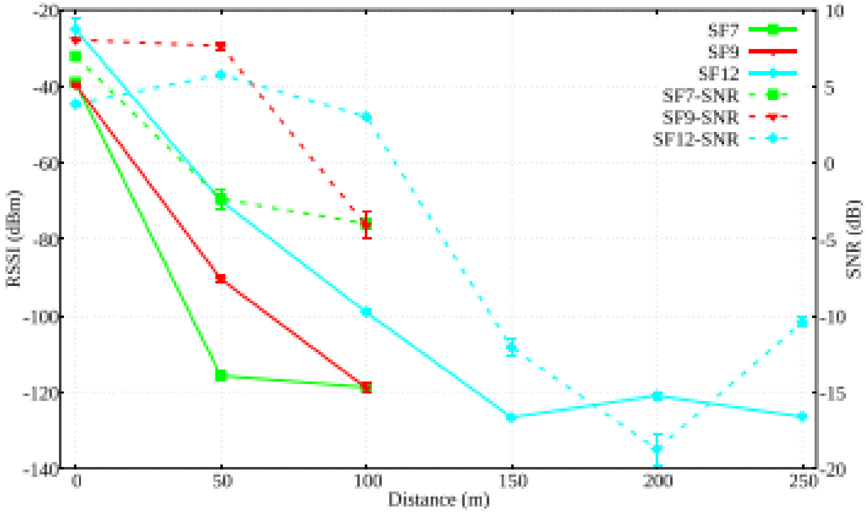

Figure 2.4. RSSI and SNR at the receiver for each distance

The power measurement is obtained from the RSSI information. Due to the degradation of the vegetation, string attenuation is observed.

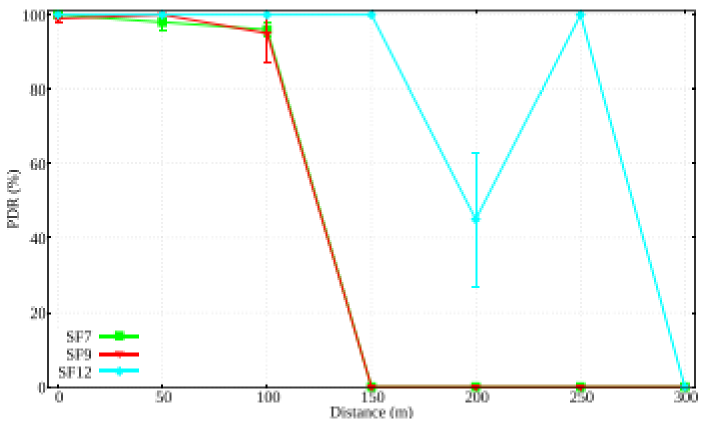

Figure 2.5. PDR measured for each distance.

This figure shows the packet delivery ratio of the link. We can see the link is inversely proportional to the distance, where the packet delivery ratio of the link is decreasing with the distance.

Long term static scenario

This scenario is carried out to evaluate the signal variation for a longer time for the characterization.

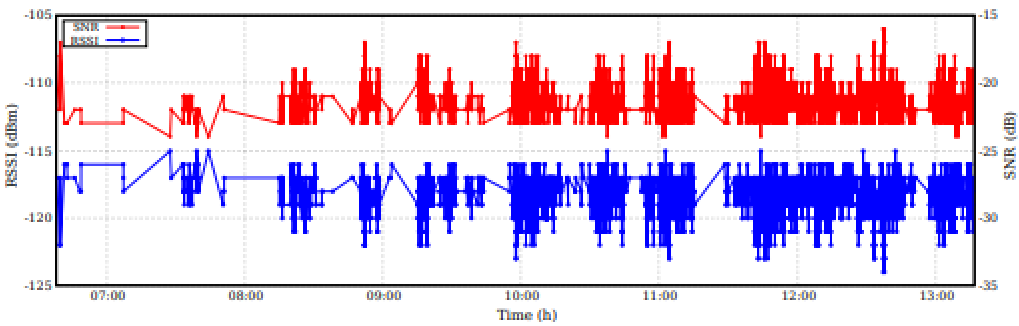

Figure 2.6. SF12 long-term test at 250m

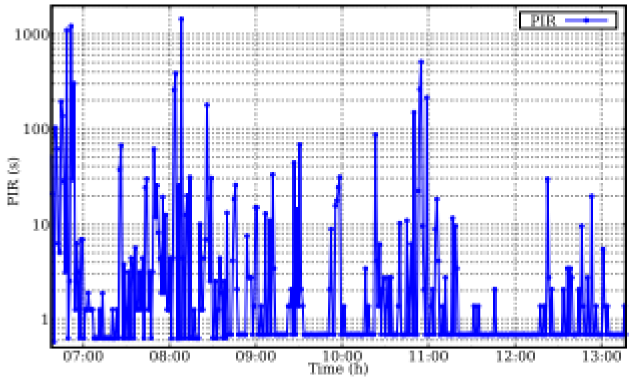

Figure 2.7. PIR time at 250m

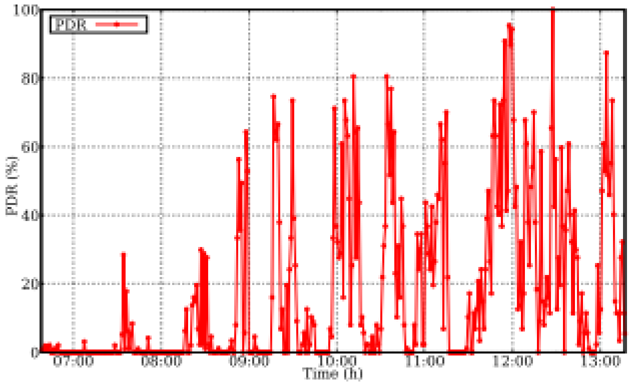

Figure 2.8. PDR measured for each distance.

Using long-term scenario together with short-term one, allows them to study the communication between fixed nodes inserted in the vegetation. These scenarios make it possible to assess the range and performance of the link between fixed points, as well as their temporal variability.

2.2.2 Performance evaluation of monitoring IoT systems using LoRaWan.

This research is a study of LoRaWAN and the performance as well as the application development that can be used as rescue monitor system. For this reason, the study start by describing LoRa as an ideal low power and long-distance communication protocol to IoT devices compared to the Wi-Fi network. Various simulations in term of time on air transmission, bit error rate by changing important metrics is performed to study the behaviour of the whole mechanisms.

2.2.2.1 Architecture

LoRa refers to the protocol an architecture of the general communication, while LoRa refers to the physical layer. LoraWan uses a mechanism to filter multiple copies of the same packets from the available GWs. The equation beneath refers to the mathematical relation of symbol and data rate:

$$R_b = SF * \frac{1}{\left[\frac{2^{SF}}{BW}\right]} bits/s$$

Figure 2.9. relation of symbol and date rate formula

Where SF refers to the used spreading factor and variable BW to the bandwidth in Hz.

The SF value used in the scenario are used to adapt the radio signal speed having in mind the range between the GWs and the end-nodes. BW remains one of the most significant metric of the LoRa study.

Bit Error Rate (BER) or in other term, package loss in comparison to energy per bit to Noise density ratio is being studied in this section. From theoretical point of view the mathematical relation is shown below:

$$E_b/N_0(dB) = SNR(dB) + 10\log\frac{BW}{R_b}(dB)$$

Figure 2.10. Bit Error Rate formula

LoRa utilizes three distinctive BW values, 125kHz, 250kHz and 500kHz. The first use case is usage of 125kHz BW and SF alteration from 7 to 12. The result are shown below:

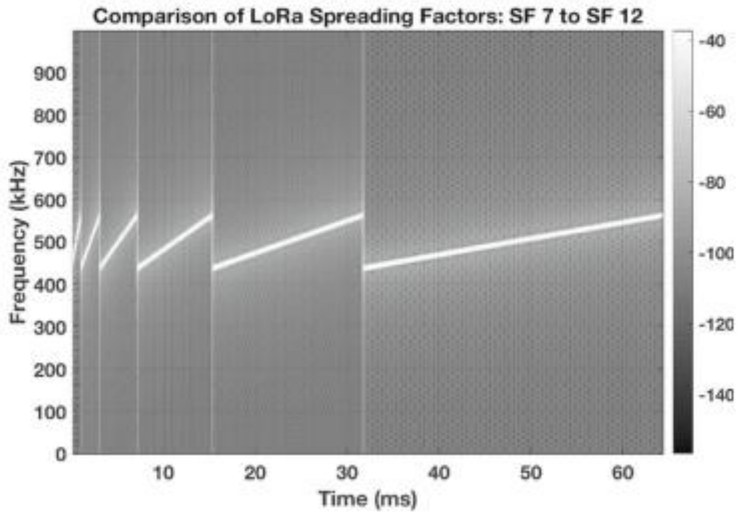

Figure 2.11. SF generation using 125kHz BW.

From the diagram we are able to notice the distinction on over the air transmission time and data rate in case of 125kHz. From figure 2.11, as spreading factor (SF) changes on the testbed 7 to 12, the over tie airtime increases significantly.

By increasing BW from 125kHz to 250kHz and 500kHz, the data rate seems to expand as the bandwidth changes. One the other hand, transmission time is being decrease evetime the bandwidth is increased.

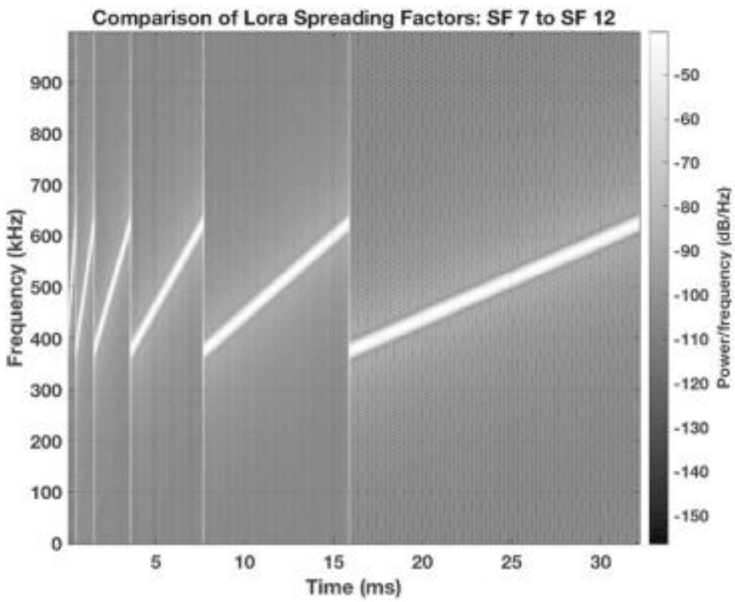

Figure 2.12. SF generation using 250kHz BW

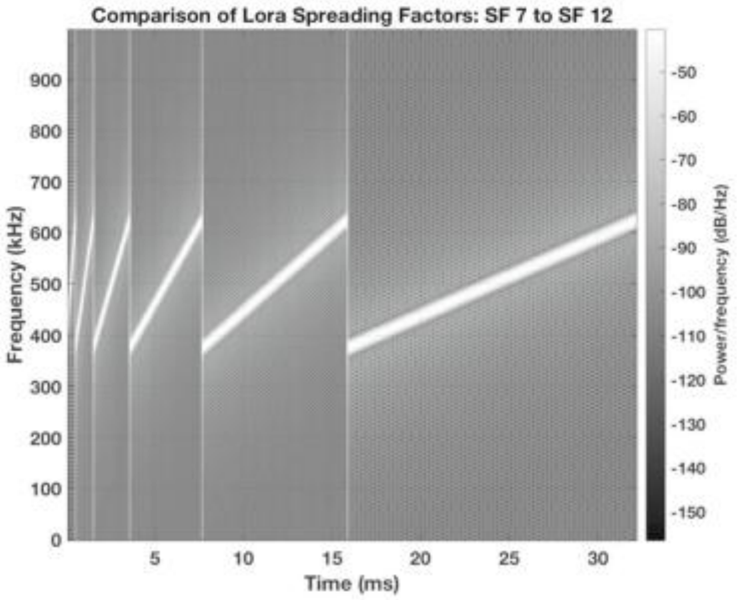

Figure 2.13. SF generation using 500kHz BW.

Local Area Network (LAN) have well established standards such as Wi-Fi, Bluetooth, Zigbee and Z-Wave. But in term of IoT application, the biggest obstacle being the energy consumption as well as the transmission coverage. In this study, it proves that LoRa and Wi-Fi technology were studied as network candidates for IoT monitor application. LoRaWAN is perfect for long-range utilizing in low energy consumption yet additional bandwidth communication.

2.2.3 Experimental Performance Evaluation of LoRaWAN: A Case Study in Bangkok

This section discusses about the case study made in Bangkok regarding performance evaluation of LoRaWAN to explore the limit of communication ranges in both outdoor and indoor environment.

Performance Evaluation

The study focuses on the performance evaluation in both indoor and outdoor environment where the experiment is composed of one end-device, one gateway and one servicer with MQTT protocol. The end device is composed of Arduino connected to Libelium LoRa module via the UART interface which periodically send command to LoRa module.

Time on air