Analysis of the SIGFOX LPWAN and comparison with LoRa.

Josué ALVAREZ, Cécile DUTHOIT

November 2016

1 Introduction

Sigfox is the name of an operator and its LPWAN technology. Sigfox technology is protected by Intellectual Property, and only Sigfox and its partners have the rights to operate the network.

2 Sigfox PHY layer

The physical layer of Sigfox consists of an Ultra Narrow Band BPSK modulation[3], with a bandwidth of 100 Hz, which allows a bitrate of around 100 bps for each device. The carrier frequency can be chosen in a 192 kHz band inside the 868 Mhz band (Europe).

There are two problems to address when using UNB :

- First, the transmission can suffer from flat fading (i.e. the average strength of the signal can be randomly lowered on all its frequency components). That is why Sigfox uses frequency hopping in order to avoid it.
- Second, UNB means that the frequency uncertainty (the shift between the desired frequency of the oscillators and the actual frequency generated) is higher that the signal bandwidth (100 Hz here). In such conditions, it is not possible to obtain non-overlapping frequency channels with small guard intervals. This means that if we try to divide the 192 kHz in frequency slots, we will probably waste a lot of this band in guard intervals. Hopefully, Sigfox MAC protocol has been designed to address this issue.

3 Sigfox MAC layer

3.1 Uplink

Sigfox uses Random Frequency and Time Division Multiple Access (RFTDMA) as medium access control technique for uplink (i.e. from devices to gateways).

The advantages of this protocol are :

- Energy consumption : because the nodes need to consume the smallest possible amount of power, they don't sense the medium before emitting data. RFTDMA makes it possible to (partially) avoid collisions : the nodes will transmit signal at random time intervals and in a random frequency within the 192 kHz band.

- Oscillator precision : the carrier frequencies are chosen in that band inside a continuous interval, rather than using a discrete set of frequency slots.This helps reducing the bandwidth wasted in guard intervals, and also enables the use of cheaper oscillators (that do not need to be extremely accurate).
- Also, as the time slots are chosen randomly, there is no need of time synchronisation between the nodes. However, emitting in random time slots and frequency slots can lead to interferences if they are too many nodes in the network.

For this reason, and to address the issue of flat fading, each uplink message is transmitted up to 3 times on different frequencies.

The receiver then scans the whole 192 kHz band, identifies spectral signatures of UNB signals then demodulates these signals. These operations can be performed using advanced Software Designed Radio algorithms.[3]

3.2 Downlink

For downlink, Sigfox uses a GFSK modulation with a 500 bps bitrate inside a 600 Hz wide spectrum segment. The downlink can be used for both acknowledgements and data transmission. However, the downlink data is limited to 4 messages a day and data can only be transmitted at specific times because the emitting device only listens for messages a few seconds (25 s max) after emitting.

3.3 Packet Structure

Sigfox packets are composed of [3]:

- a preamble of 4 bytes,
- a frame synchronization part of 2 bytes.
- a device identifier of 4 bytes.
- a payload of up to 12 bytes.
- a Hash code to authenticate the packet in SigFox network, the length of this hash code is not fixed.
- Cyclic Redundancy Check (CRC) syndroms of 2 bytes for security and error detection.

The total protocol overhead is up to 26 bytes.

4 SigFox network characteristics

4.1 Message volumetry and engagement offers

The number of messages that can be transmitted depends on the engagement offer the device has subscribed to. There are 4 offers available[2]:

- Platinum : 101 to 140 messages + 4 downlink
- Gold : 51 to 100 messages + 2 downlink r
- Silver : 3 to 50 messages + 1 downlink
- One : 1 to 2 messages + no downlink

For all these offers, the payload is always 12 bytes.

4.2 Range

The TX emitting power is +14 dBm and the RX sensitivity of the base stations is around -142 dBm which given a link budget of approximately 160 dBm. With that link budget, Sigfox claims a coverage of about 20-40 kms in open air, and 2-5 kms in urban environment.

4.3 Energy consumption

Sigfox devices consume 20 mA to 70 mA while active, and a few uA while idle.
As Sigfox devices send up to 140 messages a day, they consume little power.

4.4 Security

According to [1], the security layer is composed of : a hash code to authenticate the packet in Sigfox network, a 2 bytes CRC code, and message scrambling and sequencing techniques. However, this encryption mechanism is used only to authenticate the device. The payload is not encrypted !

The only goal of this security layer is to ensure that no third party device emits with the original device identity.

4.5 Doppler sensitivity

As mentioned earlier, frequency shifts does not impact the transmission quality because the devices emit at random frequencies and the gateways scans the whole 192 kHz band to find the signal. Thus, Doppler effect does not have any important effect on the transmissions.

4.6 Geolocation

Because this network aims to be deployed with a reasonable number of cells, the purpose of LP-WAN is to have a very long range, which leads to limited LBS accuracy. Therefore, as the network is getting more and more used and densely deployed, it will become more and more accurate and the precision of geolocation will increase[4].

For now, it is unfortunately not possible to locate precisely by triangulating with SigFox. It can be used to detect if an object is in a neighborhood or a city for example. To get a precise location using SigFox, it is needed to use a GPS module.

4.7 Sigfox VS GSM

GSM technology was designed to serve human communications with more bandwidth requirements than M2M communication targeted by Sigfox. It might be a solution for applications with higher bandwidth usage, however, for low bandwidth usage, Sigfox has the following advantages over GSM :

- Modem cost : as mentionned earlier, Sigfox devices does not require high oscillator precision and can be built with cheap components. The modem cost of a Sigfox device is around $1, while a GSM modem can cost $10.
- Higher range : lower density of base stations needed.
- Fewer power consumption : as the GSM modem needs to be constantly scanning the network (because it uses TDMA modulation, channel selection etc...) and monitor the signal strength it consumes more power.

	SIGFOX UNB	COMPETITION GSM/Cellular
DENSITY of ANTENNAS TO COVER A CITY (1M inhabitants)	3	60
DENSITY of ANTENNAS TO COVER a 1000 km² RURAL AREA	1 to 3 per 1000 km²	10 to 20 per 1000km²
DENSITY of OBJETCTS / BASE STATION	High +	Low
SENSITIVITY	High +	Low
POWER CONSUMPTION (in µW)	50µW mono / 100µW bidir	5000 µW
RADIATED POWER / EM POLLUTION	Very Low	Medium to high
TYPICAL STAND-BY TIME (in years) for 2.5 Ah battery	20	0,2
SECURITY LEVEL	High	High +
SIGNAL PENETRATION into buildings	High	Medium
VERSATILITY	Worldwide	Subject to license
MODEM COST ESTIMATION (with silicon integration)	Below 1$	10$
TYPICAL COMMUNICATIONS COST (yearly subscription + traffic per device)	< 3$	30$

Figure 1 : Comparison table between SigFox UNB and GSM network [10]

5 Comparison with LoRa

5.1 Some information about LoRa technology

LoRa is a proprietary spread spectrum modulation scheme that is derivative of Chirp Spread Spectrum modulation (CSS)[1].

The MAC layer is managed by LoRaWAN, a protocol that allows dynamically the optimisation of the link between LoRa devices et base station by choosing the frequency channel, the power, the bitrate, etc. The LoRaWAN protocol can be operated by a telecommunications operator or privately.

Semtech also developed a method where the actual data rate is adjusted to ensure reliable packet delivery, optimal network performance, scale for capacity and battery optimisation ; it is called Adaptive Data Rate (ADR). For example, nodes close to the gateway will use a higher data rate (shorter time on air) and a lower output power. Only nodes that are at the very edge of the link budget will use the lowest data rate and highest output power.

5.2 Problem of bidirectionality

For both SigFox and LoRa solutions, the bidirectional aspect is limited because of the closeness of the frequency bands allocated to emission and reception. That means the antenna must stop listening to messages when sending messages to the devices.

A solution to this problem would be to install more antennas to allow some of them to cut their reception to send messages when other antennas of the site would be still listening. Therefore, it is not an extremely important problem because this type of network is made for communications from the devices to the cloud and not the opposite.[8]

5.3 Future of these networks

With the multiplication of connected devices in many domains, the next generation of mobile networks standard, the 5G, will probably regroup all the mobile technologies to get a better utilisation of the frequency bands.[9]

5.4 Comparison Table

Criteria	**SigFox**	**LoRa**
Conceptor	SigFox	Semtech
Launch	2009	2012
Proprietary network	Yes	No
Frequency	868 MHz (EU) 902 MHz (US)	868 MHz
Bandwidth	SigFox	125 kHz
Frequency of emission	0 - 140 per day	LoRa
Bitrate	300 bits/s	0.3 kbps to 50 kbps
Payload size	max 12 bytes	max 256 bytes
Bandwidth	SigFox	125 kHz
Modulation	BPSK	FSK or LoRa (switchable)
Bidirectional	Yes but very limited	Yes (under conditions)
Precise geolocation	No	No

Figure 2 : Comparison table between LoRa and SigFox

5.5 Comparison of SigFox and LoRa deployment

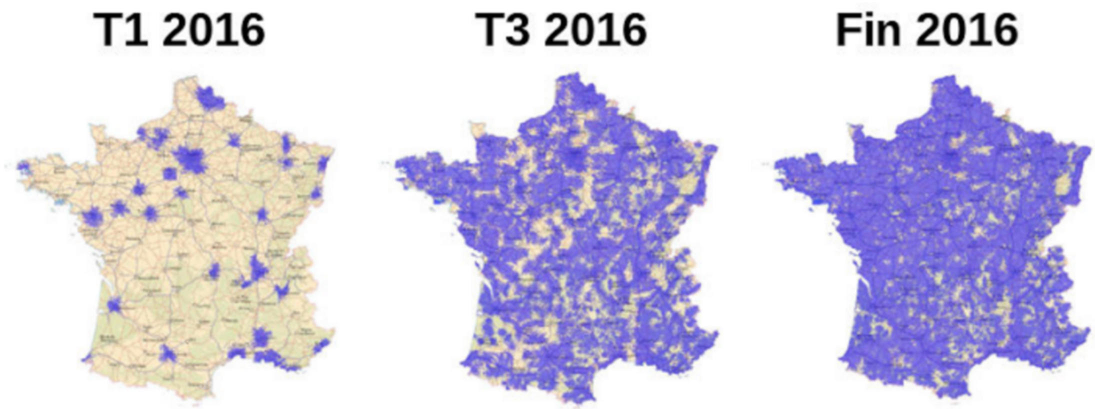

Figure 3 : Evolution of the deployment of the LoRa network by Bouygues Telecom in France in 2016[13]

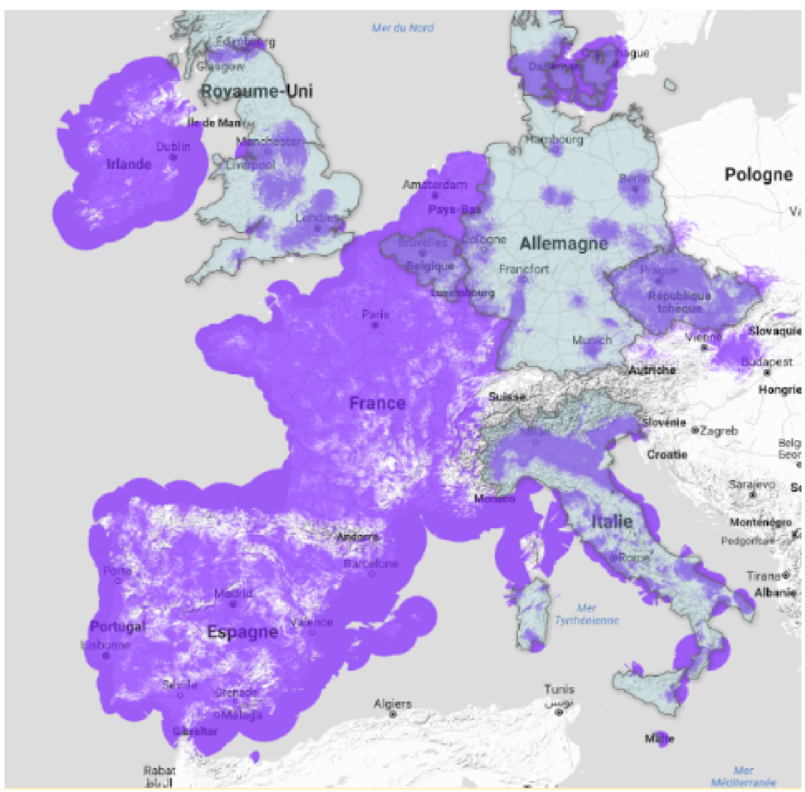

Figure 4 : Deployment of the SigFox network in West Europe (nov 2016)[12]

6 References

Publications :

[1] **G. Margelis, R. Piechocki, D. Kaleshi and P. Thomas**, ”Low Throughput Networks for the IoT: Lessons learned from industrial implementations,” 2015 IEEE 2nd World Forum on Internet of Things (WF-IoT), Milan, 2015, pp. 181-186.
URL: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=arnumber=7389049isnumber=7389012

[2] **K. E. Nolan, W. Guibene and M. Y. Kelly**, ”An evaluation of low power wide area network technologies for the Internet of Things,” 2016 International Wireless Communications and Mobile Computing Conference (IWCMC), Paphos, 2016, pp. 439-444.
URL: http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=arnumber=7577098isnumber=7577016

[3] **C. Goursaud, J-M. Gorce**. ”Dedicated networks for IoT : PHY / MAC state of the art and challenges”, EAI endorsed transactions on Internet of Things, 2015, ¡10.4108/eai.26-10-2015.150597¿. ¡hal-01231221¿
URL : https://hal.archives-ouvertes.fr/hal-01231221/file/eai.26-10-2015.150597.pdf

Other :

[4] **F. Oudot**, ”Geolocation capability”, question on Sigfox forum.
URL: http://ask.sigfox.com/questions/216/geolocation-capability.html

[5] **Semtech**, ”LoRa^{TM} Modulation, Basics”, Datasheet AN1200.22.
URL: http://www.semtech.com/images/datasheet/an1200.22.pdf

[6] **Semtech**, ”LoRaWAN^{TM} For Developers”
URL: https://www.lora-alliance.org/For-Developers/LoRaWANDevelopers

[7] **Anonymous as Arthur L.**, ”Tout savoir sur le réseau de Sigfox”. February 10, 2016
URL: http://www.objetconnecte.com/tout-savoir-sur-sigfox/

[8] **T. Watrigant**, ”Sigfox, LoRa : quelles différences entre les réseaux M2M pour objets connectés ?”. April 22, 2015.
URL: https://www.aruco.com/2015/04/sigfox-lora-reseaux-m2m/

[9] **Link-Labs**, ”SigFox Vs. LoRa: A Comparison Between Technologies Business Models”. January 13, 2016.
URL: http://www.link-labs.com/sigfox-vs-lora/

Figures :

[10] **O. Male**, ”Sigfox, technologie de rupture pour le M2M”. February 25, 2014.
URL: http://www.domotique-info.fr/2014/02/sigfox-technologie-de-rupture-pour-le-marche-du-m2m/

[11] **SigFox**, "Coverage"
URL: http://www.sigfox.com/en/coverage

[12] **Les numériques (anonymous)**, "LoRa et SigFox : les premières cartes de couverture".
February 3, 2016.
URL: http://www.lesnumeriques.com/objet-connecte/lora-sigfox-premieres-cartes-couverture-n49509.html