
# ICTIA project

## Performance analysis of the LoRa module

## LoRa™ mode

The LoRa™ mode is an advanced and private modulation that increases the range comparing to classic modulations. The LoRa™ long range mode provides ultra-long range spread spectrum communication and high interference immunity (whilst) minimizing current consumption.

| Mode | BW | CR | SF |
|---|---|---|---|
| 1 | 125 | 4/5 | 12 |
| 2 | 250 | 4/5 | 12 |
| 3 | 125 | 4/5 | 10 |
| 4 | 500 | 4/5 | 12 |
| 5 | 250 | 4/5 | 10 |
| 6 | 500 | 4/5 | 11 |
| 7 | 250 | 4/5 | 9 |
| 8 | 500 | 4/5 | 9 |
| 9 | 500 | 4/5 | 8 |
| 10 | 500 | 4/5 | 7 |

*Figure: LoRa configuration modes*

It combines digital spread spectrum, digital signal processing, and forward error correction coding to achieve notable performance. LoRa™ also provides significant advantages in both blocking and selectivity over conventional modulation techniques.

LoRa has three configurable parameters:

- Bandwidth (BW)
- Coding Rate (CR)
- Spreading Factor (SF)

The combination of these values defines the **transmission mode**. It is possible to set a predefined mode or to set these three parameters manually.

There are **ten predefined** (from 1 to 10) modes in the API, including the largest distance mode, the fastest mode, and eight other intermediate modes that Libelium has found interesting. All of them can be modified or deleted, and also it is possible to attach new modes in the appropriate function. The predefined modes and its properties are shown in the table on the left. The user will be able to choose the most suitable mode for that application after appropriate testing phase because **there is not a perfect mode for any situation**. In fact, it exists a compromise between distance range and speed of transmission.

## Description of the experiment

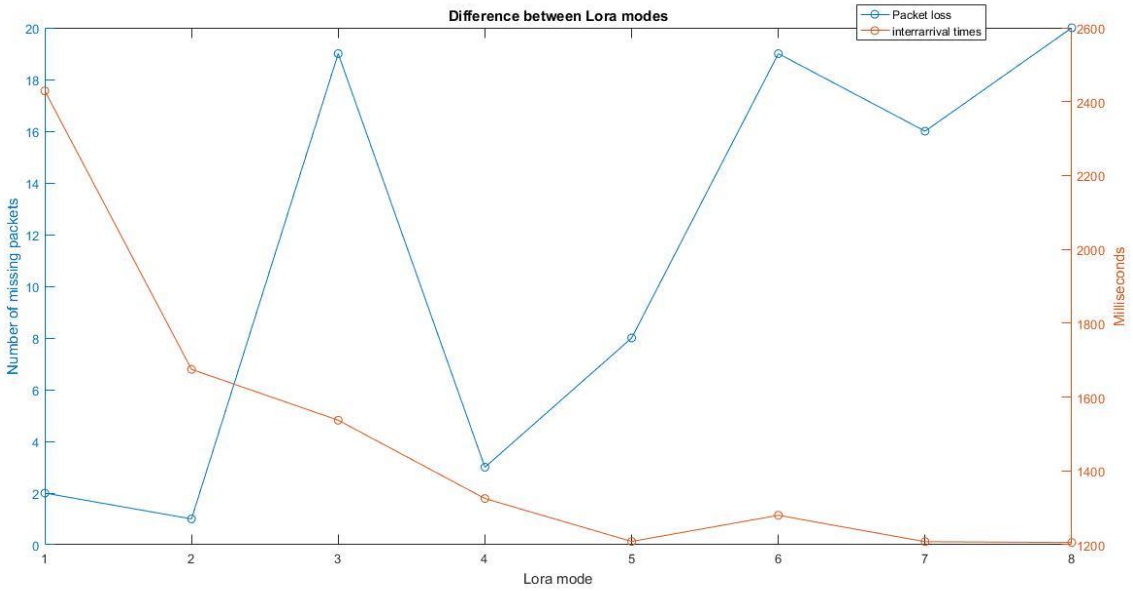
In order to find the most suitable mode we needed to use a mobile transmitter and a static receiver. We would like to simulate “Formula SAE” scenario, it means that transmission sketch was performed in an Arduino Mega 2560 situated inside a vehicle while receiver sketch was performed in an Arduino Mega 2560 collocated in the corridor of the second floor in the “corpo D” of “Dipartimento Ingegneria dell’Informazione”. This position for the receiver side was in front of a window in which the receiver would mostly be in line of sight with the Rx antenna during the car laps. The vehicle in which there was the transmitter **has made the path in the figure below for each Lora mode**, starting from “Texmat” and making a loop.

It must be noted that we had conducted measurements only from 1$^{st}$ to 8$^{th}$ mode.

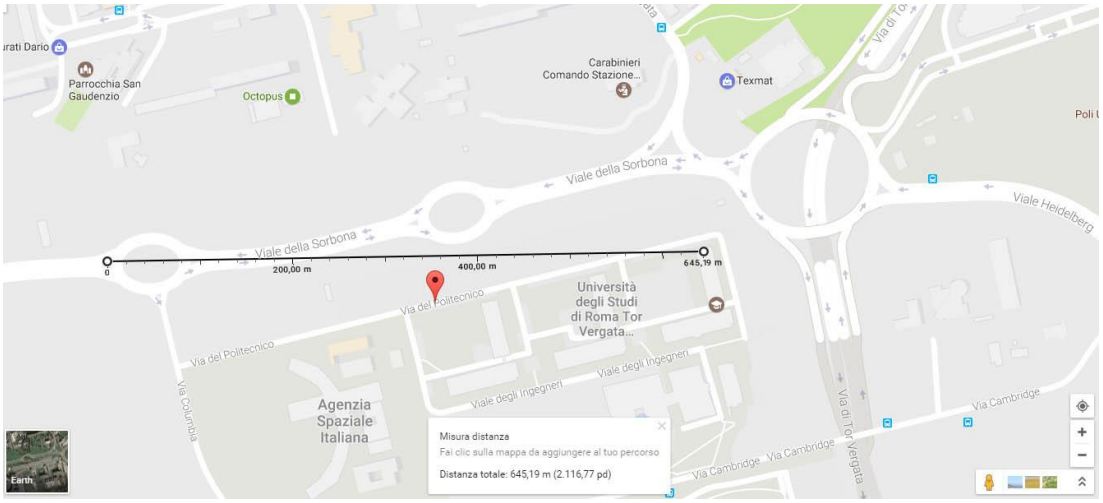
## Experiment results

In this section, we will discuss about result obtained by the experiment, and then about what will be the suitable choice for our application.

First, we compute what is **the number of packet lost** and what is the **average time difference** between each packet and the next one in each LoRa mode. How you can see in the figure the first modes show a lower number of packets lost but a higher average interarrival time while the last modes show the opposite behavior.




There exists a compromise to take in account between transmission time and number of packets lost. Thus we identify two configurations seem be interesting in our case: **mode 2** and **mode 4**. Moreover, if we come back to the experiment we can notice that there are time intervals in which there is a degradation of quality of the channel (link sensitivity tables). These intervals are associated to two different part of the lap in which **range and Doppler become significant**, generating differences between Lora modes. The longest path between TX and RX antenna is about 650 meters.

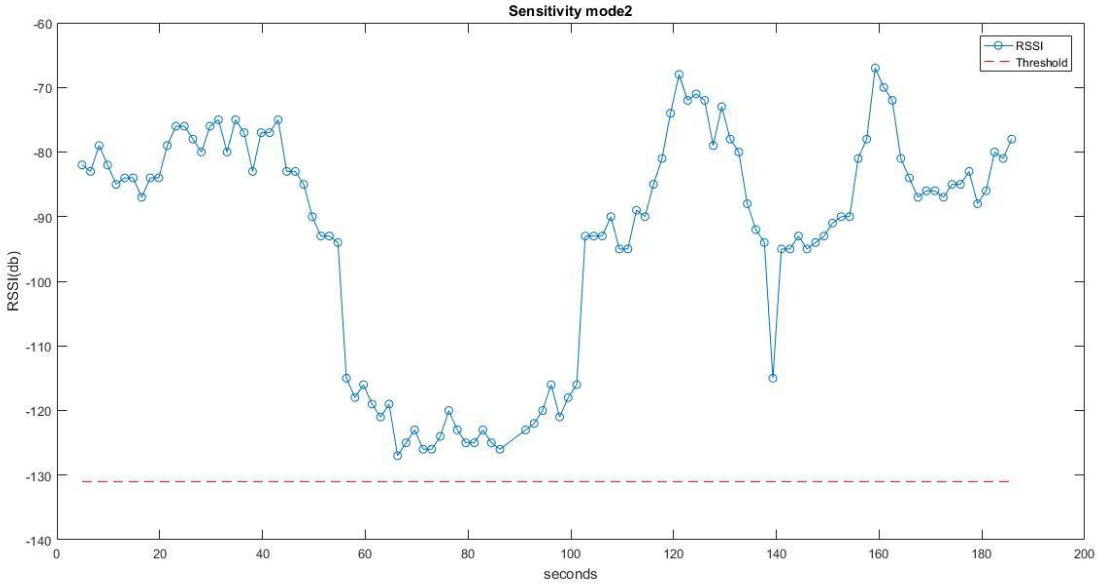


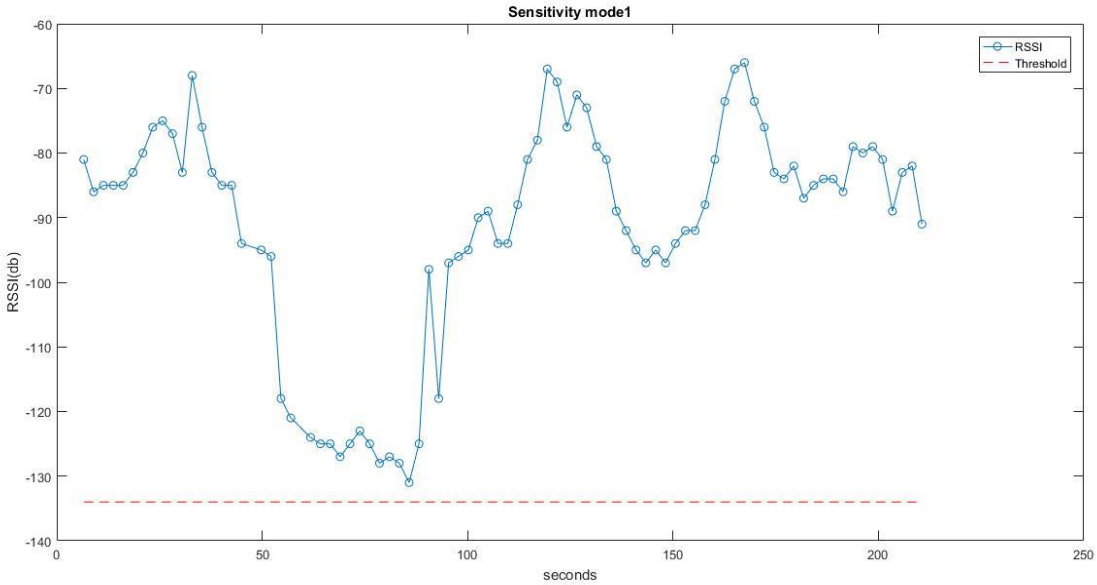
# Appendix A – Sensitivity tables

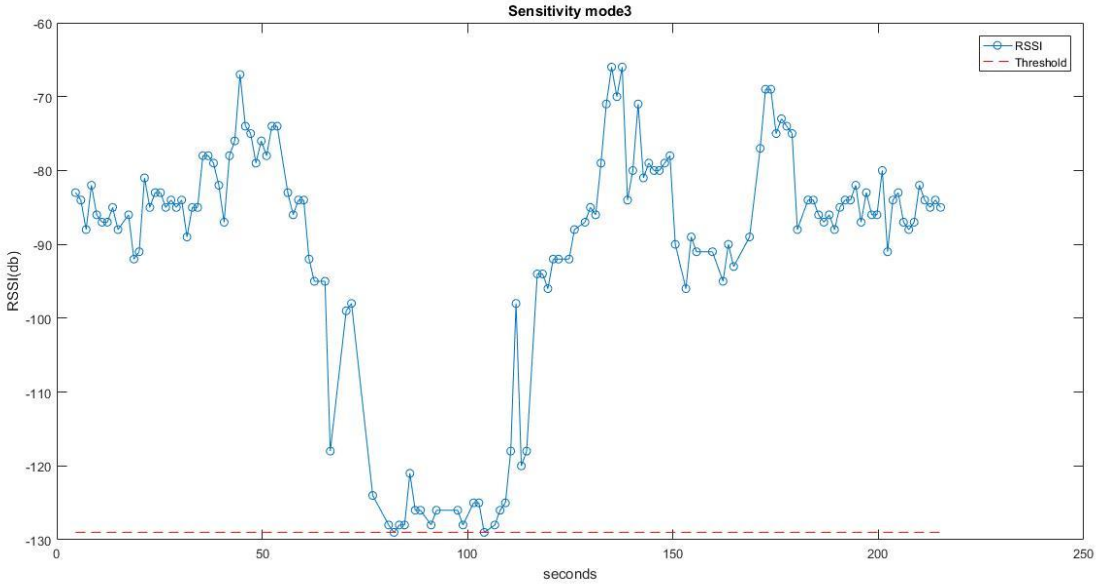
For each mode, ranging from 1 to 8, we show below the RSSI (dB) values captured.

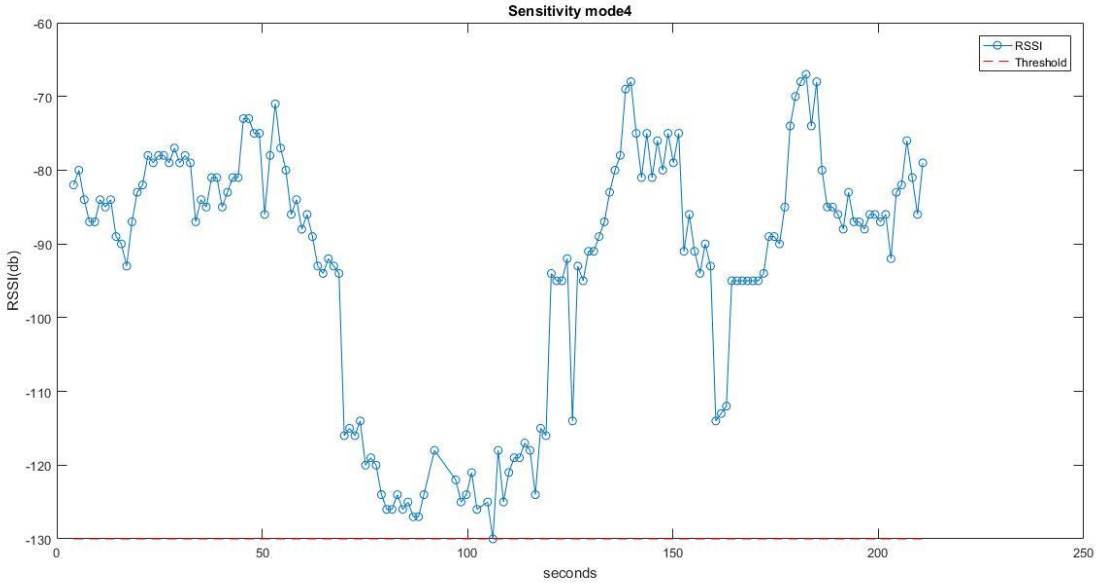
The red line represents the theoretical limit for each mode reported in the datasheet.

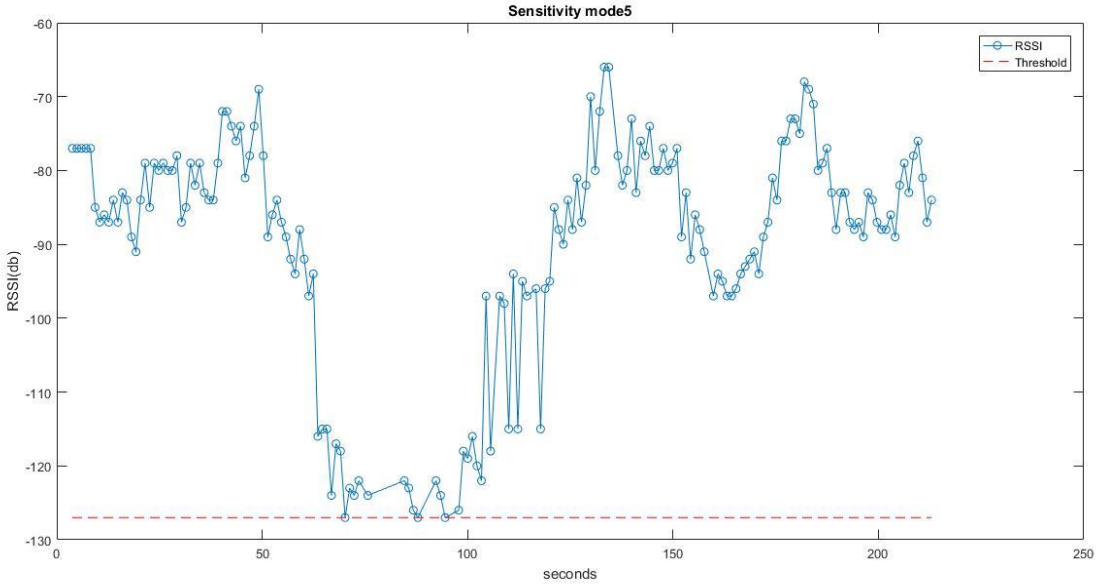
The absolute minimum is scored at the longest distance (650 meters, not in LOS). The subsequent two high peaks have been measured when the car was passing in front of the building with the RX antenna.

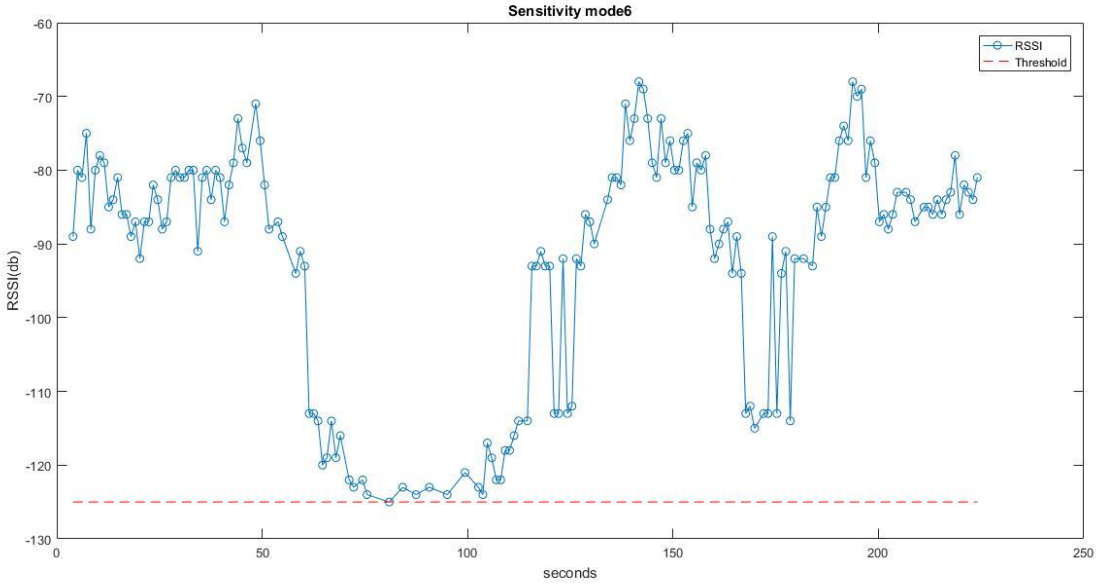


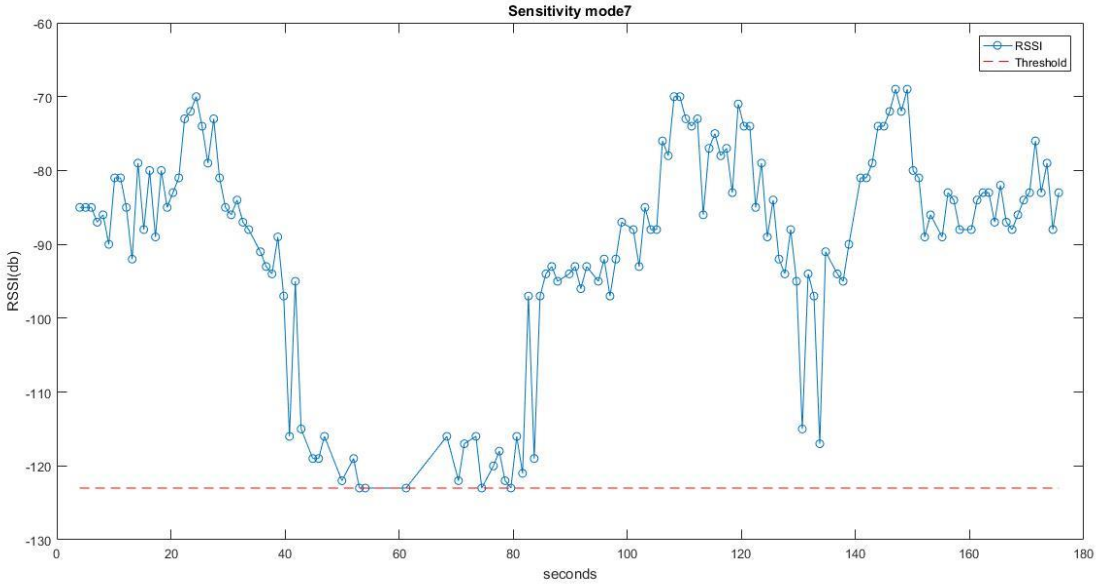



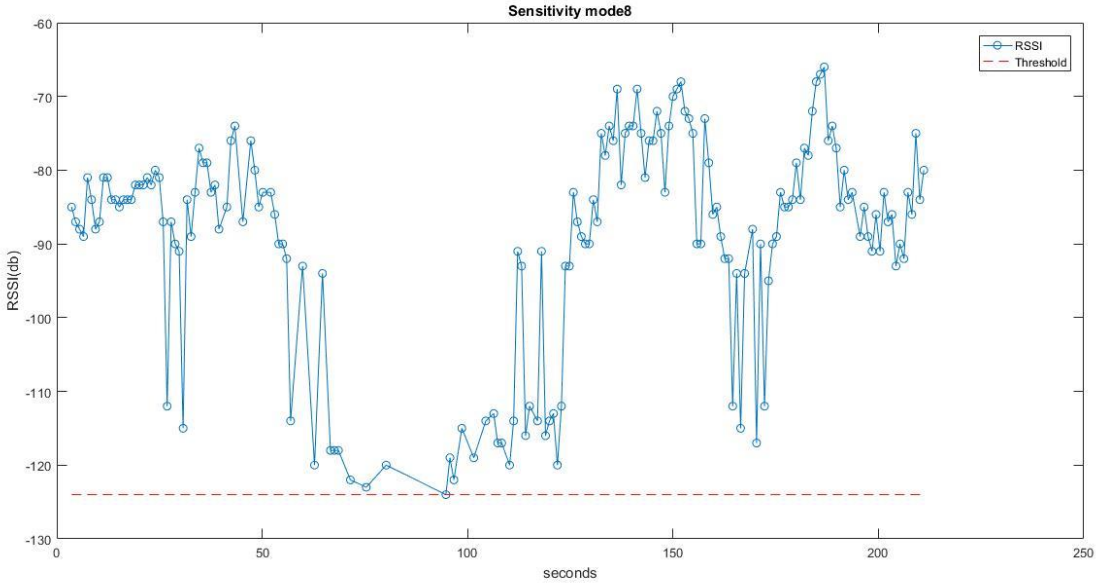

Sensitivity mode3
RSSI
Threshold
RSSI(db)
-60
-70
-80
-90
-100
-110
-120
-130
0
50
100
150
200
250
seconds


Sensitivity mode4
RSSI
Threshold
RSSI(db)
-60
-70
-80
-90
-100
-110
-120
-130
0
50
100
150
200
250
seconds


Sensitivity mode5
RSSI
Threshold
RSSI(db)
seconds
-60
-70
-80
-90
-100
-110
-120
-130
0
50
100
150
200
250


Sensitivity mode6
RSSI
Threshold
RSSI(db)
seconds
-60
-70
-80
-90
-100
-110
-120
-130
0
50
100
150
200
250


Sensitivity mode7
RSSI
Threshold
RSSI(db)
seconds
-60
-70
-80
-90
-100
-110
-120
-130
0
20
40
60
80
100
120
140
160
180


Sensitivity mode8
RSSI
Threshold
RSSI(db)
seconds
-60
-70
-80
-90
-100
-110
-120
-130
0
50
100
150
200
250