LPWAN Narrowband Technologies (LoRaWAN, SigFox, etc.) for M2M Networks and Internet of Things Design

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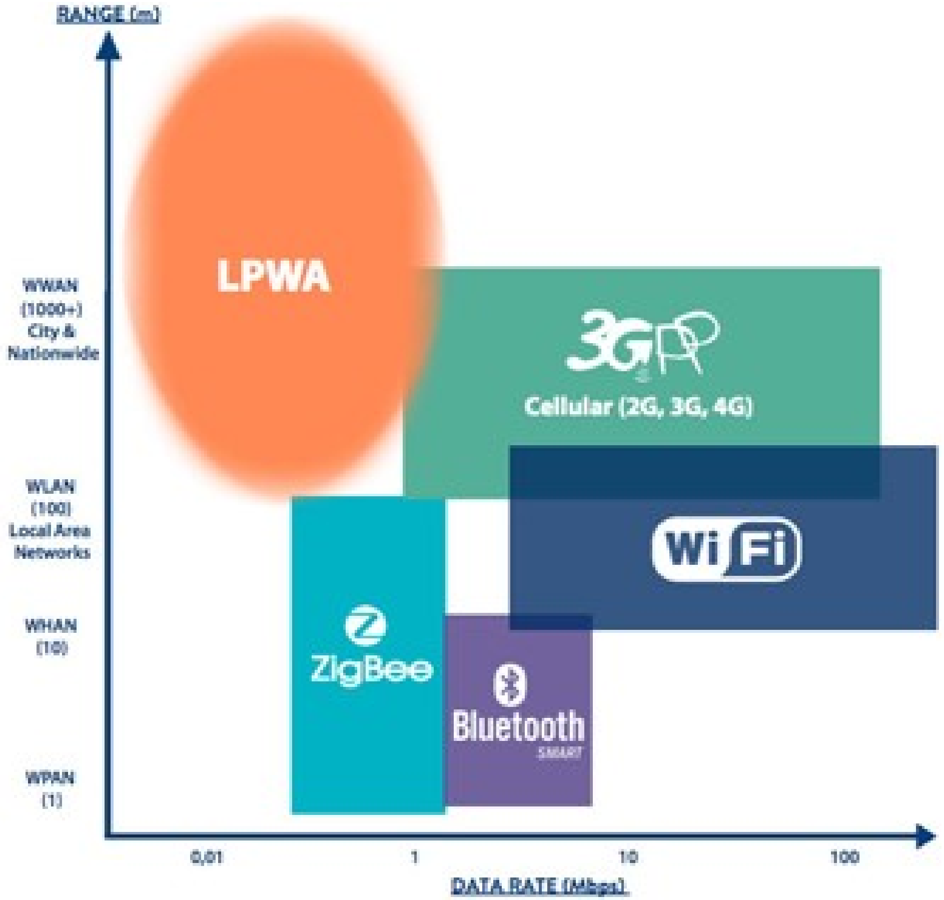
Content

- LPWAN technology family and key features
- LPWAN technologies with unlicensed and licensed spectrum for radio access to M2M and Internet of Things networks
- Standardization of LPWAN technologies
- Features of LPWAN technologies utilization
- LoRaWAN technology usage in M2M and Internet of Things networks

LPWAN Concept for IoT/M2M Services



Low-power WAN (LPWAN) is a wireless wide area network technology that interconnects low-bandwidth, battery-powered devices with low bit rates over long ranges.

LPWAN technologies represent narrowband radio technologies with low radiation power and an extended coverage zone with a radius of up to several kilometers.

LPWAN is not a single technology, but a group of various low-power, wide area network technologies that take many shapes and forms. LPWANs can use licensed or unlicensed frequencies and include proprietary or open standard options.

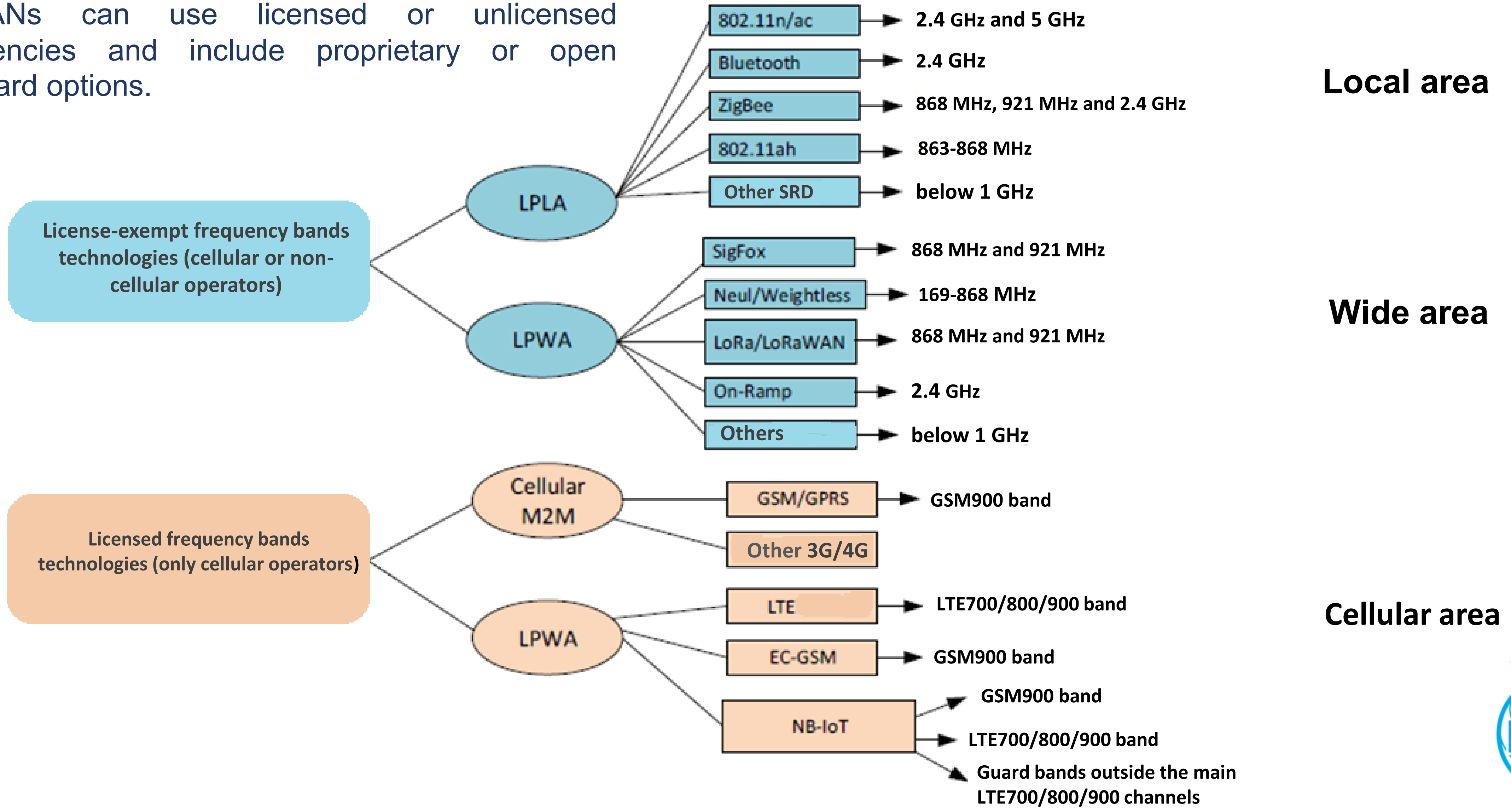
Technical requirements for narrowband LPWAN technologies were formed on the basis of the following prerequisites:

• Most IoT devices are simple sensors with low level of generated traffic;
• The range of communication from several to tens of kilometers with line of sight;
• The amount of transmitted data is between 10 and 50 bits for several times a day;
• The main data traffic is transmitted in the uplink (from the IoT device to the base station (radio gateway)).

https://internetofthingsagenda.techtarget.com/definition/LPWAN-low-power-wide-area-network

Radio spectrum utilization by LPWAN

LPWANs can use licensed or unlicensed frequencies and include proprietary or open standard options.



Standardization of Wireless Technologies by IoT Industrial Alliances

НИИТС
ТЕХНОЛОГИИ И СВЯЗЬ

International Industrial Alliances of IoT standards

LoRa Alliance

Over 527 (January 2018)

Actility, Cisco, Eolane, IBM, Kerlink, IMST, MultiTech, Sagemcom, Semtech, Microchip Technology, Bouygues Telecom, KPN, SingTel, Proximus, Swisscom, and FastNet (part of Telkom South Africa)

WEIGHTLESS

4770 (May 2018)

Neul, Landis+Gyr, Cable & Wireless, and ARM

DASH7 ALLIANCE

Instytut Logistyki i Magazynowania
Wroclaw University of Technology
arynga
cortus
KAWANTECH Digital traceability solutions
聚星仪器 VI SERVICE NETWORK
MATRIX PRODUCT DEVELOPMENT
nornir stringed things
MOSAIC Modeling Of Systems And Internet Communication University of Antwerp

https://www.postscapes.com/internet-of-things-alliances-roundup/

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LPWAN Networks Spectrum Usage for Access to IoT Services

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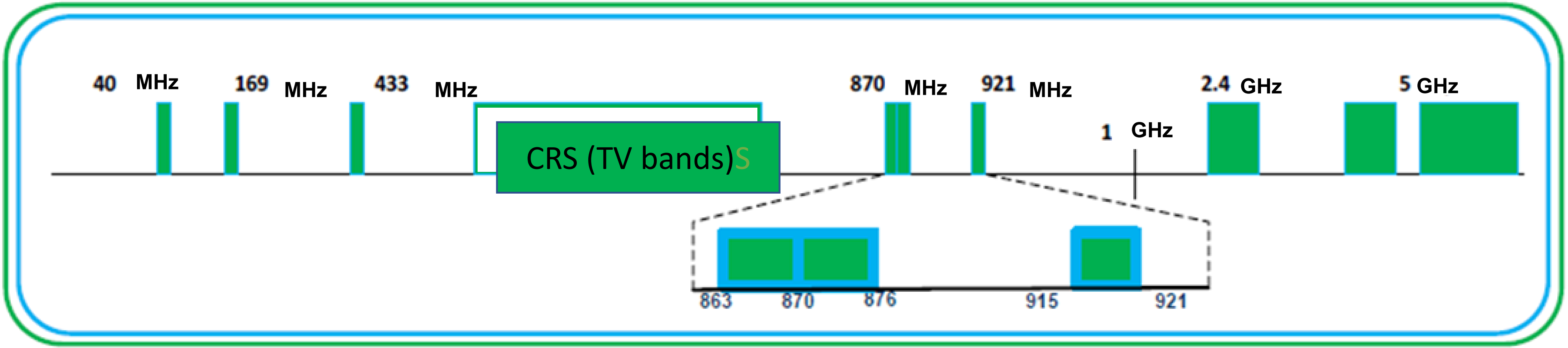
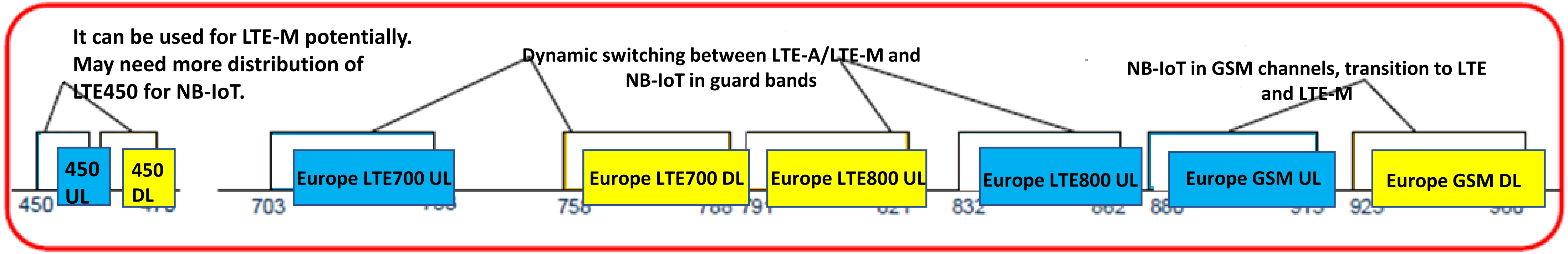
Unlicensed frequency bands

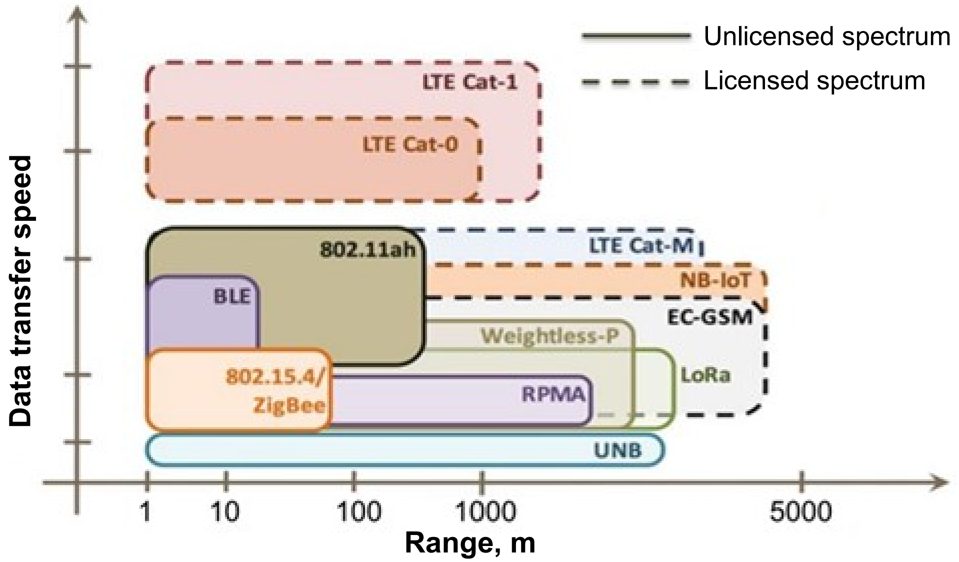


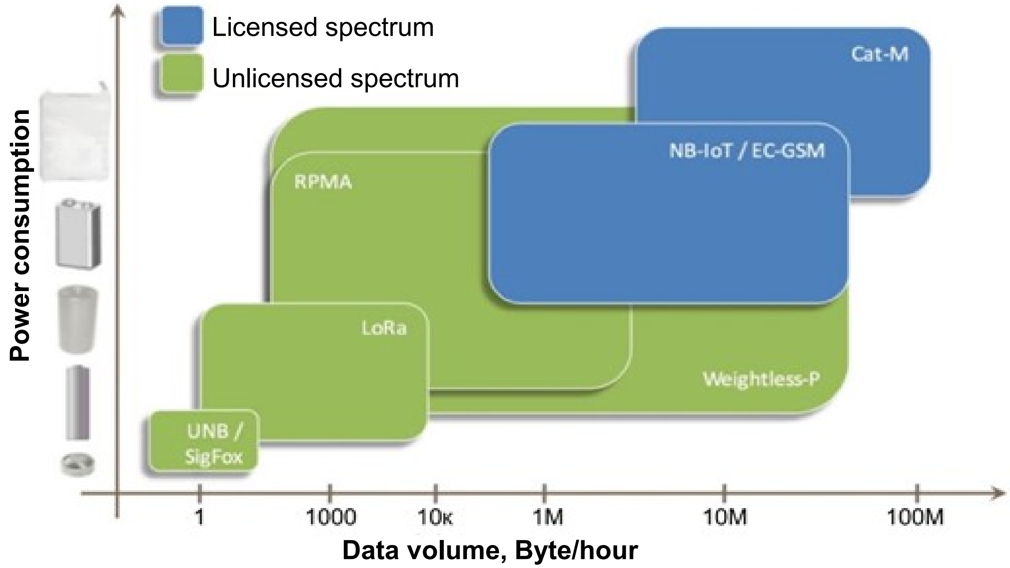
Licensed radio frequency bands below 1 GHz



Technological diversity of Radio access networks for IoT/M2M devices connecting

LPWANs can accommodate packet sizes from 10 to 1,000 bytes at uplink speeds up to 200 Kbps. LPWAN's long range varies from 2 km to over 10 km, depending on the technology.





Standards for local applications – Low Power Area (LPLA)

Comparison of LPWAN Radio Access Technologies for IoT/M2M Devices Connection

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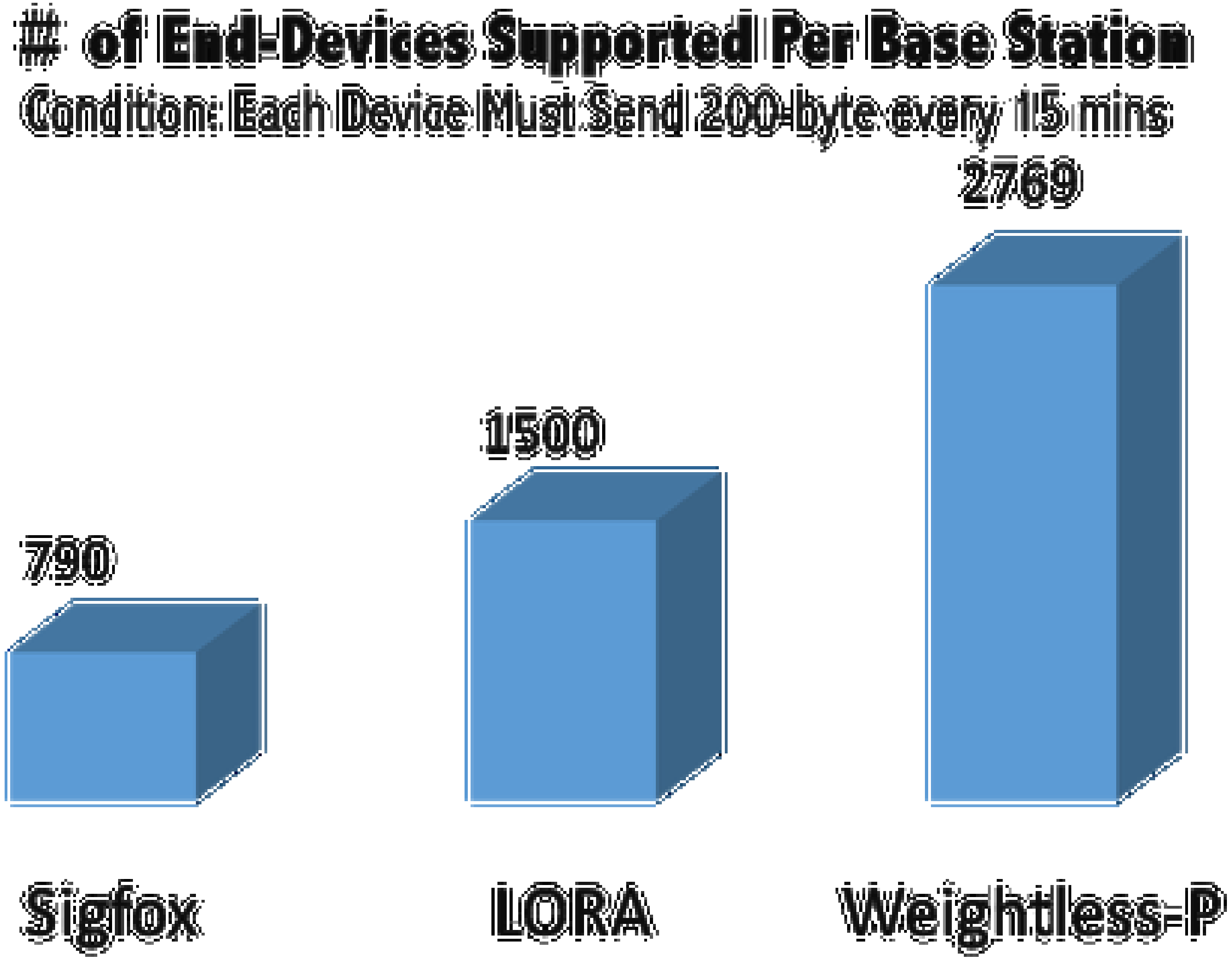
Technical characteristics	LoRa	SIGFOX	NB-IoT	Weightless P
Modulation method	CSS	–	OFDMA/DSSS	FDMA / TDMA
Band	ISM	ISM	Lisensed	ISM
Rate	0,3-50 kbit/s	100 kbit/s	**UL**: 1-144 kbit/s **DL**: 1-200 kbit/s	0,2-100 kbit/s (adaptive)
Bandwidth	Wide <500 kHz	Narrow 100 kHz	Narrow 200 kHz	Narrow 12,5 kHz
Autonomy time	> 10 years	–	< 10 years	3-5 years
Frequency	868,8 MHz (Europe) 915 MHz (USA) 433 MHZ (Asia)	868,8 MHz (Europe) 915 MHz (USA)	700/800/900 MHz	169/433/470/780/ 868/915/923 MHz
Security	AES-64 & 128 Byte	AES & HMACs	–	AES-128 / 256
Range	Up to 2,5 km in urban parts, up to 45 km in rural parts	Up to 10 km in urban parts, up to 50 km in rural parts	–	Up to 2km in urban parts
Support	LoRa Alliance, IBM, Cisco, Actility, Semtech...	SigFox, Samsung	3GPP, Ericson, Nokia, Huawei, Intel...	Ubiik Weightless SIG

Bandwidth of LPWAN Technology Base Stations with Unlicensed Spectrum Access



Unlicensed SigFox Technology

SigFox technology was invented and patented in 2009 by a French company with the same name. Now the office of the company is located in the south of France near the city of Toulouse. The first SigFox network was deployed in France in 2012, and by 2014 the nationwide coverage of the country was provided.

By 2015, SigFox planned to enter the US market, but it faced problems in the USA-allowed frequency range of 902 MHz. The frequency range used in the USA is more susceptible to interference than the European range. At the same time, SigFox technology has spread to the countries of the Asia-Pacific region.

Currently, SigFox is present in more than 60 countries. However, there are no SigFox networks in CIS Countries and in Russia yet.

Technical Characteristics of SigFox Technology

SigFox uses an ultra-narrow frequency band (UNB) with binary phase shift keying (BPSK) for data transmission and changes the carrier wave phase for data coding. This allows you to reduce the noise level on the receiving side, hence making receiving devices cheaper.

- **range: 30-50 km** (3-10 km in noisy and inaccessible areas);
- lifetime of devices without battery replacement: **20 years from 2 AA batteries**;
- frequency bands: **868 MHz** (Europe) and **902 MHz** (USA);
- network topology: a star (the base station to which the endpoints are connected).

The existing SigFox standard defines the maximum number of messages from the base station to the end device per day: **140 messages**, with each message being **no more than 12 bytes** in size (excluding the message header and transmission information). And also the number of messages originating from the target device: 4 messages per day with payload of 8 bytes.

Architecture of SigFox Network

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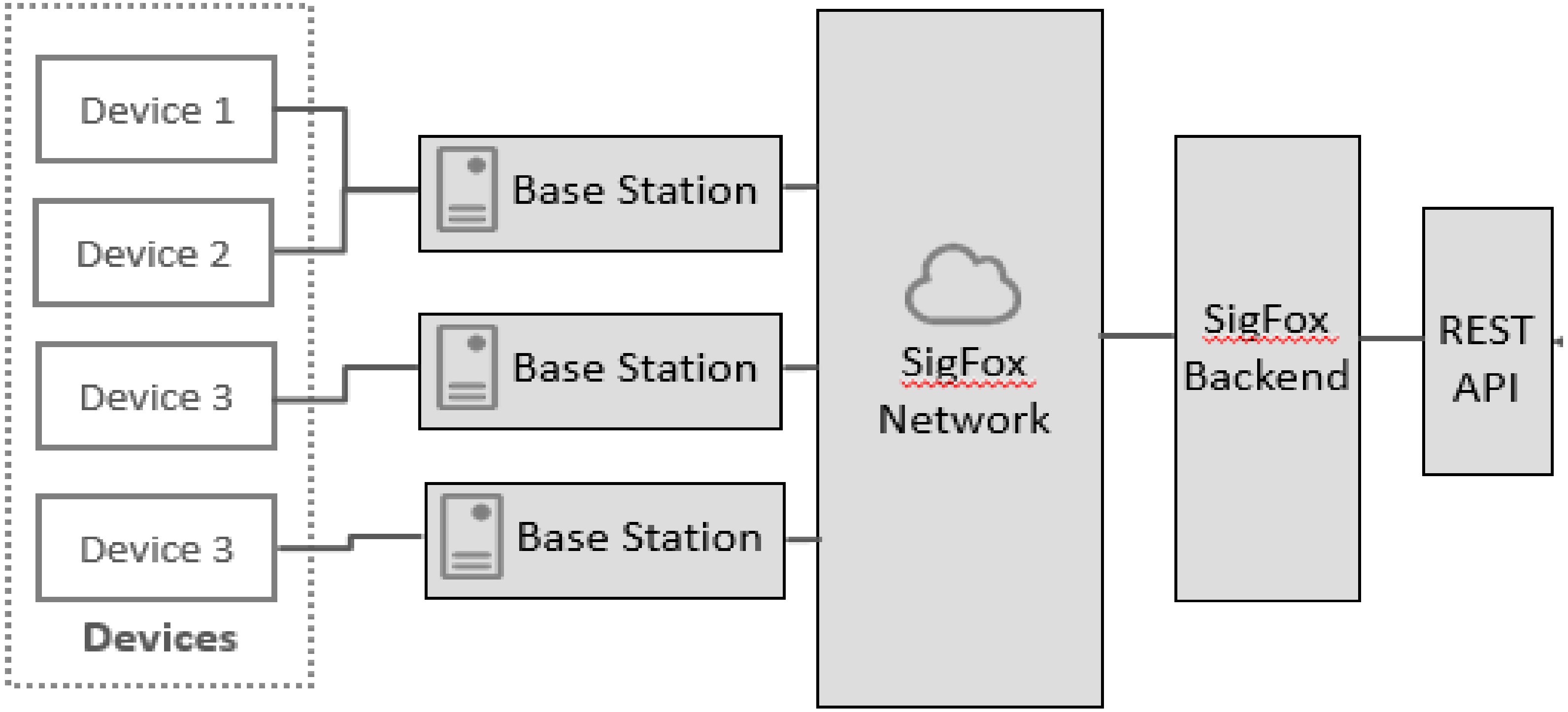


SIGFOX network is similar to the cellular infrastructure, but it is less expensive. SIGFOX uses an ultra-narrow band (UNB) based on radio technology to connect devices to the global Internet.

The use of UNB is a key factor in ensuring a very low power level of the device transmitter. The network operates in Europe in the widely used band 868.8 MHz (as defined in ETSI and CEPT), and in the USA it operates in band 915 MHz (as defined by FCC).

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).

The nodes can connect directly to each other and immediately send messages, while sending is free **in P2P mode**. A combination of SIGFOX and P2P modes is used **in Hybrid mode**. It allows only certain messages to be sent over the network. In this case one node is used as the network gateway (P2P + SIGFOX mode) and the other nodes are in P2P mode.

Unlicensed Weightless Technology

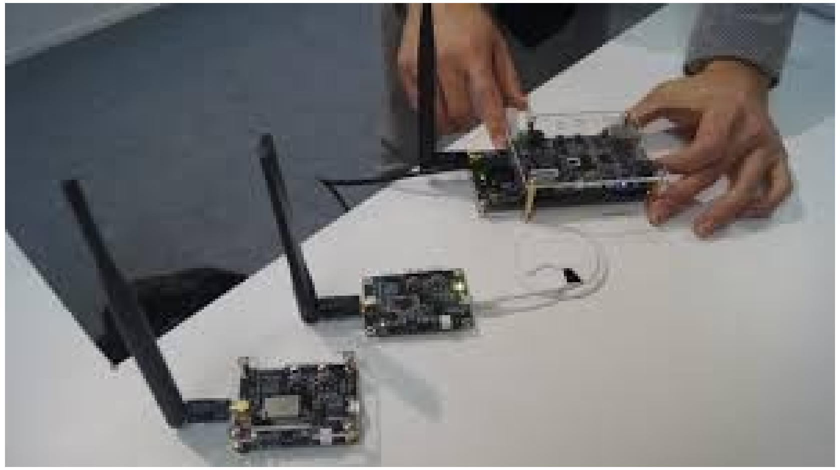
The Weightless Technology family is an open standard for high-power LPWAN networks designed for network performance. Special Interest Group (SIG) offers a family of three different protocols - Weightless-H, Weightless-W, and Weightless-P, which support various forms and uses.

Weightless-W technology is an open technology standard, designed for operation at 470-790 MHz TV range frequencies (TV white space, TVWS). Weightless-W technology with 5 km coverage zones is suitable for use in applications for the oil and gas industry.

Weightless-N technology is designed for creating wide coverage areas at low data rates of 500 Bits/s. It provides unidirectional communication up to 10 km. Weightless-N supports a wide range of ISM frequencies and low power consumption. Weightless-N is ideal for sensor networks for temperature measurement, reservoir level control and much more.

Weightless-P technology is a technology standard designed for narrowband IoT solutions that require high density devices, long battery life and bi-directional communication. Features of this technology are scalability, the ability to optimize communication lines down or up, creating wide coverage areas, long battery life and network security.

Technical Characteristics of Weightless-P Technology



Weightless-P uses 12.5 kHz narrowband channel, which makes it possible to transmit 7 times more data than SIGFOX, and 98 times more data than LoRaWAN in urban conditions.

The main characteristics of Weightless-P:

- used frequency channel width - 12.5 kHz;
- sensitivity – 134 dBm for 0.625 Kbps;
- transmitter power of the subscriber unit - 14 dBm;
- use of synchronized communication channels (TDMA/FDMA);
- spectral-effective modulation - OQPSK;
- use of any ISM frequency bands for deployment: 169/433/470/780/868/915/923 MHz;
- provides roaming;
- communication range of 2 km in urban parts;
- synchronization time of base stations for efficient radio resource planning and use;
- the possibility of sharing infrastructure;
- adaptive data transfer rate: 200 bit/s - 100 kbit/s;
- transmission power control in the lines down and up reducing interference and increasing network bandwidth.

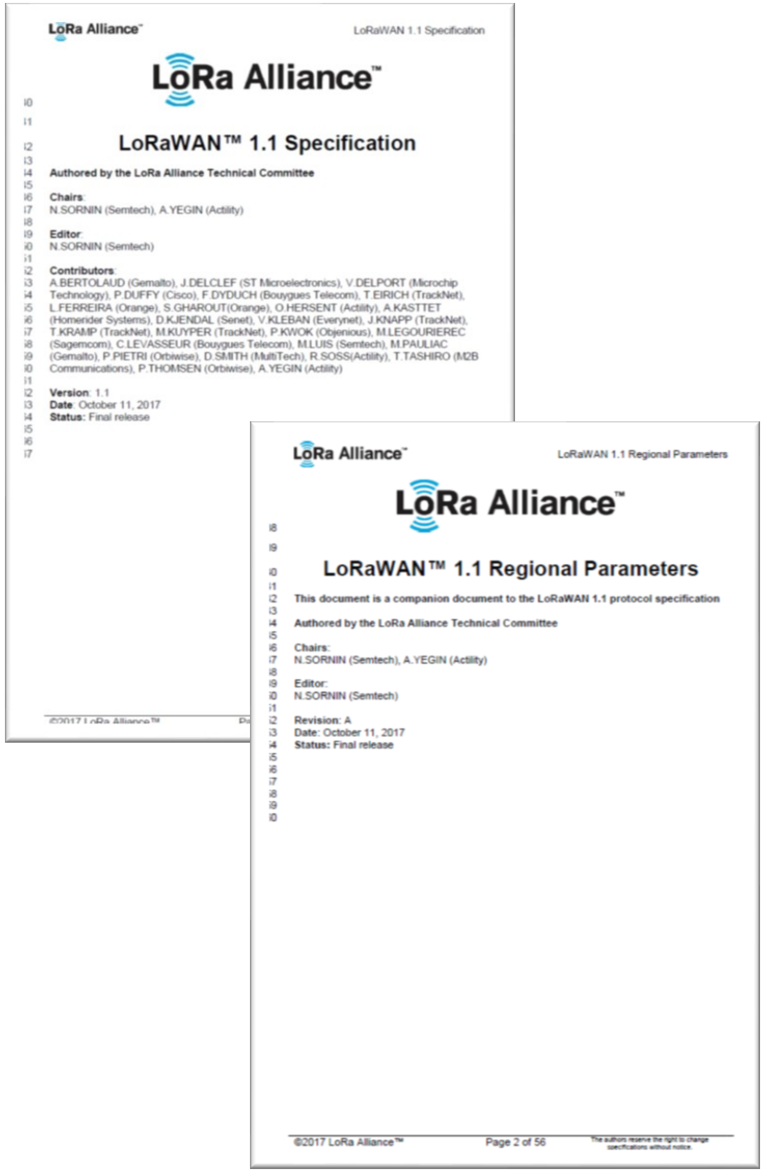
LoRaWAN Technology Features

LoRa technology is a radio technology that allows the creation of radio access networks to connect different sensors at a great distance with various applications of Internet of Things.

LoRa technology is based on the technology of spreading spectrum, which allows to increase the communication range by almost 10 times in comparison with conventional direct radio systems with the same characteristics of transmitters. This is achieved by applying:

- chirp spread spectrum (CSS) modulation;
- Frequency Shift Keying (FSK) signals;
- broadband spread spectrum modulation; the data is encoded by wide-frequency pulses with linear frequency modulation (LFM) with a frequency increasing or decreasing over a certain time interval with a spreading factor SK = 7-12.

Standardization of LoRaWAN Technology by the LoRa Alliance



LoRa Alliance™ LoRaWAN 1.1 Specification

LoRa Alliance™

LoRaWAN™ 1.1 Specification

Authored by the LoRa Alliance Technical Committee

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LoRa Alliance™ LoRaWAN 1.1 Regional Parameters

LoRa Alliance™

LoRaWAN™ 1.1 Regional Parameters

This document is a companion document to the LoRaWAN 1.1 protocol specification

Authored by the LoRa Alliance Technical Committee

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Editor:
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The equipment manufacturers and operators have created a consortium - the LoRa Aliance, which is developing and improving the technical characteristics of LoRa and business models. Manufacturers: Actility, Cisco, Eolane, IBM, Kerlink, IMST, MultiTech, Sagemcom, Semtech, and Microchip Technology; operators: Bouygues Telecom, KPN, SingTel, Proximus, Swisscom, and FastNet.

The creation of LoRa Aliance was announced formally at the Mobile World Congress MWC-15 in Barcelona.

The first release of technical specifications LoRaWAN 1.0 was published in June 2015. Then there was a 3-year development of LoRa technology in Releases 1.0.1 to 1.1.

Current specifications:

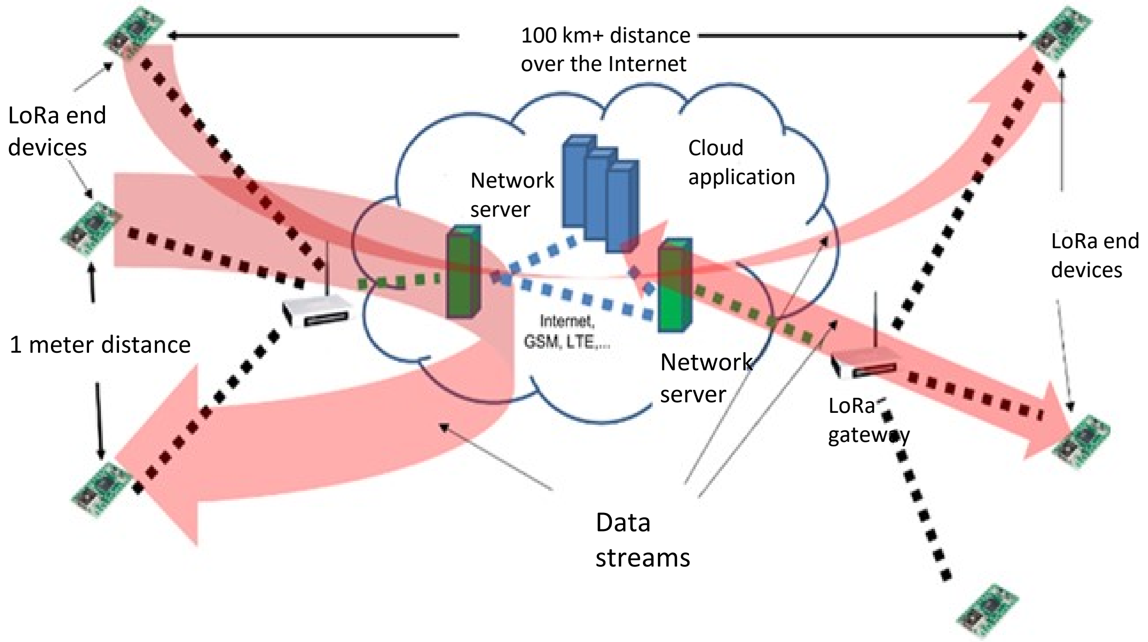
1. LoRaWAN ™ 1.1 Specification, 2017 LoRa Alliance, Inc.
2. LoRaWAN ™ 1.1 Regional Parameters, 2017 LoRa Alliance, Inc

Differences in Regional LORAWAN Technology profile

The technical characteristics of LoRa technology networks differ depending on Regulator requirements. For example: CEPT in Europe and FCC in the USA. LoRaWAN networks in Europe use ISM-band channels defined by the ETSI EN 300.220 standard in the 864-868 MHz band at the discretion of the network operator.

Parameters	CEPT Regulations	FCC Regulations
Frequency range, MHz	867-869	902-928
Number of radio channels	10	64+8+8
Radio channel width, kHz	125/250	125/500
Transmission Power, line up	+14 dBm	+20 dBm typical (+30 dBm permissible)
Transmission power, line down	+14 dBm	+27 dBm
SF spectrum spreading coefficient in the uplink	7-12	7-10
Data transfer speed	250 bps – 50 Kbps	980 bps – 21,9 Kbps
Downlink budget, dB	155	154
Uplink budget, dB	155	157

The Architecture of LoRaWAN

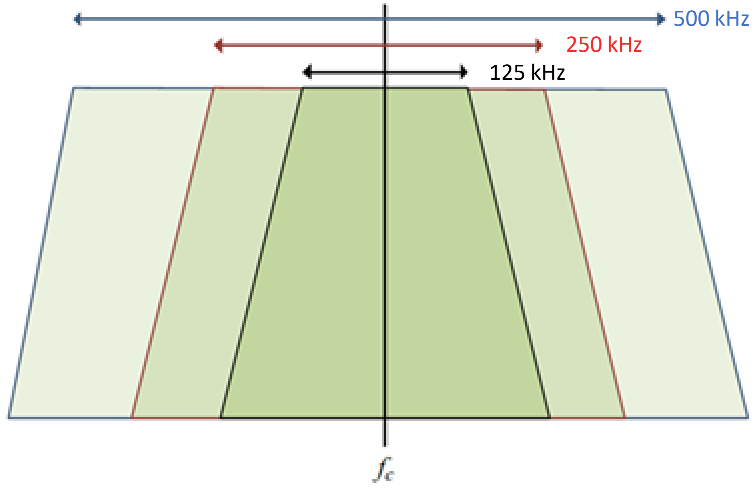


LoRa technology is based on two main elements:

- **The physical layer radio interface** that defines all aspects of radio signals transmission between different network nodes (LoRa gateways) and terminal devices (IoT sensors). The physical air interface LoRa is based on the use of **broadband radio signals with a large base B**, which is much greater than one. The LoRa radio interface sets operating frequencies, modulation types, power levels and signaling between sending and receiving devices in LoRa network;
- **LoRa network architecture**, which includes IoT/M2M subscriber devices, LoRa gateways (base stations), network servers connected via the transport network to the Internet and the application server.

The IoT/M2M **subscriber devices** of LoRa network are, as a rule, devices that include sensors or sensors in addition to the modem which transmit data only at short intervals according to a given schedule.
LoRa gateways (base stations) are designed to build a radial network architecture (a "star" type) of a long range based on LoRaWAN technology.
The central server of LoRaWAN network which addresses devices (end-node), gateways of the network and c LoRaWAN access network with the application server.

Unlicensed Spectrum utilization by LoRaWAN Technology



LoRa technology typically uses unlicensed spectrum segments that are defined and regulated on the basis of regional restrictions defined in LoRaWAM 1.1 Technical Specification Regional parameters represents the following frequency bands:

430 MHz - for the regions of Asia;
780 MHz - for the region of China;
433 MHz - for the Europe region;
866 MHz - for the Europe region;
915 MHz - for the USA regions.

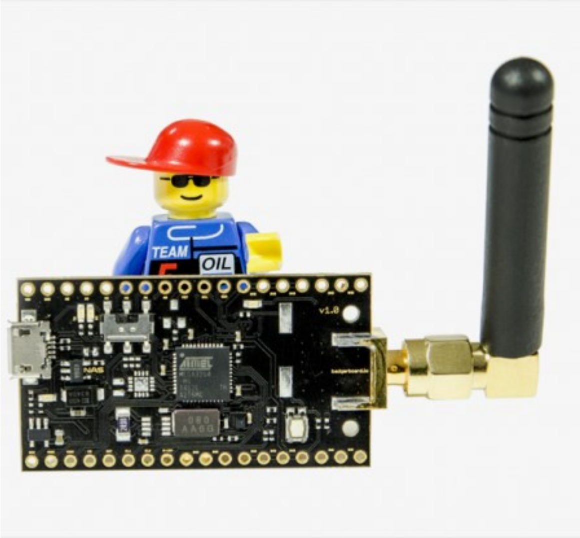
Three common access frequency channels are used in LBT mode (after mandatory listening) in the frequency band 864-868 MHz on all LoRa subscriber units and gateways**: 868.10; 868.30; 868.50 MHz**, as well as three frequency channels **864.10; 864.30; 864.50 MHz** in order to guarantee the receipt of requests (JoinReq message) in the broadcast shared channel for the network management.

LoRa transceivers generate CSS radio signals with bands of 125, 250 and 500 kHz. LoRa technology supports the different frequency bandwidth and rate in the IoT/M2M network:

- from 250 bps to 5.47 kbps with a **channel width of 125 kHz**;
- up to 11 kbps with a **channel width of 250 kHz**;
- up to 50 kbps with FSK modulation with a **channel width of 500 kHz**.

Typical values of the radio channel width for LoRa network depend not only on technological solutions, but also on requirements of regional regulators of the radio-frequency spectrum.

Characteristics of User Equipment of the LoRaWAN Network



LoRa network IoT/M2M subscriber devices are, as a rule, sensors that transmit data only at short intervals on a given schedule and are **divided into three classes**. Each class has its own characteristics, determined by the purpose:

- Bidirectional **Class A** endpoint devices.

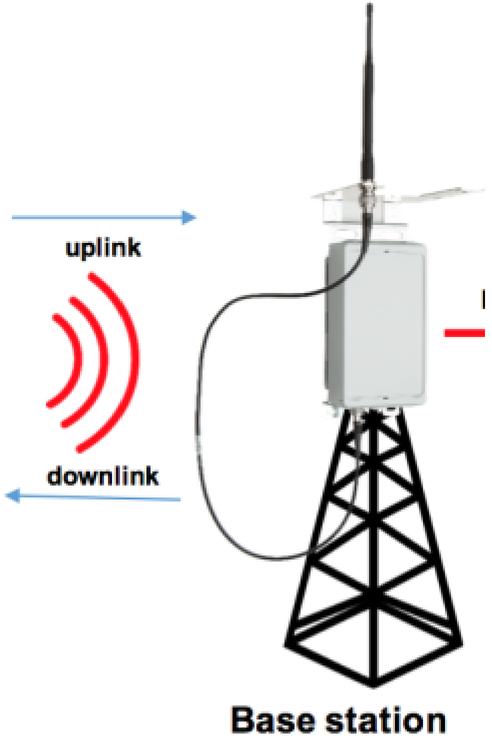
Such LoRa devices allow bidirectional exchange and data transfer to the gateway by short bursts according to a specified schedule. The connection initiates the device, after which it allocates two time windows during which a response from the server is expected. The transmission interval is planned by the end device. Class A devices have the lowest power consumption and are used in applications where data transfer from the server is required only after the end device sends data to it. The transfer of data from the server to the end node is possible only after the latter is contacted.

- Bidirectional end devices of **class B**.

Such devices in addition to the functions of Class A devices open an additional receiving window according to a specified schedule. They are synchronized by a special reference signal from the gateway (beacon) in order to open the receiving window. This allows the server to determine the point in time when the destination device is ready to receive the data.

- Bidirectional **Class C** endpoints with a maximum receiving window.

These devices have an **almost continuously open reception window**, which is closed only for the time of data transfer. This type of end devices is the most energy intensive and is [illegible] tasks where it is necessary to receive large amounts of data.



LoRa gateways (base stations) are designed to build a radial network architecture (a "star" type) of a long range based on LoRaWAN technology. The gateways are typically multichannel multimodem transceivers that can demodulate multiple channels simultaneously to ensure a high capacity of LoRa network. They even simultaneously demodulate multiple signals on the same channel. This is an ability of the gateway that directly affects the maximum density of LoRa subscriber units (end-node) on a terrain site serviced by one base station.

The gateways **serve to transfer the data between** LoRa devices (end-node) and the central server without modifying the messages themselves ("transparent bridge") and primarily playing the role of traffic concentrators and encapsulating it in IP traffic.

The connection between the BS and the central LoRaWAN server is provided by the **operator's backhaul network** based on traditional technologies (Ethernet, WiFi, GSM) over the TCP/IP protocol. If the BSs are connected to the network server via standard IP connections, the end-nodes use a wireless connection to one or more gateways. All LoRa (end-node) devices are usually bidirectional, but they also support and operate in a mode that allows the group to update the software over a radio channel or broadcast, thereby reducing transmission time. **Different versions of the LoRa BS** are available depending on the desired channel capacity and location. They can be installed **indoor** or outdoor (**on towers** or buildings).

LoRaWAN Central Server

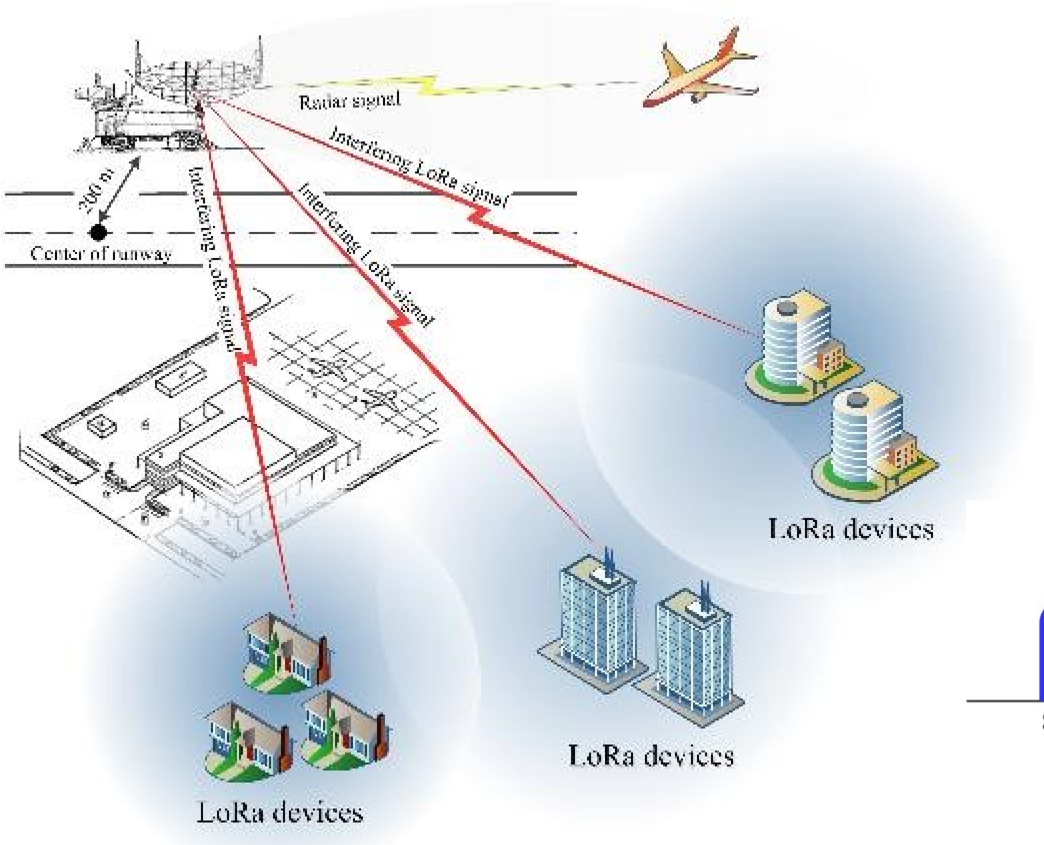
The central server of LoRaWAN network that **manages end-node devices**, network gateways and also connects LoRaWAN access network with the application server. The central LoRaWAN server of the network, which **sends control commands** through the BS to LoRa (end-node) devices in the network, **allocating time slots for sending and receiving individually** for each LoRa device (end node), solves issues of traffic collisions and BS overload. **Addressing** devices in the network occurs at the 32-bit device address, which is unique to each LoRa subscriber end-node device.

The central LoRaWAN server **decides** on the need to change the data rate of LoRa end-node devices, the transmitter power, the transmission channel selection, its start and the time duration, controls the end-node battery charge, i.e. fully monitors the entire network and manages each subscriber unit separately. Each LoRaWAN data packet sent by LoRa subscriber end-node unit has a unique application identifier AppEUI. It belongs to the application on the server of the service provider for which it is intended. This ID is used by the central LoRaWAN server for further routing the packet and its processing by the application on the application server (App Server) of the service provider. This is the service operator of Internet of Things.

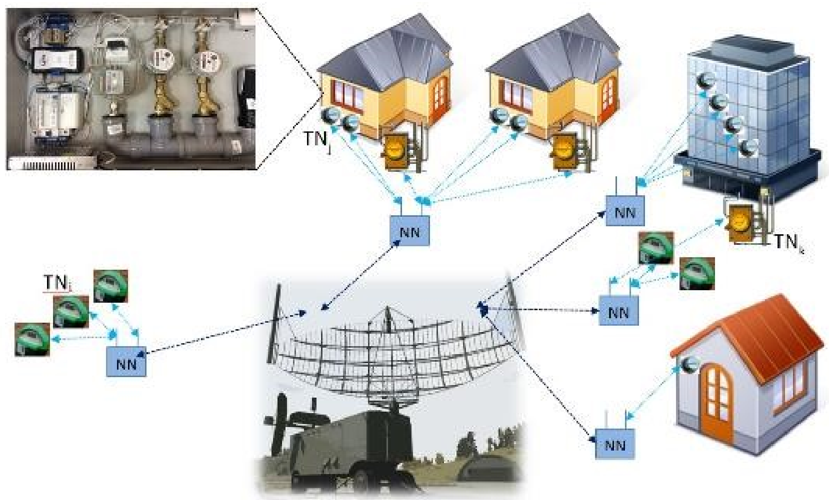
Electromagnetic Compatibility of LoRa Network with Air Traffic Control Radar in the 800 MHz Band

ТЕХНОЛОГИИ И СВЯЗЬ

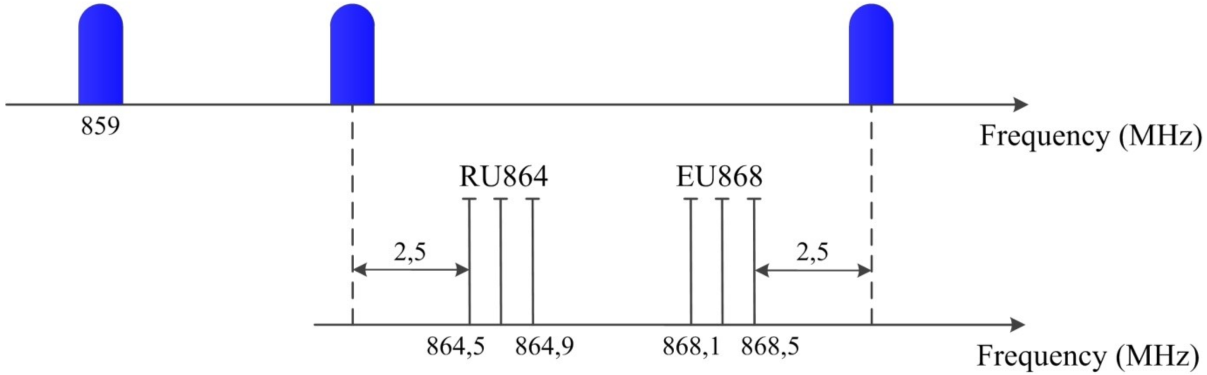
Scenarios of influence of subscriber units of LoRa technology network on the air traffic control radars in the range 800 MHz



Scenario 1. LoRa devices placement in the airport



Scenario 2. LoRa subscriber units in residential buildings close to the airport zone



LoRaWAN Market

Now there are **62 announced LoRaWAN™ operators in the world**, with coverage expansion ongoing.

Countries	IoT/M2M operator	LoRa network characteristics	Notes
France	Orange, Numericable-SFR	National network of 15 thousand BS. The first BS are deployed in Grenoble	Planned profit of 635 million dollars by 2018
USA	Senet	The network covers San Francisco, San Jose, Los Angeles, New York, Boston, Atlanta, Austin, Houston, Dallas, Chicago	More than 150 BS, covering 100 thousand square miles, 25 million people.
Belgium	Proximus	The network operates in 10 major cities of the country: Brussels, Ghent, Antwerp, Liege, and others.	Whole territory of Belgium was covered by the beginning of 2017
Russia	LACE R-Telecom MTT	The network in 15 cities with population over one million	Parking, housing and public utilities
United Kingdom **Germany**	Open TRV	One BS in Central London	Testing
Germany	Digimond	Networks in Hanover, Hamburg and Berlin	Testing

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Thank you for attention!