Wireless communication - Sigfox Study case

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1 What are the frequency ranges used by Sigfox (in Europe) ?

Sigfox uses 6 different Radio Configuration (RC) for communications between the device and the network. These RC define the macro-channels used for download (DL) and upload (UL) communications. The following table, taken from the radio specifications of Sigfox, sums up the different configurations.

Table 2-1 : UL and DL operating macro-channels of SNW

Frequency (in MHz)	RC1	RC2	RC3	RC4	RC5	RC6
UL low boundary	868.034	902.104	923.104	920.704	923.204	865.104
UL center	868.130	902.200	923.200	920.800	923.300	865.200
UL high boundary	868.226	902.296	923.296	920.896	923.396	865.296
DL low boundary	869.429	905.104	922.104	922.204	922.204	866.204
DL center	869.525	905.200	922.200	922.300	922.300	866.300
DL high boundary	869.621	905.296	922.296	922.396	922.396	866.396
Δf_{GAP}	+1.395	+3.000	-1.000	+1.500	-1.000	+1.100

We can find easily which countries is using different radio configuration. Countries are grouping according to this list :

- RC1 : Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, United Kingdom.
- RC2 : Brazil, Canada, Mexico, Puerto Rico, USA.
- RC3 : Japan.
- RC4 : Argentina, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Nicaragua, Panama, Peru, Trinidad, Tobago, Uruguay, Australia, Hong Kong, Indonesia, Malaysia, New Zealand, Singapore, Taiwan, Thailand.
- RC5 : South Korea.
- RC6 : India.

2 What is the modulation used by Sigfox ? What is the binary data rate ? What is the bandwidth ?

For the uplink, Sigfox implements Differential Phase-Shift Keying (DBPSK). The binary data rate can be 600bps for all RC, but can also be 100bps if we are using RC1, RC3, RC5 or RC6. For the dowlink, it uses Gaussian Frequency-Shift Keying (GFSK) with a data rate of 600bps for all configurations.

The bandwidth of each macro-channel is 192kHz. However, they should be divided into 6 contiguous 25kHz wide micro-channels and implement FHSS if the local regulations require it.

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

3.1 Uplink

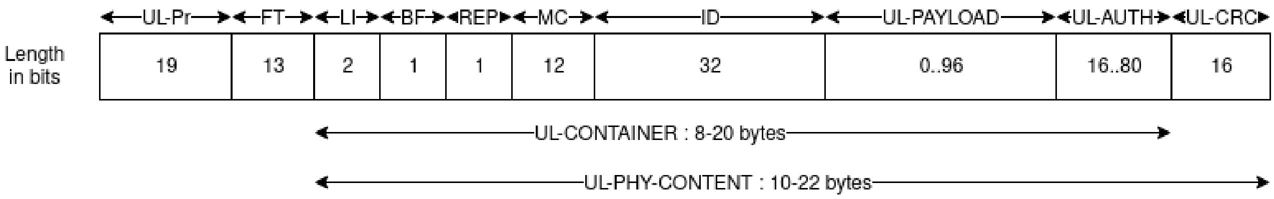

Figure 1: Uplink packet structure

- UL-Pr : packet preamble
- FT : Frame type
- LI : Length indicator, the value depends on UL-PAYLOAD
- BF : Bidirectional Frag, select between U and B procedure
- REP : should be set to 0
- MC : Message Counter
- ID : endpoint identifier
- UL-PAYLOAD : Can be application data or control data
- UL-AUTH : To provide authentication and/or encryption, size depends on UL-PAYLOAD length
- UL-CRC : 16-bit CRC to perform error detection

We will compute an upper limit to the throughput, so we will consider a maximum message length and a minimum overhead, we thus chose the following parameters :

- 12 bytes UL message content
- 600 bps mode (baud per second)

According to Sigfox specs, for a 12bytes UL-PAYLOAD, the UL-AUTH field is 2bytes long. The UL-CONTAINER would therefore be 20bytes long and UL-PHY-CONTENT 22bytes. The total packet size is then :

$$|UL - Pr| + |FT| + |UL - PHY - CONTENT| = 19b + 13b + 22B = 26B = 208b$$

The time-on-air is then $208/600 \approx 0.437s = 437ms$
As we are sending 12B = 96b of applicative data, the throughput is $96/0.437 \approx 220b/s$

3.2 Downlink

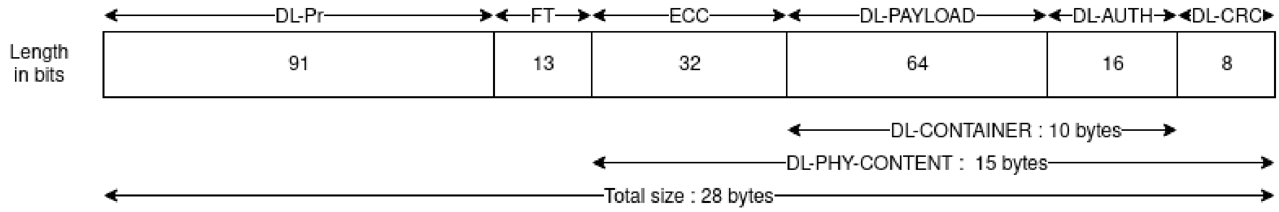

Figure 2: Downlink packet structure

- DL-Pr : packet preamble
- FT : Frame type
- ECC : Error correction code
- MC : Message Counter
- DL-PAYLOAD : Can be application data or control data
- DL-AUTH : To provide authentication and/or encryption
- DL-CRC : 16-bit CRC to perform error detection

The size of the packet is always the same 28B = 224b. Downlink data rate is always the same 600bps.

The time on air is then : $224/600 \approx 0.373s = 373ms$

As we are effectively sending 8B = 64b of applicative or control data, the throughput is $64/0.373 \approx 172b/s$

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

In order to reduce the effect of interferences, the target end-point radiated sensitivity is -126 dBm, evaluated with a dipole antenna and with FER=10%. So by accepting less sensibility than the target value we will improve resistance to interferences.

Carrier offset	C/I
3.5 kHz	-30 dB
10 kHz	-50 dB
>1 MHz	-60 dB

Table 1: Interference level

Carrier offset	Blocker level
±10 MHz	-50 dBm

Table 2: Blocking levels

Moreover, Sigfox is using Ultra-Narrow Band (UNB) which is extremely robust in an environment with other signals, including spread spectrum signals. However, spread spectrum networks are affected by UNB signals. Ultra-Narrow Band is therefore the best choice to operate in the public industrial, scientific and medical (ISM) band.

Sigfox messages are sent over a random channel has well as 2 replicas on different frequencies and time. This way, we minimize the impact of an interfering signal by having some redundancy and time. The message is also handled by any base station that receive it, so if there are interferences between the device and base station A, the message can still be correctly handled by base station B.

Sigfox also uses CRC in uplink packets and error correction code in downlink packet to detect and/or correct bit errors that may occur.

5 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.

The maximum transmitted power depends on the geographical area. The maximum values are given below.

Radio Configuration Area	RC1	RC2	RC3	RC4	RC5	RC6
Tx Power Max (dBm)	16	24	16	24	14	16

These values correpond to the target transmit power (EP-PwrTARG)(given by Sigfox). An end-point device can transmit at these value but also at lower transmit power. For that, four Tx Power classes have been created.

According to the Sigfox specifications, the theoretical sensitivity is around -126 dBm for Sigfox devices giving a theoretical range of 850 km.

However, in practical cases, the sensitivity is less important for the devices. We can find typical applications of Sigfox receiver with a sensitivity around -64dBm. The typical link budget represents:

$$ReceivedPower(dBm) = TransmittedPower(dBm) + Gains(dBm) - Losses(dBm)$$

$$-93dBm = 23dBm + 0dBm - 116dBm$$

In a busy environment (shopping area in downtown Aalborg). The link budget is better in other circumstances (as in a business area):

$$-75dBm = 23dBm + 0dBm - 98dBm$$

6 If a free space environment is considered, what is the radio range of Sigfox ?

First, we ill assume that antennas are isotropic, thus no directivity to consider. The station is a standard Sigfox station SMBS-T4 and the device a Wisol SFM10R1. The Path loss $L_p(dB)$, for a free space environment, is described with :

$$L_p(dB) = 32.4 + 20log(D) + 20log(f)$$

with

- d the separation distance in km
- f the frequency in MHz

where we can isolate D :

$$D = 10^{\frac{L_p(dB) - 32.45 - 20log(f)}{20}}$$

First case uplink (From device to station) :

$$D = 10^{\frac{14+132-32,45-20*log10(868)}{20}} = 548km$$

Second case downlink (From station to device) :

$$D = 10^{\frac{23+127-32,45-20*log10(868)}{20}} = 869km$$

This two range are pretty high, let's consider now an urban environment instead.

7 For an outdoor application, evaluate the radio range of Sigfox. The model COST231-Hata will be used for this purpose (see next slide). The following parameters could be used: Hb = 15 m, Hm = 1 m.

The Path loss $L_u(dB)$, for this particular case, is described with :

$$L_u(dB) = 69.55 + 26.16log(f) - 13.82log(H_b) - A(H_m) + (44.9 - 6.55log(H_b)) * log(d) - B$$

where we can isolate d :

$$d = 10^{\frac{L_u(dB)-69.55+B-26.16log(f)+13.82log(H_b)+A(H_m)}{44.9-6.55log(H_b)}}$$

with

$B = 30 - 25log(Building\_Area\%)$
$A(H_m) = (1.1log(f) - 0.7) * H_m - (1.56log(f) - 0.8)$
d the separation distance in m
f the frequency in MHz

If we consider an urban outdoor application with a Buildin_Area% of 30% and we take the $L_u(dB) = 150dB$ (cf 6.), we have :

$$d = 45.4m$$

We can see that the value is much lower than in the free space environment.

References

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