Empirical Evaluation of LORA Link Performance for Smart City/Smart Campus Environments

Muhammad Danial Bin Ismail, Mohd Hadi Habaebi

Abstract: The Concept Of Smart City Become Undeniable Mission By All The Major City In The World To Improve Human lifestyle, assets and resources efficiently. Smart city concept really depends of advancement of network technology, to be specific internet of things (IoT). One of the recent innovations that enable smart city concept to be operated with low power consumption and low cost is LoRa (long range). LoRa's advantages such as convenience, low cost, high efficiency and strong scalability might be a reliable gateway for sensors, transducers and monitoring devices to establish a seamless connection with centralized monitoring system [11]. This report aims to provide data analysis on implementation of LoRa technology as gateway for smart city. In the report, LoRa gateway link performance will be tested using RF1276 LoRa modules from Appcon Wireless for Kuala Lumpur smart city and International Islamic University Malaysia Gombak Campus for smart campus. The performance metrics to be used are the Packet Deliver Rate (PDR), Data Extraction Rate (DER), the number of dropped packet, delay, Node Energy Consumption (NEC) and Ping Statistics. The study is expected to consider the effect of foliage specifically for the smart campus environment. Furthermore, the overall channel effect, payload size and different LoRa PHY transmit configurations (different bandwidths and coding rates) will be quantified in terms of the performance metrics mentioned above. Initial tests were carried out in IIUM Gombak campus indicated severe degradation due to foliage effect, hence, the report will focus on its effect on the link performance. Several LoRA physical parameters will be studied including the bandwidth and spreading factor.

Key Words: LoRA, LoRaWAN, smart city, empirical evaluation.

I. INTRODUCTION

LoRa, which stand for long range wireless communication technology created by Samtech Corporation one of the LPWAN technology which can uphold wide coverage communication range. LoRa which supported by LoRaWAN system architecture expected to facilitate multi range of IoT devices.LoRa which promoted by LoRa Alliance adopts chirp spread modulation (CSS) and immune to the Doppler effect. Compare to others LPWAN technology for example ZigBee, Bluetooth Low Energy (BLE) and MiWi, LoRa can offer sensitivity of the order of -130 dBm and has longer propagation distance.

This technological advancement has low energy consumption, long battery-powered life, simple star-of-stars topology, easy configuration and low cost.LoRa can be referred as two parts which are the physical layer maintained by Semtech and communication protocol and system protocol designed by LoRa Alliance. Through the standardize protocol, the end devices able to perform a link with the gateways.

II. CHARACTERISTIC OF LORA

Cost and Power Consumption

One of the crucial parts in electronic design is the cost. It is very important for us to analyze the total cost of LoRa installations before it can be implemented into smart city concept. LoRa technology utilized the radio waves spectrum which is below 1GHz and doesn't need to be licensed. Thus, there is no issue on cost of network compared to other cellular M2M devices which cost about $30 per year [1]. The protocol implemented in LoRa technology is much simpler compared to others and can be integrated easily to variety of microcontrollers with minimal cost required. According to Techship [9], cellular LTE modules need at least $20 to be available for used. Other aspect needs to be aware in cost consideration is deployment models. LoRaWAN which is backbone of the LoRa able to utilize a mix of traditional towers, smart city gateways and build-in home gateways. The price of the gateways only up to $1600 which is cheaper compared to the LTE base stations that can cost about $15,000 each [1].Nowadays, green technology or low power consumption innovation become a must be attributes of electronic devices. LoRa technology is one those technologies which utilize battery lifetime at the expense of the spectrum utilization [1]. Battery lifetime is depending on both the implementation of protocol and the end device current consumption pattern. LoRa is based on the ALOHA protocol which allows end devices can sleep when there is no need to connect to network or send data [3]. In cellular network such as LTE end device need to periodically check in with the network, to be exact every 1.5 seconds the end device will synchronize with the network. LoRaWAN protocol used non-linear modulation which used less peak current compared to cellular network which require high battery drain linear transmitter.

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Coverage

Wide network coverage is one of the crucial parts in LoRa technology which satisfy the LPWAN specifications requirement. Based on the research paper by Jorke, Bocker, et. al. [5], the availability coverage of the LoRa is up to 5.8 km range, considering blind spots with no reception which start from range of 2 km in Dortmund, Germany. The signal reception affected by elevation and shadowing of the building and geography landscape. In the test conducted, the packet delivery rate (PDR), received signal strength indicator (RSSI) and the signal to noise ratio (SNR) are measured and analyzed using an 868 MHz and 433 MHz LoRa Network around the city. Ahmad, Segaran, Hashim and Jusoh [4] have conducted several outdoor tests in Malaysia to monitor the performances under line-of-sight (LOS) in urban area. The transmission of a series of data is applied systematically so that the reception of data can be verified and the received signal strength indicator (RSSI) can be measured over the distance. For the LOS test, various ranges between the transmitter and receiver from 20 m to 1500 m in urban area which is National Defense University of Malaysia is applied to measure the RSSI. The result shows that the minimum RSSI is -98 dBm at 1.17 km. The paper concluded that signal transmitted able to propagate well after passing several buildings as LoRa modulation can give great penetration of concrete buildings.

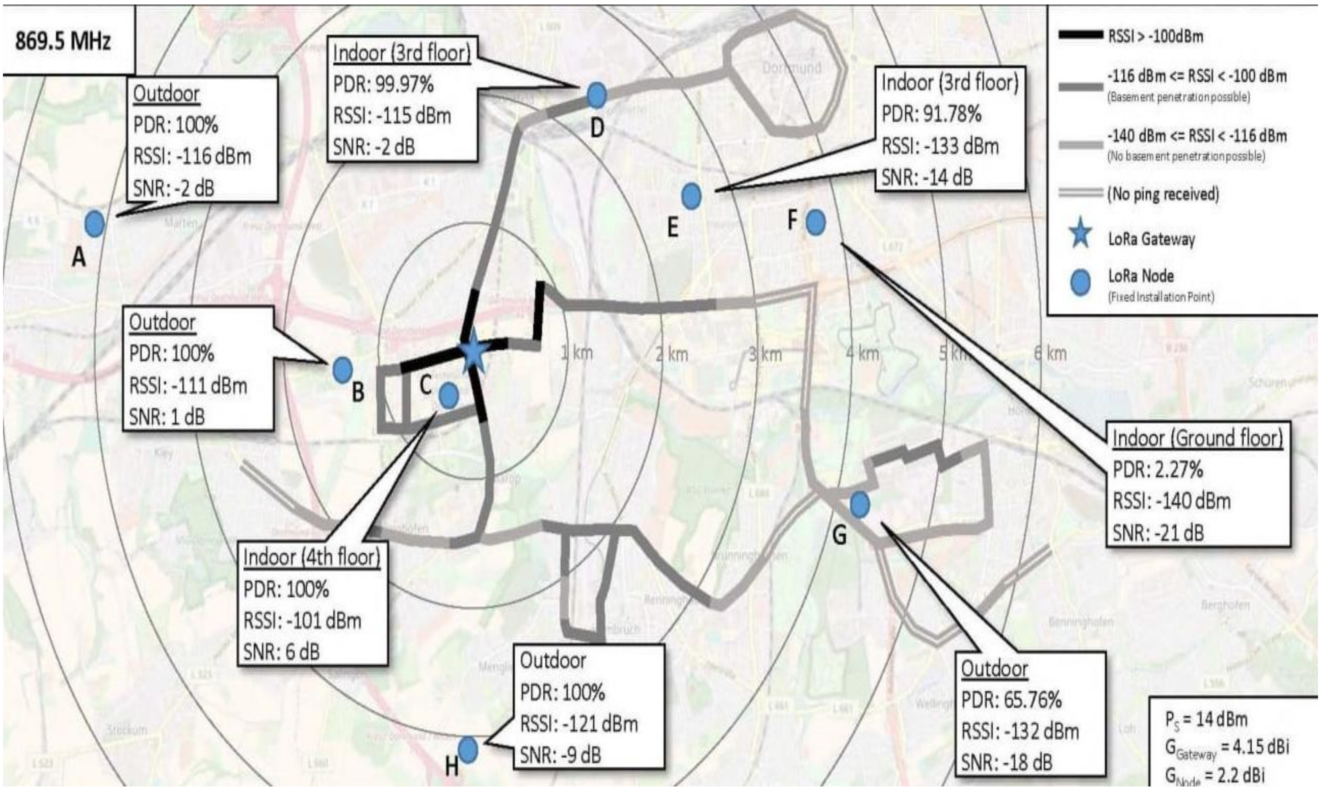

Fig . 1 The coverage analysis of LoRa [5]

Efficiency

In this part the efficiency of LoRa technology is discussed based on packet loss rate when dealing with indoor building, time of day and weather conditions. An experiment conducted by Yuan Wang et. al [8] showed that when the LoRa end device is placed in the table in room in 2nd floors buildings the packet loss is increase over distance. The result state that the packet lost is nearly 90% when the distance between transmitter which located on 9 story building and end device is about 1.2 km. based on the results, LoRa really affected by low attitude settings.

Using the same settings, another experiment is set up to identify the impact of weather on packet loss rate. The data shows that packet loss rate increase by almost 20% when there is light rain [8]. Clearly, rain become one of the factors that contribute to increase of packet loss rate significantly. Another weather factor that should be considered in calculating packet loss rate is fierce winds. A strong wind could affect the orientation of the antenna which could affect the antenna angle. Based on the result, the packet loss rate become 50% when the angle of antenna is set to 0 degrees (horizontal) [8]. Undeniable weather factor should be considered when applying LoRa technology for IoT applications that require high reliability at any time.

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III. METHODOLOGY

In this section, we will discuss the evaluation and measurement setup to determine performance of LoRa link in different scenario which resembles city environment. The evaluated metrics included is Throughput, the number of dropped packets, delay, jitter and Ping Statistics. Basically, in this Final Year Project (FYP) we can divide the measurement test into two parts. The first part will be conducted in campus area which is International Islamic University Malaysia (IIUM), Gombak. The second part will be conducted outside of the IIUM campus. The result obtained from this part will be used as reference to determine the reliability and efficiency of LoRa as IoT device for smart city and smart campus.

Equipment and Tool

RF1276 Long Distance Transceiver Module V2.0

RF1276 module is one of the LoRa module developed by Appcon Wireless which has high performance transparent two way semi duplex LoRa modulation transceiver which operate in ultra-low power. This module able to operate with frequency of 169MHz, 410MHz, 510Mhz, 868MHz and 915MHz. The module has the UART/RS485 interface, that allow user to configure baud rate, frequency, output power, air data rate and another parameter. The RF1276 module designed to provide about 32 channels and it also can transmit signal with huge data buffer.

RF1276 Long Distance Transceiver Antenna

The antenna is a part that can be directly attached to the RF1276 module using the coaxial cable. The antenna helps the module to operate more efficiently by reducing signal lost and increasing the receive signal strength that give the module an ability to transmit or receive the data about 5000 meters distance with minimum air data rate of 300bps.

RF Tool for RF1276IL Program Software

The software programs provided by Appcon Wireless provide interface for user to configure relative parameters such as operation frequency, UART rate, air rate, RF factor, RF bandwidth and data rate. The software must be operated using computer with Windows Operating System installed. Before the configuration of parameter can take place the RF1276 module must be connected to computer USB hub using USB adapter provided

Measurement Scenario

As mentioned in the overview section, empirical measurement of the LoRa performance will be conducted in two different scenario and two different places. Both scenarios involve one of the RF1762 transceiver to be as transmitter and another transceiver will be a receiver. In this case, only receiver will be moved while transmitter has fixed position. Through the part 1, the effect of environment such as type of building, height of building and dense of building can be analyzed. For part 2, the empirical evaluation will be conducted to investigate the performance of LoRa physical link in advance distance between transmitter and receiver. It is the intention to study and quantify the effect of different LoRa transmit configurations (different bandwidths and factor) on the performance metrics stated below

Fig . 2 The location of the receiver on the car

Fig . 3 The location of transmitter at a building

Background of the Empirical Evaluation

In this experiment two set of RF1276 LoRa antenna and RF1276 LoRa modules are used. One of the antennas and modules will act as transmitter and located at fixed point which is at building while another set will be a receiver which moved with the car. The receiver position is varied according to the displacement shown in Figure 3 (part 1) and Figure 4 (part 2). The height of transmitter from the ground is 10 meters. The receiver antenna will be attached on the top of a car which has 1.5-meter height from the ground.

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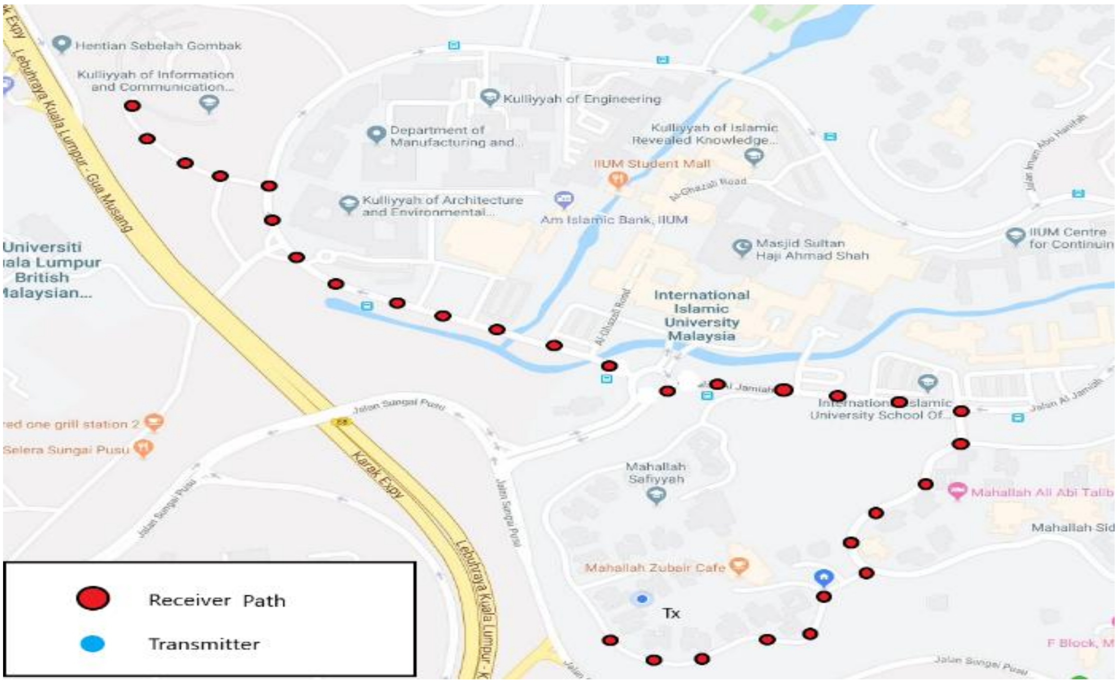

Fig . 4 Location of the transmitter and receiver (part 1)

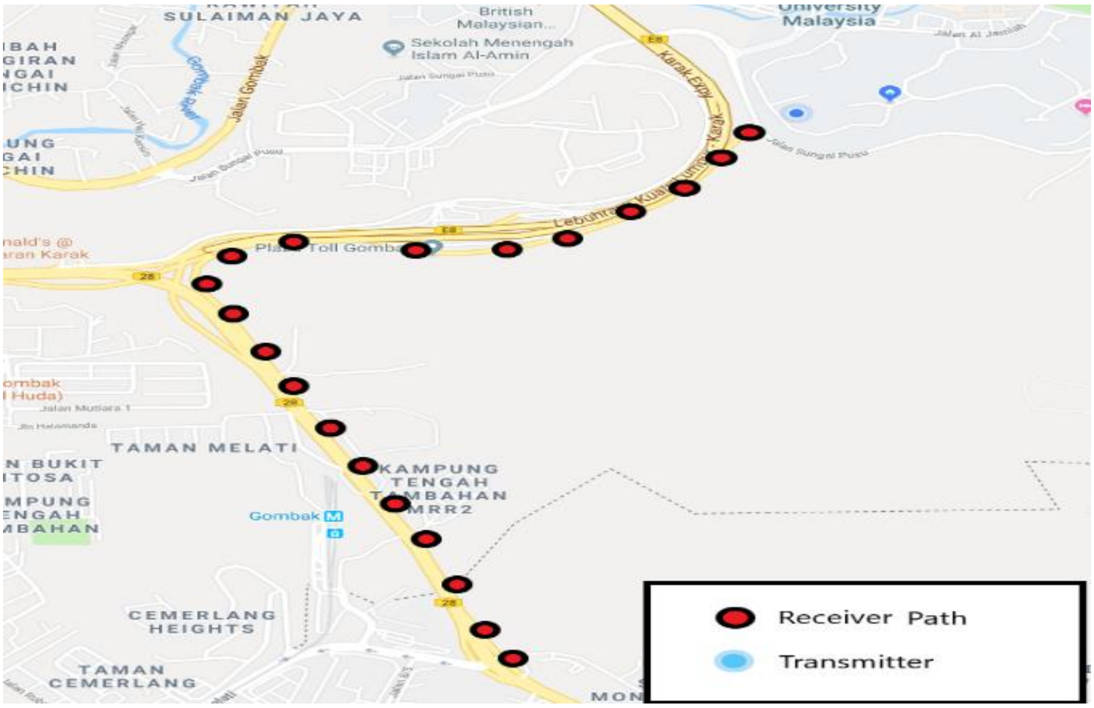

Fig . 5 Location of the transmitter and receiver (part 2)

As mentioned above, the receiver will move together with the car by following the path shown in the above figures. The experiment continued using different LoRa bandwidth and factor. The LoRa configuration and background of experiment can be summarized into the tables below.

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Tables. 1 LoRa configuration and experiment background

Set 1		
LoRa Module Bandwidth/Factor	125kHz/2048 chips	125kHz/2048 chips
Average Speed	20 km/h	40 km/h
Location	Inside campus	Outside campus
Set 2		
LoRa Module Bandwidth/Factor	125kHz/4096 chips	125kHz/4096 chips
Average Speed	20 km/h	40 km/h
Location	Inside campus	Outside campus
Set 3		
LoRa Module Bandwidth/Factor	125kHz/4096 chips	125kHz/4096 chips
Average Speed	20 km/h	40 km/h
Location	Inside campus	Outside campus
Set 4		
LoRa Module Bandwidth/Factor	250kHz/4096 chips	250kHz/4096 chips
Average Speed	20 km/h	40 km/h
Location	Inside campus	Outside campus

IV. RESULT AND ANALYSIS

In this chapter, the result of measurement of Received Signal Strength Indication (RSSI), ping statistics, delay (transmission time), throughput and jitter based on the scenario describe in chapter 3 will be presented and analyzed.

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Part 1

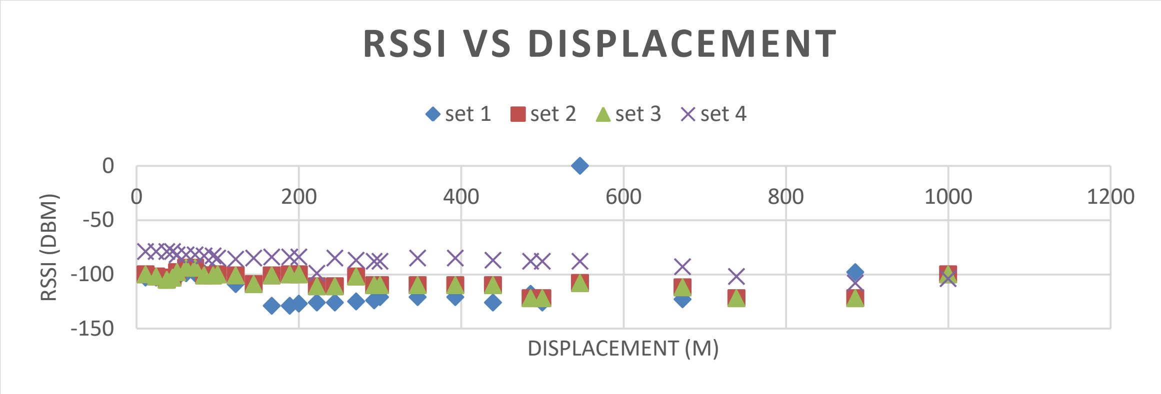

Fig . 5 Graph of RSSI vs displacement

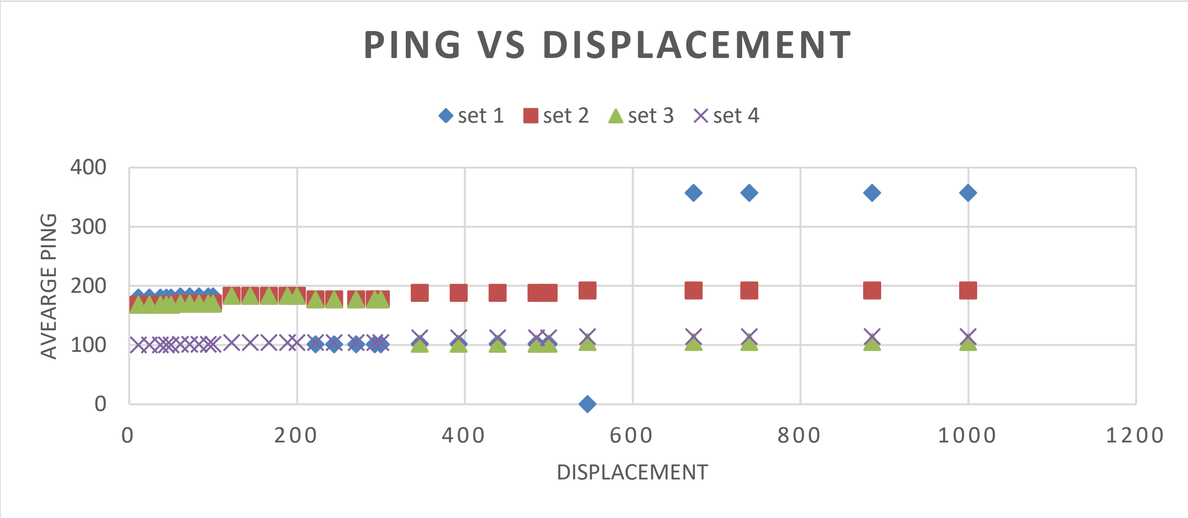

Fig . 6 Graph of ping vs displacement

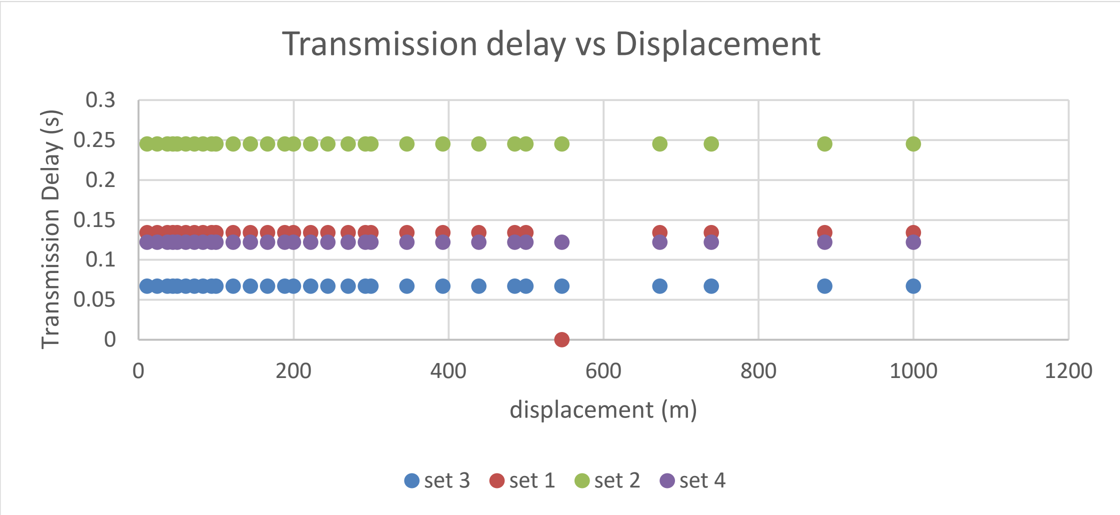

Fig . 7 Graph of transmission delay vs displacement

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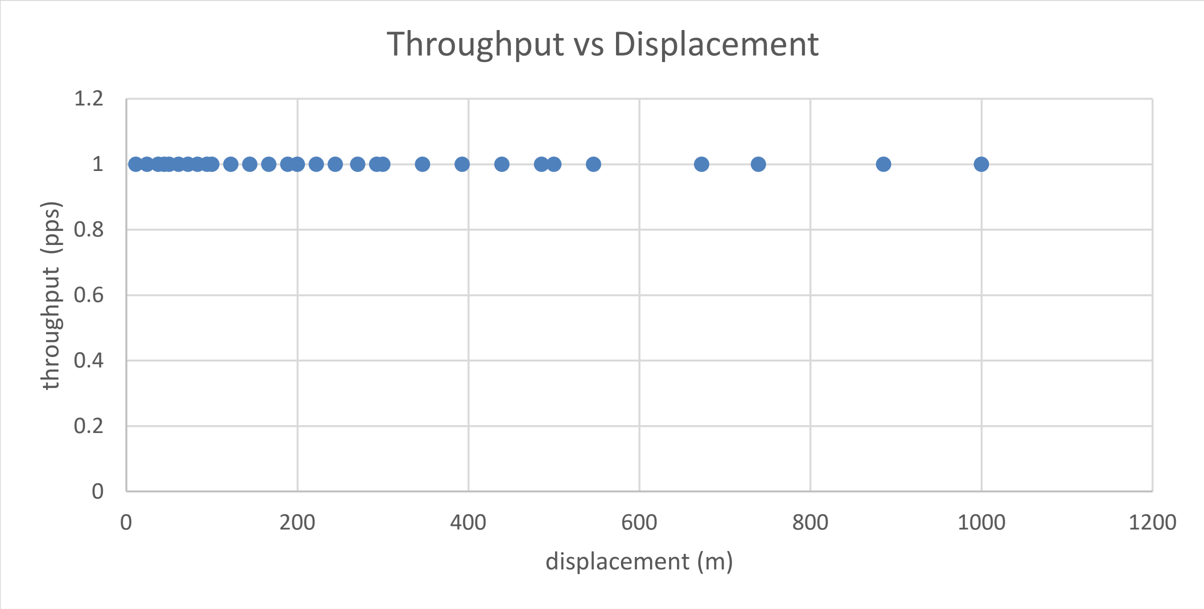

Fig . 8 Graph of throughput vs displacement

Part 2

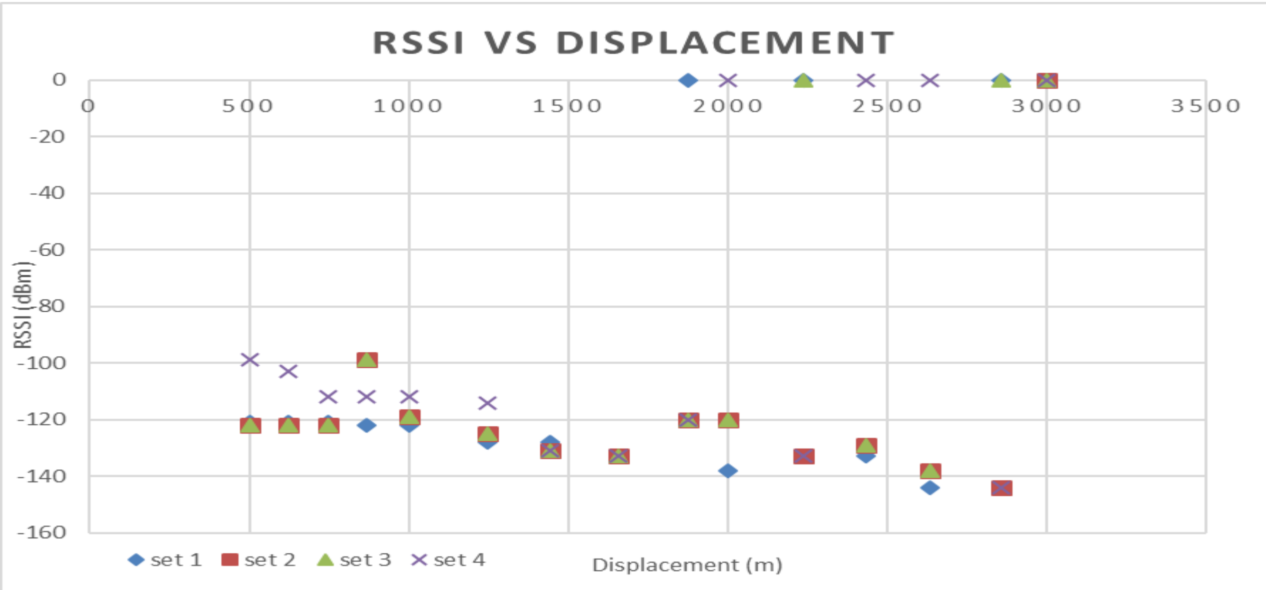

Fig . 9 Graph of RSSI vs displacement

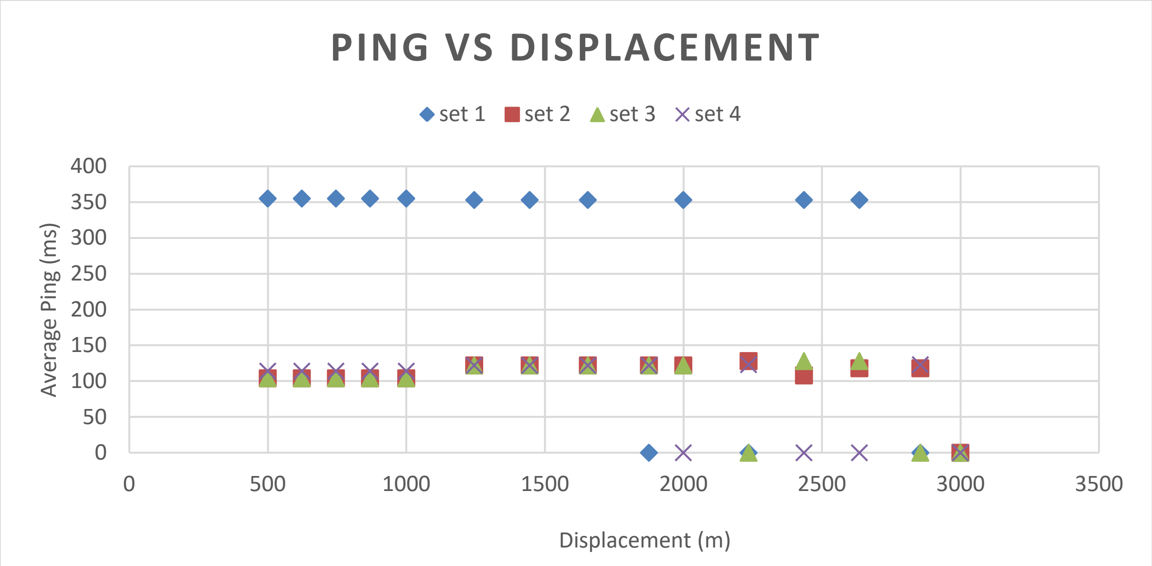

Fig . 10 Graph of Pings vs displacement

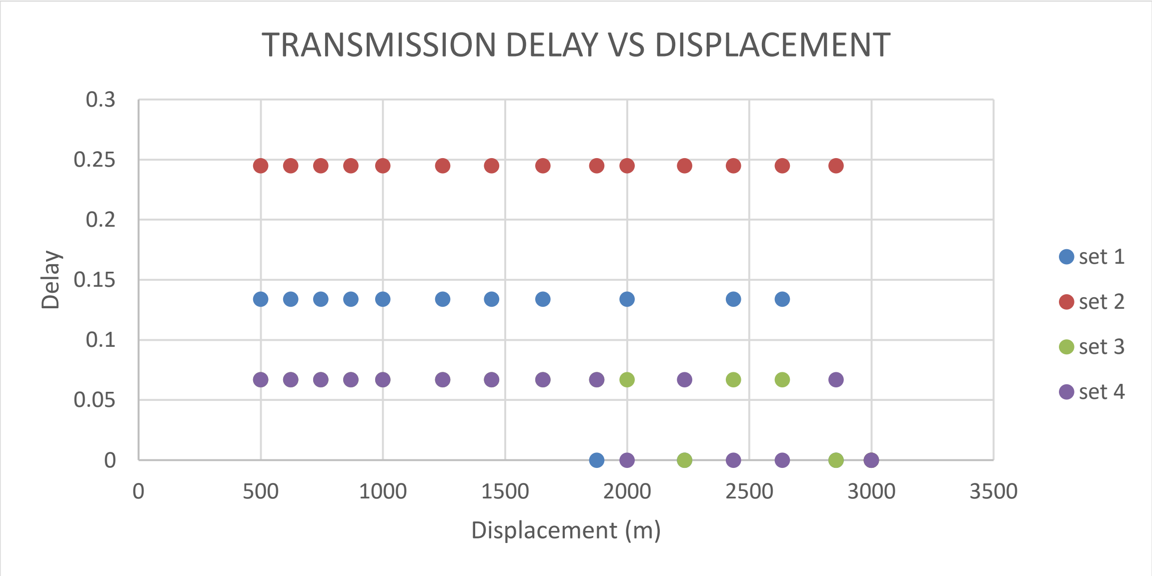

Fig . 11 Graph of Transmission delay vs displacement

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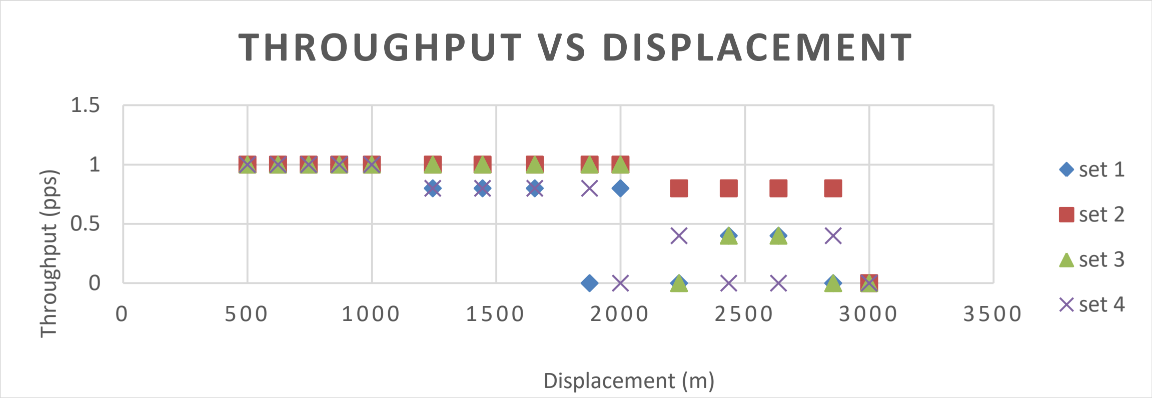

Fig . 12 Graph of throughput vs displacement

Analysis

The result obtained throughout all evaluation and experiment indicates that the all five metrics which are Received Signal Strength Indication (RSSI), throughput, transmission delay, ping statistic and jitter give a huge impact on the performance of LoRa. As seen in the result, the performance of LoRa is affected by the displacement between transmitter and receiver. As the displacement between transmitter and receiver is increased the RSSI value, throughput, ping will drop significantly, while the ping will increase which indicates the degradation of LoRa performance.

The black spot or the region whenever the connection between LoRa modules is lost can caused by several factors. One of the factors is the height of the transmitter and the location of receiver. If the transmitter located at a higher place, the attenuation caused by the tree and buildings can be avoided. The important aspect in location of the receiver is the resistances between it to the transmitter. The example of the resistances which could degrade the performance of LoRa link are air humidity, network traffic and foliage environment. Noted that Malaysia is an equatorial climate country with high crown density of the trees in Malaysia. The high density of trees could result in high signal attenuation. The increase in air humidity due to rain is one of the major degradations of LoRa performance as the moist air might be causing the probability of signal lost to be higher than expected.

For the measurement in IIUM campus, almost all the locations can receive the signal from transmitter which located at Mahallah Zubair Al- Awwam. The highest displacement recorded in this campus is about 1000 meters. However, in the outside IIUM campus scenario the receiver failed to receive any signal when the displacement is nearly 3000 meters. Based on the literature review, the theoretical coverage of the LoRa is about 5800 meters. This theory seems irrelevant to be achieved in the Malaysia environment based on the reasons stated before. The result of all the metric performance evaluation obtained in this project can be used to plan the implementation of LoRa in smart city or smart campus in Malaysia environment.

V. CONCLUSION

As a conclusion, this project presents the measurement test conducted for five metrics which are Received Signal Strength Inidication (RSSI), Ping Statistic, jitter, transmission delay and Throughput. The measurements of the five metrics have been conducted in two different scenario which are inside IIUM campus and outside IIUM campus. The performance of LoRa link will degrade when the displacement increase. In this performance evaluation test, the main reason for the signal lost and undelivered data packet is the high resistance which exist between transmitter of LoRa and the receiver of LoRa. As mentioned above, the resistances could be a high air humidity, high network traffic and foliage effect. After several analysis and comparisons, it can be determined that the performance of LoRa link in Malaysia is quite low compared to other country.

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