In-vivo experiments on LR-FHSS modulation

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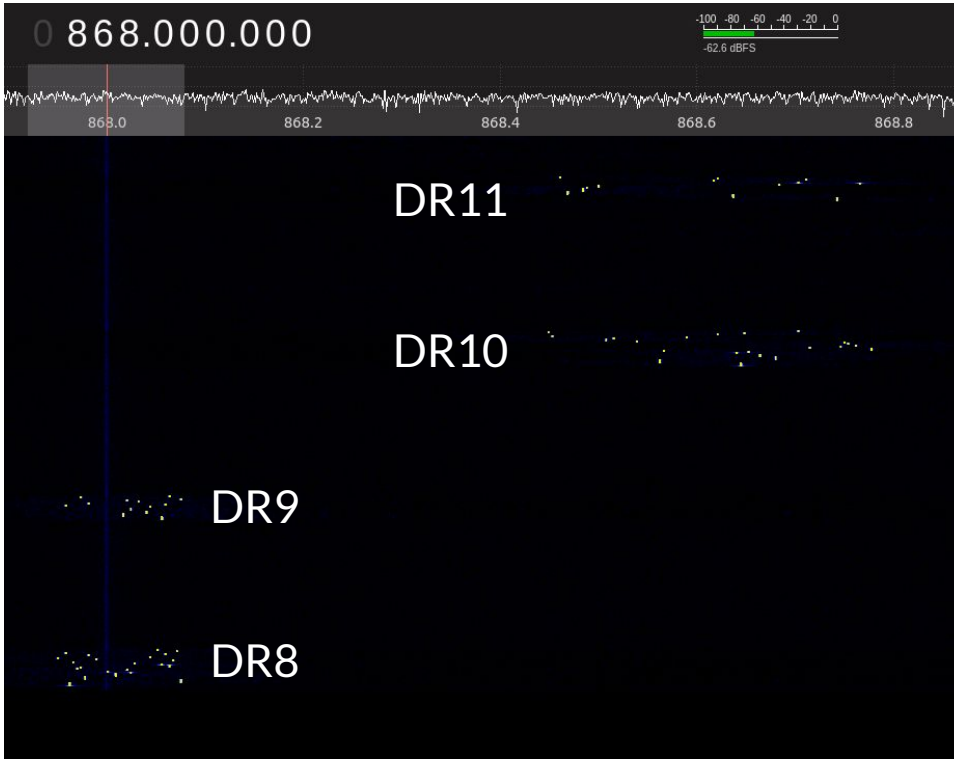
Content

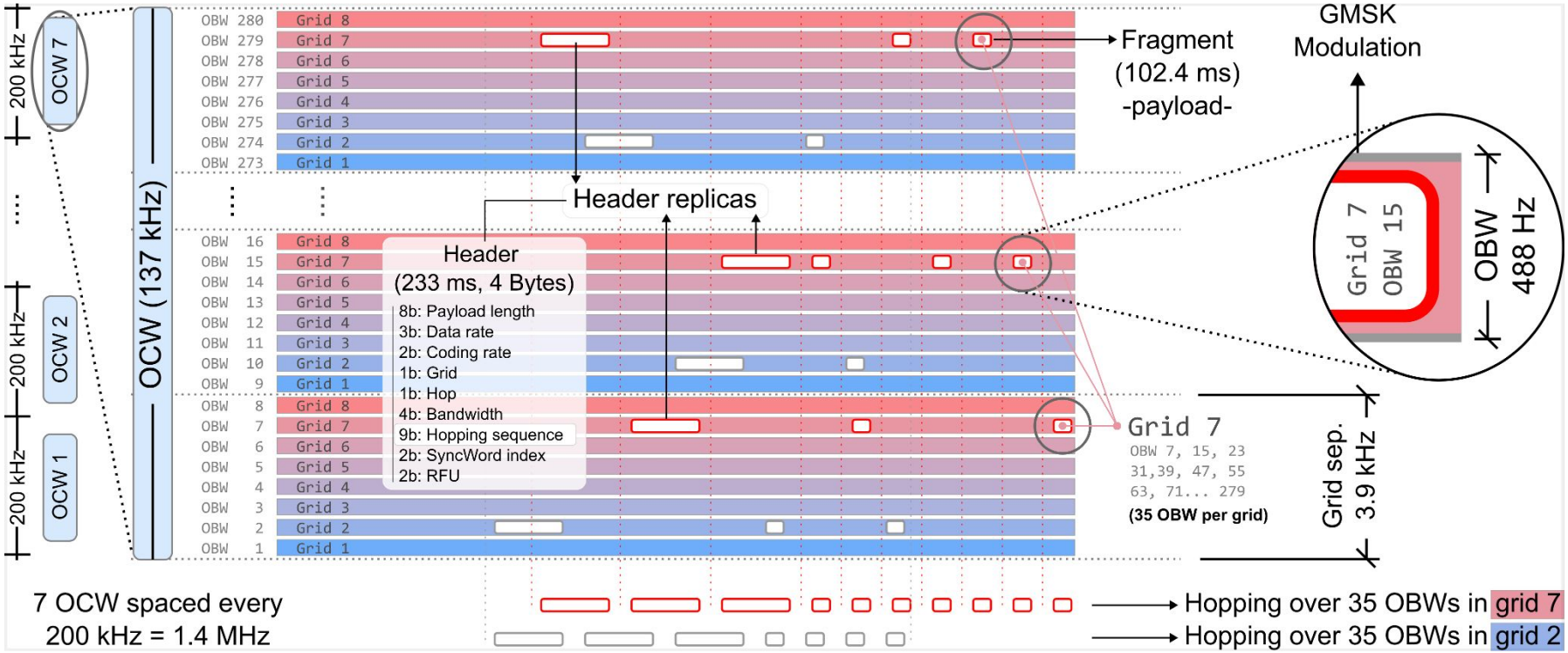
- LR-FHSS in a Nutshell
- Experiments:
  - Hardware & Software
  - Balloons experiments
  - Urban experiments in Lyon
- Conclusion
- Perspectives

LR-FHSS

- Long Range Frequency Hopping Spread Spectrum (LR-FHSS) is a modulation created by Semtech
- Intra packet frequency hopping
- Suitable for applications with low gateway density and limited spectrum, requiring a large range and high robustness (network in rural areas, and satellite applications)



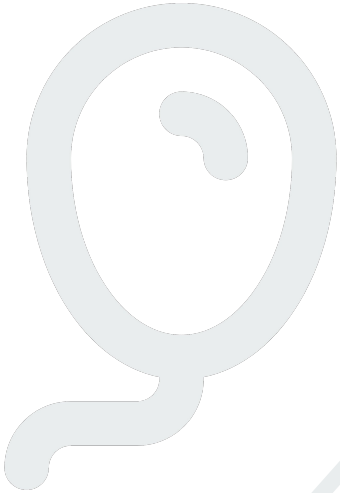
LR-FHSS Physical layer

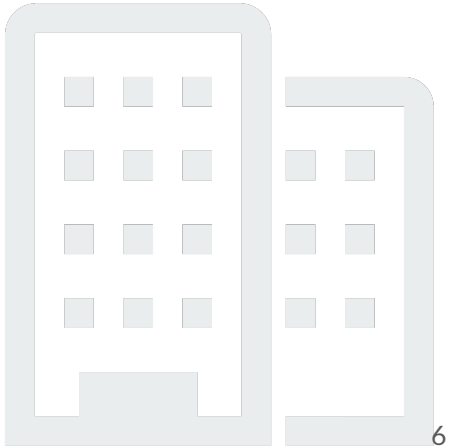


LR-FHSS - Open Questions

- How does LR-FHSS perform in space?
- How does LR-FHSS perform in an urban environment?
- How does LR-FHSS perform w.r.t. LoRa?
- Does mobility impact reliability in LR-FHSS?

LR-FHSS Experiments





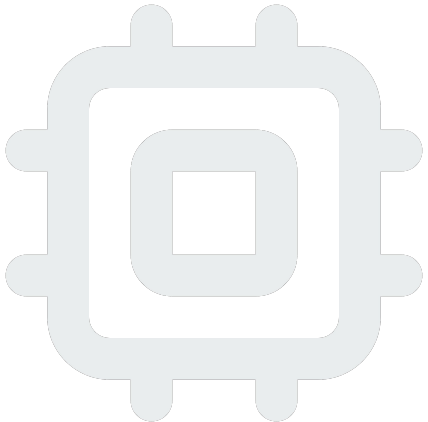
Experimental Platforms: Hardware & Software

Three ballons from Aire-sur-l'Adour (24-05-2024)

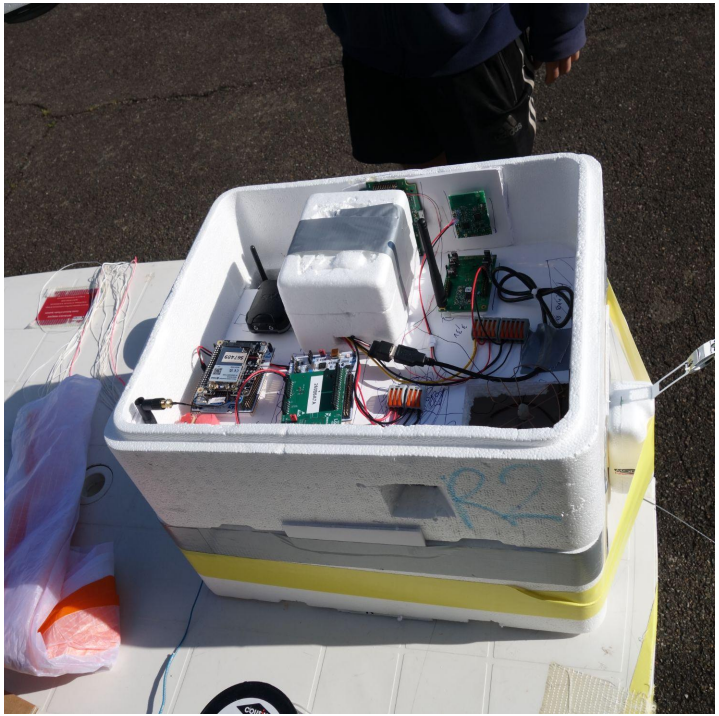
- 4 kits lr1120dvk1tbks + firmware "LoRaWAN ABP"
- 2 iBTS gateway + firmware LR-FHSS
- LNS Chirpstack v4.7 sur Azure

Lyon Urban environment

- 4x kit Nucleo LR1110 + firmware "LoRaWAN ABP"
- 1 iBTS gateway + firmware LR-FHSS
- UDP packet sniffer



Experimental Platform (Ballons)



Gateways

Two gateways, kerlink IBTS, LRFHSS enabled, respectively at the launch site (Aire-Sur-l'Adour) and at Puy-de-Dôme

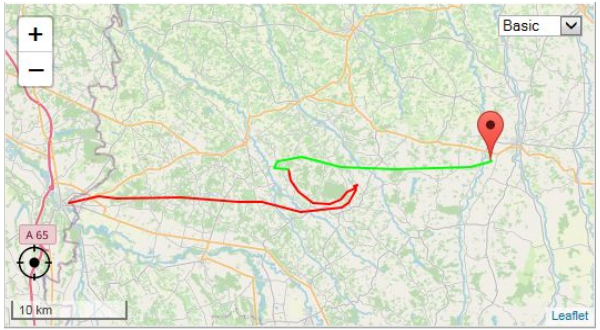
Inflation and release of the balloons

Burst of one of the three balloon

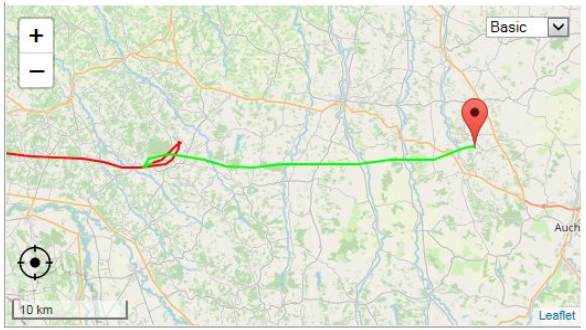
Recovery of the experimental devices

Balloon Path

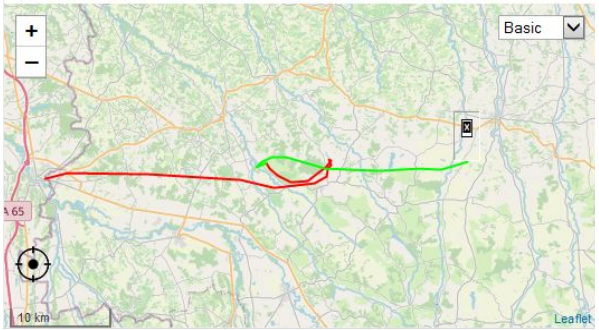
Ballon 1



Ballon 2



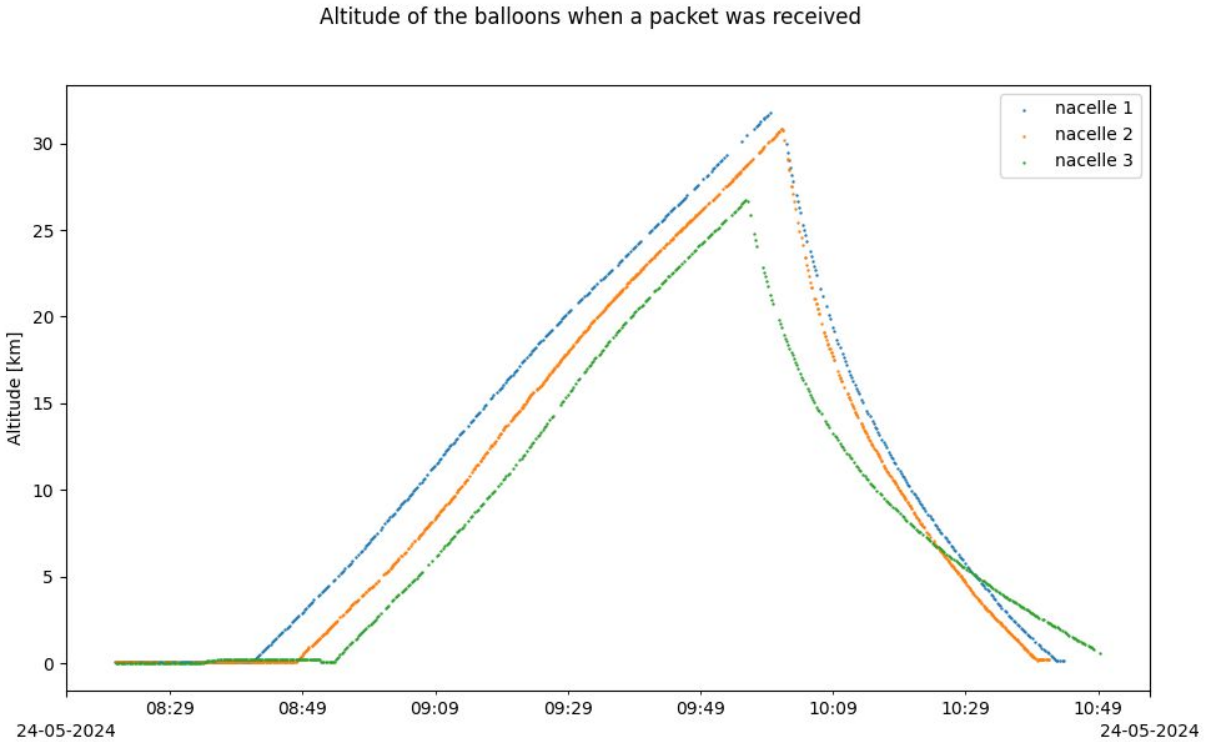
Ballon 3



Path of the three balloons. Flights went well overall, expect for balloon n°3 which burst at a lower altitude than expected, making its flight time longer and flown distance shorter.

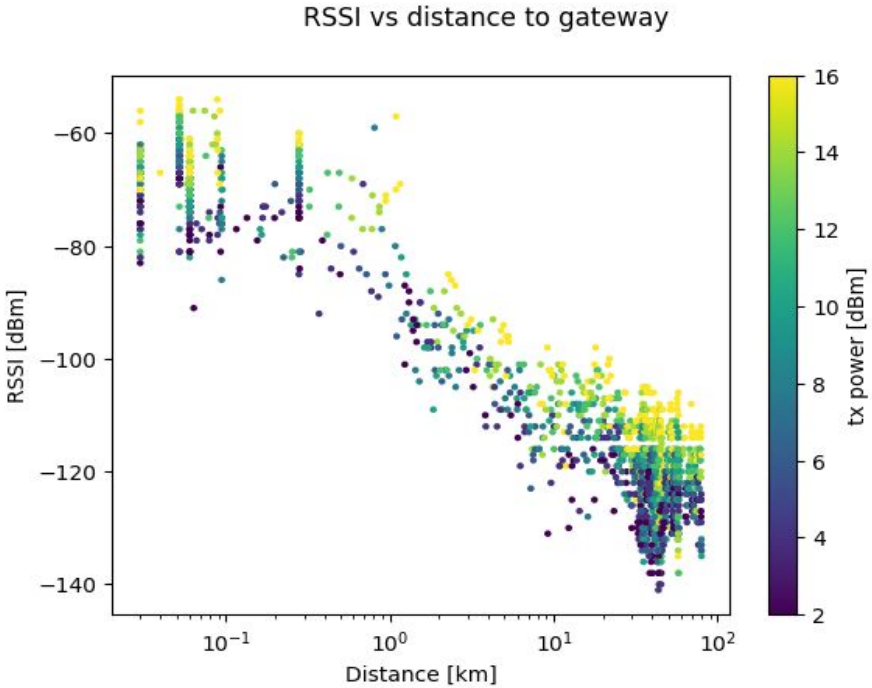
Results (Ballons)

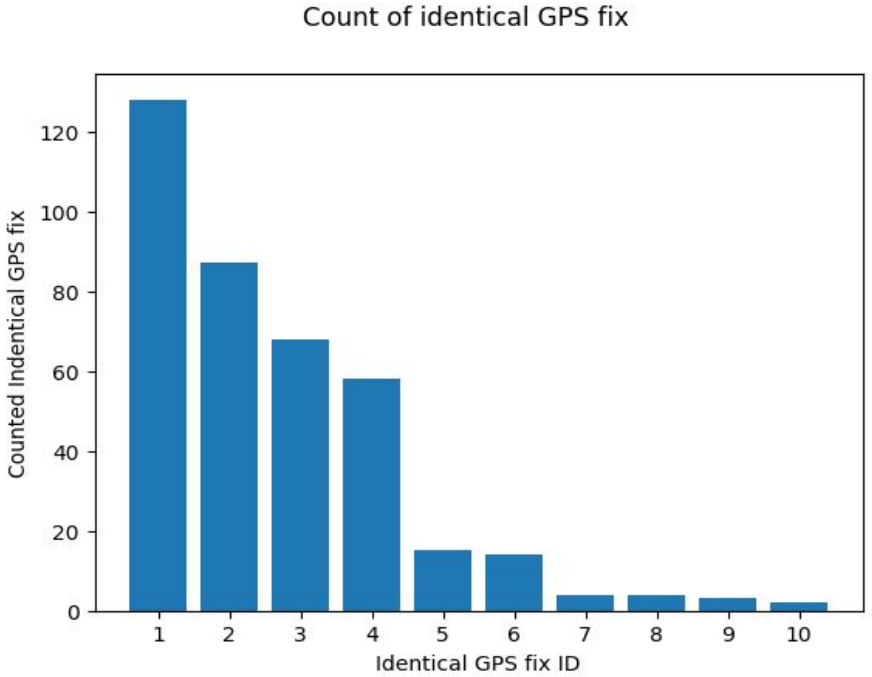
Altitude over time



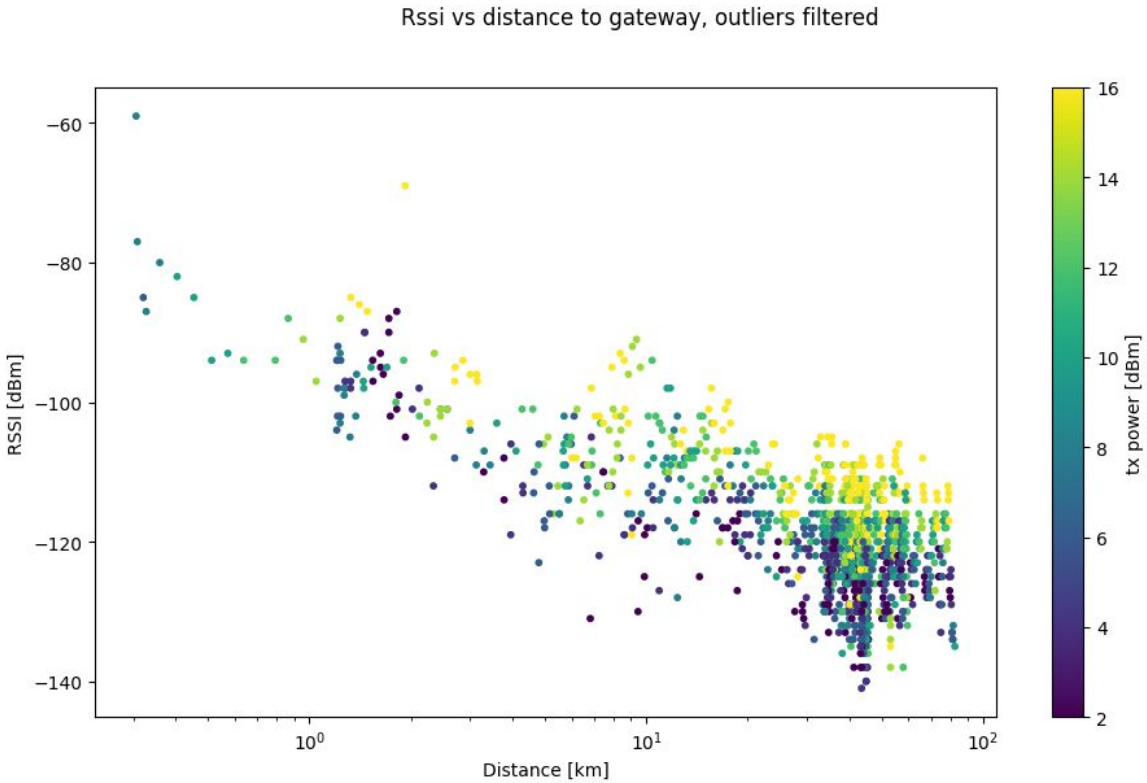
Altitude of the 3 balloons over time. Each dot is a packet sent by a LR-FHSS device

Raw RSSI

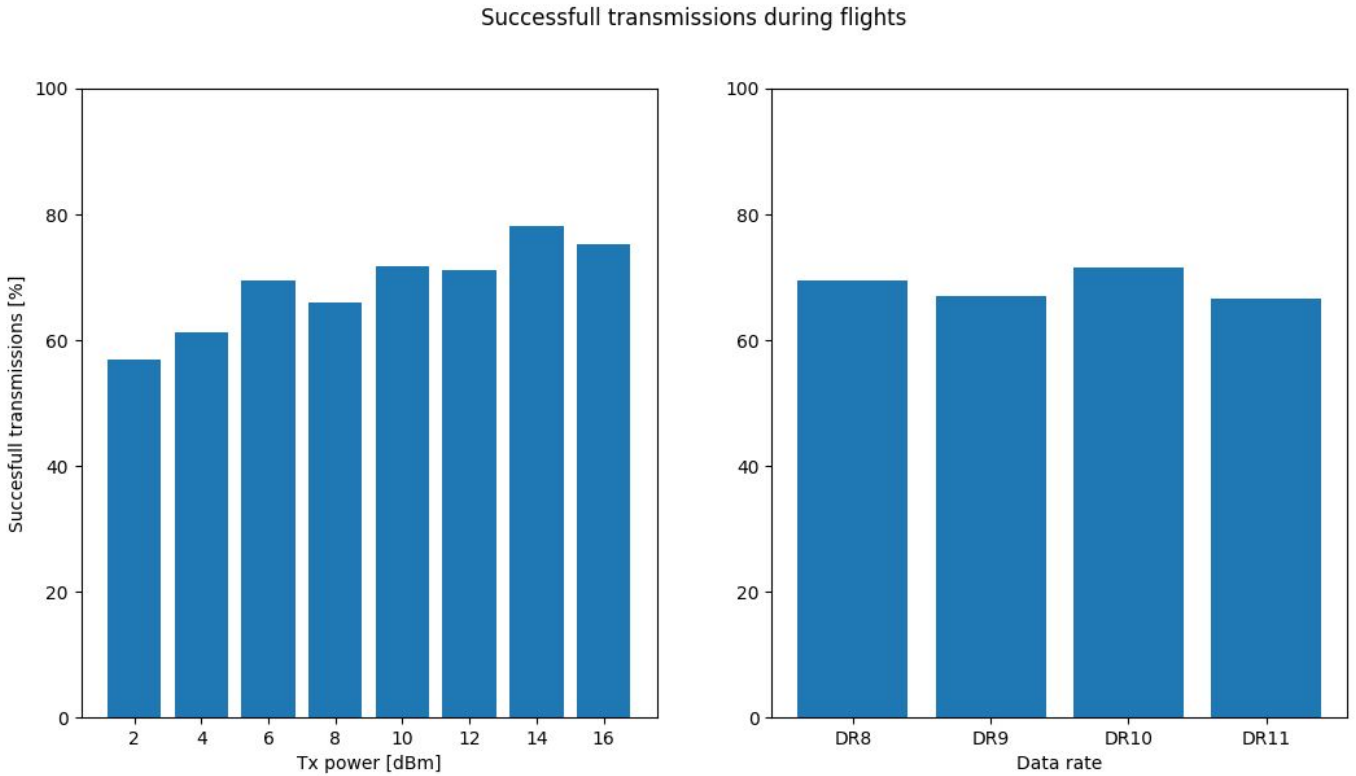

RSSI vs distance to gateway
RSSI [dBm]
−60
−80
−100
−120
−140
10^{-1}
10^{0}
10^{1}
10^{2}
Distance [km]
tx power [dBm]
16
14
12
10
8
6
4
2


Count of identical GPS fix
Counted Indentical GPS fix
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
10
Identical GPS fix ID

Filtered RSSI

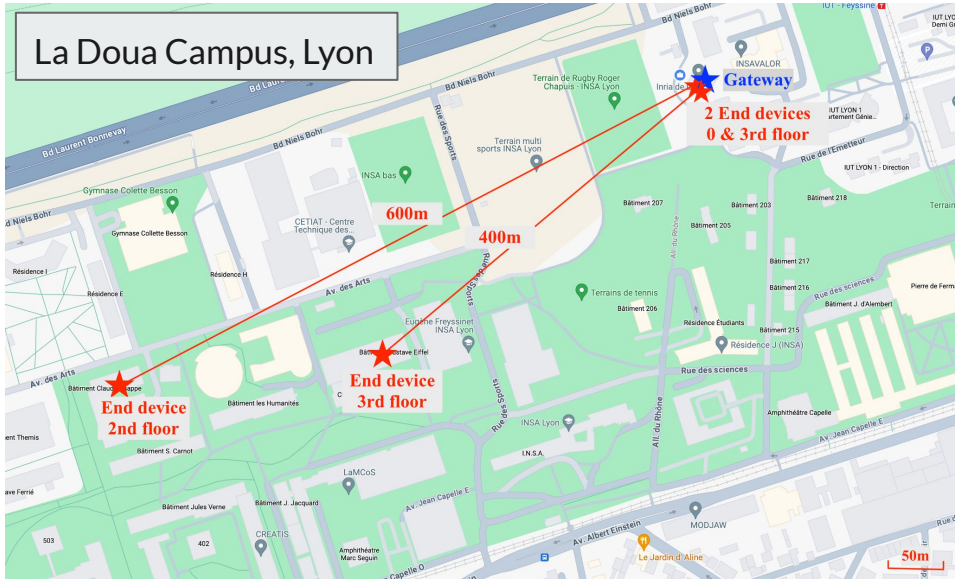


Successful transmissions by Tx and data rate



Experiments (Urban)

Experimental Platform (Urban)



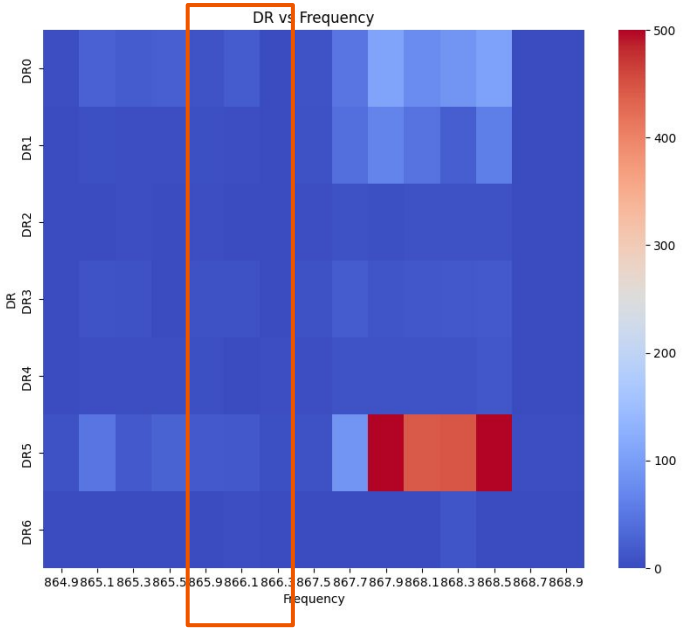
- 1 gateway: Kerlink IBTS
- Rooftop of a 4 story building

- 4 indoor end devices
- LR1110

- TX power: 2, 8, 14 dBm
- 20 bytes payload

- DR0 ---> DR11
- 3680 total packets

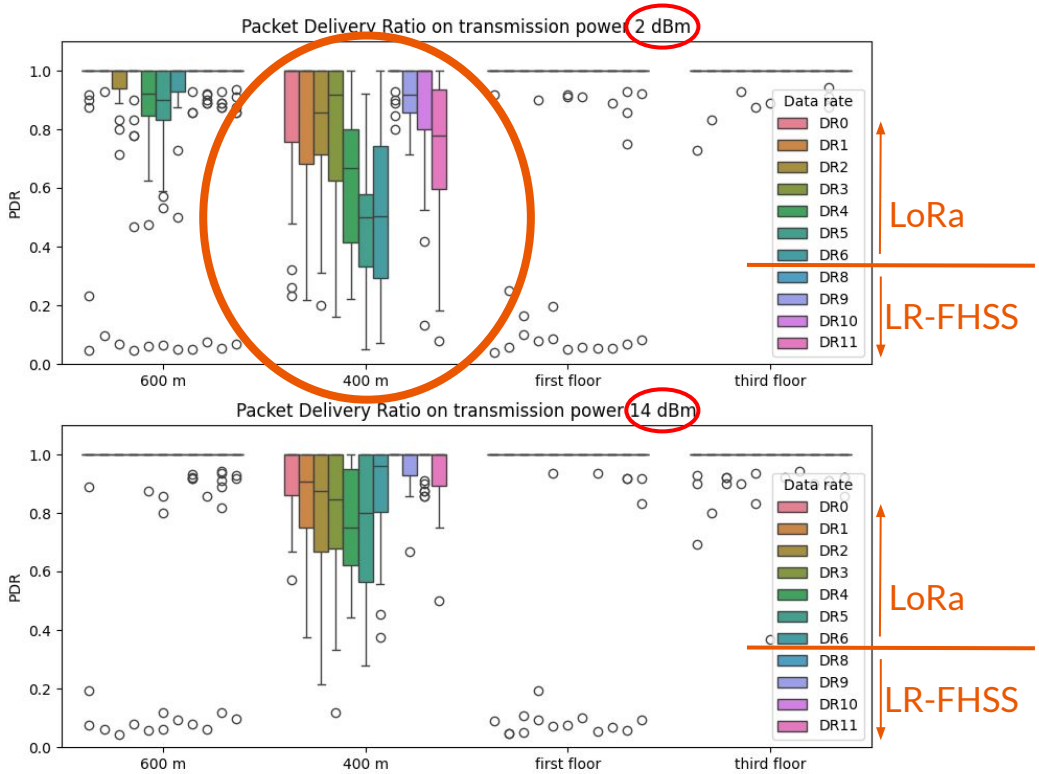
Environment Check & Setup



Attention!

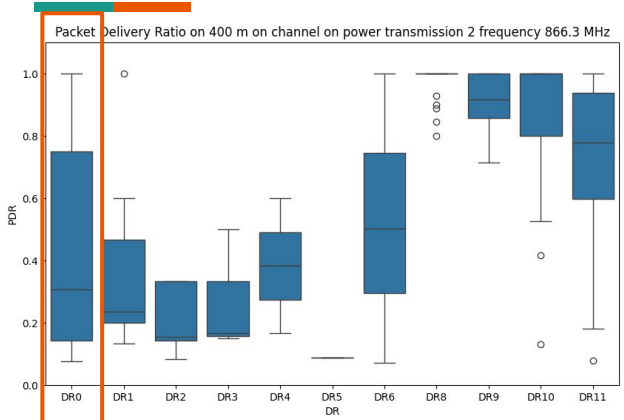
- Existing LoRa deployments
- Choose channels less used
  - 865.7 MHz
  - 865.9 MHz
  - 866.1 MHz
  - 866.3 MHz

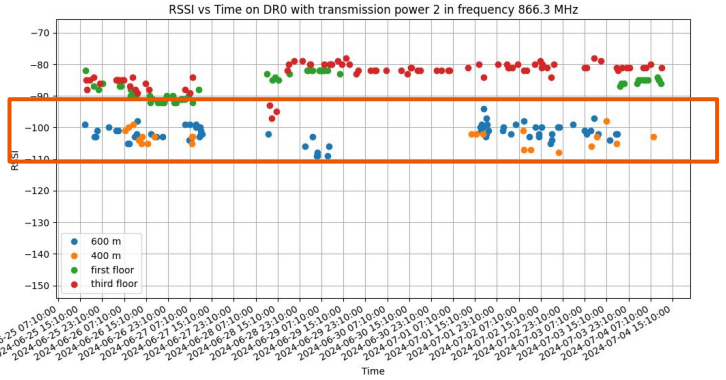
Reliability Results: Packet Delivery Ratio

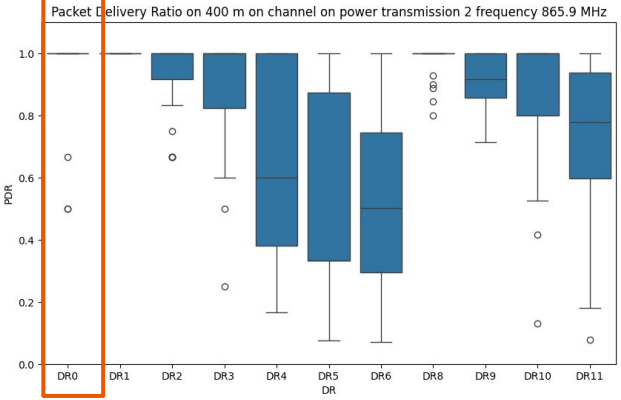


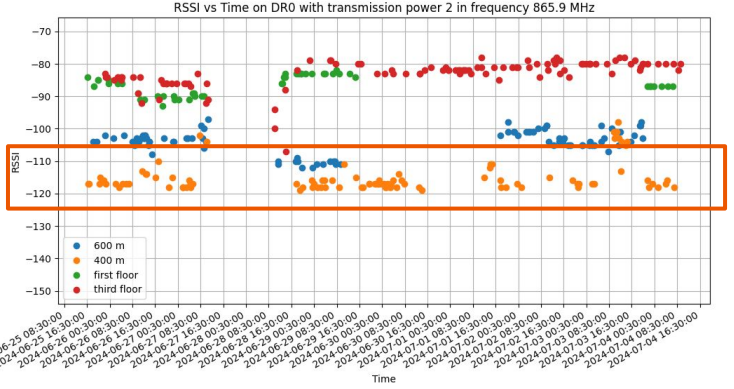
- LR-FHSS vs. LoRa for indoor communication
  - Similar PDR for DR0 (LoRa SF12) and DR8 (LR-FHSS CR1/3)
  - LoRa slightly worse in more constraint environment (at 400m)
  - What about the used channels?
- Building at 400 m
  - Recently restored building
  - Metal curtains on the exterior

Impact of Frequency Channel

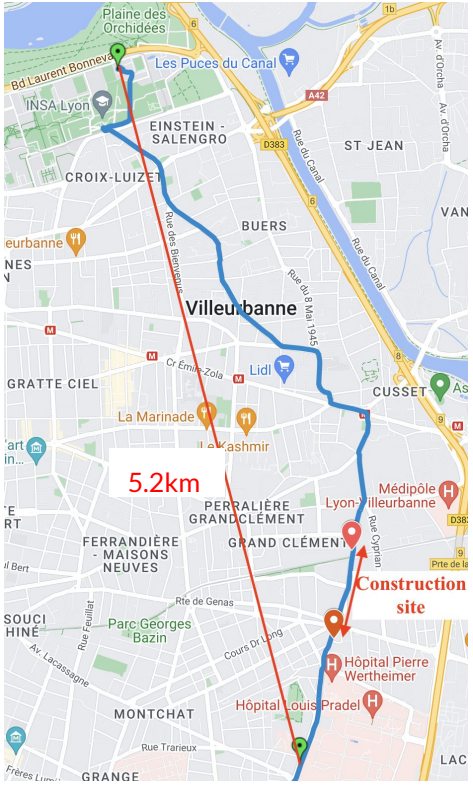


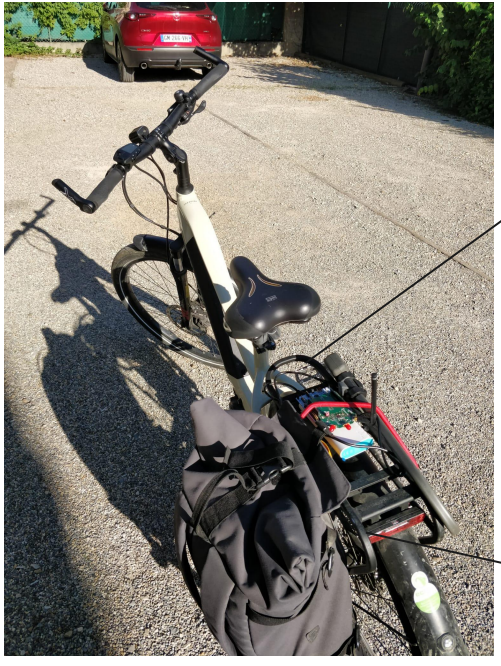




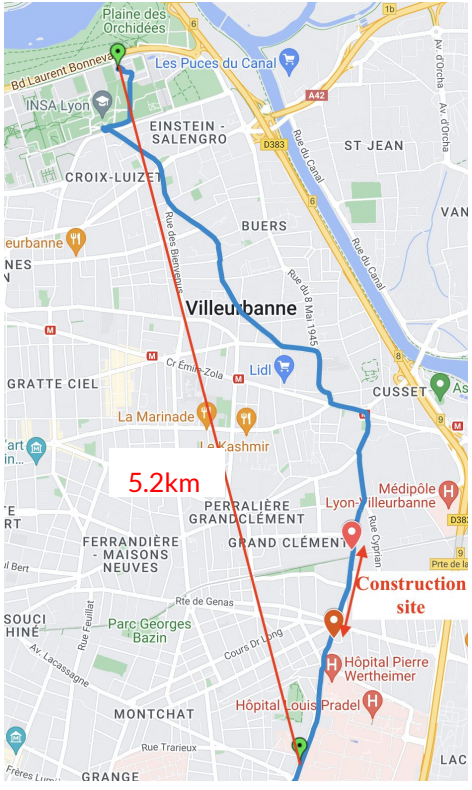


Mobility Experiments

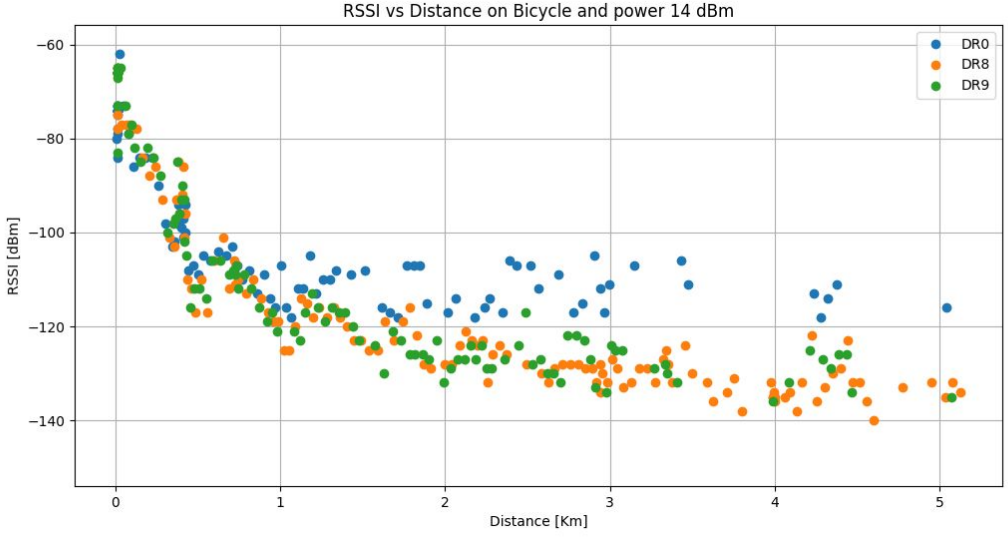




Mobility Experiments



- Biking - average speed: 17 km/h
- Max communication distance: 5.2 km



Overall PDR:

DR0: 55.8%
DR8: 81.3%
DR9: 64.3%

Urban Experiments - Conclusion

- Good performance of LR-FHSS in an urban environment
  - Indoor
  - Outdoor
  - Static
  - Mobile

- LR-FHSS can be a good solution (replacement of DR0) in urban scenarios with pre-existent LoRa deployments

Perspectives I

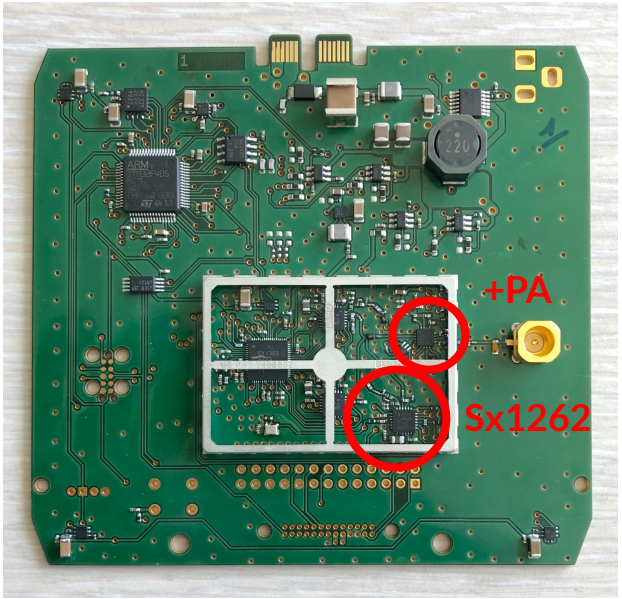
Use more devices(LR1110 Tracker …)

For example on grenoble's TourPerret

Gateway on the Fort Saint Eynard →To be made available in Slices FR

Endpoints on the Mont Blanc https://github.com/CampusIoT/datasets/tree/main/SaintEynard

Perspectives II : LR-FHSS from LEO to ground

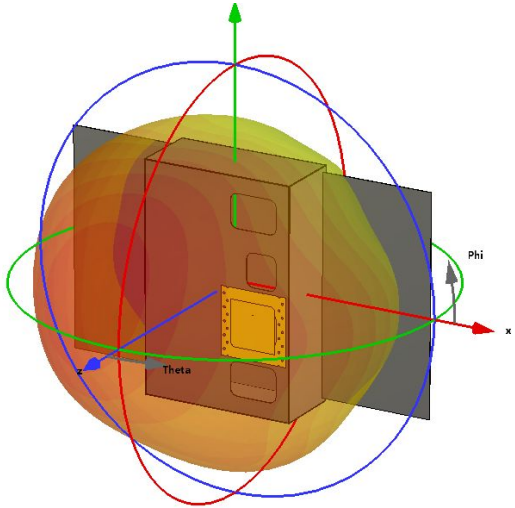


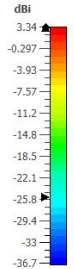
Satellite launch expected february 2025

up to 27 dBm tx power

https://gricad-gitlab.univ-grenoble-alpes.fr/thingsat/public/-/tree/master/cubesat_mission_2

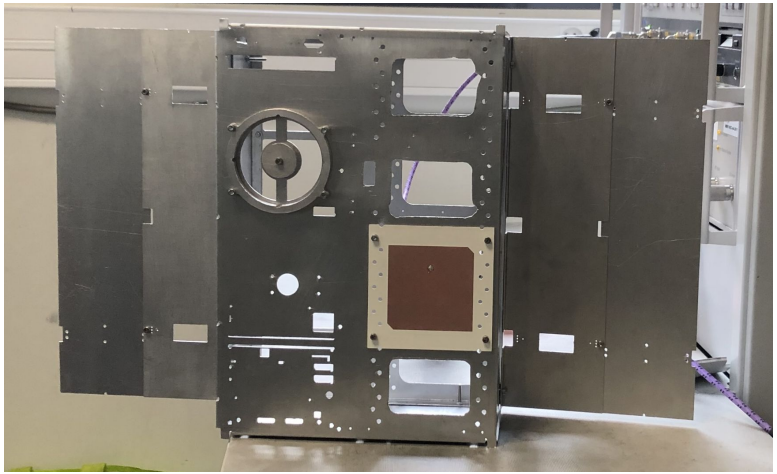
Perspectives II : LR-FHSS from LEO to ground





farfield (f=0.868) [1]

Type	Farfield
Approximation	enabled (kR >> 1)
Component	Abs
Output	Realized Gain
Frequency	0.868 GHz
Rad. Effic.	-3.874 dB
Tot. Effic.	-3.959 dB
Rlzd. Gain	3.339 dBi



https://gricad-gitlab.univ-grenoble-alpes.fr/thingsat/public/-/tree/master/cubesat_mission_2

Acknowledgment and thanks

The CSUG Team

The CNES Balloon team from l'Aire-sur-l'Adour

The Semtech team from Meylan

Nicolas Albarel, ANS Innovation

The poissonnerie Lachenal (For the devices PE boxes)

Bonus Track

Photos à la base du CNES: https://gricad-gitlab.univ-grenoble-alpes.fr/thingsat/public/-/tree/master/balloons/2024-05-24

Video des vols ballon: lien Youtube : https://filesender.renater.fr/?s=download&token=5b5f1f4d-5686-49ef-9399-eca19216831a

Dépots de données: https://github.com/CampusIoT/datasets/tree/main/LR-FHSS (notebook Jupiter)

Dépot pour l'expérimentation (la reproductibilité) : firmwares, config LNS → https://github.com/thingsat/lr-fhss