Analysis of narrowband data transfer technologies on the Internet of Things (IoT)

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Abstract. The article provides an overview and comparative analysis of narrowband data transfer technologies on the Internet of Things. For analysis, a method of comparing the parameters of each of the reviewed technologies based on data from domestic and foreign literature, scientific articles and publications was chosen. This comparative analysis helps to identify a more efficient and preferable technology.

1. Introduction

The concept of the Internet of Things appeared in 1999 as the prospect of connecting a huge number of physical objects (sensors) through radio frequency identification for interaction between themselves and with the external environment, that is, this is a new stage in the development of the Internet, which connects the objects around us into a computer network. They exchange information among themselves and work without human intervention and in real time. In fact, this is the Internet, exciting the real world.

Filling the concept with a variety of technological content and introducing practical solutions for its implementation since the 2010s are considered as a stable trend in information technologies. The development of the Industrial Internet of Things (IIoT) should be discussed separately [13]. The range of possible data transfer technologies covers all possible means of wireless and wired networks.

For wireless data transmission, such qualities as efficiency in low-speed conditions, fault tolerance, adaptability, and self-organization play a particularly important role in building the Internet of Things.

In terms of transmission range, Internet of Things communication technologies can be divided into short-distance technologies and long-range technologies (WAN, wide area network technologies). The first are represented by protocols such as Zigbee, Wi-Fi, Bluetooth, Zwave, etc.

Their typical use is "smart homes", "smart manufacturing" or stand-alone industrial scanning systems for difficult or unsafe work environments [14]. The latter are used in low-speed data services and are usually defined as Low-power Wide-area Network (LPWAN) technologies. At the same time, the development of LPWAN technologies is especially promising.
In terms of frequency spectrum licensing, LPWAN technologies can be divided into two categories: technologies operating in unlicensed and licensed frequency bands (Figure 1).

The first category is represented by Lora, Sigfox and other technologies, most of which are not licensed.

The second category is represented by some relatively old 2G/3G cellular technologies (such as GSM, CDMA, WCDMA, etc.), LTE and LTE-A technology, which support various terminal categories. Standards for these permitted spectrum communication technologies are mainly developed by international standardization organizations such as 3GPP and 3GPP2.

Due to the rapid growth of low data rate of the Internet of Things services, LPWA technology is becoming increasingly popular in industry, and its market share is gradually increasing. According to a report by Hequan Wu at the 2016 China Internet of Things Conference, intelligent IoT applications can be divided into three categories depending on the requirements for data transfer speed in 2020 [1].

| Distribution by 2020 | categories | how to connect to the network |
|----------------------|------------|------------------------------|
| 10%                  | high data rate (more than 10 Mbit/s) | 3G:HSPA/EVDO/TDS            |
|                      |           | 4G:LTE/LTE-A                 |
|                      |           | WiFi 802.11                  |
| 30%                  | average data rate (less than 1 Mbit/s) | 2G:GPRS/CDMA2K1X            |
|                      |           | MTC/eMTC                     |
| 60%                  | low data rate (more than 100 Kbit/s) | NB-IoT                       |
|                      |           | SigFox                       |
|                      |           | LoRa                         |
|                      |           | Zigbee                       |

![Figure 1. IoT technologies and their use in the radio frequency spectrum](image-url)
1. **High data rate.** The data rate is higher than 10 Mbps. Available access technologies: 3G, 4G and Wi-Fi. Mainly used in live television, electronic healthcare, automotive navigation and entertainment system, etc. The expected market share for this type of application is IoT 10%.

2. **Average data rate.** The data rate is below 1 Mbps. Available access technologies: 2G and MTC/eMTC. Such applications are, for example, a POS machine, a smart home and 8 M2M feedback. The expected market share for such applications is IoT 30%. However, in the future 2G M2M will be gradually replaced by MTC/eMTC technology.

3. **Low data rate.** The data rate is below 100 kbps. Available access technologies are NB-IoT, SigFox, LoRa, and short-range wireless technologies such as ZigBee. Applications are mainly used in LPWA technologies, including sensors, intelligent metering, product tracking, logistics, parking, and intelligent agriculture. The expected market share for such applications is IoT 60%.

Since this article analyses narrowband data transfer technologies in IoT, let us look at LORA, SigFox, and NB-IoT technologies in more detail.

2. **Technology analysis**

**LORA Technology.** The developers of LoRa Alliance believe that LoRa technology has significant advantages over WiFi and cellular networks, due to the ability to deploy machine-to-machine (M2M) connections up to 20 km at a speed of up to 50 kbps, and also has a minimum power consumption that provides several years of battery life on a single battery. The scale of applications of this technology is large: from home automation and the Internet of things to industry and smart cities [2, 7, 11].

Figure 2 describes the architecture of LoRaWAN networks 1 [6, 8].

The classic LoRaWAN network consists of the following elements: end nodes, gateways, network server and application server.

The End-Node is designed to perform control, monitoring, and measurement functions. It contains a set of necessary sensors and control elements. They usually have battery power. Nodes include data transmission for only a certain period of time (usually 1-5 seconds), at the end of which two time windows are opened to receive data. The rest of the time, the end-node transceiver is either inactive or in the receive state, depending on the device class (A, B, or C).

![Figure 2. Architecture of network LoRa](image)

The device accepting data from final devices by means of a radio channel and transferring them to transit network - the LoRa (Gateway/Concentrator) Gateway. Transit networks can be Ethernet, WiFi, cellular networks and any other telecommunication channels. The gateway and endpoints form a star network topology. Often, this device contains multi-channel transceivers for processing signals in several channels simultaneously or even, several signals in one channel. Accordingly, several such devices provide network coverage and transparent bidirectional data transmission between the end nodes and the server. Network Server is designed for network management: scheduling, rate
adaptation, storage and processing of received data. The Application Server can remotely monitor the 
operation of the target nodes and collect the necessary data from them.

3. Technology SigFox

SIGFOX is a private company that aims to create a worldwide network specially designed for devices 
(Internet of Things, IoT). The technology allows data transmission over long distances at low 
transmitter power and low battery capacity.

The network is great for simple and stand-alone devices that send a small amount of data to this 
network. So the SIGFOX network is similar to the cellular infrastructure (GSM and GPRS-3G-4G), 
but is more energy efficient and at the same time less expensive. SIGFOX uses Ultra Narrow Band 
(UNB) based on radio technology to connect devices to the wide area network. The use of UNB is a 
key factor in ensuring a very low transmitter power level that will be used during the state of 
maintaining a reliable data connection. The network operates in existing unlicensed bands (The 
industrial, scientific and medical, ISM) on a global scale and coexists in these frequencies with other 
radio technologies without the problem of network overlap or bandwidth problem. In Europe, the 
868.8 MHz band is widely used (as defined in ETSI and CEPT), and in the USA 915 MHz (as defined 
by the FCC). The coverage area of SIGFOX is about 30-50 km in rural and urban areas. Usually, if 
there is more difficulty and noise, the range decreases from 3 to 10 km. Figure 4 shows the topology 
of the SIGFOX network [9, 10].

The overall network topology was designed to provide a scalable, high-performance network with 
very low power consumption, while maintaining a simple and easy star topology based on mesh 
infrastructure.

In SIGFOX, nodes can be used in two configurations:
- P2P mode: direct communication between nodes (LAN interface);
- Hybrid mode: SIGFOX/ P2P (P2P GW in SIGFOX network).

SIGFOX technology is aimed at low cost devices where a wide coverage area is required. There are 
a number of applications that need this wireless technology. Areas in which SIGFOX networks can be 
used include:
- homes and consumer goods;
- energy communications;
- transport - including technical management;
- remote monitoring and control;
- retail point of sale, storage of updates, etc.;
- security.

The standard has a number of advantages over other basic LPWAN network technologies:
- large coverage area;
• high penetrability;
• up to 20 years of sensor operation from 2 AA batteries, i.e. ultra-low power consumption;
• low cost.
Like all technologies of the modern world, the energy-efficient SIGFOX network, unfortunately, also has negative characteristics:
• low data rate;
• dependence on cellular infrastructure;
• limited noise immunity;
• no SIGFOX networks in Russia [3].

4. Technology NB-IoT
The narrow-band Internet of things (Narrow-Band Internet of Things, NB-IoT or LTE Cat-NB1) is the large-scale technology of energy efficient network of distant range (LPWA) offered 3GPP for collecting and data processing and intended for intellectual applications with a low speed of data transmission. Typical applications are smart instrument readings and intelligent environmental monitoring.

NB-IoT provides massive connections, ultra-low power consumption, wide coverage area and bidirectional connection between control plane, and signaling and data plane.

To create networks for the Internet of Things in Russia according to the standard NB-IoT according to the decision of the State Commission on Radio Frequencies (GKRCH) of December 28 2017; SCRF No. 17-44-06, radio frequency bands allowed 453-457.4 MHz and 463-467.4 MHz, 791-820 MHz, 832-862 MHz, 880-915 MHz, 925-935 MHz, 935-960 MHz, 1710-1785 MHz 1805-1880 MHz, 2110-2170 MHz, 2500-2570 MHz and 26200-2690 MHz [4, 12]

In order to operate the communication network according to the NB-IoT technology, a frequency band of 180kHz must be allocated in the radio frequency resource, which corresponds to one LTE radio network resource unit (EUTRAN). 3GPP defines the three modes of operation shown in Figure 4 [3]:

![Figure 4. Three operating modes supported by NB-IoT](image)

**NB-IoT - stand-alone mode.** Autonomous mode of operation, which uses an independent frequency band that does not overlap with the LTE frequency band: one frequency interval of 200 kHz is allocated in the GSM band, which allows you to organize a NB-IoT radio channel with two protective intervals of 10 kHz.

**NB-IoT - guard-band mode.** The mode of operation in the protective band of the LTE network, in which one resource unit is allocated in the protective interval outside the operating band used to provide LTE services; in particular, the protective band for the LTE range with a width of 20MHz is 1MHz on each side, for the LTE range with a width of 10MHz - 500 kHz.
**NB-IoT - in-band mode.** The LTE band mode, which uses the LTE band for deployment and requires 1 Physical Resource Block (PRB) of the LTE band for deployment.

The most common is in-band operation. It is widely used in Europe, where networks with NB-IoT in-band are deployed by telecommunications companies Vodafone, Deutsche Telekom, Telecom Italia Mobile and others.

Despite the prevalence of the in-band mode of NB-IoT use, it has disadvantages. Thus, the narrowband in-band signal NB-IoT occupies a frequency of 180 kHz and in LTE networks can interfere with physical resource units (PRBs). In this mode, the NB-IoT takes away the functional resources of the cellular networks.

The NB-IoT network is shown in Figure 6, which shows that it consists of 5 parts:

1. Terminal NB-IoT. Devices IoT in all industries have access to the NB-IoT network if the appropriate SIM card is installed;
2. Base station NB-IoT. This generally applies to base stations that have already been deployed by carriers and support all three types of deployment modes mentioned previously;
3. The core of the NB-IoT network. Through the core of the network, the base station NB-IoT can connect to the cloud platform NB-IoT;
4. Cloud Platform NB-IoT. The cloud platform NB-IoT processes various services and directs results to a vertical technical center or terminals NB-IoT;
5. Vertical technical center. Receives NB-IoT service data and stores it in its own center, and also takes control of NB-IoT terminals.

Coverage Levels In most cases, NB-IoT is used to transmit mini-packets, and it is NB-IoT difficult to provide a long-term and continuous indication of channel quality change, so NB-IoT uses different coverage levels instead of a dynamic line adaptation scheme.

There are three types of coverage levels, including normal coverage, reliable coverage and extreme coverage, which correspond to minimum communication losses of 144, 154 and 164 dB, respectively [5].

![Figure 5. Network NB-IoT](image)

The original goal of the NB-IoT was 50,000 connections per cell.

Based on preliminary calculations and estimates, the current version of the NB-IoT mainly meets the requirements. However, the ability to achieve the goal in practice depends on the service model of the NB-IoT terminal in the cell, so further tests and assessments are needed.
5. Conclusion
This paper provides a comparative analysis of narrowband technologies in IoT, such as NB-IoT, LoRa, and SigFox. Comparison results are shown in Table 2.

| point                        | NB-IoT                                      | LoRa                                      | SigFox                             |
|------------------------------|----------------------------------------------|-------------------------------------------|------------------------------------|
| power supply level           | Low (10 years of battery life)               | Low (10 years of battery life)            | very much (20 years of battery life) |
| communications budget        | 164 Db                                       | 157 Db                                    | 149 Db                             |
| bandwidth                    | 180 kHz (licensed)                           | 125 kHz, ISM                              | 100 Hz, ISM                        |
| Frequency                    | 700/800/900/1800 MHz and any LTE frequency   | 858.8 MHZ (Europe), 915 MHz (USA)         | 868.8 MHZ (Europe), 915 MHz (USA)  |
| Dplnost                      | up to 11 kilometers in the city              | up to 2.5 kilometers in the city          | up to 1 kilometer in the city      |
| Number of connections        | 50000 on the sector                           | 40000 on the sector                       | 50000 on the sector                |
| Speed                        | up to 250 kbps                               | 0.3-50 kbps                               | 100-600 bit/s                     |
| Scalability                  | high                                         | average                                   | low                                |
| Coating (vs. GSM)            | more by 20 db                                | more by 20 db                             | more by 11 db                      |
| Expansion                    | reconfiguration of existing FDD or GSM LTE   | inconveniently                            | inconveniently                    |

Based on comparative analysis, it can be concluded that the standard NB-IoT a more promising technology, since it has a number of advantages:

- high density of connections (50 thousand devices IoT per sector of base station);
- provision of maximum communication range in urban conditions (up to 11 km) due to communication budget up to 164 dB;
- optimal speed (up to 250 kbps) for trouble-free operation of devices that transmit a small amount of information of the same type with a certain frequency;
- cheap use and maintenance of NB-IoT when deployed at existing frequencies.

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