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SIGFOX System Description  
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## Abstract

This document presents an overview of the network architecture and system characteristics of a typical SIGFOX Low Power Wide Area Network (LPWAN). It is intended to be used as background information by the IETF LPWAN group when defining system requirements of different LPWAN technologies that are suitable to support common IP services.

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## [1.](#) Introduction

This document presents an overview of the network architecture and system characteristics of a typical SIGFOX LPWAN, which is in line with the terminology and specifications defined by ETSI [[etsi unb](#)]. It is intended to be used as background information by the IETF LPWAN group when defining system requirements of different LPWANs that are suitable to support common IP services.

LPWAN technologies are a subset of IoT systems which specifically enable long range data transport (e.g. distances up to 50 km in open field), are capable to communicate with underground equipment, and require minimal power consumption. Low throughput transmissions combined with advanced signal processing techniques provide highly effective protection against interference. LPWAN technologies can also cooperate with cellular networks to address use cases where redundancy, complementary or alternative connectivity is needed.

Because of these characteristics, LPWAN systems are particularly well

adapted for low throughput IoT traffic. SIGFOX LPWAN autonomous battery-operated devices send only a few bytes per day, week or month in an asynchronous manner and without the needed for central coordination, which allows them to remain on a single battery for up to 10-15 years.

## [2.](#) Terminology

The following terms are used throughout this document:

Base Station (BS) - A Base Station is a radio hub, relaying messages between DEVs and the SC.

Device Application (DA) - An application running on the DEV or EP.

Device (DEV) - A Device (aka end-point) is a leaf node of a LPWAN that communicates application data between the local device application and the network application.

End Point (EP) - An End Point (aka device) is a leaf node of a LPWAN that communicates application data between the local device application and the network application.

Low-Power Wide-Area Network (LPWAN) - A system comprising several BSs and millions/billions of DEVs, characterized by the extreme low-power consumption, long-range of transmission, and typically connected in a star network topology.

Network Application (NA) - An application running in the network and communicating with the device(s).

Registration Authority (RA) - The Registration Authority is a central entity that contains all allocated and authorized Device IDs.

Service Center (SC) - The SIGFOX network has a single service centre. The SC performs the following functions:

- \* DEVs and BSs management
- \* DEV authentication

- \* Application data packets forwarding
- \* Cooperative reception support

### 3. System Architecture

Figure 1 depicts the different elements of the system architecture:

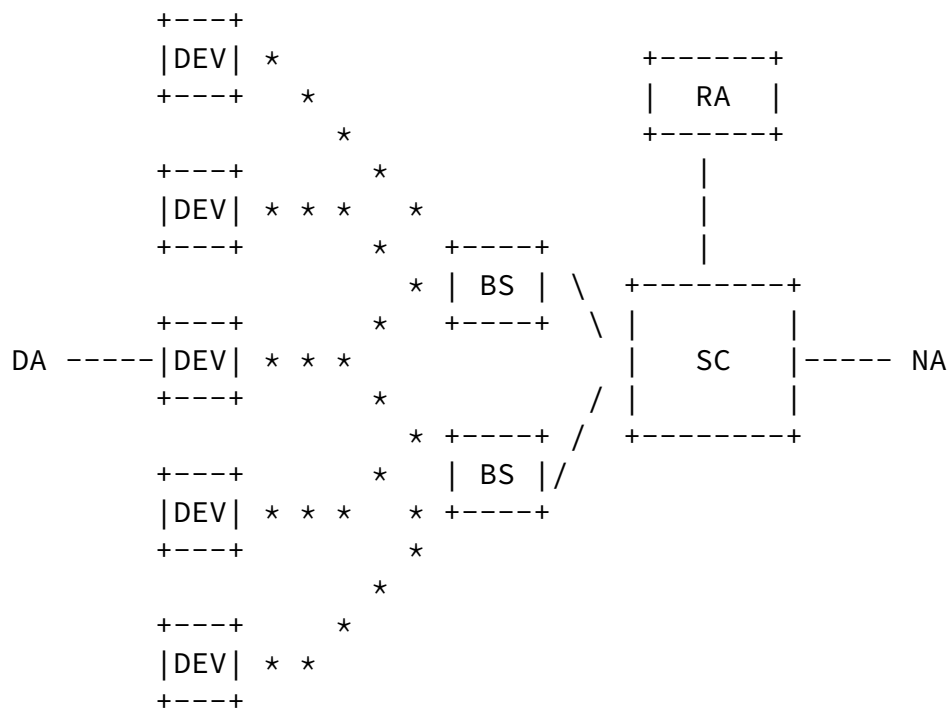


Figure 1: SIGFOX network architecture

SIGFOX has a "one-contract one-network" model allowing devices to connect in any country, without any need or notion of either roaming or handover.

The architecture consists of a single cloud-based core network, which

allows global connectivity with minimal impact on the end device and radio access network. The core network elements are the Service Center (SC) and the Registration Authority (RA). The SC is in charge of the data connectivity between the Base Stations (BSs) and the Internet, as well as the control and management of the BSs and Devices. The RA is in charge of the Device network access authorization.

The radio access network is comprised of several BSs connected directly to the SC. Each BS performs complex L1/L2 functions, leaving some L2 and L3 functionalities to the SC.

The Devices (DEVs) or End Points (EPs) are the objects that communicate application data between local device applications (DAs) and network applications (NAs).

Devices can be static or nomadic, as they associate with the SC and they do not attach to any specific BS. Hence, they can communicate

with the SC through one or multiple BSs without needing to signal for handover or roaming.

Due to constraints in the complexity of the Device, it is assumed that Devices host only one or very few device applications, which most of the time communicate each to a single network application at a time.

#### [4.](#) Radio Spectrum

The coverage of the cell depends on the link budget and on the type of deployment (urban, rural, etc.). The radio interface is compliant with the following regulations:

Spectrum allocation in the USA [[fcc\\_ref](#)],

Spectrum allocation in Europe [[etsi\\_ref](#)],

Spectrum allocation in Japan [[arib\\_ref](#)].

At present, the SIGFOX radio interface is also compliant with the local regulations of the following countries: Australia, Brazil,

Canada, Kenya, Lebanon, Mauritius, Mexico, New Zealand, Oman, Peru, Singapore, South Africa, South Korea, and Thailand.

## [5.](#) Radio Protocol

The radio interface is based on Ultra Narrow Band (UNB) communications, which allow an increased transmission range by spending a limited amount of energy at the device. Moreover, UNB allows a large number of devices to coexist in a given cell without significantly increasing the spectrum interference.

Since the radio protocol is connection-less and optimized for uplink communications, the capacity of a SIGFOX base station depends on the number of messages generated by devices, and not on the actual number of devices. Likewise, the battery life of devices depends on the number of messages generated by the device. Depending on the use case, devices can vary from sending less than one message per device per day, to dozens of messages per device per day.

Both uplink and downlink are supported, although the system is optimized for uplink communications. Due to spectrum optimizations, different uplink and downlink frames and time synchronization methods are needed.

### [5.1.](#) Uplink

#### [5.1.1.](#) Uplink Physical Layer

The main radio characteristics of the UNB uplink transmission are:

- o Occupied bandwidth: 100 Hz / 600 Hz (depending on the region)
- o Uplink baud rate: 100 baud / 600 baud (depending on the region)
- o Modulation scheme: DBPSK
- o Uplink transmission power: compliant with local regulation
- o Link budget: 155 dB (or better)

- o Central frequency accuracy: not relevant, provided there is no significant frequency drift within an uplink packet transmission

For example, in Europe the UNB uplink frequency band is limited to 868.00 to 868.60 MHz, with a maximum output power of 25 mW and a maximum mean transmission time of 1%.

### 5.1.2. Uplink MAC Layer

The format of the uplink frame is the following:

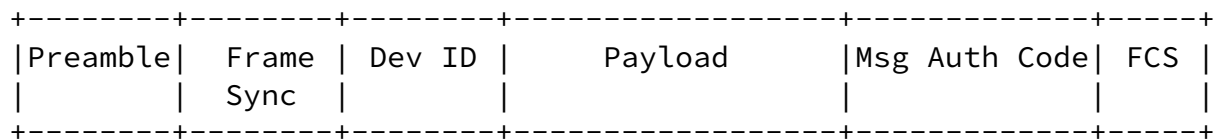


Figure 2: Uplink Frame Format

The uplink frame is composed of the following fields:

- o Preamble: 19 bits
- o Frame sync and header: 29 bits
- o Device ID: 32 bits
- o Payload: 0-96 bits

- o Authentication: 16-40 bits
- o Frame check sequence: 16 bits (CRC)

## 5.2. Downlink

### 5.2.1. Downlink Physical Layer

The main radio characteristics of the UNB downlink transmission are:

- o Occupied bandwidth: 1.5 kHz
- o Downlink baud rate: 600 baud
- o Modulation scheme: GFSK
- o Downlink transmission power: 500 mW / 4W (depending on the region)
- o Link budget: 153 dB (or better)
- o Central frequency accuracy: Centre frequency of downlink transmission are set by the network according to the corresponding uplink transmission

For example, in Europe the UNB downlink frequency band is limited to 869.40 to 869.65 MHz, with a maximum output power of 500 mW with 10% duty cycle.

#### [5.2.2.](#) Downlink MAC Layer

The format of the downlink frame is the following:

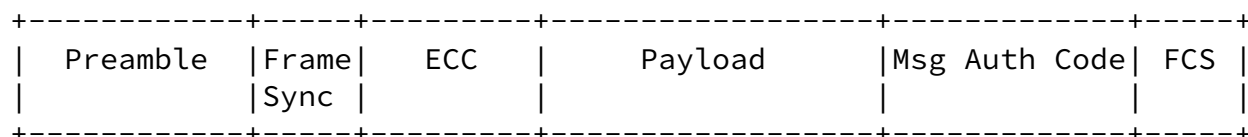


Figure 3: Downlink Frame Format

The downlink frame is composed of the following fields:

- o Preamble: 91 bits
- o Frame sync and header: 13 bits

- o Error Correcting Code (ECC): 32 bits



- o Payload: 0-64 bits
- o Authentication: 16 bits
- o Frame check sequence: 8 bits (CRC)

### 5.3. Synchronization between Uplink and Downlink

The radio interface is optimized for uplink transmissions, which are asynchronous. Downlink communications are achieved by devices querying the network for available data.

A device willing to receive downlink messages opens a fixed window for reception after sending an uplink transmission. The delay and duration of this window have fixed values. The network transmits the downlink message for a given device during the reception window, and the network also selects the base station (BS) for transmitting the corresponding downlink message.

Uplink and downlink transmissions are unbalanced due to the regulatory constraints on the ISM bands. Under the strictest regulations, the system can allow a maximum of 140 uplink messages and 4 downlink messages per device. These restrictions can be slightly relaxed depending on system conditions and the specific regulatory domain of operation.

## 6. Network Deployment

As of today, SIGFOX's network has been fully deployed in 17 countries, with ongoing deployments on 29 other countries, giving in total a geography of 2.6 million square kilometers, containing 660 million people. The single core network model allows devices to connect in any country, without any notion of roaming or handover.

The vast majority of the current applications are sensor-based, requiring solely uplink communications, followed by actuator-based applications, which make use of bidirectional (i.e. uplink and downlink) communications.

Similar to other LPWAN technologies, the sectors that currently benefit from the low-cost, low-maintenance and long battery life are agricultural and environment, public sector (smart cities, education, security, etc.), industry, utilities, retail, home and lifestyle, health and automotive.

## [7.](#) IANA Considerations

N/A.

## [8.](#) Security Considerations

Due to the nature of low-complexity devices, it is assumed that Devices host only one or very few device applications, which most of the time communicate each to a single network application at a time.

The radio protocol authenticates and ensures the integrity of each message. This is achieved by using a unique device ID and an AES-128 based message authentication code, ensuring that the message has been generated and sent by the device with the ID claimed in the message.

Application data can be encrypted at the application level or not, depending on the criticality of the use case, to provide a balance between cost and effort vs. risk. AES-128 in counter mode is used for encryption. Cryptographic keys are independent for each device. These keys are associated with the device ID and separate integrity and confidentiality keys are pre-provisioned. A confidentiality key is only provisioned if confidentiality is to be used.

## [9.](#) Acknowledgments

The authors would like to thank Olivier Peyrusse for the useful inputs and discussions about ETSI UNB SRD.

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