A Performance Study in NB-IoT Networks through the IoT Platforms in Thailand

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Abstract

Nowadays, the Low-Power Wide-Area (LPWA) could account for 70% of Cellular IoT Connections in 2020. There are three big LPWA operators in Thailand (TRUE, AIS and CAT). LPWA by CAT focusing on LoRaWAN but TRUE and AIS focusing on NB-IoT. The purpose of this study is to advance understanding of choosing to select LPWA operators; there are other factors than the price that needs to come into play. Performance, reliability, scalability, and service are key factors in choosing operators that will work best for users. This paper presents the performance study comparison of two NB-IoT operators based with Round-Trip Time (RTT) ping packets, SINR/SNR, RSRQ and RSSI for one week. There is a Pathum Thani site for testing nine popular IoT Cloud Platform (GoogleCloud, AWSamazon, OracleCloud, theThing.io, IBMwatson, Ubidot, IoTtweet, Magellan and Things Board). The obtained results demonstrate that the TRUE operator gives the highest performance of round trip time and SINR/SNR, AIS operator offers a better quality of a number of pings failed and RSRQ.

Keywords: *IoT, NB-IoT, RTT*

1. Introduction

The Internet of Things (IoT) means physical objects which make every object connect to the internet. It possible to be connected by wired or wireless and send useful data from sensing devices with various types of data from real environments every time and everywhere. With IoT technology, it can improve people's quality of life such as a smart city, smart agriculture, or a smart home. IoT devices are low-cost devices with a low power processor that can use more than ten years with one or two of batteries and a design for easy deployment even with people without specialized knowledge.

Wireless Technologies have developed various types of communication such as a short-range personal area like 802.15.4 standard, ZigBee and IPv6 over Low-Power Wireless Personal Area Networks (6lowPan) are popular, but the limitation is the coverage area length around 100 meters and consumes more battery as it tries to send from a more extended range. Next popular wireless technology is LTE (Long term evolution) as it has wide-area coverage around the country, and a high bandwidth usage but it consumes a large amount of the battery.

Recently, a low power wide area (LPWA) means wireless technology devices can send data through a radio frequency and consume a low amount of battery for mass distributed devices and lower costs for wide geographical footprints or deep within an urban infrastructure as Figure 1 compares with the other wireless technology strong point is coverage range is very far that make LPWA suitable for IoT such as Low-Power Wide-Area Network (LoRaWAN), Enhanced Machine-Type Communication (eMTC), SigFox and NB-IoT. LPWA are becoming popular because of the huge area coverage and low consuming battery make LWPA look interesteding in academic and industrial sectors. At this moment, three of the operators in Thailand namely TRUE, AIS and CAT telecom had invested a considerable amount of money in implementing LPWA by CAT focusing on LoRaWAN but TRUE and AIS focusing on NB-IoT. The mission of RTT measurement is to collect and preprocess the information from all radio modem & router nodes in the network operation. RTT is the time required for a packet to travel from the source to the destination and back again.

The NB-IoT is developed based on Narrowband Cellular Internet of Things (NB-CIoT) and has become an essential branch of the Internet of everything (IoE). The NB-IoT uses only about 180 kHz bandwidth, supports two modes for uplink. Single tone with 15 kHz and/or 3.75 kHz tone spacing Multiple tone transmissions with 15 kHz tone spacing, HD-FDD duplex mode, Pi/4 QPSK, Class 3 and 5 (14 dBm) power class and can be directly deployed on a GSM, UMTS, or LTE network, reducing deployment costs and achieving a smooth upgrade. NB-IoT is an 11 compatible version of LTE targeted for cellular-based IoT applications. The Radio measurements in Long Term Evolution (LTE) system are Channel Quality Indicator (CQI), Reference Signal Received Power (RSRP), Reference Signal Received Quality (RSRQ), and Carrier Received Signal Strength Indicator (RSSI).

The IoT platforms are emerging as the central backbone of these IoT deployments. These IoT Platforms are the key to the development of scalable IoT applications and services that connect the real and virtual worlds between objects, systems, and people. There are more than 300 IoT platforms in the market today, and the number is continuing to grow. However, as discussed not every platform is the same – IoT platforms are being shaped by varying entry strategies of different companies trying to capitalize on the IoT potential. Innovative startups, hardware, and networking equipment manufacturers, enterprise software and mobility management companies are all competing to become the best IoT platform on the market. Various strategies are visible with companies.

NB-IoT networks are designed for machine-to-machine communication, which generally requires low data rates. When building NB-IoT networks (Malik et al., 2018; Biswas & Giaffreda, 2014), it is essential to test the performance of new implementations to ensure that the required network quality is available. Tests to measure the quality of service (QoS) in NB-IoT networks are typically performed with NB-IoT modules that are controlled by software.

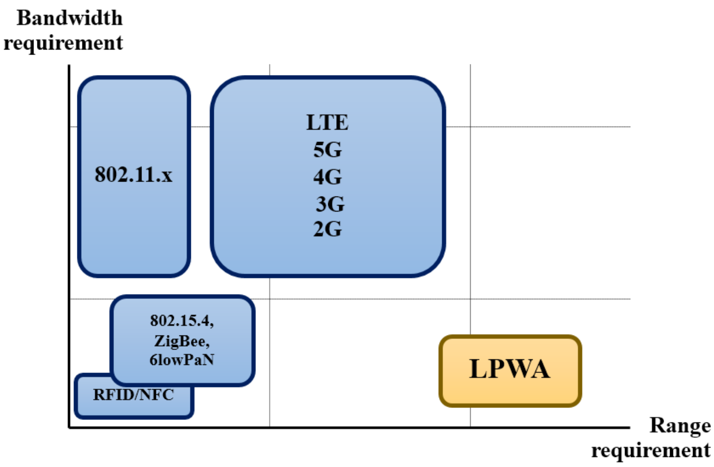

Figure 1 Show graph of bandwidth required and range capability of wireless technology

In this paper, we are going to present an overview of NB-IoT Technology and evaluate the performance by testing on real NB Devices from AIS and TRUE to show the difference for users to choose devices easier by various factors from locations in Pathum Thani.

2. Literature Review

The Mobile Technologies Performance Comparison for Internet Services in Bangkok (Chimmanee & Patpituck, 2013), is where the author tested the performance of cellular networks through three operators by three essential factors such latency, data rate, and speed test. The author set up the experiment by using a laptop with a 3G air card connected to the internet from favorite five places in Bangkok which have high congestion. By the latency test the author used ping function to check the round trip time from devices to a private server and an international server. By the data rate test the author used FileZilla to send 1 MB of data from a laptop to an FTP private server to check downlink speeds and uplink speeds. By the speed test testing, the author uses http://speedtest.adslthailand.com/ to check the data rates and round trip times in one period. From the experiment, shows AIS offered a better performance in the latency tests in both domestic and international websites. TrueMoveH offered better performance in the speed test for uploading and the user data rate tests, DTAC provided a better performance in the speed test for downloading.

Analysis in the Internet Traffic Pattern based on RTT over ADSL in Thailand (Chimmanee, Jantavongso & Kantala,2015), Author testing performance of Asymmetric digital subscriber line (ADSL) network via three operators from two locations such as Bangkok and Pathumthani by using ping packet trains with 100 bytes for 24 hours for one month to a domestic web server. Then the author presented the formula to classify the type of traffic into three types of high traffic volume, average traffic volume and low traffic volume for evaluating traffic. From the experiment, the result shows that TRUE ADSL operators in Thailand should provide the best performance compared to others.

IoT and Cloud Convergence Opportunities and Challenges, the author discusses what IoT cloud should offer. Good IoT cloud services must be attributed with ubiquity, reliability, high-performance, efficiency, and scalability

A Survey of IoT Cloud providers, according to the author, discusses the primary function of the platform as service for IoT or cloud with IoT support and what IoT needs such as hiding data generation, processing, and virtualization. The survey studies popular cloud IoT as google IoT, Amazon Web Services Azure and provide intense details about each characteristic for each site.

3. Overview of NB-IoT

NB-IoT or LTE CAT NB1 was developed by the 3rd Generation Partnership Project (3GPP) use license radio for the frequency band. Design for long-range connection more than 15 km in the countryside and 3 km in urban areas, and used Quadrature Phase Shift Keying (QPSK) modulation. Work on Evolved packet system (EPS) that sp. requires a minimum bandwidth of 180 kHz (Chen et al., 2017; Adhikary et al., 2016). Every cell site can support around fifty-five thousand nodes (Zayas et al., 2017). Cell site can use the same LTE cell site but implement an additional function to support NB-IoT that make easier for the operator who already is provided LTE the cell site before. NB-IoT familiar to LTE because LTE and NB-IoT are wireless technology that was developed by the same organization that required a sim card for access through an operator cell site but NB-IoT cut some functions from LTE such as Hand Over, Monitor the channel quality, Carrier aggregation and Dual Connectivity (Sinha, Yiqiao & Hwang, 2017). NB-IoT can deploy with three types of modes first is a stand-alone operation, second is guard band operation, and third is In-band operation.

In this research, we are focusing on a BC-95 Band 8 900 MHz NB-IoT module working with Arduino Uno or Arduino Mega because TRUE and AIS also use Quectel BC-95 NB-IoT modules and develop NB-IoT library for BC-95 by themselves.

TRUE and AIS was provided NB-IoT module designed for Arduino. Using Quectel BC95-B8 work on 900 MHz frequency uplink speed is 24 kbps downlink speed is 45.625 kbps supported user datagram protocol (UDP) and constrained application protocol (COAP) probably support other protocols later. At this moment, both operators mention that the coverage area already provides all provinces in Thailand. From Figure 2 it shows a picture of theTRUE NB-IoT module and the AIS NB-IoT module. The significant difference on NB devices from TRUE and AIS is NB devices from AIS using E-sim that are embedded on board but TRUE NB devices using sim card slot. Next is the antenna from AIS NB devices are slightly bigger than TRUE NB devices. The price of AIS NB module is 1,190 baht for one device and internet service connection 300 baht for one year and the price of TRUE NB module is 1,150 baht for one device and get 1-year free internet service connection. For the next year the expense is 300 baht per one device same as AIS.

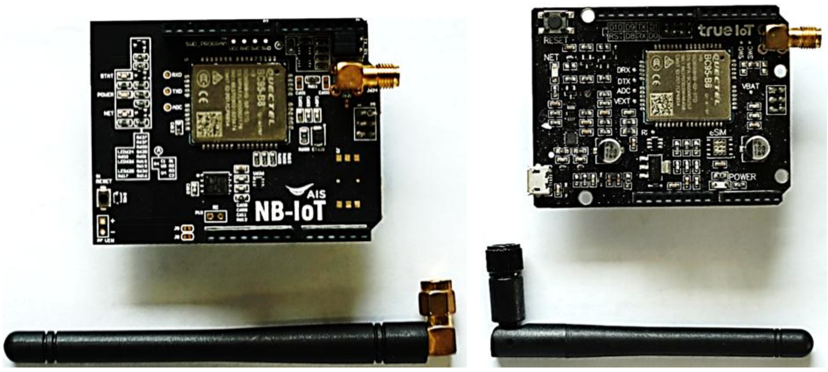

Figure 2 AIS NB-IoT module and TRUE NB-IoT module

Typically, NB-Devices will send data to IoT Cloud Platform for storing and monitoring data. IoT Cloud Platform have various types of server providers such as IBM, Amazon, Google, Oracle, etc. also has free or paid for additional functions. Cloud IoT can store data and dashboard for showing data. The dashboard from each IoT Cloud Platform may look different. Some IoT Cloud Platforms have various types of graphs for creating dashboard as some sites have analytic functions or export (.csv file) to open in Excel or Jason to create some programs for getting value and trigger something or show values in a graph. IoT Cloud Platforms have an open source like Grafrana or Thing board which makes the user able to provide their own IoT Cloud Platform. The key is a cloud for NB-IoT that should open functions which support UDP or CoAP.

4. Experiment Configuration

We prepared two NB devices from TRUE and AIS with Arduino Uno. Then we created specific modify programs to collect important factors that are readable from NB devices. Firstly, we use the ping method to get round trip time data that implies a time delay between NB devices and a destination server. Ping can fail if the round trip time value is higher than ten seconds or time to leave (TTL) value is high. Secondly, we get a Received Signal Strength Indicator (RSSI) which measures the average total received power between Board and cell site. Moreover, Reference Signal Received Quality (RSRQ) which indicates the quality of the received reference signal and some resource block for calculations. Thirdly signal to noise ratio (SNR) is defined as the ratio of signal power to the noise power. We modify the program to ping and get all data every one-minute program will reread all value for twenty-four hours. We install the same program into an AIS NB-device and TRUE NB-Device and start the experiment at the same time. The experiment started at the twenty-third of October at noon to the thirtieth of October at noon or one week. The location is at Pathum Thani. Destination nine IoT cloud platform we choose a popular server (Ray, 2016; Pflanzner & Kertesz, 2016) and quickly implemented a server which operators already supported in the library in git hub namely Google IP, AWSamazon, CloudOracle, TheThingio, IBM Watson, ubidot, IoTtweet, AISmagellan and thing board as shown in Figure 3.

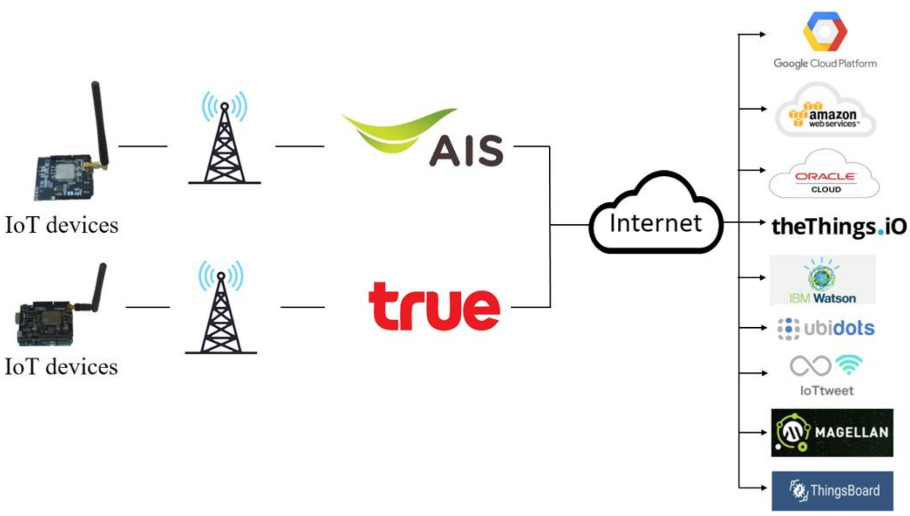

Figure 3 Show network configuration

5. Performance Evaluation

The experiment started on 23rd October 2018 at noon to thirtieth October at noon or one week at the Pathum Thani site using NB-IoT from two operators. Some 125,000 packets. Each device connects to IoT Cloud Platform by using their own operator's network.

From Figure 4 the average round trip time (RTT) from two devices work slowest on Google-IoT and fastest on IoT-tweet. The round trip time is quite high such as AIS on day six it goes almost four thousand milliseconds, but the result on the TRUE device is faster than the AIS devices. Moreover, another site's result is not too much different - just around a few hundred-millisecond stands between one and few hundred milliseconds but on day eight two devices cannot reach IBM-Watson.

AT commands the connected modules as described by Quectel NB-IoT BC95 module. During the measurement, the test flow can be quickly follow the message view showing the sent AT commands and received responses. Especially for ping tests via AT commands, BC95 module now provides signals that show the result values of the AT ping. These values can visualize in standard BC95 module views.

SINR/SNR – The signal-to-noise ratio of the given signal.

RSSI – Represents the entire received power including the wanted power from the serving cell as well as all cochannel power and other sources of noise, and it is related to the above parameters.

RSRQ – Measurement is a cell-specific signal quality metric. Similar to the RSRP measurement, this metric is used mainly to provide ranking among different candidate cells in accordance with their signal quality.

RSRP – Reference Signal Received Power is an RSSI type of measurement. It is the power of the LTE Reference Signals spread over the full bandwidth and narrowband. A minimum of -20 dB SINR (of the S-Synch channel) is needed to detect RSRP/RSRQ.

5.1 Result of Round-Trip Time (RTT)

A typical Ping execution will send 8 bytes of data to a given destination and record the time that a response arrived back. The latency is expressed as the round trip time that includes both the transfer time for the test packet and the response packet. That time is shown in milliseconds. From Figure 4 it shows the number of pings failed between TRUE, and AIS from all the packets is around one hundred twenty-five thousand divided into AIS NB-device has 62,403 pings and ping failed is 124 times or around 0.19 percent. TRUE NB-device has 62,082 pings and ping failed is 972 times or 1.56 percent. With percentages (%) packet loss, Ping failed is between 124 and 972 times of AIS lower than with TRUE packet loss.

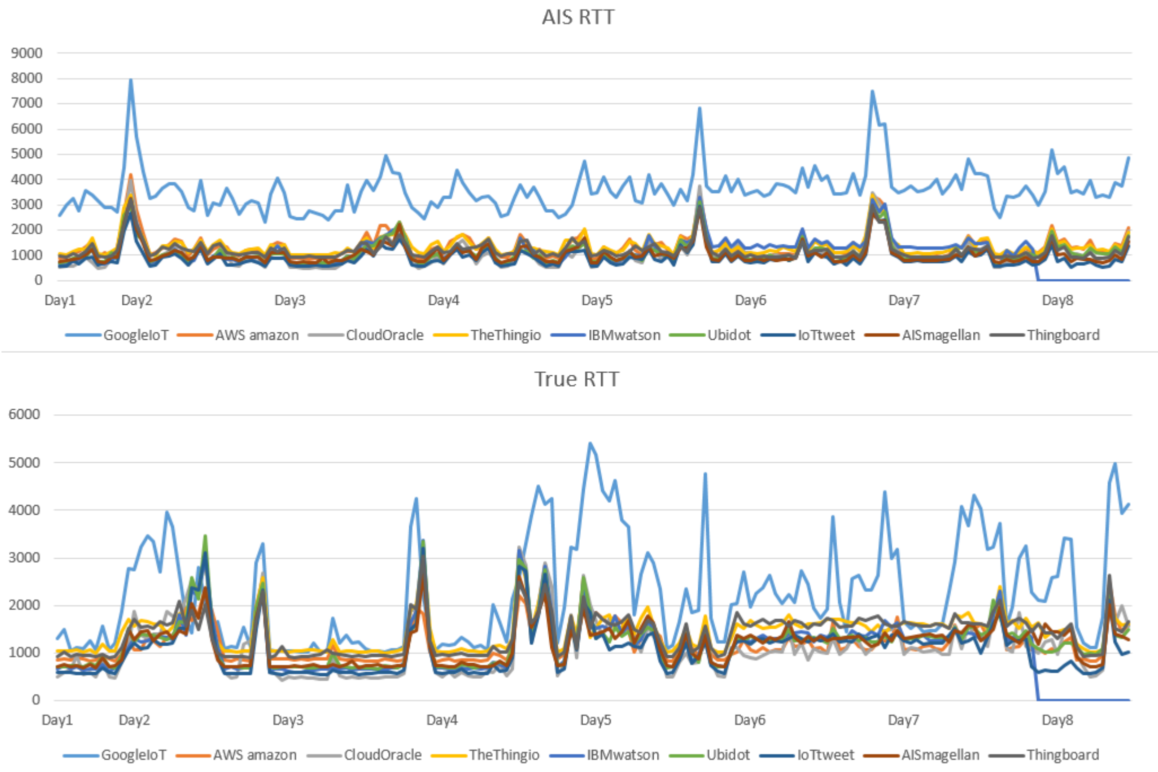

Figure 4 Show results of Round-Trip Time (RTT) for every hour

Figure 5 Show results of Round-Trip Time (RTT)

5.2 Result of RSSI, RSRQ, and SNR

RSSI measurements represent the relative quality of a received signal on a device. RSSI indicates the power level being received after any possible loss at the antenna and cable level. The higher the RSSI value, the stronger the signal. When measured in negative numbers, the number that is closer to zero usually means a better signal. As an example -50 dB is a pretty good signal, -75 dB, - is fairly reasonable, and -100 dB is no signal at all. Therefore, RSSI from TRUE and AIS NB-devices value is around -60 dB in every day of the experiment is a good signal as shown in Figure 6.

RSRQ is quality also considering RSSI and the number of used Resource Blocks (N) RSRQ = (N*RSRP)/RSSI measured over the same bandwidth. The RSRQ measurement provides additional information when RSRP is not sufficient to make a reliable cell re-selection decision. As an example -10 dB is a pretty good signal, -15 dB, - is fairly reasonable, and -20 dB is no signal at all. Therefore, RSRQ from TRUE NB-devices per day does not change much, but RSRQ from AIS NB-devices starting dropping from day four until the last day of the experiment and is a good signal as shown in figure 6.

SNR is a measure used in science and engineering that compares the level of the desired signal to the level of background noise. It is defined as the ratio of signal power to the noise power, often expressed in decibels. A ratio higher than 1:1 (greater than 0 dB) indicates more signal than noise. While SNR is commonly quoted for electrical signals, it can be applied to any form of signal. As an example >=20 dB is a pretty good signal, 13 dB to 20 dB is fairly reasonable, 0 dB to 13 dB is poor and <=0 dB is no signal at all. Therefore, we observed that TRUE NB-devices has greater SNR than AIS NB-devices from every day of the experiment and it is a good signal as shown in Figure 6.

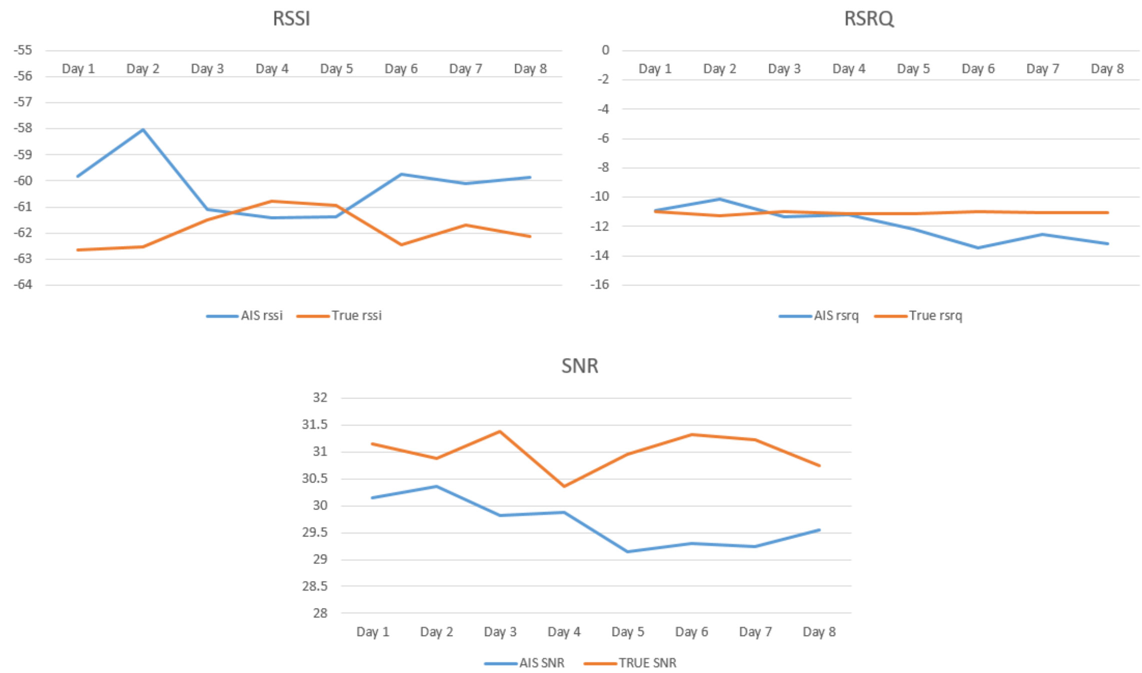

Figure 6 Show results of RSRQ, RSSI, and SNR

6. Conclusion

In this work, an analysis of some practical measurement results recorded from a live LPWA operator of Thailand (TRUE and AIS) are presented to verify the possible relationships among 4G-LTE measurements such as SINR, RSRP, RSSI and RSRQ as well as to evaluate the effects of SNR on throughput. From the experiment, performances comparison of NB-IoT devices from the two operators at Pathumthani outcome are shown. True has better performance on round trip time and SNR. AIS offers a better quality of the number of ping failed and RSRQ. In part of the IoT cloud platform, round trip time from most of the sites are not too different. It must depend on the operator networks. Some site Round Trip Time are quite high as it is may not be suitable for some technology that needs fast latency. Even AIS and TRUE NB-devices are using the same chip (Quectel BC95-B8) but have some differences like sim slot, and e-sim, antenna size, and the price is also a difference.

Form the recordings; we observed that RSRP and SNR are proportional to each other on average, and lesser the difference between RSSI and RSRP, better is the RSRQ, and if the SINR is better for a measurement slot, higher throughput is achieved. It is also noticed that when the RSRP and RSRQ of a serving cell drop below the RSRP/RSRQ of the neighbor cell, the handover event occurs to maintain the ongoing call or data session. All of these observations are found to be consistent with the theory. Our future work includes the performance analysis of a live LPWA network based on practical measurement results.

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