Evaluation of NB-IoT operating parameters

Theory

Narrow Band Internet of Things (NB-IoT) is a cellular communication technology for a high number of low power devices transmitting small amounts of data. The communication of a high number of devices is also called Massive Machine Type Communication (MTC)[1]. The NB-IoT technology in the context of networks for IoT services is illustrated in Figure 1 It is a technology operating in the license spectrum alongside cellular mobile networks.

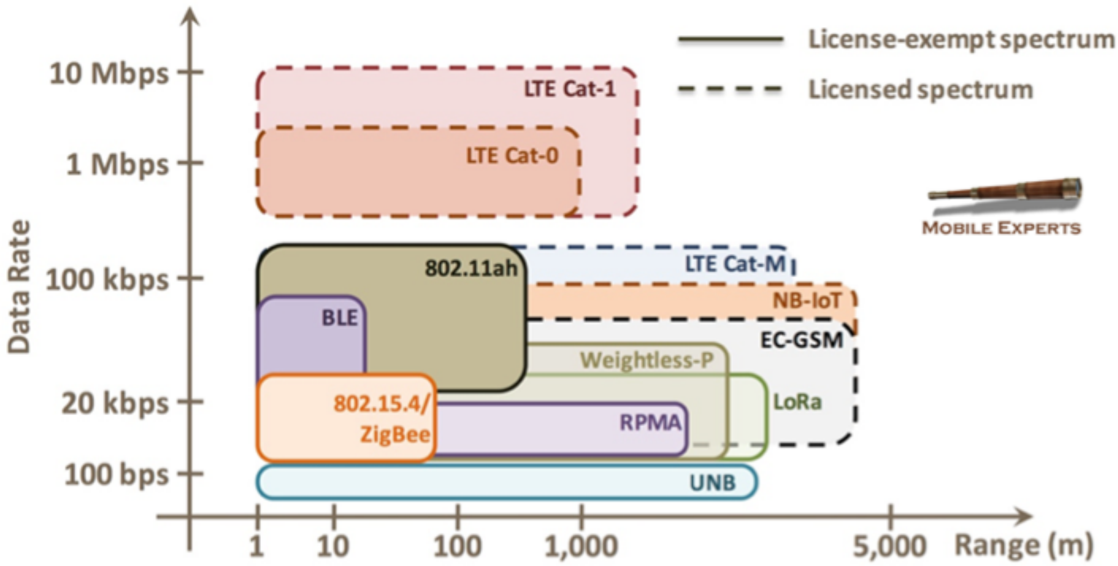

Figure 1. Comparison of IoT technologies[2].

The key features of NB-IoT[3,4,5] are:

- Approximately 10 years of operability (assuming NB-IoT device with 5 Wh battery).
- Very low cost per communication module -> low device cost (lower than eMTC devices, <5USD).
- Providing a large coverage due to ability to handle up to 164 dB maximum coupling loss, i.e., maximal total channel loss between device and NB-IoT cell antenna port. This translates to about 35 km as a maximal communication distance.
- More than 52.000 devices per cellular cell.
- Communication bandwidth of 180 kHz deployed, as shown in Figure 2:

---

[1] NOKIA, “LTE evolution for IoT connectivity”, whitepaper, 2017.

[2] http://mobile-experts-blog.blogspot.com/2016/02/a-reheated-alphabet-soup-for-iot.html,“ 2016.

[3] 3GPP TR 36.802, “Narrowband Internet of Things (NB-IoT), Technical Report TR 36.802 V1.0.0,” Technical Specification Group Radio Access Networks, June, 2016.

[4] R. Ratasuk, B. Vejlgaard, N. Mangalvedhe, and A. Ghosh. "NB-IoT system for M2M communication." In *2016 IEEE wireless communications and networking conference*, pp. 1-5. IEEE, 2016.

[5] R.S. Sinha, Y. Wei, and S.-H. Hwang. "A survey on LPWA technology: LoRa and NB-IoT." Ict Express 3, no. 1 (2017): 14-21.

1) Standalone as dedicated carrier occupying one GSM channel (200 kHz).
2) In-band within LTE carrier occupying one physical resource block (PRB) of LTE (180 kHz). The communication of IoT devices coexists with any other LTE communication and a part of LTE bandwidth is simply allocated to NB-IoT. Such in-band communication is possible for both LTE-based solutions, i.e., NB-IoT and LTE-M.
3) Within the guard-band of an LTE carrier occupying one physical resource block (PRB) of LTE (180 kHz). Guard-bands are at both sides of the spectrum to protect other bands from interference.

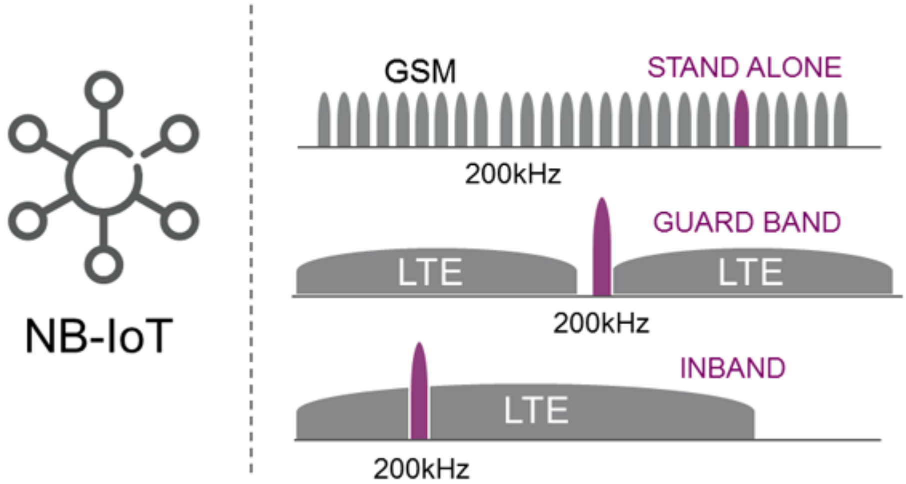

Figure 2. Deployment options for NB-IoT.

- Communication in the uplink via one of the following communication modes[6]:
  - Single tone with 15 kHz and/or 3.75 kHz tone spacing
    - High power spectral density
    - Suitable for large coverage and low bitrate scenarios
    - 1x 15 kHz over 8 ms or 1x 3.75 kHz over 32 ms
  - Multiple tone transmissions with 15 kHz tone spacing
    - Compatible with LTE
    - Short range and higher bitrate scenarios
    - 12/6/3 subcarriers with spacing of 15 kHz over 1/2/4 ms
- Max data rates are 250 kbit/s for multitone configuration and 20 kbit/s for single tone configuration[7], with device categories[8]:
  - Standard Cat-NB1 (3GPP Release 13) - 26 kbps (downlink)/62 kbps (uplink)
    - Maximum transmission power classes 20/23 dBm
    - Transmission Block Size (TBS), i.e., block size of the data that can be transmitted (including overhead) of 680/1000 bits (downlink/uplink)
  - Standard Cat NB2 (3GPP Release 14) - 127 kbps (downlink)/159 kbps (uplink)
    - Increased TBS to 2536 bits (both uplink and downlink)
    - 2 Hybrid automatic repeat requests (HARQs) instead of 1 for Cat-NB1
    - Maximum transmission power classes 14/20/23 dBm
    - Supporting multicast communication, mobility, push to talk services

[6] 3GPP TS 36.211, “Physical channels and modulation”, v15.5.0 March 2019.
[7] S. Tabbane, "IoT Standards Part II: 3GPP Standards", Training on PLANNING INTERNET OF THINGS (IoTs) NETWORKS, September 2018
[8] https://haltian.com/resource/nb1-vs-nb2-complete-comparison-table-and-overview/

- Simplifications of control and management
    - Significantly reduced broadcast system information
    - Reduction in number of HARQ processes
    - The NB-IoT follows the LTE frame structure, i.e., frame with duration of 10 ms, and Orthogonal Frequency Division Multiple Access (OFDMA) used in downlink, while Single Carrier - Frequency Division Multiple Access (SC-FDMA) is used in uplink for medium access
- For duplexing it is exploited Half Duplex Frequency Division Duplex (HD-FDD), i.e. transmission can occur at once only in a one direction, while uplink and downlink communication is done over separate frequencies
- Used modulations in uplink (BPSK or QPSK), downlink (QPSK)

The communication protocol stack for IoT communication technologies is shown in Figure 3. It is shown, that on top of the communication technology, in our case NB-IoT, is the whole communication protocol stack that exploits either User Datagram Protocol (UDP) or Transmission Control Protocol (TCP) for communication.

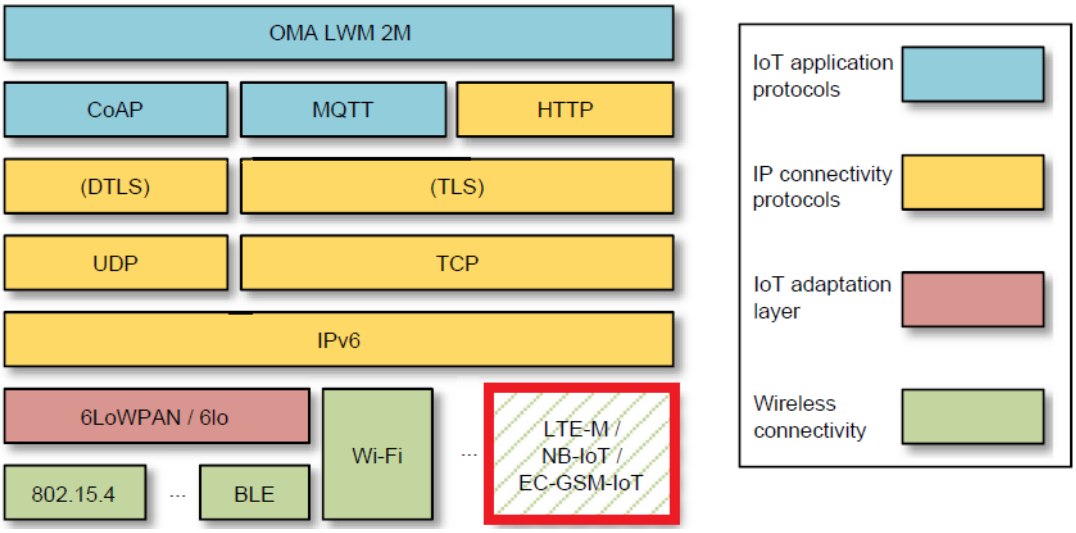

Figure 3. Protocol stack for IoT[9].

Communication service parameters

The evaluation of the usability of communication technology for a given service can be done in multiple ways. One way is to evaluate the service according to the selected criteria and then find a suitable communication technology that would meet the communication requirements. An example of different communication types and their requirements are shown in the tables below.

Table 1. Communication requirements of individual services with regard to reliability and security.

Communication type (service)	***Traffic type***	***Required data rate***	***Delay***	***Dependability*** ***"++" is higher requirement***	***Security*** ***"++" is higher requirement***

[9]https://www.embedded.com/cellular-iot-unlicensed-spectrum-usage

Commands	burst	1kB/min.	1s	++	++
Status info for consumer	burst	10kB/min.	1s	+	+
Status info for technical support	burst	10kB/hour	10s	+	+
Data messages between devices	burst	1kB/min.	1s	++	++
Monitoring	burst	10kB/hour	1s	+	+
Instruction and process information for consumer	burst	100kB/hour	1s	+	+
Voice commands	Realtime stream	20kb/s	0,3s	++	++
Pictures (photography)	burst	100kB/min.	1s	+	+
Video stream	Realtime stream	1Mb/s	0,3s	+	+
Firmware update	burst	10MB/day	1 hour	+	+

Table 2. Suitable communication technologies for various communication types.

Communication type (service)	*LP WAN*	*NB-IoT*	*LTE/5G*	*Wi-Fi*	*Zigbee*	*Bluetooth*
Commands	-	+	++	++	+	+
Status info for consumer	+	+	++	++	+	+
Status info for technical support	+	+	++	+	-	-
Data messages between devices	-	+	+ ++	++	++	+
Monitoring	-	+	++	++	+	+
Instruction and process information for consumer	-	+	++	++	-	+

Voice commands	-	-	++	++	-	+
Pictures (photography)	-	-	++	++	-	+
Video stream	-	-	++	++	-	+
FW update	-	+	++	++	-	-

Description and meaning of LTE network parameters

The parameters obtained from the radio modem can be used to estimate the quality of communication. These are the following quantities and ranges, as usually interpreted[10]:

RSSI (dBm) – (Received Signal Strength Indication) - a measurement of the power present in a received radio signal:

- More than -73 dBm – excellent,
- From -75 dBm to -85 dBm – good,
- From -87 dBm to -93 dBm – fair,
- Less than -95 dBm – poor.

RSRQ (dB) - (Reference Signal Receive Quality) - identifier of the quality of the received reference signal:

- More than -9 dB – excellent,
- From -10 dB to -15 dB – good,
- From -16 dB to -20 dB – fair,
- Less than -20 dB – poor.

RSRP (dBm) - (Reference Signal Receive Power) – average power received from a single reference signal:

- More than -79 dBm – excellent,
- From -80 dBm to -100 dBm – good,
- From -101 dBm to -109 dBm – fair,
- Less than -110 dBm – poor.

SINR (dB) - (Signal to Interference plus Noise Ratio) - a quantity used to give theoretical upper bounds on channel capacity (or the rate of information transfer):

- More than 21 dB – excellent,
- From 13 dB to 20 dB – good,
- From 0 dB to 12 dB – fair,
- Less than 0 dB – poor.

[10] https://usatcorp.com/faqs/understanding-lte-signal-strength-values/