Protocols for the Connected Objects

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Introduction

Sigfox is a French company founded in 2009 that builds wireless networks to connect low-power objects such as electricity meters and smartwatches, which need to be continuously on and emitting small amounts of data. These networks use the Sigfox protocol, which is especially adapted for IoT purposes.

Let's see briefly how Sigfox networks work:

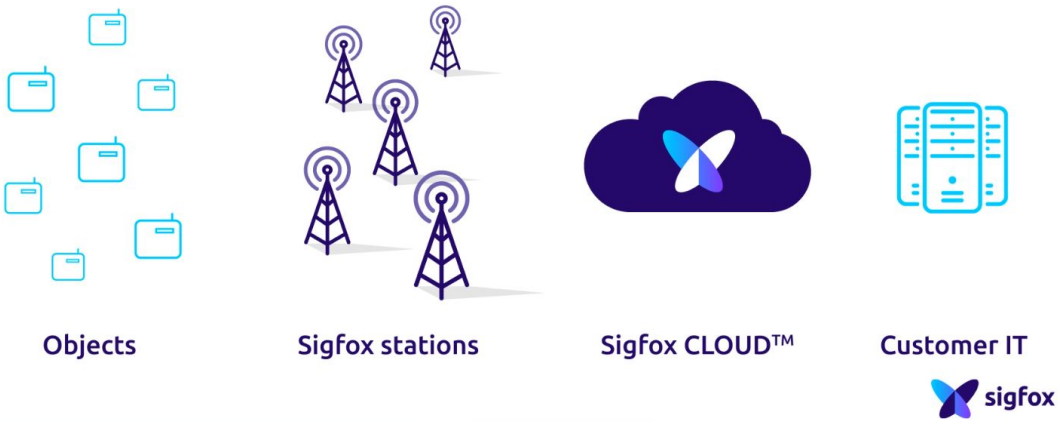

figure 1 - Sigfox network architecture

On the Sigfox network architecture above, IoT objects on the left send data to the Sigfox stations. Then, this data is stored in the Sigfox CLOUD, and the customer can access it thanks to his connected device.

In this document, we are going to study the Sigfox communication protocol and some of its aspects.

1. Physical layer

1. 1. Frequency

The band used by Sigfox depends on the location:

- **in Europe** for example, the band used is between 868 and 868.2 MHz
- **in the rest of the world**, the band used is between 902 and 928 MHz with restrictions according to local regulations.

1. 2. Bandwidth and Modulation

The bandwidth used by Sigfox to communicate is 192 kHz, and this does not change depending on the location of the devices.

The emitted signals modulation is based on ultra-narrow band (UNB) physical layer where the binary data are broadcast with a Differential Binary Phase Shift Keying (DBPSK) modulation at a very low rate. Each message is 100 Hz wide and transferred with a data rate of 100 or 600 bits per second depending on the region.

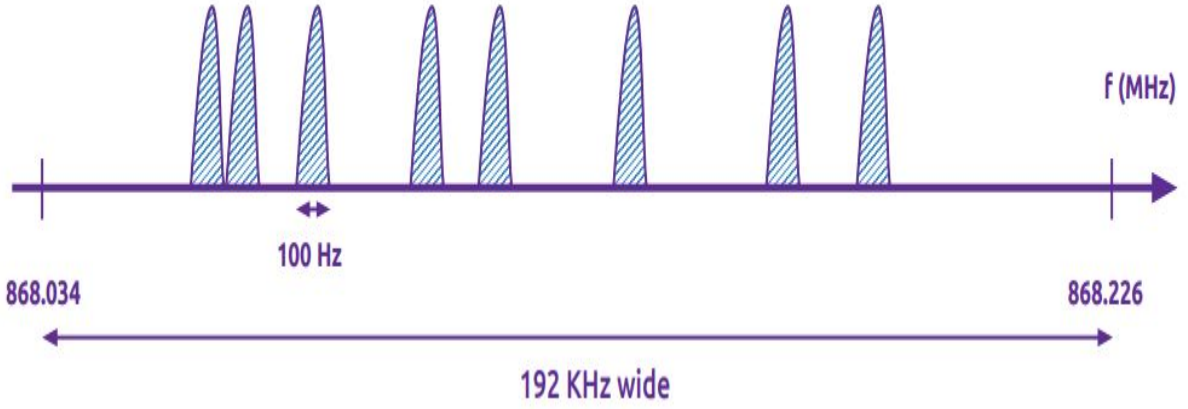

figure 2 - Sigfox communication band in Europe

The signals received by Sigfox Ready devices are modulated with GFSK (Gaussian Frequency Shift Keying) modulation, in which the binary data is brought by frequency variations, and no more with phase variations.

1. 2. 1. DBPSK Modulation

DBPSK stands for Differential Binary Phase Shift Keying. The main concept in this type of modulation is the Phase-Shift Keying (PSK). This modulation uses phase shifting to transmit data.

Then, we can focus on the BPSK, the Binary Phase Shift Keying. The added word Binary signifies that the values sent can either be 0 or 1.

Finally, the word Differential means that the data is not simply contained in the value of the signal phase, but it is contained in the phase-shifting in two successive signals. More precisely, for a time slot, if a phase shift is observed, then the value received is a 1, and if no phase shift is observed, then the value received is 0.

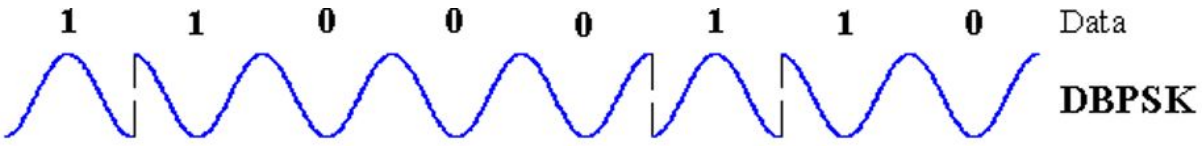

figure 2 - DBPSK modulated signal example

1. 3. Time Hopping

Time hopping is a method of transmitting radio signals more securely by repeatedly and rapidly changing the transmitter frequency, used to counter interference, monitoring, etc.

Sigfox nodes use a Random Frequency and Time Division Multiple Access (RFTDMA) to transmit their signals. It means that:

1. Each device use a frequency randomly chose inside the Sigfox bandwidth to communicate
2. Several devices can use the same frequency to transmit data, but for one frequency, each device has several time slots to communicate (the transmission time is divided).

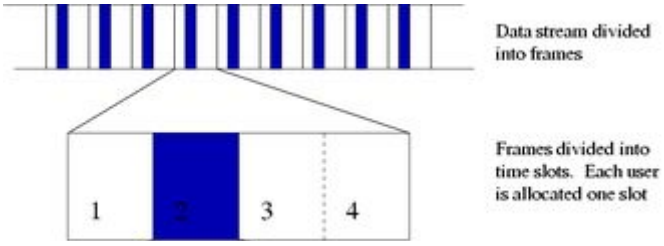

figure 2 - Time-Division Multiple Access explanation scheme

2. Power consumption

2.1 Devices consumption

Sigfox is known for its low power consumption.

Data transmission using Sigfox technology consumes between 10mA and 50mA (depending on the chip used). But most of the time (about 99% of the time), the system is in an idle state, in which it only consumes around 6nA (accordingly to Sigfox technical presentation).

More exactly, the data transmission takes 6 seconds, so the system is in idle state during $99 * 6 = 594s$.

Let's consider a device supplied by 3.3V:

- Sleep consumption: $P = 3.3 * 6 * 10^{-9} = 19.8 * 10^{-9}\ W = 19.8\ nW$
- Transmission consumption:
  - $P_{min} = 3.3 * 10 * 10^{-3} = 3.3 * 10^{-2} W = 33\ mW$
  - $P_{max} = 3.3 * 50 * 10^{-3} = 165 * 10^{-3} W = 165\ mW$

2.2 Energy per bit

During data transmission, the energy consumed by a Sigfox device is:

- $E_{min} = 33 * 10^{-3} * 6 = 198 * 10^{-3} J = 198\ mJ$
- $E_{max} = 165 * 10^{-3} * 6 = 990 * 10^{-3} J = 990\ mJ$

We know that each Sigfox data frame is composed by 26 bytes when the payload has its maximum size which is 12 bytes.

We are going to calculate the consumption per bit when the payload is minimum (0 bytes), and when it is maximum:

- $E_{min}.bit^{-1} = 198 * 10^{-3}/(26 * 8) = 0.95 * 10^{-3} J.bit^{-1}$
- $E_{max}.bit^{-1} = 990 * 10^{-3}/(14 * 8) = 8.84 * 10^{-3} J.bit^{-1}$

3. Medium Access Control (MAC) layer

Sigfox Mac layer relies on RFTDMA. It allows active nodes to access randomly in time and frequency to the wireless medium without any contention-based protocol.

It is based on ALOHA protocol, however the carrier frequencies are chosen in the bandwidth inside a continuous 2 interval, instead of a predefined discrete set.

At the receiver side, the demodulator listen on the totality of the bandwidth B without recognizing a priori the carrier frequency used by the emitting device. Therefore, identifying the emitted message can be obtained only after decoding all received signals in B.

The random access seems to be efficient in protecting the device from interferences and seems to be likewise of interest since it limits the device's energy consumption.

5. Routing and IP

Each Sigfox Ready device, when it needs to send a message, starts by sending a radio broadcast message to the Sigfox base stations, so that the nearest one can receive the message.

Then, the message is analysed and securely checked as explained in the Security part. Once this is done, the data is transmitted to the Sigfox Core Network using 4G/LTE.

Finally, the customer can access the data directly in the Sigfox Cloud thanks to his IoT application.

If the device requires a response, it will be sent to it by the IoT application following the opposite way (IoT application, Sigfox Core Network, access stations, and finally Sigfox Ready device).

4. Security

“Sigfox Ready” devices (devices which use Sigfox) do not use the Internet protocol to communicate, and they are not connected to the Internet neither.

It is also important to know that a very strict firewall protects Sigfox Ready devices from Internet threats.

Each Sigfox Ready device has an unique authentication key. Each message sent or received by a device is encrypted with a token computed based on the device authentication key. It allows the authentication by the base stations of both the sender and the receiver, and the integrity of the message. The Sigfox Core Network and applications servers use VPN and HTTPS protocol to ensure security.

Sigfox also implements anti-replay functionality, able to avoid replay attempts, and the possibility for the users to add their own security protocol for radio messages (basically dropped in the air without any encryption).

figure 3 - Data sending from Sigfox Ready devices to IoT apps encrypted

Conclusion

As a conclusion, Sigfox is a secure and low-energy communication protocol which provides a powerful architecture for IoT purposes.

Taking in consideration the range (around 15 km) and the deployment of new modules with GPS function, we can assume that Sigfox is the best alternative for IOT in terms of autonomy,miniaturization and especially range.

However, Sigfox is a bit behind other IoT technologies like LoRa Alliance in terms of bidirectional communication.

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