

# Demo: Software Suite for NB-IoT Measurement Analysis

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## Abstract

Narrowband-Internet of Things standard is in its early stage of deployment. The lack of a diagnostic and measurement toolset hinders the problem analysis and device development in the community. In this demo, we present NBViewer, a software suite that exposed important and detailed low-level insight of the deployed NB-IoT network without the assistance from the operators. NBViewer also supports hosting and communication with multiple peripheral modules to provide concurrent power measurement and geolocation information. With such a comprehensive tool at hand, researchers and developer can identify potential problems, understand the energy profile, and propose possible solutions with less encumbrance.

## 1 Introduction

Narrowband-Internet of Things (NB-IoT) is a Low Power Wide Area Network (LPWAN) radio-access technology developed by 3rd Generation Partnership Project (3GPP) [1].

Compared with other LPWAN standards such as LoRaWAN [2] and Sigfox [5], NB-IoT offers three key advantages. First, NB-IoT achieves better network coverage because it re-uses existing deployments of LTE eNodeB base stations. Second, NB-IoT offers better communication security by leveraging the security features of legacy LTE technology. Third, NB-IoT offers a better quality of service because it avoids the ISM spectrum where coexisting wireless devices can cause strong interference. These features make NB-IoT a promising technology for a wide range of IoT application scenarios such as smart metering, manufacturing automation, smart appliance [4], and logistic tracking [3].

Despite the increasing interest on NB-IoT, the communication reliability, energy efficiency, and protocol-level interactions of NB-IoT networks in real-world deployments remain unclear to both industrial and academic research com-

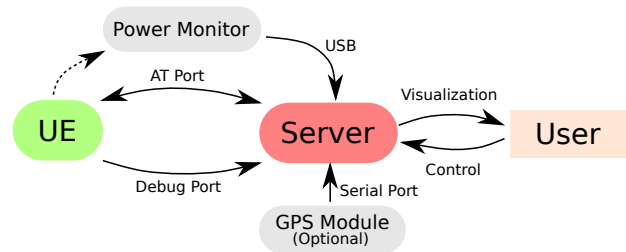


Figure 1. System diagram

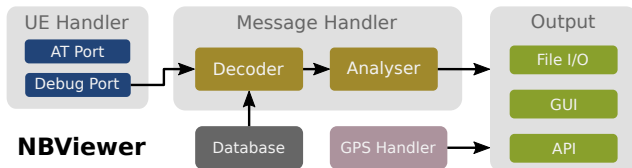
munities. Our preliminary field test results show complex adaption to the NB-IoT communication protocols that degrades link reliability and causes substantial energy waste. However, the off-the-shelf NB-IoT nodes do not expose low-level cell measurement results and protocol messages to the application layer, which prevents detailed diagnosis and deeper understanding of the performance degradation.

This demo presents a software suite called NBViewer to collect, process, and analyze the UE debug messages for the operational NB-IoT network. It is an extensible software suite that is mainly built on top of the debug trace logs exposed by the UE to extract and visualize the key low-level protocol adaptation and interaction as well as their impact on the UE power consumption. An optional GPS module can be added to the software suite for geolocation logging along with the debug trace logging simultaneously. In our demo, a power monitor is also employed to provide concurrent energy consumption measurement. The combination of the debug logs, geolocation, and the power profile helps one gain an insight into the status of UE and the deployed NB-IoT network.

## 2 System Design

Figure 1 shows the system diagram of the NBViewer demo. The software suite runs on a server, which is a Linux or Windows PC hosting the peripherals shown in the diagram. The server reads their output stream, and processes the data in real-time to visualization. First, it communicates with an NB-IoT UE via a serial port using AT commands. Both NB-IoT uplink (UL) and downlink (DL) transmission are handled by the AT serial port. Second, the hexadecimal debug logs containing detailed low-level message exchange are streamed via the Debug serial port. Third, the server also

supports reading data from an external GPS module, from which we record the geolocation of the experiment. This is important when one tries to correlate the measurement result with a specific location. Finally, the power monitor is connected to the server to measure the power consumption of a UE under different working modes, such as UL or DL transmission, Power Saving Mode (PSM), or Extended Discontinuous Reception (eDRX). Currently, the power monitor is handled by the tools provided by its manufacturer. We plan to integrate its API to our software suite in the future.



**Figure 2. Software architecture of the NBViewer**

Next, we provide a detailed discussion on the NBViewer software architecture, as shown in Figure 2. Five parallelized threads handle the following tasks respectively:

- Send AT commands to the UE and read the response from the UE.
- Read hexadecimal raw messages from the UE debug port. Filter out the unwanted messages. For example, time synchronization messages in PHY layer occupies a large portion of the logs while providing little value to the user. Therefore, we discard these messages to save the computational overhead in the latter processes. The integrity of the message packet is also checked to determine whether this is a decodable packet.
- Query the database of message definitions. Convert the raw messages to readable logs. The logs are then forwarded to the message analyzer. Any valuable information about the cause of exceptional power consumption is extracted during this phase.
- Read the geolocation from the GPS module. Convert the NMEA standard-complaint data to actual velocity, latitude, and longitude.
- Handle output. It includes exporting debug log to files, updating GUI display and providing APIs. Specifically, the APIs support functions like querying the value of a particular parameter or changing the configuration of the NBViewer.

Every thread is responsible for a specific task. To improve the robustness of the program, the inter-thread messages are carefully handled and passed between threads to avoid potential program halting or crashing.

The system is able to capture protocol debug messages from all NB-IoT protocol layers, including but not limited to PHY, MAC, RLC, PDCP, RRC, NAS, EMM, and ESM. One can also collect geolocation information, power consumption simultaneously.

### 3 Implementation

Figure 3 shows the implementation of our system. First, the UEs we are using are Quectel BC95 or BC28. Second,



**Figure 3. System implementation**

two serial-USB converters are used to provide the IO connection for the AT and Debug ports of the UE to the server respectively. Third, the GUI of the software suite is implemented by the PyQt5 library, which is based on Qt<sup>1</sup>. Fourth, the GPS module is a VK172 dongle. It supports adaptive baud rate and outputs NMEA information continuously. Finally, the power monitor is the Monsoon HVPM [6]. The power trace is collected by the PowerTools software independently.

### 4 Conclusions

NB-IoT is a promising cellular IoT standard that supports long battery life, deep coverage, and massive connection LP-WAN applications. In this demo, we present NBViewer, a software suite that interacts with an NB-IoT UE to extract the fundamental details of the operational NB-IoT network without the support from the operators. Researchers and system developers can use it to detect potential system loopholes, analyze the cause of performance degradation, and suggest corresponding troubleshooting solutions. As this software suite is also in its early stage, more expected features will be added to the software suite in the future.

### 5 Acknowledgments

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### 6 References

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<sup>1</sup><https://www.qt.io/>

## **Appendix: Demo Setup**

This page shows the requirement of the demo.

### **Hardware Used**

We will bring the following hardware to the venue.

- A laptop
- A GPS dongle
- A Monsoon HVPM

- Quectel BC95 dongle, BC28 dongle
- Two USB-Serial converters.

We will setup the demo by ourselves. The venue should prepare an outlet for the power.

### **Space Needed**

A desk with 100 cm length and 60 cm width.

### **Special Instructions**

The venue should be in the NB-IoT coverage, otherwise the UE does not work normally.