Rapport SIGFOX

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Introduction

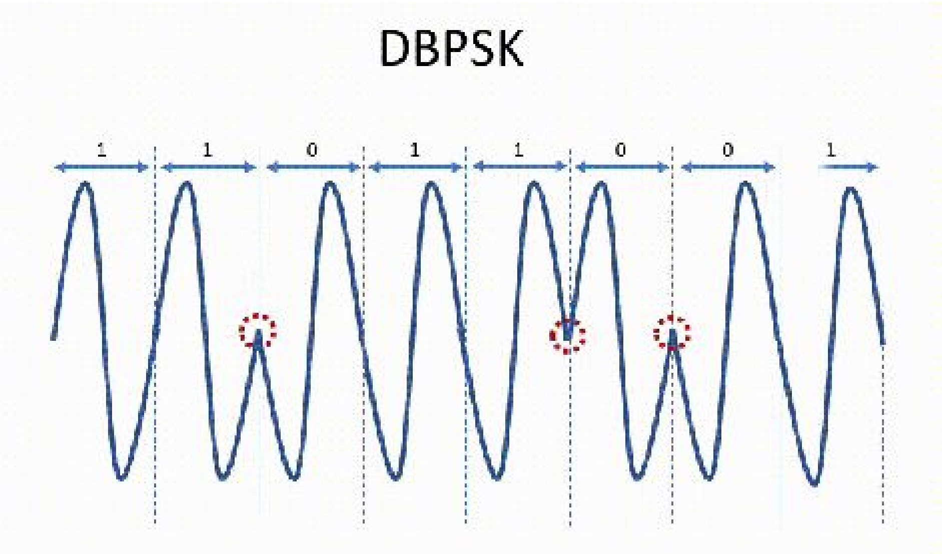
In this report, we are presenting Sigfox communication for IoT. We answered about several questions showing the advantage of this protocol. We discussed about MAC and Physical layers of Sigfox protocol in order to demonstrate its performance in IoT domain. We also calculated the consumption, the range, the data rate, the Time on Air, the throughput and the sensitivity for a typical Sigfox receiver.

Frequency Ranges in Europe:

Europe is part of the RC1 group which operates in the range 868-878.6 MHz.
The frequency ranges used by Sigfox in Europe is 868 MHz which reach a high distance with a very low consumption of energy.

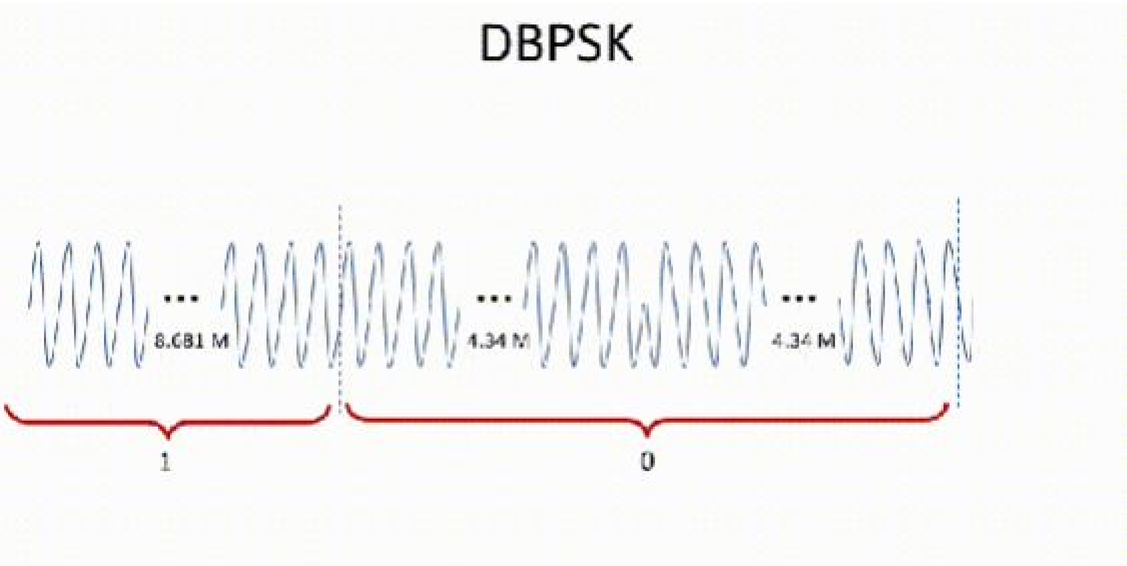
Uplink center frequency	Downlink center frequency
868.130 MHz	869.525 MHz

Modulation used by Sigfox - Binary Data Rate - Bandwidth:

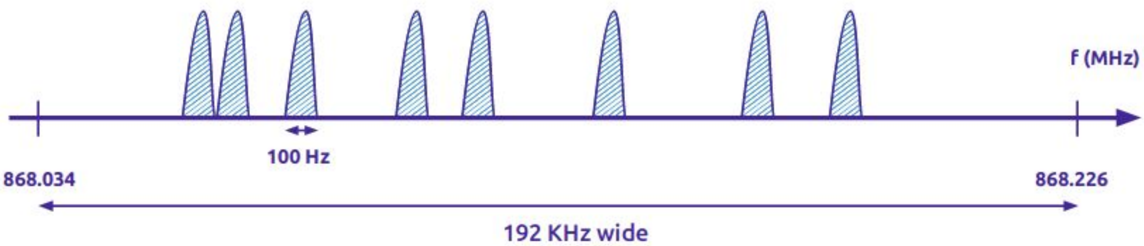


In the above example the value 1 is identify by no change in the signal phase when the 0 is identify by a phase change during the transmission. This is the way Sigfox is encoding the information on the radio medium. That said there is a big difference between Sigfox encoding and this animation : In the animation is encoding 1 different bit per signal period. At

868MHz it means 868Mb / s … As you may know Sigfox is far away from this bitrate and basically a such encoding would have been really difficult to decode even in a short range.
The Sigfox DBPSK encoding is based on a sequence of periodic signal : when they all have the same phase the bit value is a 1, if the phase change in the middle of the time slot the bit value is a 0. In this way the receiver is less impacted by local phase variation. Each message is 100 Hz wide and transferred with a data rate of 100 or 600 bits per second depending on the region. [1]



At the end, Sigfox send information with these methods reducing the bit-rate and limiting error.



Define the packet structure. What is the actual throughput of Sigfox (precise all the hypothesis for this evaluation) ? What is the time on air ?

The Sigfox MAC packet is composed of different field as you can see on the following picture.

We can notice the preamble which helps a receiver to detect the beginning of a frame. The frame sync allows the receiver to synchronise its clock to correctly find the beginning of each of the bits. The end-device uniquely identify a device. The frame check sequence (FCS) is used to detect potential errors.

Sigfox MAC Frame Uplink:

32 bits	16 bits	32 bits	0 to 96 bits	variable bits	16 bits
Preamble	Frame Sync	End-Device ID	Payload	Authentication	FCS

Sigfox MAC Frame Downlink:

32 bits	13 bits	2 bits	8 bits	16 bits	variable bits	0 to 64 bits
Preamble	Frame Sync	Flags	FCS	Auth	Error Codes	Payload

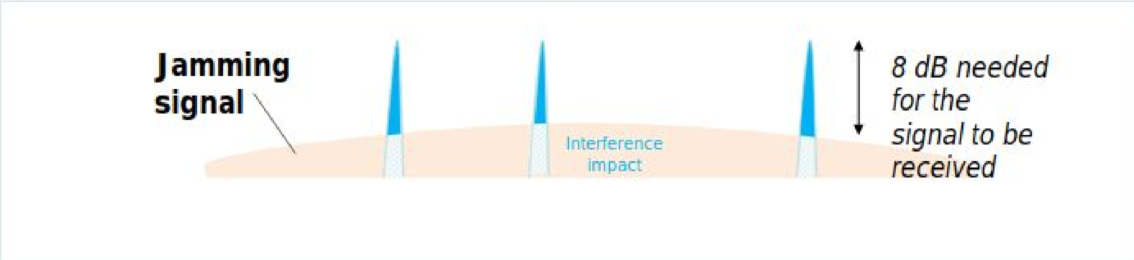
An asset of Sigfox is to have uplink and downlink about transfer. Each transmision direction have a particular data rate.

	Uplink	Downlink
Data rate	100 bits/s	600 bits/s
Payload size	12 bytes	8 bytes
Throughput	9,6 Kbits/s *	38,4 Kbits/s
Time On Air (s)	6	6
Message per day (a device can emit for 36 seconds per hour)	144 **	4

- * Calcul : Throughput = 100 * 12 * 8 = 9,6 kbits/s
- ** Message per day = 6 messages/hour * 24h = 144

What are the features used by Sigfox to reduce the effect of interferences ?

Sigfox has a high resilience to the interferences which can be reduce thanks to an ultra-narrow band modulation (UNB). UNB is extremely robust to an environment with other signals, including Spread Spectrum signals (SSS).
This UNB intrinsic ruggedness coupled with spatial diversity of the base stations offer anti-jamming capabilities.



scheme 3: Resilience to interferers provided by UNB

An observation, shows SSS are very impacted by noise due to a higher in common interface that propulse the UNB as first choice for the ISM public band. Thus, UNB like we observe on the above scheme has also intrinsic ruggedness because the overlap between the signal and the noise, it isn’t sufficient.
In order to properly receive a message, the signal have to be 8 dB greater than the noise.
But, a high efficiency in the spectrum concentrate all of the energy into a very small bandwidth.
The massive reception means cause some issue and random FDMA and repeat of frames are solution to interferences.

What is the maximum transmitted power ? What should be the theoretical sensitivity of a Sigfox receiver? What is the typical sensitivity of a Sigfox receiver ? Compute the typical link budget of a Sigfox wireless network.

To answer this question, we established the link budget of Sigfox. The link budget is the sum of the sensitivity of the base station, the antenna gains and the output power on the object’s side:

Received power(dBm)=Transmitted power(dBm)+Gains(dB)−Losses(dB)

Data Rate (DL):0.6 Kb/s

Data Rate (UL): 0.1 Kb/s
the gains represent the sensitivity of the receiver Sigfox.
the maximum transmitted power is 159 dB.

With Sigfox EU, the link budget is unbalanced in upload (UL) and download (DL). At 163 dB, UL is five dB better than DL 158 dB link budget.
Sigfox cannot guarantee symmetrical upload and download for several reasons. The asymmetry with UL and DL is only one of the reasons for a lack of download possibilities with Sigfox radio protocol.
A perfect transmission occurs when the PER rate is less than 1%.

The maximum output power of 25 mW and a maximum mean transmission time of 1% in Europe.

Thus, to calculate $P_{(dBm)} = 10 \cdot \log_{10}(1000 \cdot P_{(W)} / 1W) = 10 \cdot \log_{10}(P_{(W)} / 1W) + 30$

$= 10 . \log_{10}(0.025) + 30$

$= 13.98$ dbm

In US the maximum transmitted power is with 22 dbm due to a higher current which obliged a higher power of transmission.

$$P_{(W)} = 1W \cdot 10^{(P(dBm) / 10)} / 1000$$
$$= 10^{((P(dBm) - 30) / 10)}$$
$$= 10^{((22 - 30) / 10)}$$
$$= 0.158\ W / 158\ mW$$

The theoretical sensitivity of the base station depends of the devices' transmission bit rates :

0.1 Kbps ⇔ − 142 dBm

0.6 Kbps ⇔ − 134 dBm

At **0.1 Kbps**, device transmissions are around 16 dBm, the antenna gain at the base station is 5 dB and the sensitivity is **-142 dBm**.

The link budget at 0.1 Kbps :

Link Budget (dB) = Transmitted power (dBm) + Gains(dB) - Sensitivity(dB)

= 14 + 2 + 142

= 158 dB

At **0.6 Kbps**, if we use the same device transmissions which is around 16 dBm and the same antenna gain at the station which is 5 dB and the sensitivity, **-134 dBm**.

The link budget at 0.6 Kbps:

Link Budget (dB) = Transmitted power (dBm) + Gains(dB) - Sensitivity(dB)

= 14 + 2 + 134

= 150 dB

Based on some research, the typical sensitivity of a node is -137dBm.

Transceiver	Transmit power (dBm)	14 dBm (max in EU)
	Transmitter Antenna Gain(dBi)	2 dBi (depends of the antenna)
	Transmit losses (dB)	0
	PIRE (dBm)	16 dBm
Receiver	Receiver Sensitivity (dBm)	-137 dBm
	Receiver losses (dB)	0
	Receiver Antenna Gain (dBi)	3 dBi (depends of the antenna)

	Entrance minimum Power (dBm)	-140 dBm
Maximum propagation losses		156 dB

Hence, the link budget is about 156dB.

Estimation of the radio range

In this part, we will discuss about the radio range of Sigfox protocol. First, we will consider a transmission in a free space environment.

We can calculate the loss of a signal in a free space environment using the formula below
$L_{FreeSpace}(dB) = 20log(d) + 20log(f) + 32.44$ (d in km, f in MHz)
⇒ $d = 10\hat{}((L_{FreeSpace}(dB) - 20log(f) - 32.44)/20)$

Typical link budget of Sigfox transmission is about 159dB. It means that the loss can have a value of 159dB

Using this value, we find a range of 2451 km ! That is a tremendous value that is not realistic. The use of a free space environment model is not suitable since it does not represent the world in which we live. There are many parameters that will add noise to our signal (buildings, weather…)

In order to have a more accurate idea of the radio range, we can use the model that was given in the subject (COST 231). This is a semi-empirical path loss model that was elaborated from several others models. The frequency range of the given model (800 - 1800 MHz) is valid for Sigfox which operates at 868MHz.
Here is below the formula of the model.
$L_u(dB) = 69.55 + 26.16log(f) - 13.82log(H_b) - A(H_m) + (44.9 - 6.55log(H_b)) * log(d) - B$

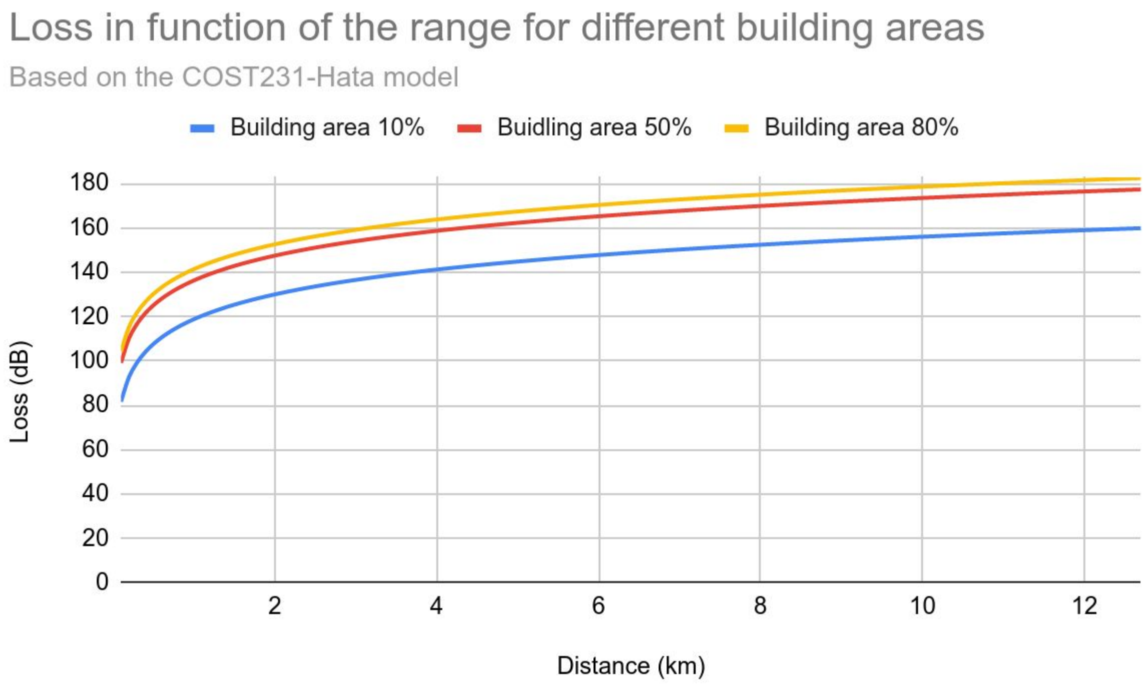
With correction factors

$A(H_m) = (1.1log(f) - 0.7) * H_m - (1.56log(f) - 0.8)$
$B = 30 - 25log(BuildingArea\%)$

In our situation, we can consider that

$H_b = 15m$ and $H_m = 1m$
$f = 868MHz$

The chart below represents the loss evolution in function of the range for three different areas percentage (10%, 50%, 80%).



We can notice that higher the building area percentage is, higher the losses are. It is quite normal since buildings are obstacle for radio waves and avoid them to propagate correctly.
As previously, we can consider that the link budget has a value of 159dB.
In the table below are represented the maximum for the three building areas percentage values. Those values are obtained by reading the graph.

Building Area	Maximum Range
10%	12km
50%	4km
80%	3km

These values are obtained using theory and do not certainly represent every cases. In order to get reliable results, experiments have to be conducted. Nevertheless it can give an overview of the achievable radio range.

Sources :

[1] https://www.disk91.com/wp-content/uploads/2017/05/4967675830228422064.pdf
[2]https://www.ismac-nc.net/wp/wp-content/uploads/2017/08/sigfoxtechnicaloverviewjuly2017-170802084218.pdf
[3] Sigfox System description: Juan Carlos Zuniga Benoit Ponsard
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