A Performance Analysis of General Packet Radio Service (GPRS) and Narrowband Internet of Things (NB-IoT) in Indonesia

By Wayan Bima

A Performance Analysis of General Packet Radio Service (GPRS) and Narrowband Internet of Things (NB-IoT) in Indonesia

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Abstract

Internet of Things (IoT) refers to a concept connecting any devices onto internet. The IoT devices are able to not only use a service or server to be control at distance but also to do computation. IoT has been applied in any fields such as smart city, industries and logistics. The sending of IoT data can use the existing GSM networks such as GPRS. However, GPRS is not dedicated particularly for the transmission of IoT data in consideration to its weaknesses in terms of coverage and power efficiency. To increase the performance of the transmission of IoT data, Narrowband-IoT (NB-IoT), one alternative to replace GPRS, is offered for its excellences in coverage and power.

This paper aims to compare the GPRS and NB-IoT technology for the transmission of IoT data specifically in Bandung region, Indonesia. The results obtained showed that the packet loss from clients for the GPRS network was at 68%, while the one for NB-IoT was at 44%. Moreover, NB-IoT technology was found excellent in terms of battery saving compared to GPRS for the transmission of IoT data. This then showed that NB-IoT was found more suitable for transmitting the IoT data compared to GPRS.

Keywords*: Internet of Things (IoT), General Packet Radio Service (GPRS), Narrowband-IoT (NB-IoT), packetloss*

1. Introduction

Internet of Things (IoT) is a concept to connect any devices or appliances onto internet. An appliance will be seen as "Internet of Thing" if it is able to do a processing on the embedded processors or microcontrollers, communicate, and be controlled or use a server or service on Internet [1]. The structure of IoT consists of three components: hardware (sensor, actuator, embedded system, and communication), middleware (data processing from IoT, analytical) and presentation (visualization and interpretation) to users[2]. Based upon the architecture of IoT in [3], it requires an internet connection to connect things. The internet connection on IoT can use the networking technology that has been available in the today telecommunication network such as GSM technology. In essence, any network connections can be used for IoT data as long as their structure is compatible with the characteristics in IoT data.

One of GSM technology that can be used for the transmission of IoT data is General Packet Radio Service (GPRS). This technology, nevertheless, still has two weaknesses in its implementation regarding the use of high power and low coverage area. A solution offered is the network of Narrowband-IoT (NB-IoT), a protocol proposed by 3GPP to replace GPRS protocol [4]. NB-IoT can use a little part of LTE network [5] and has a gain of 20dB in an indoor environment (such as in a tunnel) in comparison to GPRS. In addition, NB-IoT is more power saving for being designed to the low power devices, off-the-grid / dependent upon the battery and has a network performance resembling GPRS [4].

The use of Narrowband-IoT has widely been applied on the smart metering or smart grid application [6]–[10]. Other Narrowband-IoT-based applications include smart parking [11], [12], smart cities [13]–[20]. Any applications that can be employed using NB-IoT network need to adjust with the regulation of its deployment area. In Indonesia, not all base-stations support the NB-IoT

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network. To make IoT application can be used well in the NB-IoT network, then there is a need for a study on the properness in the usage of the network for the IoT data transmission. This paper presents a performance test on the properness of the usage of NB-IoT network in Indonesia – particularly in Bandung. This test can be seen in terms of latency, throughput, packet loss, and power usage.

The paper is organized as follows: Section 2 describes the research method, Section 3 describes the simulation, result, and discussion of performance evaluation, and Section 4 explains the conclusion and future works.

2. Research Method

In this research, the performance test from GPRS and NB-IoT was conducted to compare the network in transmitting the data from device onto cloud server. GPRS and NB-IoT are a mobile network requiring Base Transmission Station (BTS) from a cellular operator for communication. The mobile network applies a mechanism of radio wave to build a network in transmitting the data. The radio wave is used to provide the service of mobility and capacity to cover a wide area [4], [21], [22]. The longer the transmitted radio wave, the larger the delay. Delay occurs when the transmission can be influential in the throughput of a network. Therefore, the measurement of performance towards the throughput is very important as the parameter of performance in mobile network [21], [23].

Radio wave also has the uplink or downlink when transmitting a data. The transmission of uplink occurs between device and BTS tower; on the other hand, the downlink transmission occurs between BTS and device [4], [21]. Each transmission of uplink and downlink also brings an effect on the performance of data transmission. The Round Time Trip (RTT) of the data sent from a device to a BTS and then forwarded to the server and returning to the device through BTS is the parameter of performance of uplink and downlink of a mobile network [21], [24].
In addition, the power usage in device brings an effect on the transmission of uplink and downlink on mobile network. The radio wave transmitted by the device is also determined by the electrical power existing in the device. The longer the transmission of radio wave in the device, the larger the power required [19], [25].

Based on the justification of the measurement methods above, then the performance test was conducted to achieve the following Key Performance Indicators (KPI):

1. The measurement of throughput for the performance of the network in data transmission.
2. The RTT measurement to measure the time between the transmission and receipt of data package.
3. The measurement of power consumption to measure the power use when the device transmits the data.

Once KPI had been determined from the measurement to be done, then a test scenario was made. In this research. It began by explaining the coverage area from the network of NB-IoT and GPRS existing in Bandung area, Indonesia. The information about the coverage was used to find out to what extent the coverage area from the network of NB-IoT and GPRS to make it possible to be used as the reference of the mobility of the test. Subsequently, two scenarios of test on the network performance of the analysis were defined consisting of test towards the throughput and RTT from the data transmission. To figure out the power consumption of GPRS and NB-IoT when transmitting the data, then the test scenario of the power consumption was made.

2.1. Coverage Area

Prior to measure the performance of mobile networks on GPRS and NB-IoT it was necessary to know the coverage area of the two technologies. The test would be conducted in the campus area of Telkom University, Bandung, Indonesia. The first thing to do to find out the coverage area was to measure the signal strength in the test area, as seen in Figure 1. Signal strength on mobile networks is commonly measured by using the units of dBm (decibel-milliwatts). Signal strength is the representation of how much signal is received from cellular networks (downlink mode) [26], [27].

Table 1. Signal strength condition standard from 2G and 3G network

RSSI	Signal strength	Description
>= -70dBm	Excellent	Strong signal with maximum data speeds
-70dBm to -85dBm	Good	Strong signal with good data speeds
-86dBm to -100dBm	Fair	Fair but useful, fast and reliable data speeds may be attained, but marginal data with drop-outs is possible
< -100dBm	Poor	Performance will drop drastically
-110dBm	No signal	Disconnection

Table 1 shows the condition of signal strength on the 2G and 3G mobile network. Those two networks could be used as the indicators to determine whether the mobile network signal of GPRS and NB-IoT in one coverage area were deemed suitable for making data communication. Table 1 is declared valid to measure the signal strength of GPRS and NB-IoT as both are the mobile network technology with the same class [4], [22].

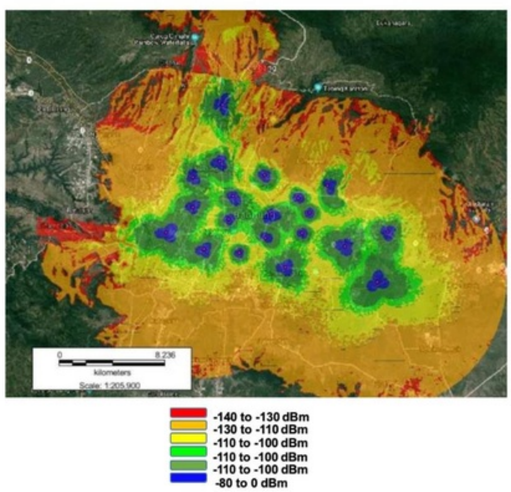

Figure 1. NB-IoT coverage area in Bandung, Indonesia.

Figure 1 depicted the BTS in Bandung, Indonesia which has already supported NB-IoT technology.

2.2. Network Performance Analysis

There are two scenarios of measurement in the network measurement to be done. The first measurement was related to the throughput of GPRS and NB-IoT networks. In the tests conducted, measurement of throughput was calculated using equation (1)

$$T = \frac{\sum nKbit}{s} \tag{1}$$

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Throughput refers to the actual bandwidth measured by time units and certain network conditions to send data with a certain size. Based on equation (1), the throughput test was carried out by sending a certain amount of data carried out over a certain period of time. The transmission was made from the device to the server via GPRS and NB-IoT networks. The second measurement was related to RTT from GPRS and NB-IoT networks. In the tests carried out, RTT measurements were calculated using equation (2)

$$RTT = tA - tD \tag{2}$$

From equation (2), the RTT test was to measure the time range between the time of data transmission and the time of arrival of the transmitted data. Test was to calculate the RTT of data sent from the device to the server and returned to the device.

2.2. Power Consumption Analysis

In the test of power consumption, two testing categories of testing were analyzed. First, it was regarding the overall power usage on the device when using GPRS and NB-IoT networks. Second, the device utility was analyzed when transmitting data on GPRS and NB-IoT networks. In the utility test, the measurement of power consumption estimation on the battery usage when transmitting and using the GPRS and NB-IoT was also done. The overall measurement of power usage on GPRS and NB-IoT networks used the Joule unit. In the measurement of overall power consumption performed on GPRS and NB-IoT was calculated using equation (3)

$$J = \frac{W}{s} \tag{3}$$

Testing using equation (3) measured the overall power usage of the device. The overall measurement of power consumption included power usage when using GPRS / NB-IoT networks and reading data from sensors.
The measurements of GPRS and NB-IoT usage were conducted using two scenarios. First, power consumption was measured when the device transmitted the data. Second, the time estimation towards the power in the battery was measured. Those two measurement scenarios were expected to illustrate the power usage used by devices with GPRS or NB-IoT mobile networks. In the first utility measurement, the power consumption was measured when the device transmitted the data. The measurement was conducted on GPRS and NB-IoT and calculated using equation (4)

$$PC = \frac{T}{Tp} \tag{4}$$

From equation (4), the power consumption was measured based upon the size of the throughput generated at one time data transmission. The size of the throughput was compared to the transmit power when transmitting or receiving data. The measurement of power consumption when the device transmitted the data was conducted on GPRS and NB-IoT and calculated using equation (5)

$$Estimated\ Time = \frac{\frac{Transaction * data\ length\ (byte)}{Transaction\ interval\ (s)} * Transmit\ power\ (W/byte)}{Battery\ capacity\ (Ws)} \tag{5}$$

$$Power\ consumption = \frac{Throughput\ Speed}{Transmit\ power} \tag{6}$$

Based on equation (5) and (6), the measurement would be focused on the power usage when transmitting the data only using the network of GPRS or NB-IoT. The measurement was initially done to the data transaction to be transmitted. Furthermore, the measurement was combined with the amount of power consumption in each data transaction. This was then continued by comparing the battery power used to turn on the device.

3. Results and Discussion

1.1. Feasibility Design

Narrowband-IoT employs traditional GSM topology, Figure 2 is the simplified version of the network topology.

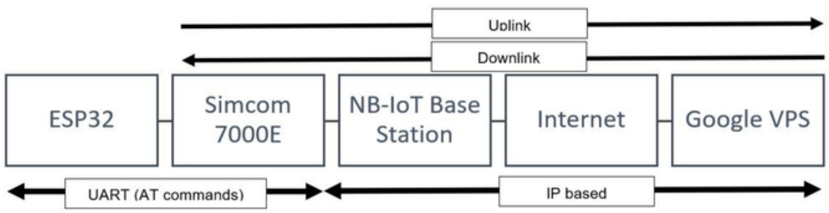

Figure 2. Topology Diagram

1.1.1. Test scenario and parameters

These lists are test parameters, devices specifications, and location.

a) Devices and equipment
   a. ESP32 WROOM (4 MB flash, 512 KB RAM)
   b. Waveshare SIMcom 7000E module
      Specification and capabilities [28] :
      - Frequency bands: GSM (900 Mhz / 1800 Mhz), LTE-M1, LTE-NB1
      - GNSS for geolocation data
      - Operating voltage: 3.3 volts – 4.03 volts (module built in with 3.3 volt to 5 volt regulator)
      - Transmit power:
        - GPRS: 2 W (EGSM 900), 1 W (DCS1800)
        - EGDE: 0.5 W (EGSM 900), 0.4 W (DCS1800)
        - LTE: 0.25 W
      - Data transmission speed:
        - LTE-NB1 : 34 Kbps DL, 66 Kbps UL
        - LTE CAT-M: 300 Kbps DL, 375 Kbps UL
        - GPRS: multi-slot class 12
        - EDGE: multi-slot class 12
      - UART interface (115200 bps)
      - USB interface
   c. Laptop/Tablet as debugging/terminal display
   d. SANFIX DM-888 multimeter for power usage measurement.
   e. Google cloud VPS as test server
      - Runs ASP.net core 2.0 web API server
      - Python 3.0 for UDP server
      - Located in Singapore

b) Test location and signal coverage
   a. Jalan Telekomunikasi, Universitas Telkom, Bojongsoang, Bandung
   b. GPRS signal strength: -71 dBm
   c. NB-IoT signal strength -87 dBm

3.1.2 Data payload:
   a. TCP using HTTP:
      - Upload: 5 KB
      - Download: 10 KB
      - Time out: 60 seconds
   b. UDP:

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- Send: 1 KB
- Receive: 1 KB (echo)
- Time out: 10 seconds

c. Test iteration: 50 times
d. eDRX configuration for NB-IoT: 5.52s (1st cycle)

3.1.3 Pseudocode

a. Downlink throughput

```
function Download(N, iteration) → real
    Dt ← []
    Time1 ← 0
    for (I ← 0 to iteration) do
            Time1 ← millis()
            // request dummy data with N bytes
            If(Http.Get("http://testserver.com/api/value/"+N)) then
                    Time2 ← millis()
                    Dt.append(N / (Time2-Time1))
            Else
                    //timeout
                    Dt.append(0)
    Return Dt.average()
```

b. Uplink throughput

```
function UploadTest(N, iteration) → real
    Dt ← []
    // create dummy array, fill it with As
    dummyData ← new char[N]
    memset(dummyData, 'A', N)
    Time1 ← 0
    for (I ← 0 to iteration) do
        Time1 ← millis()
    //send that array, we assume that server only sent empty response,
only measuring uplink throughput
        If(Http.Post("http://testserver.com/api/value/"+N, dummyData,
            Time2 ← millis()
            Dt.append(N / (Time2-Time1))
        Else
            //timeout
            Dt.append(0)
    Return Dt.average()
```

3.2 Performance profiling

These are the result during network performance and power test. Table 2 depicted the result of TCP benchmarking for GPRS and NB-IoT, with 1 KB data upload, 5 KB data download, 50 attempts, and timeout 60 seconds. Application used in the TCP protocol was HTTP. Meanwhile, Table 3 described the result of UDP benchmark, also for GPRS and NB-IoT, with 1 KB data upload, 50 attempts, and timeout 10 seconds.

Table 2. TCP benchmark for GPRS and NB-IoT

Network	Average Upload	Average Download	Fail Attempt (Upload)	Fail Attempt (Download)
GSM/GPRS	347.3 B/s (2.776 Kbit/s)	2593.280 B/s (20 Kbit/s)	13	9
NB-IoT	350.760 B/s (2.806 Kbit/s)	348.839 B/s (2.7907 Kbit/s)	7	17

Table 3. UDP benchmark for GPRS and NB-IoT

Network	Average Latency (round trip echo)	Server received packets	Client received packets	Packet loss (echo didn't reach client)
GSM/GPRS	1531.814 ms	24/25	17/25	68%
NB-IoT	1434.091 ms	25/25	22/25	44%

Meanwhile, the energy usage for both GPRS and NB-IoT was measured in the operating voltage of 3.3 volt. Device sent 50 KB (1 KB each) UDP packets during transmit power test. Transmit power also measured within 20 seconds timeframe. This benchmark measured from modem power consumption. The result is depicted in Table 4.

Table 4. Energy usage of GPRS and NB-IoT

Network	Start up	Idle & Connected	Idle	Transmit
GSM/GPRS	7 J (0.35 W)	4.7 J (0.235 W)	6.15 J (0.307 W)	14.75J (0.737 W)
NB-IoT	8.25 J (0.412 W)	5.1 J (0.225 W)	5.05 J (0.252 W)	8.1 J (0.405 W)

Small power consumption improves device's battery life. As seen in Figure 3, the power consumption of transmitting power from NB-IoT was smaller than GPRS in the uplink mode. But the power consumption of transmitting power from NB-IoT was bigger than GPRS in the downlink mode, as seen in Figure 4.

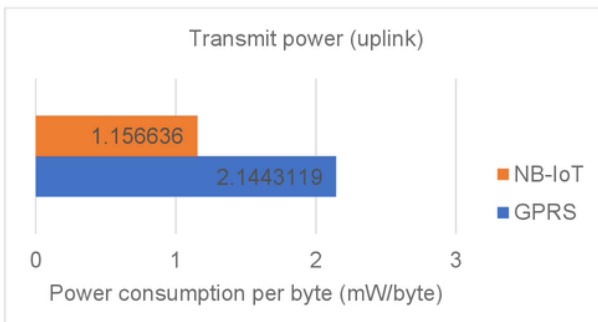

Figure 3 Uplink trasnmit power (smaller = better)

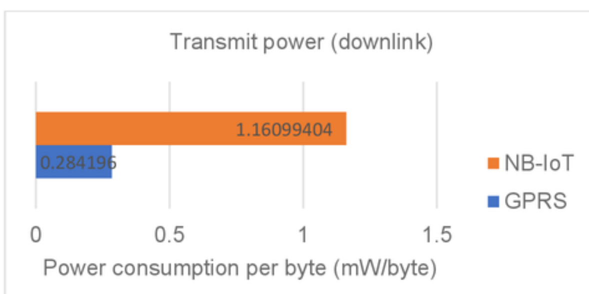

Figure 4 Downlink trasnmit power (smaller = better)

Figure 5 shows estimated common 18650 Li-Ion battery life with capacity 2560 mAh or 8.448 W/h [29]. This estimation does not include external component other than the modem itself.

Further, the estimated battery life was calculated using formula in Equation (6). The scenario used to compute the estimated battery life was: transaction interval was every hour, data length was 512 Byte, and battery capacity was 8.448 W/h.

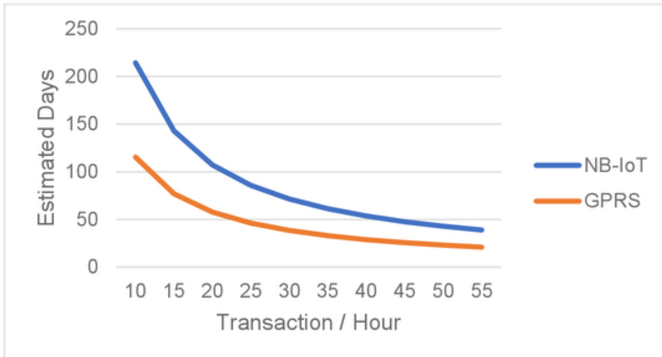

Figure 5 Estimated battery life

From Figure 5 we can conclude that where if the number of transaction increases, the power usage will decrease, for both of GPRS and NB-IoT technology. The GPRS consumed more energy more than NB-IoT for the same number of transactions, which means that NB-IoT is better than GPRS in the aspect of energy savings.

4. Conclusion

IoT data can be sent using GPRS and NB-IoT technology. This paper compared the GPRS and the NB-IoT technology for sending IoT data using TCP and UDP protocols. The coverage area used in the deployment was Bandung, Indonesia. From the results we can obtained that throughput, packet loss, and energy usage are superior to the NB-IoT network compared to GPRS. This result means that NB-IoT is more feasible to send IoT data better than GPRS.

Research development can be done by utilizing of both technologies for the real IoT applications, for example: smart tracking, smart cities, or smart transportation. Thus, the performance of both technologies can be seen better when they are used in real applications.

6. Notation

T	: Throughput (Kbps)
nKbit	: The number of data (Kbit).
s	: Time (s).
RTT	: Round Time Trip from device to server (ms).
tA	: Arrival time of echo data from server to client (ms).
tD	: Departure time of echo data from client to server (ms).
J	: Total power consumption from device (Joule).
W	: Power from device (mW).
Tp	: Transmit Power (W/byte).
PC	: Power Consumption (mW/byte).

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