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PERFORMANCE ANALYSIS OF SIGFOX DEPLOYMENT

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Abstract

Low-power wide area network (LPWAN) has become a promising communication technology as alternative solutions on long range communications, low power consumption and low cost that overcome the problems faced by traditional communications. An example of LPWAN technology is Sigfox that uses a zero generation (0G) technology. However, there is not many literatures discussed on this technology especially on its applications. The objective of this paper is to study the coverage of Sigfox in Malaysia by tracing its network coverage using a Sigfox module that is integrated with an Arduino microprocessor. In this paper, we reported the experiments performed on real device and field test as well as observed the performance of the proposed technology. This system was tested using two different Sigfox development module which has device ID 4126D0 and 3E3D05. Two locations were selected to observe the connectivity of the Sigfox network. The results showed Sigfox deployment gave impact on a coastal location compared to urban area. Based on this finding, Sigfox is expected to have an improvised performance in the future especially applications in rural and coastal areas.

1 Introduction

Low Power Wide Area Network (LPWAN) is a category of wide area network for wireless telecommunications. LPWAN has become a new alternative solution for Internet of Things (IoT) applications for solutions that promising long range communication that covers up to hundred metres, low power consumption, low cost and low data rate that covers up to hundreds of kbps [1]–[7]. In addition, LPWAN is the fastest growing IoT application. Because of its advantages such as, it would help save time, reduce costs and protect the environment [8]. LPWAN also has become a popular technology to overcome the problems of short range communication, high power consumption, low scalability and cost issues faced by traditional communications [4], [8]. LPWAN supports low data rates with low power consumption so that the devices can have a long battery lifetime that covers up to 10 years. There are several LPWAN technologies such as Sigfox, Long Range (LoRa) and Narrow Band (NB-IoT) that would be utilized for different applications and objectives [3]. Meanwhile, the application examples of LPWAN are in agriculture managements, sensor networks in smart farming, monitoring systems, pollution monitoring and smart cities [2], [4], [9], [10].

One of LPWAN technologies that getting more attention is the Sigfox which was developed in 2010 by a start-up company in Toulouse, France by a global network operator [1], [11]. Sigfox has become a performance solution because, there is very little existing literature covering the performance of Sigfox especially in Malaysia. The most suitable applications of Sigfox in Malaysia are smart farming, control environment and agriculture because it requires long range communication, ultra-low power consumption, long battery lifetime, low cost and low data rate. The advantage Sigfox over other LPWAN technologies is it uses an ultra-narrow band (UNB) of 100Hz [4], [12]. The effects of using UNB are to reduces the noise thus increasing its range communication and supporting a ultra-low power consumption so that the devices can have a long battery lifetime [11], [13]. Sigfox is an unlicensed bands with a frequency ranges from 868MHz until 902MH [13]. Thus, the devices enable to transmit the data to the cloud using low power. Sigfox also supports low data rates for infrequent communication over long range and is therefore ideal for applications that transmits only an 8 to 12 bytes payload per day. Hence, Sigfox proposes a small payload length compared to other LPWAN technologies which suitable to send small data sizes [9].

Based on literature by Patel et al, Sigfox covers network up to 10km in urban areas and up to 50km in rural areas [11]. Sigfox has its own base stations compared other LPWAN technologies so that devices can be connected to one of them similar to conventional cellular networks [13]. In Malaysia, Sigfox network is still new and does not have wide coverage, as shown in Figure 1. The Sigfox network mostly covers the west coast of Peninsular Malaysia and several locations at east-coast of Peninsular Malaysia and Borneo Island. From Figure 1, the blue colour represents the position of a single base station, the green colour represents 2 base stations while the red colour represents 3 base stations and more by the network provider. The allocation of base stations were based on the projects or number of users intended to use Sigfox network at that area. The Sigfox range is more than 40 km covering 1 base station for 1 city compared to the NB-IoT. The coverage of NB-IoT ranges less than 10 km and the coverage of LoRa ranges less than 20 km that covering 3 base stations for a city [9]. This means Sigfox network covers a wider network range with minimal number of base stations.

Fig. 1 Sigfox coverage in Malaysia.

Sigfox is operated globally with network coverage in 7 different geographical zones throughout the globe under Sigfox Radio Configurations (RC). The RC is the radio parameter for an operating device such as operating frequency range, output power and transmission area. Malaysia is in the RC4 category for Asia Pacific together with Australia, New Zealand and Latin America countries.

2 Methodology

As mentioned by Farooq et al., Sigfox is considered an ideal solution for continuous monitoring, tracking and controlling [14]. We focused on the Sigfox deployment module to test and observe the performance of the proposed technology in 2 locations in Malaysia which are Shah Alam, an example of urban area, and Tanjong Karang, an example of rural area.

Figure 2 shows an illustration of a Sigfox network schematic divided into two layers. Layer 1 is a network equipment consisting of end device and Sigfox base station and Layer 2 is the application layer that has backend service integrated with a cloud system, web interfaces and user customer system. Sigfox receiver can handle up to 50,000 end devices [9]. Sigfox module is an example of an end device to the Sigfox network that is integrated with an Arduino Uno board attached with a shield. The shield integrated with the Sigfox module has embedded sensors, temperature, pressure, light, reed switch, 3D accelerometer, 2 LEDs, a push button and a USB port.

Using these instruments, the Sigfox network is connected to a base station to receive uplink messages from the end device and then transmit it to the Sigfox support system. This process is only at uplink transmission of Sigfox and no downlink transmission. This is because the maximum payload length of a Sigfox packet is 12 bytes for the uplink transmission and 8 bytes for the downlink transmission [12], [15]. Therefore, the acknowledging each uplink message is not fully supported.

Based on Figure 2, the Sigfox network architecture has 2 layers whereby the first layer uses a star topology. The function of star topology in the first layer are for long range communication and allows the end device to connect to the Sigfox base station. Furthermore, the advantage of a star topology is that it has relatively low power consumption [1], [5], [16]–[18]. Layer 2 consists of Sigfox support system, business support system and customer system. In the Sigfox support system there are Sigfox cloud and other backend services. Sigfox devices transmit messages to Sigfox network server which is called Sigfox backend services. The responsibility of the Sigfox support system is to process the uplink messages and transmit it through callback services to the customer system.

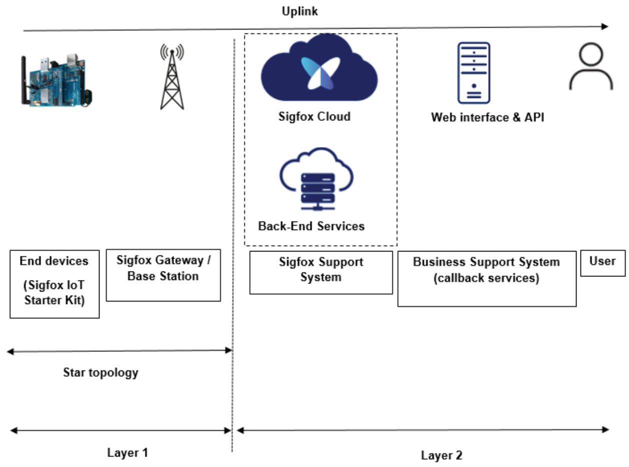


Fig. 2 Illustration of a Sigfox network schematic.

In this paper, field tests are conducted and the parameters collected from the Sigfox module are recorded. This situation indicates a static test which is the Sigfox module is located in a fixed location without moving. The parameters collected which containing data on the coverage area, messages and statistics received. This method can then be improved by implementing smarter methods in the future.

This system was tested using two different Sigfox development module which has device ID 4126D0 and 3E3D05. Two locations were selected to observe the connectivity of the Sigfox network. The 4126D0 module was tested at Tanjong Karang, Selangor, a rural area in west coast of Malaysia, meanwhile the 3E3D05 module was tested in Shah Alam, a city area and a capital of Selangor state. We successfully received messages via email after setting up the procedure on the Sigfox portal. The test was repeated at a different location to observe the coverage and connectivity of Sigfox network. Figure 3 shows the flow process of the Sigfox connection setup.

3 Results

In this paper, we observed a performance analysis of Sigfox deployment. The Sigfox module is integrated with an Arduino Uno board supplied with a shield that sends a message consisting of the device ID, temperature value, pressure value, the output voltage from the photovoltaic sensor and the acceleration every 10 minutes. The measured value is scaled to a two-byte integer since the maximum payload length of a Sigfox message is limited to 12 bytes only for uplink [9], [11]–[13], [15]. Thus, a message is expected to take only a short time with an average of 2 seconds to reach the base station [4]. Table 1 shows the messages received by the device 4126D0 located in a rural area containing a temperature value of 35.63 ºC, pressure value of 100566.00 Pa and an output voltage value of 0.37V. Also shows the messages received by the 3E3D05 device located at a city containing a temperature value of 32.27ºC, pressure value of 100029.00 Pa and an output voltage value of 0.32V.

Table 1 The example of received messages on 4126D0 and 3E3D05 devices.

Device ID	Location	Temperature	Pressure (Pa)	Output voltage
4126D0	Tanjong Karang	35.63ºC	100566.00	0.37V
3E3D05	Shah Alam	32.27ºC	100029.00	0.32V

Sigfox technology has proven its good network coverage especially in coastal areas such as in Sekinchan, Tanjong Karang and Kuala Selangor. Figure 4 shows the Sigfox with a good coverage by device 4126D0 that was located at Tanjong Karang, Selangor. The results from the shield were obtained from Sigfox backend at this location. The location was identified by the Sigfox module has latitude and longitude and transmitted through a callback services. The latitude and longitude in the coordinates of Tanjong Karang are 3.414610° N, 101.165576° E, respectively.

Next, the similar test was conducted at Shah Alam as shown in Figure 5. This figure shows the coverage of Sigfox area by device 3E3D05. The latitude and longitude of this location are 3.072550° N, 101.489829° E, respectively. This result proved that Sigfox coverage is good for urban areas even surrounded by skyscrapers and high buildings. However, compared to network coverage in Figure 4, 5(a) and 5(b), Shah Alam has slight poor coverage performance than the one at Tanjong Karang.

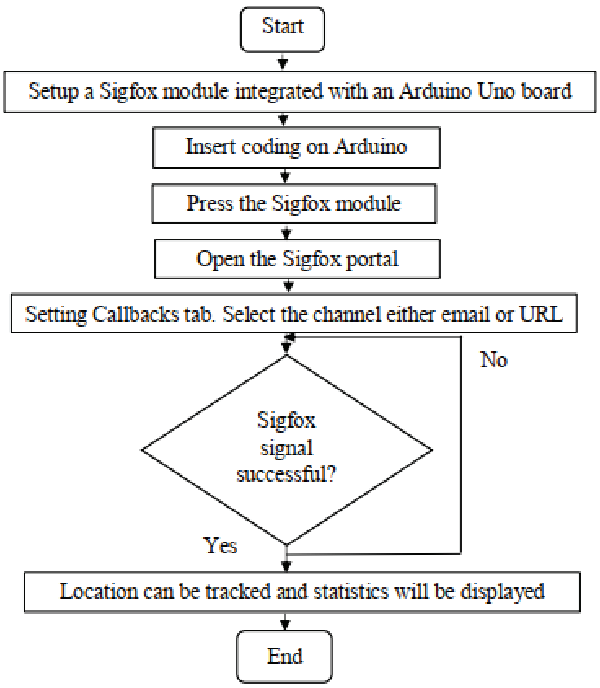


Fig. 3 Process flow of Sigfox connection setup.

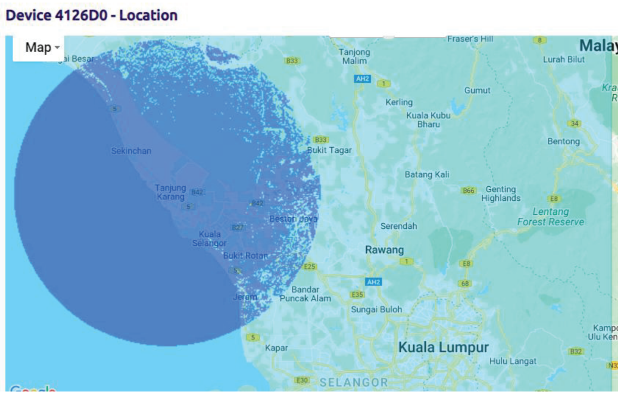
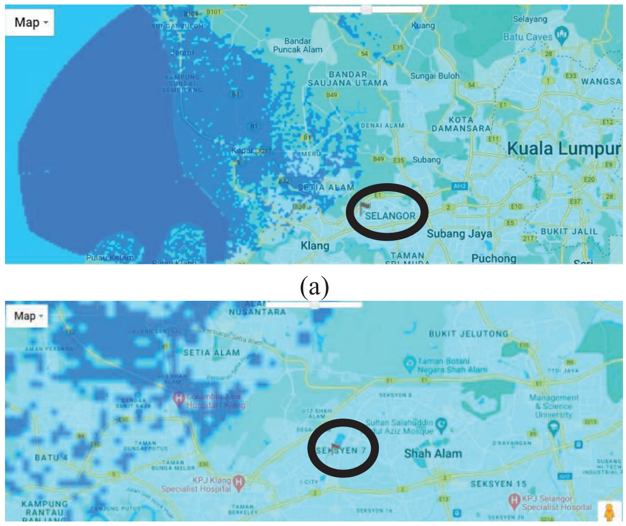


Fig. 4 Location of the device 4126D0 on Sigfox backend.



(a)

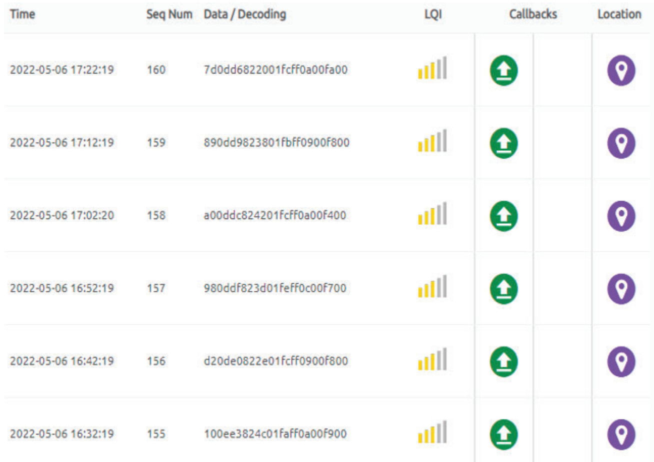
(b)

Fig. 5 (a) Network coverage around device 3E3D05 on Sigfox backend, (b) location of the device 3E3D05.

Based on these observations, Figure 6 and Figure 7 showed the messages received by the 4126D0 and 3E3D05 devices on Sigfox backend including time, date, data and decoding, sequence number, Link Quality Indicator (LQI), callbacks and location the messages were transmitted and successfully received by the base station. The time and date recorded on Sigfox backend are synchronised with messages through an email or Uniform Resource Locator (URL). Next, the data and decoding are the data collected from Sigfox development kit. LQI indicates the quality signals whether the signals are limited, average, good or excellent. The function of callbacks is to show the status state of Sigfox signal either an ‘OK’ or ‘Error(s)’. The callbacks contain the recipient, subject and messages. From these results, it indicates that the location can be tracked and the location information can be received frequently.

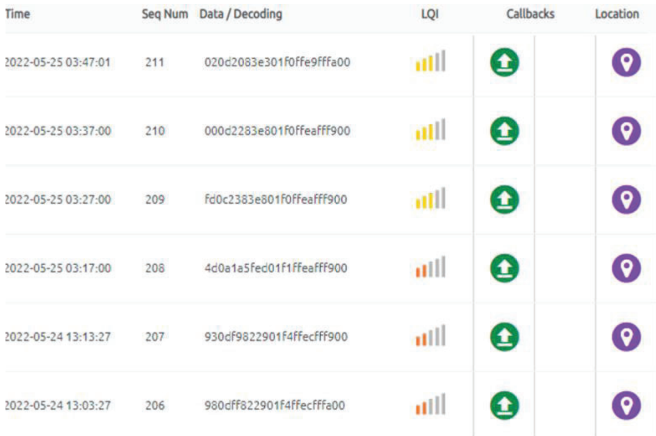
Figure 6 shows the device 4126D0 has the sequence number of 156, data and decoding to display d20de0822e01fcff0900f800, with average LQI and callbacks status is OK on 6 May 2022 at 16:42. All statuses showed the Sigfox network has average coverage and transmitted messages successfully to Sigfox backend from Tanjong Karang, Selangor.

For the statuses of device 3E3D05 showed in Figure 7, the result shows the device has the sequence number of 211,



Time	Seq Num	Data / Decoding	LQI	Callbacks	Location
2022-05-06 17:22:19	160	7d0dd6822001fcff0a00fa00			
2022-05-06 17:12:19	159	890dd9823801fbff0900f800			
2022-05-06 17:02:20	158	a00ddc824201fcff0a00f400			
2022-05-06 16:52:19	157	980ddf823d01feff0c00f700			
2022-05-06 16:42:19	156	d20de0822e01fcff0900f800			
2022-05-06 16:32:19	155	100ee3824c01faff0a00f900			

Fig. 6 Messages of the device 4126D0 on Sigfox backend.



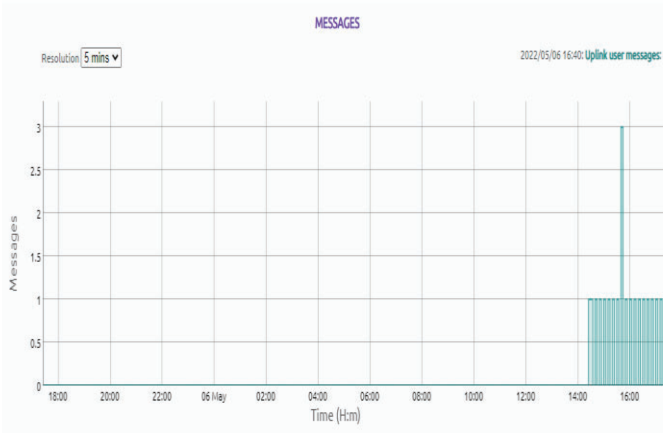
Time	Seq Num	Data / Decoding	LQI	Callbacks	Location
2022-05-25 03:47:01	211	020d2083e301f0ffe9fffa00			
2022-05-25 03:37:00	210	000d2283e801f0ffeafff900			
2022-05-25 03:27:00	209	fd0c2383e801f0ffeafff900			
2022-05-25 03:17:00	208	4d0a1a5fed01f1ffeafff900			
2022-05-24 13:13:27	207	930df9822901f4ffecfff900			
2022-05-24 13:03:27	206	980dff822901f4ffecfffa00			

Fig. 7 Messages of the device 3E3D05 on Sigfox backend.

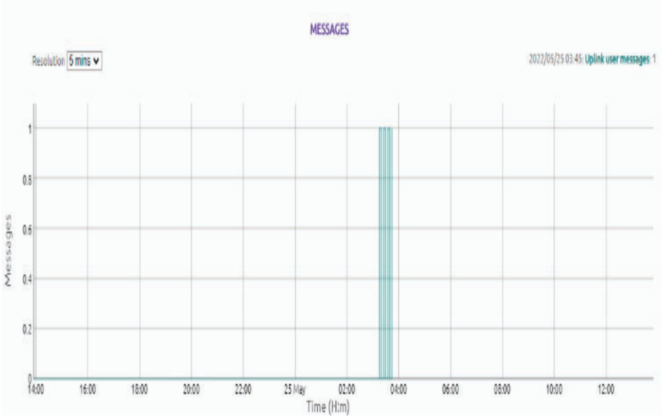
data and decoding to display 020d2083e301f0ffe9fffa00, LQI is average, callbacks is OK status on 25 May 2022 at 03:47. The statuses showed the Sigfox network has average and limit coverage then successfully transmit messages to Sigfox backend from Shah Alam, Selangor.

Sigfox allows the number of the transmitted packets per day to be limited to 140 messages in the uplink and 4 messages in the downlink [4], [19]. Since, Sigfox can send only 1 message every 10 minutes equivalent to 6 messages per hour then the maximum messages per day is 144 messages [20]. Figure 8 shows the continuously sending uplink messages for both devices whereby Figure 8(a) shows the result for device 4126D0 on Sigfox backend on 6 May 2022 at 16:40. Meanwhile, Figure 8(b) shows the maximum uplink user messages by the device 3E3D05 on 25 May 2022 at 03:45. This result showed the maximum uplink user messages is 1 message. From these results, it is shown that all uplink messages were successfully transmitted without failure.

Figure 9 shows the Received Signal Strength Indicator (RSSI) of both devices on Sigfox backend. The function of RSSI is to measure how well the device can receive, detect or hear a signal from an access point. This parameter is useful in determining whether the Sigfox signal is enough to get a good wireless connectivity. Figure 9(a) shows the maximum RSSI of the device 4126D0 on 6 May 2022 at 16:40 was -117. Meanwhile, Figure 9(b) shows the



(a) Device 4126D0



(b) Device 3E3D05

Fig. 8 Statistics (messages) on Sigfox backend.

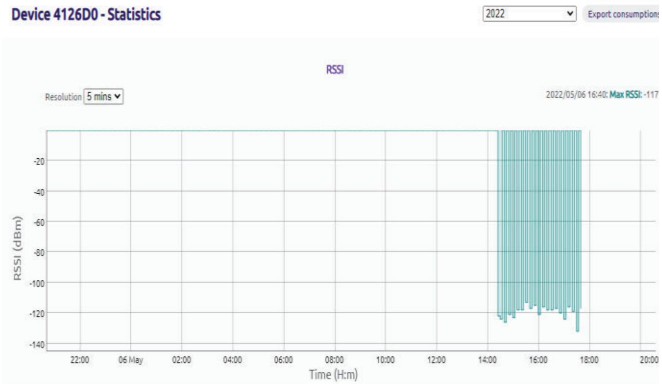
maximum RSSI of the device 3E3D05 on Sigfox backend was -125 on 25 May 2022 at 03:45.

The signal strength is considered stronger when the RSSI value is closer to zero and if it is closer or beyond -100, the signal is considered weak signals. Based on the results of these two devices, the RSSI values were in the weaker signals due to their distances from the base stations.

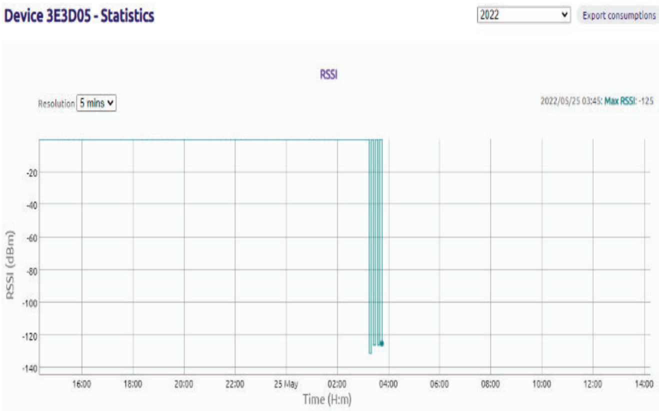
Figure 10 shows the success of HTTP callbacks of both devices to observe the Sigfox performance. Figure 10(a) shows all messages were successfully received on 6 May 2022 at 14:20 through nearly 18:00. This result shows all received messages have success status with 1 message except transmission at 15:45 with 3 messages. Meanwhile, Figure 10(b) shows all messages were successfully received on 25 May 2022 at 03:45 with success status of 1 message.

Figure 11 shows the duration for each message received on Sigfox backend for both devices. The duration of messages received in these figures were in various values. In Figure 11 (a), the result showed the duration of received messages was 4.38×10^{8} taken on 6 May 2022 at 16:40 for device 4126D0. For Figure 11 (b), the result showed the duration of received messages was 4.71×10^{8} taken on 25 May 2022 at 03:45 for device 3E3D05.

There are two ways the user can check the channel callbacks or transmission succession, either via email or weblink. For email, the Sigfox backend will send a notification with the device ID and a message containing the time and analog data values.



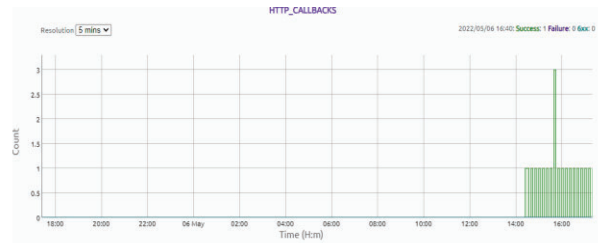
(a) Device 4126D0



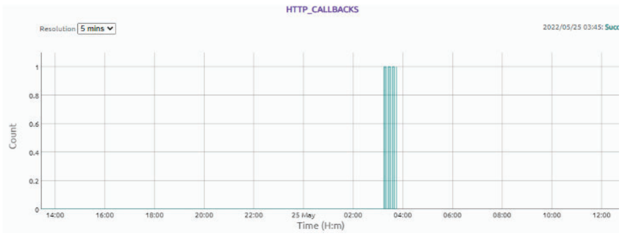
(b) Device 3E3D05

Fig. 9 RSSI statistics on Sigfox backend.

The summary of the data taken on the Sigfox module backend are recorded in Table 2 and Table 3 for the device 4126D0 and 3E3D05, respectively. These tables list the data of area coverage, received messages and received statistics on Sigfox backend at 2 locations, which one was in rural area near coastal area in Tanjung Karang, and one was in an urban area in Shah Alam. From these results, we found that the Sigfox coverage was better at the rural area compared to urban area due to the distance from base station and numbers of obstacles around the area that we placed out Sigfox module. More tests will be conducted before we test any system or application to be integrated with the Sigfox communication module in the future.

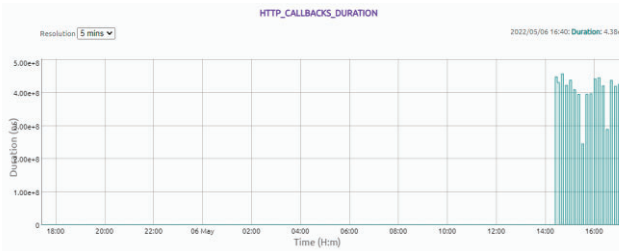


(a) Device 4126D0

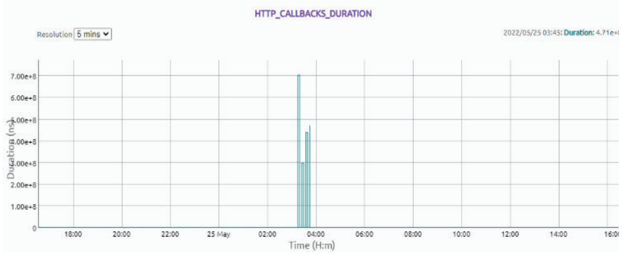


(b) Device 3E3D05

Fig. 10 Statistics (HTTP_callbacks) on Sigfox backend.



(a) Device 4126D0



(b) Device 3E3D05

Fig. 11 Statistics (HTTP_callbacks_duration) on Sigfox backend.

Table 2 The data collected in on 4126D0 device at Tanjong Karang, Selangor.

Date	**Time**	**Channel**	**Data**	**Uplink user messages**	**RSSI**	**HTTP callbacks status**	**HTTP callbacks duration**
6 May 2022	15:40	Email	e70df3827c01fcff0c00f800	3	-117	Success	3.95×10^8
6 May 2022	16:40	Email	d20de0822e01fcff0900f800	1	-117	Success	4.38×10^8

Table 3 The data collected in on 3E3D05 device at Shah Alam, Selangor.

Date	**Time**	**Channel**	**Data**	**Uplink user messages**	**RSSI**	**HTTP callbacks status**	**HTTP callbacks duration**
25 May 2022	03:17	Email	4d0a1a5fed01f1ffeafff900	1	-131	Success	7.04×10^8
25 May 2022	03:47	Email	020d2083e301f0ffe9fffa00	1	-125	Success	4.71×10^8

4 Conclusion

This paper describes the design performance analysis of Sigfox deployment. Sigfox is still under development in Malaysia thus it is encouraging to study it. This paper presented the performance evaluation study using Sigfox network on two different locations, rural area located in Tanjung Karang and city area located in Shah Alam. The study was successfully conducted with observations of several parameters in the transmission. The system could help increase the limits and scalable networks in various applications such as for smart cities and smart agriculture. Other issues such as performance of data transmission, scalability and payload length need to be studied and evaluated in the future before deploying into any application.

5 Acknowledgements

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