Keysight Technologies
NB-IoT and LTE Cat-M1 Field Measurements and SLA Verification

Application Note

Anite is now part of **Keysight Technologies**

KEYSIGHT TECHNOLOGIES
Unlocking Measurement Insights

Introduction

Internet of Things (IoT) is today's megatrend in wireless communication industry. Machine-to-machine (M2M) wireless connectivity is being adopted in various verticals at increasing pace. The number of IoT devices deployed by 2020 is expected to increase to approximately 20 billion.

Cellular IoT (CIoT) is defined as a set of technologies under the 3GPP umbrella to enable IoT connectivity using the licensed frequencies, co-existing with the legacy cellular broadband technologies, such as LTE, UMTS and GSM. The main CIoT technologies being rolled out globally are NB-IoT and LTE Cat-M1. The term CIoT is used to make the distinction to non-3GPP IoT technologies, such as LoRa and SigFox, which are deployed in unlicensed bands.

IoT applications can be categorized to massive IoT and critical IoT. Massive IoT includes smart metering, home security, etc. The requirements for massive IoT include years of battery life, scalability to very large number of devices, robust coverage, and deep indoor facilities. The NB-IoT technology is optimized for this use case. Critical IoT includes applications, such as health care and connected car, where very low latency levels on ultra-reliable networks, often combined with very high throughput is required. LTE Cat-M1 is optimized to meet these requirements.

	LTE Cat-M1	**NB-IoT**
Heritage	LTE	Clean-slate
Bandwidth (downlink)	1.4 MHz	180 kHz (12 by 15 kHz)
Bandwidth (uplink)	1.4 MHz	Single-tone (180 kHz by 3.75 kHz or 15 kHz) or multi-tone (180 kHz by 15 kHz)
Multiple access (downlink)	OFDMA	OFDMA
Multiple access (uplink)	SC-FDMA	Single-tone FDMA or multi-tone SC-FDMA
Downlink peak bitrate	1 Mbps	250 kbps
Uplink peak bitrate	1 Mbps	250 kbps(Multi-tone) 20 kbps (single-tone)
Latency	10 ms-15 ms	100 ms ~8 s
Coverage (link budget)	~156 dB	~164 dB in standalone deployment ~149 dB in/guard-band deployment
Mobility	Full	Nomadic
Applications	Critical IoT: health care, home care, traffic SoC, connected car, etc.	Massive IoT: smart metering, home security, etc.

Table 1. Comparison between LTE Cat-M1 and NB-IoT

Cellular IoT Field Testing – Verifying the Real Performance

The emergence of IoT poses various challenges for network operators as well as for industrial customer verticals and M2M connectivity providers. What level of Quality of Service (QoS) and Service Level Agreements (SLAs) can be achieved and committed to? Are there any differences in performance between network equipment manufacturers, IoT device manufacturers, and different operators? How should the network be configured and planned to achieve optimal performance? Is the service coverage network wide, including deep inbuilding? How long is the battery life of my IoT device?

Answers to these questions depend on the field performance of the commercial network equipment and IoT devices, interoperability between the equipment, and the network design and configuration. The 3GPP specification provides boundaries for the performance and operation of IoT, but the equipment implementations and the network design play major roles on the real field performance. Hence, field measurements are needed to obtain definite answers.

Specifications vs. commercial implementations

The 3GPP standard defines the technologies to deliver the key features of IoT, but many of the details on how these technologies are used and implemented are proprietary and vendor-specific. Further, the device antennas and housing may have significant impact on the practical performance achieved. Hence, the testing and benchmarking of network equipment manufacturers as well as the devices available in the market is crucial to verify the interoperability and performance of the equipment to be deployed. In this initial field/lab testing phase, tools providing a holistic view from the application-level down to RF metrics and control plane signaling are needed.

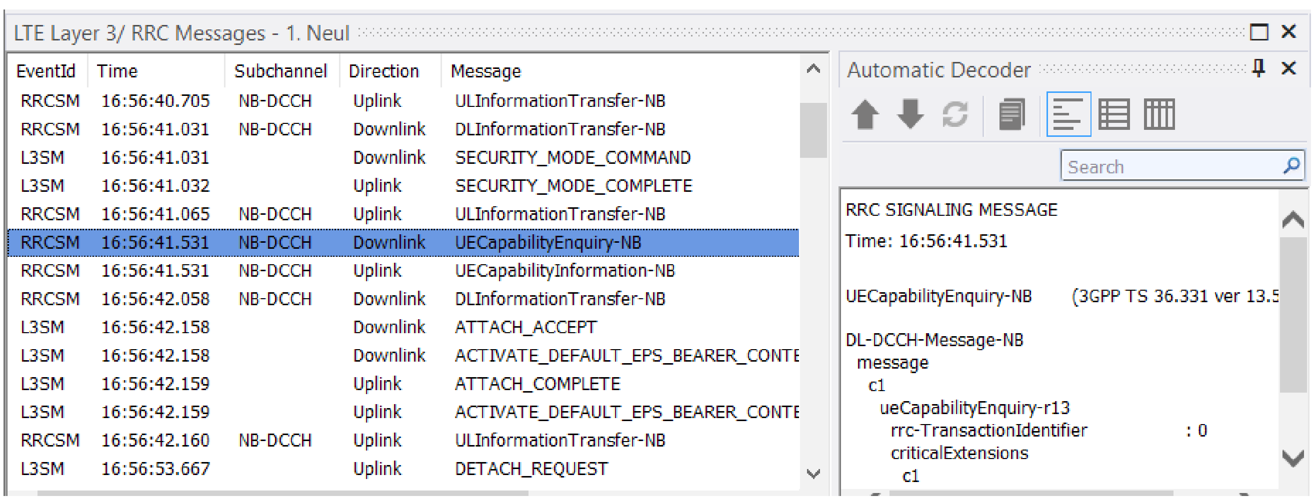


Figure 1. Signaling flow of NB-IoT device connection as seen from Keysight's Nemo Outdoor data collection tool

Signal coverage

IoT is designed to offer better coverage when compared to existing mobile broadband technologies. The maximum coverage gain over regular LTE is expected to be 23 dB for NB-IoT and 15 dB for LTE Cat-M1. The real gain may be less, depending on the deployment method and configuration. Increased coverage enables operators to deploy cellular IoT technologies in the existing LTE base station grid, achieving deep inbuilding coverage with or without reduced additional indoor cell and DAS deployments. The target is to provide sufficient coverage for smart meters and other IoT appliances that are typically located in basements and similar deep inbuilding locations.

Since IoT coverage is better than with any of the existing cellular technologies, and the existing base station grid is designed to provide sufficient coverage for established cellular broadband technologies such as LTE, no major coverage issues are expected in outdoor environments when IoT is deployed in the existing base stations. When the IoT coverage is verified with measurements, the focus must be on deep inbuilding to push the system to the designed performance limits, and to gather an understanding on how deep the indoor coverage really is.

Service coverage

Another important point to consider when testing NB-IoT is service coverage. Determining the IoT coverage is not simply a matter of signal strength and block/bit error rate. Coverage in both NB-IoT and LTE Cat-M1 is improved most at the expense of latency, bandwidth, and spectral efficiency. One of the key techniques used is repetition, that is, redundant transmissions of the same frame multiple times, and combining the repeated transfers at the receiving end. Every repetition increases the coverage by 3 dB, assuming ideal channel estimation and TX/RX chain. However, the latency experienced by the application is doubled, and throughput and spectral efficiency are sliced to half. As a result, round trip time may be increased up to ~10 s and throughput decreased down to 100 bps in extreme low coverage.

As discussed, spectral efficiency is also decreased drastically in extreme low coverage. This goes easily unnoticed at the early stages when the IoT network capacity is not yet limited, but will have a big impact down the road when the IoT technologies are widely adopted and the number of users in a cell increase to thousands. A seemingly small difference in the number of repetitions needed has a huge impact on the number of IoT users that can be accommodated in a cell.

It is important to first establish the minimum accepted QoS in terms of latency and bit rate, and then verify the coverage against that boundary. This must be kept in mind also when benchmarking the performance of network equipment and/or IoT devices. All equipment may reach the extreme coverage, but with very different QoS levels.

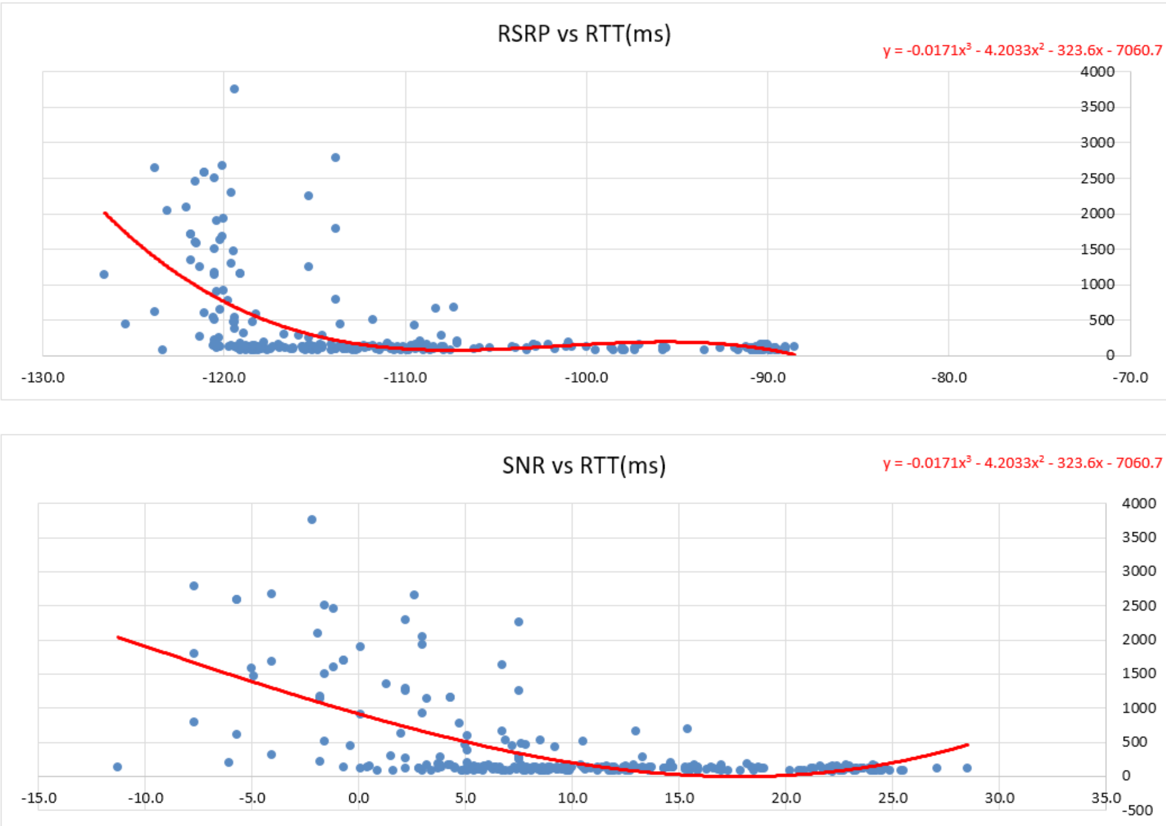


Figure 2. Cat-M1 service coverage (RTT - round trip time) verification results from live network active tests using Keysight's Nemo Analyze post-processing tool

The only way to verify service coverage accurately is to perform active tests with an IoT device connected to a measurement tool SW and to generate load over the connection between the device and the network with a test protocol, such as Ping. The measurement application collects the application performance readings, as well as the radio metrics, by tapping into the diagnostics interface of the IoT modem/chip of the device.

The outcome of the service coverage test is the minimum signal coverage and quality threshold for achieving acceptable QoS. Once the thresholds are known, network scanners can be used to measure the signal coverage and quality in a wider area more efficiently. Scanners can simultaneously measure the signal strength of all cells, from all operators, making it possible to assess the coverage accurately enough for optimization, troubleshooting, and benchmarking purposes. The scanner results can then be mapped with service coverage results.

IoT devices typically measure only serving cell quality and coverage during an active connection, not neighbor cells. In NB-IoT this is because the standard does not support seamless mobility and handover. In LTE Cat-M1 handovers are supported according to the 3GPP specification but not configured in all live networks due to power saving reasons. Hence, IoT devices cannot be used to collect signal coverage and quality readings comprehensively in drive testing, and scanners will be needed for this purpose. On the other hand, it is more important to start performing active tests using IoT devices to verify the service coverage. Also, IoT testing is expected to focus on inbuilding where stationary and low mobility testing is performed, and scanner measurements are less important.

Battery life and power consumption

The power consumption of IoT devices is another important factor, directly linked to the coverage as well as to network design and configuration. Both LTE Cat-M1 and NB-IoT are designed to significantly decrease power consumption over broadband cellular technologies. The key power saving technique is DRX (discontinuous reception) in a few different flavors. The main principle in these techniques is that the modem is effectively switched off during idle periods. In NB-IoT, the maximum battery life expected is in the range of 10 years in applications where small data packets are sent sporadically. Long battery life is important for many low-cost, unmanned IoT sensor applications. Ideally the battery should last for the whole lifecycle of the device to avoid costly maintenance.

Coverage has a big impact on the battery life. In low coverage, more repetitions are needed to successfully transfer the data. The more repetitions, the longer the duty cycles of the IoT modems and higher the power consumption, respectively. Excess repetitions due to network misconfiguration or network implementation also have a similar impact. In a given deep inbuilding location, there may be a difference of tens of dBs in the coverage between operators. This can result in years of difference in the maximum battery life of an IoT device deployed in that location. Hence, coverage remains an important benchmark KPI between operators.

Summary

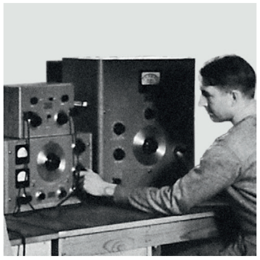
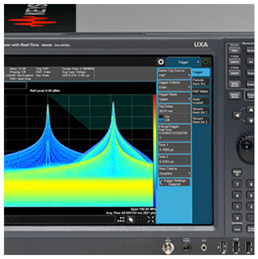
Cellular IoT performance is heavily dependent on IoT devices, network equipment implementation, interoperability between the equipment, and network design. Field measurements are important for operators and industrial IoT customers to verify and benchmark the performance of IoT solutions.

Enhanced coverage is one of the key features of Cellular IoT. The coverage boost is achieved at the expense of quality of service (QoS). Hence, active testing and verification of both QoS and signal coverage are needed to understand and benchmark the true service coverage. Coverage also has a direct impact on the network capacity and device power consumption.

Keysight Network Testing develops and sells RF measurement and analysis equipment under the Nemo brand. Nemo Outdoor drive test solution has been used by operators in multiple pilots and coverage measurements in IoT networks.

Evolving Since 1939

Our unique combination of hardware, software, services, and people can help you reach your next breakthrough. We are unlocking the future of technology.
From Hewlett-Packard to Agilent to Keysight.


myKeysight

myKeysight
www.keysight.com/find/mykeysight
A personalized view into the information most relevant to you.

NEMO

Keysight Nemo Solutions
www.keysight.com/find/nemo
Keysight's Nemo solutions provide testing, measurement, optimization, and analytics systems to the global wireless market based on its specialist sector knowledge and proprietary software and hardware products. Customers include major manufacturers of mobile devices, chipsets, and network equipment, mobile network operators, regulatory authorities, and independent test houses.

Keysight Channel Partners
www.keysight.com/find/channelpartners
Get the best of both worlds: Keysight's measurement expertise and product breadth, combined with channel partner convenience.

www.keysight.com/find/nemo

For more information on Keysight Technologies' products, applications or services, please contact your local Keysight office. The complete list is available at:
www.keysight.com/find/contactus

Americas

Canada	(877) 894 4414
Brazil	55 11 3351 7010
Mexico	001 800 254 2440
United States	(800) 829 4444

Asia Pacific

Australia	1 800 629 485
China	800 810 0189
Hong Kong	800 938 693
India	1 800 11 2626
Japan	0120 (421) 345
Korea	080 769 0800
Malaysia	1 800 888 848
Singapore	1 800 375 8100
Taiwan	0800 047 866
Other AP Countries	(65) 6375 8100

Europe & Middle East

Austria	0800 001122
Belgium	0800 58580
Finland	0800 523252
France	0805 980333
Germany	0800 6270999
Ireland	1800 832700
Israel	1 809 343051
Italy	800 599100
Luxembourg	+32 800 58580
Netherlands	0800 0233200
Russia	8800 5009286
Spain	800 000154
Sweden	0200 882255
Switzerland	0800 805353
	Opt. 1 (DE)
	Opt. 2 (FR)
	Opt. 3 (IT)
United Kingdom	0800 0260637

For other unlisted countries:
www.keysight.com/find/contactus
(BP-9-7-17)

DEKRA Certified
ISO9001 Quality Management System

www.keysight.com/go/quality
Keysight Technologies, Inc.
DEKRA Certified ISO 9001:2015
Quality Management System

KEYSIGHT TECHNOLOGIES

Published in USA, January 09, 2018
5992-2747EN
www.keysight.com