Comparative analysis of standards for Low-power Wide-area Network

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Abstract— **This paper examines and analyzes the existing standards NB-IoT, LoRA, Wi-Fi HaLow (802.11ah) used in wireless networks of Low-power Wide-area Network (LPWAN). Also, the paper reviews main applications of wireless networks of three different standards. The main features of these standards are analyzed, their pros and cons are determined.**

Keywords—internet of things (IoT); wireless network; LPWAN; LoRaWAN; Wi-Fi HaLow (802.11ah); NB-IoT

I. INTRODUCTION

To date, various technologies are gaining popularity all over the world to simplify the everyday affairs of people. One such technology is Low-power Wide-area Network (LPWAN) [1-2]. This technology is used to transmit data over long distances and low speed. LPWAN – a new technology, which is specially designed to provide a non-complex, cheap and reliable method of communication for devices located at large distances from each other with low power consumption and undemanding to the data transfer speed. It is considered that the emergence of such networks is primarily related to the data transfer needs for devices that have built-in technologies that allow interacting with each other and with the external environment. To date, such devices have the definition of "Internet of things" [3]. As a rule, for such devices, data transmission speed is not as important as long autonomy of work, low cost and minimal price of data transfer. The relevance of the LPWAN technology is in the fact that every year the coverage area of the Internet increases and at the same time there are technical capabilities that allow it to manage various devices.

LPWAN allows realizing the environment for data collection from various devices, such as sensors, detectors and so on. The principle of setup of such technology is similar to the operation of mobile communications networks. The LPWAN topology can be implemented as a "star", as a result of which each device interacts directly with the base station, for example, the sensor transmits data over the radio channel to the base station. The base station receives signals from all sensors within its range, after which it processes the received information and transfers it to the server (Fig. 1). Data received on the server is used to further make various decisions.

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It is worth noting that the key parameters of LPWAN networks are the transmission range of the radio signal, data rate, central frequency and bandwidth, performance of the base stations, cost of components and network deployment.

II. LPWAN STANDARDS

LPWAN is aimed at applications that require transfer of small amounts of data with long battery life and large network coverage. It is possible to identify the main areas in which this technology can be applied, such as wireless sensors, control systems of various levels. LPWAN applications are quite different:

- Housing communications: control system for electricity, water, heat, gas;
- Agriculture: humidity and temperature control in the soil and collecting information about other characteristics;
- Security: access or fire control systems;
- City: parking control system, air pollution and others;
- Medicine.

Below, some existing standards, used in the construction of Low-power Wide-area Network (LPWAN) will be reviewed and analyzed: NB-IoT, LoRA, Wi-Fi HaLow (802.11ah) [4-9]. The proposed standards will be compared by main parameters and characteristics.

A. Frequency bands and occupied bandwidth

NB-IoT uses LTE frequency band (e.g. 2530-2540 MHz, 2650-2660 MHz, 847-854.5 MHz). In accordance with the specification 3GPP Rel.13 it is possible to work in the band of the main signal, the guarding interval, or in a separate range. The occupied bandwidth depends on the device category and varies from 15 kHz to 20 MHz for Downlink and from 3.75 kHz to 20 MHz for Uplink. The average value for most typical applications is 200 kHz. LoRaWAN standard uses unlicensed frequency bands, which may vary depending on the local laws of the specific country. For example, in Europe this is the frequency range in the area 868 MHz, and in USA 915 MHz. In Russia, for these applications, there are two main ranges - the ranges 864-865 MHz and 868.7-869.2 MHz. In the

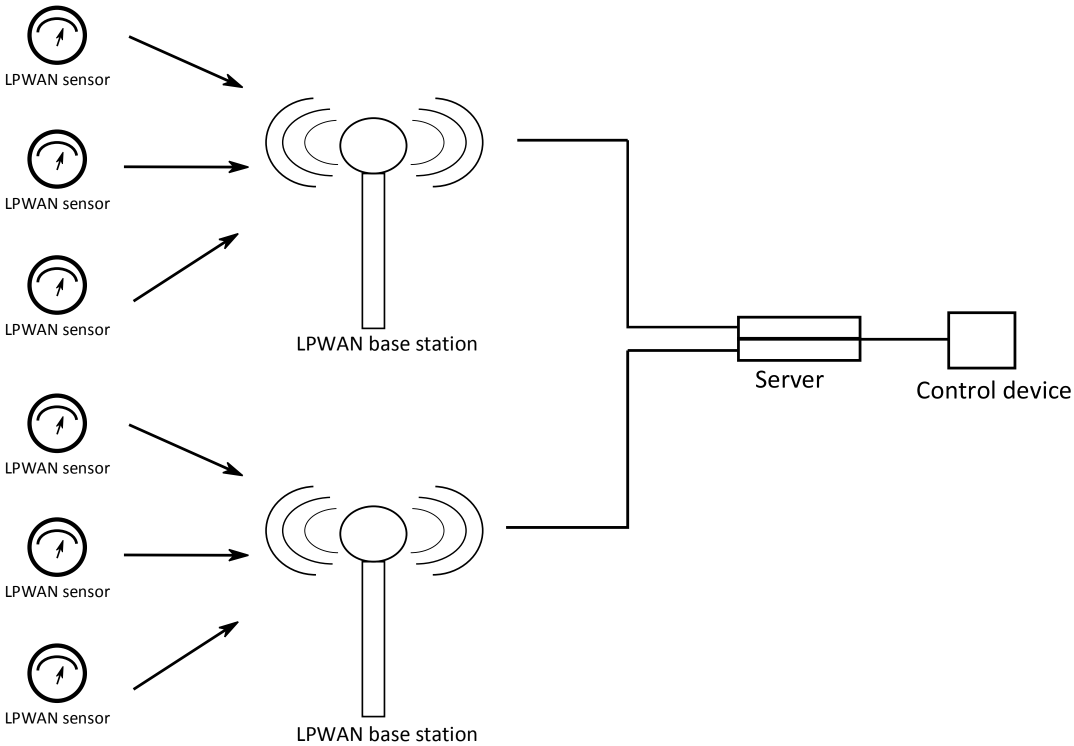

Fig. 1. LPWAN network topology

specification of the LoRaWAN standard with current edition 1.0.2 work in two frequency bands is provided – 125 and 250 kHz. The last standard considered WiFi HaLow (802.11ah) is also designed to operate in unlicensed frequency bands, as well as LoRaWAN, therefore, the provisions mentioned above are also valid for him. However, according to the current description of the standard, the bands of operating frequencies are much wider and constitute 1/2/4/8/16 MHz depending on the type of device and the required data rate.

B. Radiated power and sensitivity of the receiver

For all three standards, the maximum radiated power of the transmitter according to the specification is 500 mW. If we compare three standards by sensitivity of the receiver, then the maximum achievable sensitivity is for NB-IoT and this value is equal to -141 dBm, for LoRaWAN this value can vary from -108 to -136 dBm, depending on the modulation type used. Due to the fact that the WiFi HaLow (802.11ah) technology is not completely standardized, only the estimated sensitivity of the receiver is present, and it is in the range from -120 to -130 dBm.

C. Transmission data rate

The maximum data rate is not the key characteristics of these standards, as it is often sacrificed to other more important parameters - the maximum range and power consumption. However, it can be important for certain types of devices that have the need to transmit a large amount of information, such as images or video. The highest maximum data transfer rate is in WiFi HaLow (802.11ah), for which it can be up to 346.666 Mbps (with a minimum of 150 kbps). A slightly smaller maximum transmission speed - up to 4 Mbps is provided by NB-IoT technology. However, the standard for it is 200 kbps, and the minimum - 0.3 kbps. LoRaWAN is primarily designed for organization of sensor networks, which do not require the transfer of large amounts of information, with the battery life on the first place; therefore the maximum transmission speed is significantly limited and is in the range 0.3-50 kbps.

D. Types of modulation

NB-IoT and WiFi HaLow use identical types of modulation, such as OFDM with BPSK, QPSK, QAM on the subcarriers depending on the data rate and signal quality. LoRaWAN has its own and patented modulation based on Spread Spectrum Modulation and Chirp Spread Spectrum (CSS) variations with integrated Forward Error Correction (FEC).

E. Cost of devices

An important factor for operators is the cost of deploying the network in terms of one base station. The most expensive solution is the NB-IoT technology, because for its implementation this standard requires the modernization of existing base stations, the cost of which starts from $ 15,000. The cost of base stations for the other two remaining standards is much smaller and varies from $ 100 to $ 1000, with the massive spread of technology and access to the broader user market, further price reductions are possible.

After analyzing the main features of these standards, we can identify their advantages. The benefits of the NB-IoT standard include: the ability to deploy network based on existing LTE networks, a large coverage area, and high quality of customer service. Advantages of the LoRaWAN standard are low cost of network deployment and user terminals, large coverage area, long service life of user terminals, high penetrating power, but relatively low achievable data rates. And for the last one considered WiFi HaLow (802.11ah) they are the possibility of integration with Wi-Fi networks and open access. Due to this, it will be of interest to a large number of device manufacturers, which will reduce the cost of the devices. Also its advantages are high signal penetration and MIMO support, which will be very useful because the sensor can be installed not in line of sight.

The parameters by which the comparison was made, as well as additionally conditions, are presented for each standard in Table I.

TABLE I. COMPARATIVE CHARACTERISTICS OF THE STANDARDS

	NB-IoT	**LoRa**	**Wi-Fi HaLow (802.11ah)**
Frequency range	Corresponds to LTE networks range (e.g., 2530-2540 / 2650-2660 MHz, 847-854.5 / 806-813.5 MHz), possibility of working in the band of the main signal, the guarding interval, or in a separate range	Europe: 868 MHz, in specification: 868.1, 868.3, 868.5 MHz USA: 915 MHz Australia: 430 MHz Russia: 864-865MHz, 868.7-869.2 MHz	Europe: 868 MHz USA: 915 MHz Australia: 430 MHz Russia: 864-865MHz, 868.7-869.2 MHz
Bandwidth	DL from 15 kHz to 20 MHz (Cat1) UL from 3.75 kHz to 20 MHz (Cat1) Typical 200 kHz	125, 250 kHz (Europe, Russia)	1/2/4/8/16 MHz
Maximum transmitter power	500 mW	500 mW	500 mW
Receiver sensitivity	-141 dBm (maximum achievable), typical -120 dBm	Depending on the type of modulation from -108 to -136 dBm	Estimated -120 ..- 130 dBm
Data rate	0.3 - 4000 kbps Typical 200 kbps	0.3 - 50 kbps	346 - 0.150 Mbps
Modulation, channel separation	OFDM with BPSK, QPSK, QAM	LoRa modulation is based on Spread Spectrum Modulation and Chirp Spread Spectrum (CSS) variations with integrated Forward Error Correction (FEC). Patented technology	OFDM with BPSK, QPSK, QAM, 16-QAM, 64-QAM or 256-QAM
Area coverage	It is determined by the BS coverage zone (about 10 km)	Up to 10 km	Up to 1 km
Number of devices for one BS	Up to 50 thousand devices per base station sector, speed up to 250 Kbps	Up to 5000	Up to 8191
Cost for operator	Requires a base station upgrade. Estimated cost is $ 15000 for the BS	$ 100-1000 per BS	$ 100-1000 per BS
Battery life	Less than what the LoRa and 801.11ah devices do because of the more complex signal structure and network	Up to 10 years (when using a 2000 mAh battery)	Up to 10 years
QoS	High	Low	Medium
Status	Standardized by the consortium 3GPP (Rel.13)	Standardized, proprietary (closed)	Not standardized
Features	The presence of a SIM card, which provides the possibility of integration into existing cellular networks, the option of electronic SIM cards is developed (without physical media)	Successful implementation in France	The ability to create a single point of access Wi-Fi - Wi-HaLow and its integration with the gateway into the mobile network

III. LPWAN IN RUSSIA

The implementation of LPWAN standards operating in non-licensed bands (LoRa and 802.11ah) in Russia will face great difficulties due to the limitations of the State Radio Frequency Commission on power and dedicated bands (Annex 11 to the decision of the State Radio Frequency Commission of May 7, 2007 № 07-20-03-001). So, the maximum range for LoRa and 802.11ah is indicated for the radiated power of 500 mW, which is the maximum allowed in Europe. In Russia, the maximum transmitter power in these unlicensed bands without a license is 20 times smaller and is 25 mW. In addition to direct proportional reduction of range due to power reduction, there will be problems with interference between different systems (communication, security, remote control, etc.). Therefore, these systems, most likely, if there is no legislative change, will be applicable only for deployment in confined spaces and indoors (because of their better penetrating power). Technology NB-IoT works at frequencies assigned to telecom operators, so these limitations will not affect it, but now it can be used only in big cities with good LTE coverage.

IV. CONCLUSION

Thus, in this paper we compare three standards (NB-IoT, LoRAWAN, Wi-Fi HaLow (802.11ah)) used in Low-power Wide-area Network (LPWAN).

Among the solutions considered for LPWAN at the moment the most mature solution ready for use is LoRaWAN. This standard has the following advantages: low cost of network deployment, long battery life, simple operation, high penetrating ability of radio signals and operation in the unlicensed range. However, in Russia this standard will face such a problem as the power limitation in the allocated frequency band.

Deployment of networks and mass development of devices with NB-IoT support will take place in the next year or two (pilot projects are being implemented at the moment), industrial implementation of 802.11 ah is in two to three years (the standard is not approved).

The main advantage of the 802.11ah standard is its ability to integrate with other Wi-Fi standards. In this regard, we can expect that in the near future will be released routers for Wi-Fi networks with support for Wi-Fi HaLow, which will significantly simplify the deployment of networks and the large expansion of this technology among the users. It is likely that 802.11ah will eventually replace LoRaWAN (if this standard remains closed), since their characteristics are similar.

The most advanced and promising from a technical point of view is the NB-IoT standard. The NB-IoT network can be deployed on the basis of existing LTE networks using all of their advantages. However, the spread of this technology is constrained by the high cost of upgrading the base stations and setting up the new ones, which makes NB-IoT technology unprofitable for telecom operators.

Another important fact, which is worth paying attention to is the increasing need to develop new and relatively inexpensive transceiver for the "Internet of things". As a result, the relevance of LPWAN networks will only increase, and this technology will become one of the most popular variants of inter-machine communication. One can add to this that already today, due to technical merits, LPWAN can really be used to create local networks that will replace short-range networks, such as Wi-Fi and Bluetooth, most often used to create a wireless communication system within the home or office for inter-machine communications.

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