



**Report ITU-R SM.2423-0**  
(06/2018)

**Technical and operational aspects of  
low-power wide-area networks for  
machine-type communication and the  
Internet of Things in frequency ranges  
harmonised for SRD operation**

**SM Series**  
**Spectrum management**



## Foreword

The role of the Radiocommunication Sector is to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including satellite services, and carry out studies without limit of frequency range on the basis of which Recommendations are adopted.

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<b>SF</b>	Frequency sharing and coordination between fixed-satellite and fixed service systems
<b>SM</b>	<b>Spectrum management</b>

*Note: This ITU-R Report was approved in English by the Study Group under the procedure detailed in Resolution ITU-R 1.*

*Electronic Publication*  
Geneva, 2018

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## REPORT ITU-R SM.2423-0

**Technical and operational aspects of low-power wide-area networks  
for machine-type communication and the Internet of Things  
in frequency ranges harmonised for SRD operation**

(2018)

**1 Introduction**

A new type of wireless systems has been developed under the generic name of Low-Power Wide-Area Network (LPWAN) that may operate under the regulations for short range devices (SRD). Such innovations complement the range of existing wireless solutions. LPWAN systems do not rely on a single technology, but a group of low-power, wide-area network technologies that may be proprietary or open standards.

These new systems can help to address the challenges raised by the wide-ranging applications under development where numerous devices need only to transmit a few messages per day. Section 4 of this Report provides details on the applications targeted by LPWAN, such as those related to smart cities, manufacturing, home automation, environment and agriculture, transport and logistics, energy and utilities.

These solutions have a number of common technical and operational characteristics that make them suitable for facilitating massive Machine Type Communications (mMTC) and Internet of Things (IoT) applications.

Section 5.1 of this Report provides details on technical aspects, including common spectrum access techniques, a flat network architecture, and frame sizes in the order of tens of bytes transmitted a few times per day at ultra-low speeds.

Section 5.2 of this Report provides details on LPWAN operational capabilities enabling a massive number of connections from cost efficient radio equipment with relatively low output power levels to provide connectivity on average over several kilometres, while maintaining longer battery lifetimes.

In response to Resolution ITU-R 66 "Studies related to wireless systems and applications for the development of the Internet of Things, this Report provides the technical and operational aspects of LPWAN for MTC and IoT in frequency ranges harmonised for SRD operation"

**2 Relevant ITU-R Resolutions, Recommendation and Report**

- Resolution ITU-R 54 "Studies to achieve harmonization for short-range devices"
- Resolution ITU-R 66 "Studies related to wireless systems and applications for the development of the Internet of Things"
- Recommendation ITU-R SM.1896 – Frequency ranges for harmonization of short range devices
- Report ITU-R SM.2153 – Technical and operating parameters and spectrum use for SRDs

**3 Abbreviations**

AFA	Adaptive frequency agility
APC	Adaptive power control

APT	Asia-Pacific Telecommunity
CEPT	Conference of Postal and Telecommunications Administrations
CFR	Code of Federal Regulations (United States of America)
CSS	Chirp spread spectrum
DL	Down-Link communications from access stations to devices
ETSI	European Telecommunications Standards Institute
IETF	Internet Engineering Task Force
ISM	Industrial, scientific and medical
IoT	Internet of Things
LPD	Low power devices
LIPD	Low interference potential devices
LPWAN	Low power wide area network
LTN	Low throughput network
M2M	Machine-to-Machine
MTC	Machine type communications
mMTC	massive Machine Type Communications
RFID	Radio frequency identification
SDR	Software defined radio
SDO	Standardization Development Organization
SRD	Short range devices
UL	Up-Link communications from devices to access stations
UNB	Ultra-narrow band
xPON	Passive optical networking

#### 4 IoT applications based on LPWAN system

LPWAN can support the various physical devices connected to the IoT network to optimize the efficiency of city operations and services and connect to citizens. Amongst the sectorial applications foreseen, a range of typical use cases covered by LPWAN systems has also been described in ETSI TR 103 249 V1.1.1 (2017-10) on Low Throughput Network (LTN), a subset of LPWAN sensors and control networks.

Some examples of use cases based on existing LPWAN solutions are listed below:

- **Traffic and transportation system management**  
LPWAN can support strategically placed devices with sensors to detect lights working status on a 24×7 basis, with minimal chances of congestions or accidents.
- **Water supplying system**  
LPWAN can support sensors/devices to tackle faulty or outdated infrastructure in cities, by detecting leakages and overflows, and notifying the authorities.
- **Public lighting**  
LPWAN technology can be utilized for the management of these smart public lighting networks, and enhance safety considerations as well by relaying information/scenes of road accidents/roadblocks to nearby locations.

– **Smart parking system**

LPWAN can be used for optimal utilization of municipal parking lots and areas through informing users about available parking spot(s) nearby.

– **Pollution monitor**

For rapidly rising environmental pollution, LPWAN technologies can play its part in maintaining the ecological balance with smartly placed sensors informing the concerned officials about the pollution monitors in the locality. In the vicinity of power plants and heavy industries, these devices can track the overall consumption/wastage of environmental energy as well.

– **Waste bin management**

LPWAN can help for proper waste management with smart sensors to detect the fill-level of the bins when they are full and need to be emptied. And these sensors are also expected to collect data on the type of waste being disposed of by the public.

– **Smart freight and inventory management**

LPWAN powered sensors can be a handy addition in smart inventory systems (i.e. in the freight trucks and the ports between which they carry the inventory). The sensors would relay regular, updated information on the location of the freight vehicles and the status of the inventories. And LPWAN can also notify the operators as and when running repairs and other maintenance work have to be done on the freight vehicles.

– **Fire detection systems**

Fire alarms and sensors powered by LPWAN technology can be used to swiftly sent emergency notifications to the local fire departments to provide relief and limit the extent of damages.

– **Connected fire hydrants**

Those devices help the detection of faulty hydrants and frauds. They could also monitor the water usage of fire hydrants.

– **Urban green spaces management**

Soil moisture, soil temperature, outdoor temperature sensors optimize the management of public green spaces and reduce water consumption.

– **Energy consumption**

Monitoring systems enable more accurate and frequent billing.

– **Livestock Management**

Localisation system for livestock farms offers monitoring and traceability capabilities, detecting anomalies due to changes such as the temperature, activity, behaviour and calving of the livestock.

– **Smart irrigation**

Reduce the amount of water resource usage and enable the development of irrigation strategy to attain marketable products and to reduce product losses.

– **Package Pick-up Service**

Smart button placed inside the mailbox can notify the mailman that a package has been placed in it and allow customers to send packages from home.

– **Industrial asset management system**

Spare part tracking between factories and suppliers' sites.

– **Battery management of railroad crossing's fences**

The solution limits the service failure of critical assets. The maintenance operator is instantly notified of any detected events on the backup power supply.

– **Stolen Car Recovery**

Locate and recover stolen assets through a small and hidden GPS tracking device.

## 5 Technical and operational aspects of LPWAN

### 5.1 Technical aspects

Main technical commonalities of LPWAN to address massive IoT use cases are listed in the following sections. The following typical values come from standards and regulations under which LPWAN systems operate worldwide (i.e. ETSI EN 300 220, 47 CFR 15.247, etc.).

#### 5.1.1 Transceiver parameters

– **Transmitter output power/radiated power**

LPWAN systems connect objects and devices through gateways and access stations. All systems are not always balanced and the equivalent isotropic radiated powers vary according to the technologies and the role of each transmitter in the systems.

Typical values range (e.i.r.p.) between 200 mW to 4 W for the access stations and 5 mW to 500 mW for the end-points.

– **Antenna characteristics**

Most of the transmitters use omnidirectional antenna. Typical value ranges between 0 dBi to 6 dBi.

– **Class of emission**

There is no specific class of emission used for LPWAN systems. Most of the systems use complex or combination of digital modulations.

– **Modulation bandwidth**

This parameter depends upon the technology used. Typical modulation bandwidths range from 100 Hz to 500 kHz.

– **Unwanted emissions**

Low power devices (LPD) must comply with the unwanted emissions set by relevant regulations and standards. Typical limits of the ITU Regions are based on Recommendation ITU-R SM.329 and are further described in the Report ITU-R SM.2153 on technical and operating parameters for short-range radiocommunication devices. These limits should be defined in accordance with services and systems allocations in adjacent bands.

– **Receiver sensitivity**

LPWAN systems have extremely high sensitivity (i.e. -140 dBm in 100 Hz) which enables low power devices and equipment to provide long range communication. This is a key characteristic of LPWAN systems, which rely on various techniques such as follows:

Ultra-narrow bands (UNB) solutions, where high selectivity filtering combined with narrower signal bandwidth improves sensitivity threshold (see ETSI TR 103 435 V1.1.1).

Direct Spread Spectrum or Chirp Spread Spectrum (CSS) techniques which reduce the sensitivity level below the noise floor thanks to coding gain depending on the spreading factor (see ETSI TR 103 526 V1.1.1).

### 5.1.2 Spectrum access techniques

LPWAN systems are mostly made to support massive IoT use cases with low throughput requirements. Spectrum access for LPWAN may be considered under short-range device regulations that are generally considered licensed-exempt with specific access conditions for different applications.

In addition to spectrum management techniques generally used for short-range devices, LPWAN systems may employ random access techniques using system design mechanisms to maximize sharing between systems and to optimize traffic capacity and quality of service.

Mechanisms or restrictions to ensure appropriate sharing between all LPWAN users are typically a "duty cycle" limit ranging from 1% to 10%, "adaptive frequency agility" systems that rely on spectrum sensing or "listen before talk", and "frequency hopping" functionalities.

Software Defined Radio (SDR) capabilities combined with time and frequency diversity are also often used in access stations to enhanced traffic capacity management and the quality of service.

### 5.1.3 Access stations functionalities

The gateway functionalities are generally divided between access stations and core infrastructures.

The access stations are deployed between the devices and the communication networks and can use different communication technologies (e.g. 3G, 4G, xPON, Wi-Fi and Ethernet) to transfer data to the LPWAN core network. They support communication bridging between devices and communication networks, and multiple communication technologies to interact with communication networks and SRD.

This main function is complemented by additional capabilities which contribute to end-to-end security and identification features in the system.

## 5.2 Operational aspects

### 5.2.1 Massive number of connections

The typical topology of LPWAN systems is a star topology where tens to hundreds of thousands of devices, in a given area of services, are connected to one access station. The expected node density of LPWAN is the following:

- devices: up to 100k end-points per square kilometre;
- access stations: typically, 1 per 10 square kilometres (or 0.1 per km<sup>2</sup>).

LPWAN systems are intended for carrying a low volume of traffic per device, typically up to 1 kbyte of user data per day in each direction: uplink, from a device to an access station, and downlink from an access station to a device.

The pattern of data flow depends on the application. Some examples from ETSI TR 103 249 V1.1.1 (2017-10) on LTN use cases and system characteristics are provided in Table 1.

TABLE 1

**Examples of traffic characteristics in LPWAN**

<b>Business Area</b>	<b>Detailed need</b>	<b>Tx Period</b>	<b>Payload size</b>	<b>Communication</b>
Water Metering	Index transmission	4/day 1/day	10 200	Mainly UL
Smart Cities	Smart parking	min. to hours	A few bytes	UL and DL
	Sewage management	1/day to 5/day	1-15 bytes	Mainly UL
	Gunshot detection	Occasionally	10-100 bytes	UL
Automotive	Geo-location assistance	Occasionally	250-1 000 bytes	UL and DL
	Out of hours driving	Occasionally	100-200 bytes	UL or UL+DL
	Stolen vehicle monitoring	1/min	10-20 bytes	Mainly UL
Electric network monitoring	Transformer monitoring	1/hour	10-20 bytes	UL
	Fault path detection	Once a year	3 bytes	Mainly UL
Agriculture	Soil quality	1/day – 4/day	Few bytes per sensor	UL

In order to mitigate the risks of spectrum congestion or traffic overload, some LPWAN systems may use spectrum management strategies to improve their communication functionalities.

The spectrum adaptation functionalities can include features such as transmission scheduling, Adaptive Power Control (APC), data rate adaptation, spectrum occupancy detection or interference detection, Adaptive Frequency Agility (AFA), etc.

### **5.2.2 Wide coverage capability**

IoT addresses a large range of industry sectors; therefore, it is anticipated that LPWAN may provide coverage to both urban and rural areas where devices need internet connectivity. LPWAN use digital radio communication that gives a high link budget, even with a low power transmitter in the devices. This feature can be enabled with improved sensitivity through modulation techniques (such as UNB and CSS) and is enhanced by mean of SDR implementations.

### **5.2.3 Energy efficiency and battery lifetime**

Large fleets of scattered devices require long battery life to reduce operational cost and ensure long term services. LPWAN are originally designed to optimize battery consumption to connect battery-powered devices with lifetimes up to 15 years. The optimisation of power consumption in devices is obtained by using low transmit power and by reducing the protocol overhead in sleep mode. The reduction of protocol overhead in sleep mode is possible with "attachment-less" protocol: devices transmit without prior synchronisation or connection to the network. Access stations use software defined radios to listen the operational spectrum continuously.

### **5.2.4 Reduced complexity and cost efficiency**

LPWANs address massive connection of IoT devices. This type of deployment scenario requires both simplicity and cost efficiency. Out-of-the-box connectivity, without the burden of device



provisioning in the field, is a key enabler for the LPWAN adoption. Management of the devices and their connectivity registration throughout their entire life is also mandatory for applications where economic balance is only possible with a massive number of nodes and/or sensors.

## **6 Consideration on authorization regimes for LPWAN**

LPWAN are designed to operate in a radio environment with multiple stakeholders using the same bands (other LPWAN, alarms, RFID, etc.) with a low interference potential. With this respect LPWAN systems comply with the definition of SRD from Report ITU-R SM.2153, as they provide either unidirectional or bidirectional communication and have low capability of causing interference to other radio equipment.

LPWANs do not require exclusive access to spectrum and operate in shared spectrum environment on a non-interference and non-protection basis.

The general authorisation regime, or licence exemption, is generally applied when no geographical coordination is needed to ensure coexistence between radio services and systems. This category of regime authorizes any stakeholders to access the spectrum, provided the radio equipment complies with spectrum access requirements and operational conditions. General authorization scheme would allow LPWAN application in the field to use the spectrum without needing to secure an individual license. In some cases, where additional coordination is required, a light licensing regime may be applied.

## **7 Spectrum considerations to enable LPWAN operation**

### **7.1 Types of spectrum needed**

Spectrum requirements for LPWAN vary according to the technologies used and the traffic scenarios. In the case of LPWAN based on UNB systems, ETSI TR 103 435 showed that for very dense urban areas, a required bandwidth estimated at 600 kHz for uplink communication can support 55 000 messages per day per square kilometre by 2023. Another band of 600 kHz is also required for downlink.

Market and technical developments have led to a general support from industry to deploy and operate LPWAN in sub-1 GHz bands. These bands offer propagation characteristics, which allows for better coverage areas and building penetration than higher frequency bands. These characteristics make it possible to deliver mMTC services into less densely populated areas and inside buildings.

More specifically, LPWAN solutions, which are designed to operate in a shared spectrum environment in the sub-GHz range, are anticipating deployment in SRD bands. The implementation of the same spectrum access techniques and minimum requirements as those used for SRDs is particularly appropriate to support a very large number of low power and low throughput devices. In this way, new digital technologies, capable of providing innovative services and coexisting with other technologies, can be deployed in the same frequency bands.

Most of the devices connecting to LPWAN use the same eco-system of chipsets and modules as those used for the existing SRD market. This commonality, combined with existing regional harmonization of SRD bands, contributes to LPWAN increasing the manufacturing economies of scale.

### **7.2 Examples of frequencies used to support the implementation of LPWAN**

Spectrum harmonization can bring many socio-economic advantages:

- greater reliability and power efficiency of devices when travelling abroad;

- broader manufacturing base and increased volume of equipment (globalization of markets) resulting in economies of scale and expanded equipment availability;
- reduced cost of devices for customers and solutions providers;
- reduced risk of harmful interferences between systems.

Recommendation ITU-R SM.1896 provides frequency ranges for harmonization of short range devices.

Report ITU-R SM.2153 provides the technical and operational parameters and spectrum use for SRDs.

LPWAN systems are currently deployed spectrum bands harmonized regionally for SRD as follows.

– **ITU Region 1**

In CEPT countries, most of LPWAN infrastructures are operated in the 865-870 MHz SRD band. In particular, they rely on the bands 865-868.6 MHz at 25 mW e.r.p. and 869.4-869.65 MHz at 500 mW e.r.p. by using mitigation techniques like duty cycle restriction. Equipment should comply with the ETSI EN 300 220.

Similarly, LPWAN systems are operated under those conditions in some African and Middle Eastern countries that have implemented SRD regulations in the 865-870 MHz range.

– **ITU Region 2**

In the 902-928 MHz ranges, unlicensed usage with a transmit power up to 4 W e.i.r.p. is generally enabled. An example may be found in 47 CFR 15.247.

– **ITU Region 3**

LPWAN deployments are done on a country specific basis. Recently, several administrations in Asia-Pacific have authorised LPWAN services in 915-925 MHz range on the basis of different spectrum access techniques and standards, such as ARIB STD-T-108 in Japan.

Europe/CEPT has recently studied SRD operation in the 900 MHz range (917.3-919.4 MHz) and is planning to finalize relevant regulations in 2018, enabling a band for SRDs that could be used for LPWAN systems in countries of all three ITU Regions.

TABLE 2  
Examples of frequency usage for LPWAN

Frequency range	Relevant Recommendation and Report	Remarks	Region 1	Region 2	Region 3
865-870 MHz	Rec. ITU-R SM.1896 Report ITU-R SM.2153	The whole of this band can be considered as a tuning range. Only parts of this tuning range are operationally available for LPWAN in a number of countries due to the use by commercial mobile systems or restrictions on the scope of SRD applications. See national regulations.	Available	Not available	Available in some countries
902-915 MHz	Rec. ITU-R SM.1896 Report ITU-R SM.2153	902-928 MHz is an ISM band in Region 2 (RR No. <b>5.150</b> ). The whole band can be considered as a tuning range. This band is not operationally available for LPWAN in a number of countries including in Region 2, due to the use by commercial mobile systems	Not available	Available in some countries	Not available
915-928 MHz	Rec. ITU-R SM.1896 Report ITU-R SM.2153	902-928 MHz is an ISM band in Region 2 (RR No. <b>5.150</b> ). The whole band can be considered as a tuning range. Only parts of this tuning range are operationally available for LPWAN in a number of countries due to the use by commercial mobile systems or restrictions on the scope of SRD applications. See national regulations.	Available in some countries.	Available	Available in some countries