Narrowband-IoT network for asset tracking system

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Abstract. Narrowband-IoT is one of the emerging LPWAN technologies in the market. Traditionally asset tracking employs Global Positioning System (GPS) and General Packet Radio Service (GPRS) connections to send telemetry data to database servers. Compared to GPRS, NB-IoT has a smaller power usage, given proper implementation. This paper discusses NB-IoT implementation in asset tracking applications. Our test includes these parameters: latency, throughput, packet loss, and power usage for both technologies. The result obtained showed that NB-IoT was underperformed in HTTP but in UDP test, NB-IoT showed better power consumption compared to GPRS (0.352 W vs. 0.542 W) even though both have similar uplink throughput (around 350 B/s). From these findings, this new cellular standard is deemed appropriate in the Asset Tracking application, given the correct protocol and architecture.

1. Introduction

The needs for high coverage and low power networks are greater than ever, thanks to the public demand for interconnected smart devices for industry and personal use. It is projected by 2025, and there will be more than 1 billion IoT devices [1]. The emergence of LPWAN (Low Power Wide Area Network) come from the needs for low power, wide-area coverage, and adequate throughput for small to medium size data telemetry. There are many competing LPWAN technologies such as LoraWAN, LTE-M, and Sigfox.

Narrowband-IoT (NB-IoT) is a new LPWAN standard released by 3GPP in 2016 [2], and it has many capabilities regarding high coverage, low power usage, small bandwidth with the simplicity of traditional cellular network [3], and new support to serve around 100,000 devices in single base station or cell [4]. NB-IoT operates on a licensed network while other proprietary LPWAN standard operates on unlicensed spectrum. NB-IoT can coexist within GPRS and LTE network for being possible to be deployed by in-band (resides in LTE spectrum), guard band (piggybacking in the edge of LTE spectrum), or standalone (operating in unused GSM spectrum) [5].

Even though GPRS and NB-IoT have a similar bandwidth size (200khz) [6], NB-IoT is more tolerant and still capable of maintaining the network connection in marginal or lousy (up to disconnection level in GPRS/3G/LTE network) cellular signal quality [7,8]. With this capability, NB-IoT technology is seen suitable for the device which needs to operate in a basement, underground, or rural and remote area to accommodate the contour of the terrain, which can block and reduce signal quality [6].

Although NB-IoT has already been deployed and used on trial in many countries such as Indonesia [9], the full coverage of the GPRS network is still available for use in M2M devices. With a hybrid cellular modem available in the market and telecoms providing hybrid SIM with 2G/3G and LTE/NB-
IoT connectivity, it is possible to migrate from GPRS to NB-IoT or switch to an appropriate network type on the fly depending on signal quality.

This paper discusses the study case of NB-IoT technology implemented in the asset tracking prototype to measure and assess the performance in throughput, power usage, signal strength, and latency compared to the GPRS network. In previous work, a similar asset tracking system was developed based on GPRS networks [10].

2. Research methods

Multiple performance aspects in power usage, latency, and signal strength were measured using a microcontroller in conjunction with a current sensing device, which monitors the modem power usage. The recorded real-time current usage data was sent over serial, while geolocation, and signal strength data were sent to the private server running ASP.net core via HTTP service. The server also measured HTTP throughput for the device. For the UDP test, latency and packet loss information was sent over serial.

2.1. Data payload and protocol

HTTP was used to transfer telemetry data to the server. The body request was encoded in JSON format and contained modem current usage (idle, activity, and GPS), geolocation data (elevation, longitude, latitude, velocity, direction, accuracy), connectivity status (network operator, connection type, signal strength), and miscellaneous data (timestamp, tamper status, log description). Header request contained authorization, which held JWT token and Content-Type. Total request length combined was in the range of 957B to 970B (490 (may vary) body, 467 headers).

2.2. HTTP throughput

This equation measured HTTP throughput based on HTTP payload size (headers and body) and the time it took to complete the request. This measurement did not account TCP handshake. Because of this, measurement is considered coarse and requires multiple measurements. Δt refers to a difference between server time vs. device and T is throughput in Byte/S.

\[
T = \frac{\text{payload}}{\Delta t}
\]  

(1)

2.3. Power usage

INA219 current measuring module was used to measure the real-time power or current usage of the modem. Current data were sent to the microcontroller via FC and passed to serial interface for measuring purpose.

2.4. NB-IoT Modem and SIM card

SIMCom7000E module was connected to the main microcontroller via UART. This modem supports GPRS, NB-IoT, and LTE-CATM [11]. GPS and GLONASS positioning are also available on the modem. NB-IoT capable SIM card is required to connect with NB-IoT cellular networks. Power saving mode (PSM) was enabled, and the EDRX cycle was set to 122.8 seconds.

2.5. Microcontroller and additional support device

This prototype employed ESP32 as a microcontroller that was used to generate HTTP requests which were sent to the modem, and recorded power consumption data. A Windows-based tablet was then connected to this microcontroller to gather current data, provide a debugging interface, and power for the modem with other onboard peripherals.
3. Results and discussion
Benchmark was taken place from Jalan Pandanus VII, Lengkong, Bandung, West Java to Tugu Revitalisasi Kawasan Braga, Braga, Sumurbandung, Bandung City, West Java 40111, round trip on 24 November 2019.

Users can manage device records and see location logs by visiting the web portal with associated accounts and devices (Figure 1).

![Asset tracking web interface.](image)

**Figure 1.** Asset tracking web interface.

3.1. HTTP throughput

| Network     | Number of the test taken | Request completed in (s, avg) | Throughput (B/s, avg) |
|-------------|--------------------------|-------------------------------|-----------------------|
| NB-IoT      | 10                       | 39.554                        | 40.74775              |
| GPRS        | 15                       | 9.06                          | 111.094               |

HTTP throughput measurement was taken from the logged HTTP request during the road trip test (Figure 1). Request time was measured by subtracting the logged server time and timestamp data from the device (included in the payload).

The reason for a different number of the test taken in HTTP throughput test for NB-IoT was because the test took too long, up to 1-2 minutes to complete which could skew throughput measurement for NB-IoT.

HTTP throughput test in Table 1 shows that NB-IoT is not suitable for HTTP application or TCP with a large payload. An alternative transport method, such as UDP, can be used to improve connectivity throughput and reliability.

There is an alternative to replace the JSON serialization method such as Protobuf which can reduce the payload down to 20% by encoding data in binary format instead of a string [12]. JWT authentication is also not suitable for this application because for being large and taking nearly a half kilobyte.
Registered IMEI might be used as a token to authenticate but it may be susceptible to replay attacks if the attackers know the IMEI [13].

3.2. Current usage Vs. signal strength

The reason why NB-IoT underperformed was compared to GPRS because of the very poor signal quality, payload, and transport method. Repeat transmission mechanism used in NB-IoT is HARQ (Hybrid Automatic Retransmission Request), ensuring that every data frame is retransmitted until it passes the CRC test or retransmission limit [6]. With poor signal quality, the data frame may have retransmitted from 128 up to 2048 retransmission attempt [14], which may lead to poor power consumption in the HTTP test result. Payload size and protocol also play a role in poor performance on NB-IoT. While the maximum payload size on NB-IoT is 1.6KB, the recommended payload should be under 200Bytes [4].

Figures 2 and 3 on the left side depict the geotagging activities as indicated by white square waves pattern on the bottom.

![Figure 2. NB-IoT power consumption vs signal quality (1 unit of time = 0.05 s).](image)

![Figure 3. GPRS power consumption vs signal quality (1 unit of time = 0.05 s).](image)
3.3. **UDP Ping Benchmark**

| Network   | Round Trip Time (Avg) | Payload did not reach the server | Echo did not reach the client |
|-----------|-----------------------|----------------------------------|------------------------------|
| GSM/GPRS  | 1531.814 ms           | 1/50                             | 33/50                        |
| NB-IoT    | 1434.091 ms           | 0/50                             | 28/50                        |

Latency performance for NB-IoT and GPRS have shown from the UDP ping test result in Table 2 suggest that 1KB UDP payload is too large for both networks. This result also showed that NB-IoT is not very suitable for large downlink payload.

3.4. **UDP Current Usage (Uplink only)**

Figure 4. NB-IoT power consumption vs. signal quality (1 unit of time = 0.05 s).

Figure 5 shows that GPRS sending a single UDP packet takes longer and requires more power than NB-IoT. NB-IoT activity and paging cycle can be examined, as shown in Figure 4 on the left. High spikes at t = 100 to 200 indicate the data transfer, and at t = 800 is RRC (Radio Release Control) phase; subsequently the UE (User Equipment, the modem) entered the idle mode with DRX cycles (repeating pulses). The UDP test was taken stationary at Universitas Telkom, Bandung.
4. Conclusion
While NB-IoT performed marginally vs. GPRS in HTTP throughput and power consumption test, it was capable of maintaining the data link with very poor signal quality. Spotty signal quality and large payload (header and body) also contributed to the underperformed result.

With the results in mind, NB-IoT is best suited with UDP based application, for its simplicity, suitability with small and medium payload size, and connectionless socket that can save battery life as the UE does not need to receive a response. A new authentication method is required to replace JWT which is heavy for NB-IoT to secure and to prevent device spoofing. There are some alternatives to reduce payload size such as by replacing JSON to ProtoBuf.

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