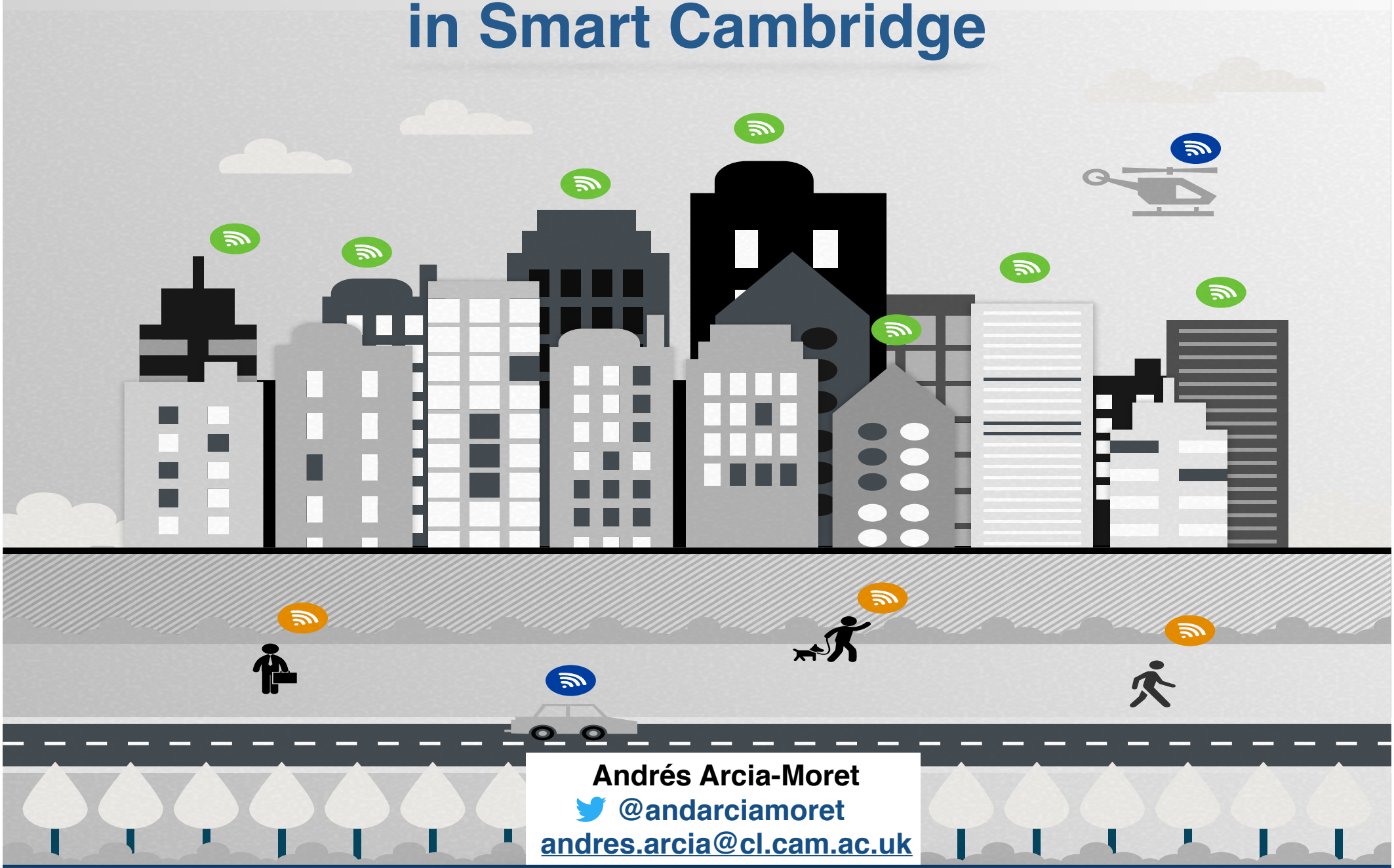
A mobile approach to IoT spectrum monitoring in Smart Cambridge



Andrés Arcia-Moret

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UNIVERSITY OF CAMBRIDGE

smart CAMBRIDGE
Solutions for the city and beyond

DATABOX

Work in progress

Do we need spectrum monitoring in smart cities relying on LPWAN?

Ideally the collected (spectrum) data should be …

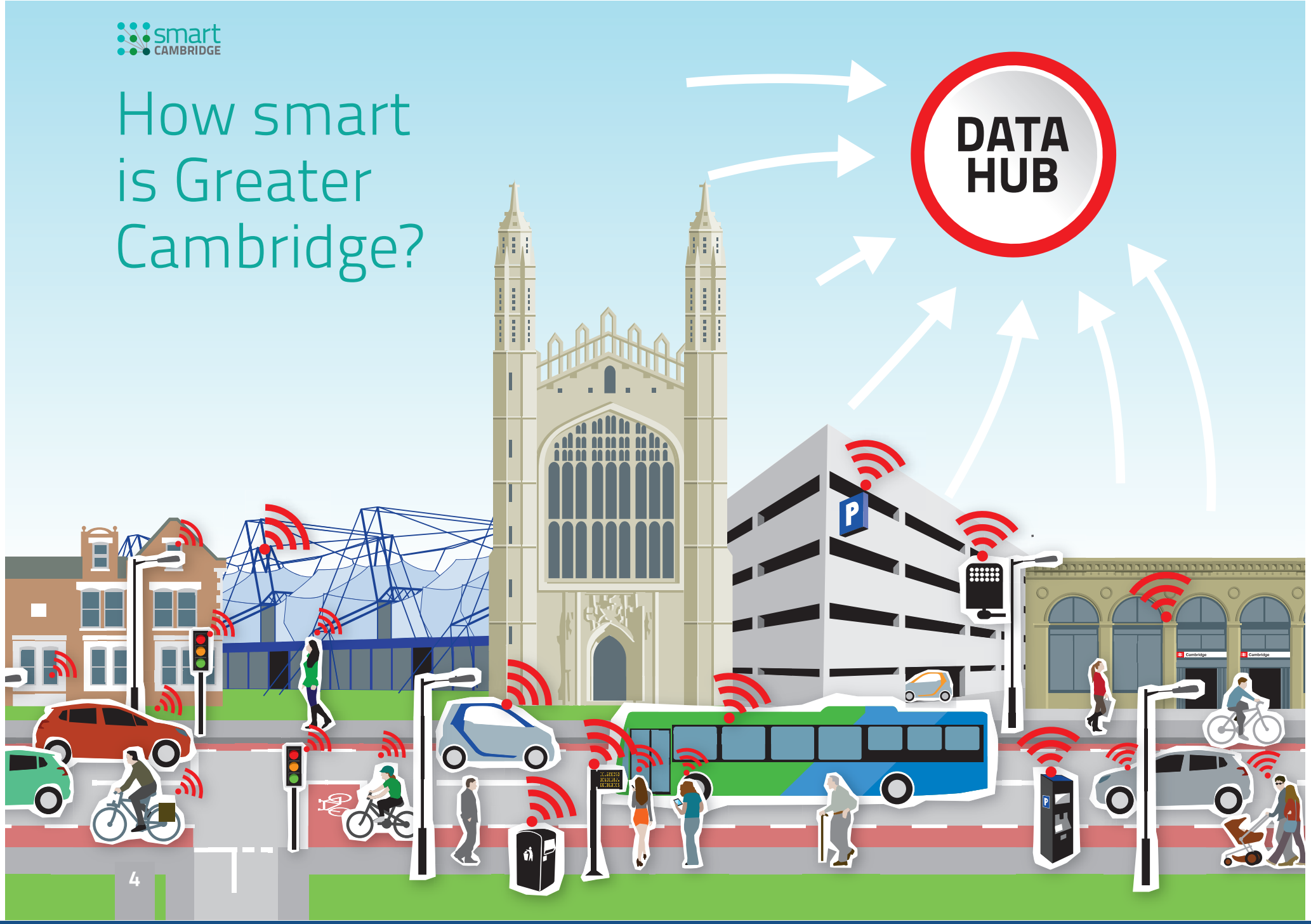
sharable at a low-cost in

Agenda

- Smart Cambridge
- Infrastructure organisation
- LPWAN in Cambridge (simulation/measurements)
- Key takeaways

smart CAMBRIDGE

How smart is Greater Cambridge?



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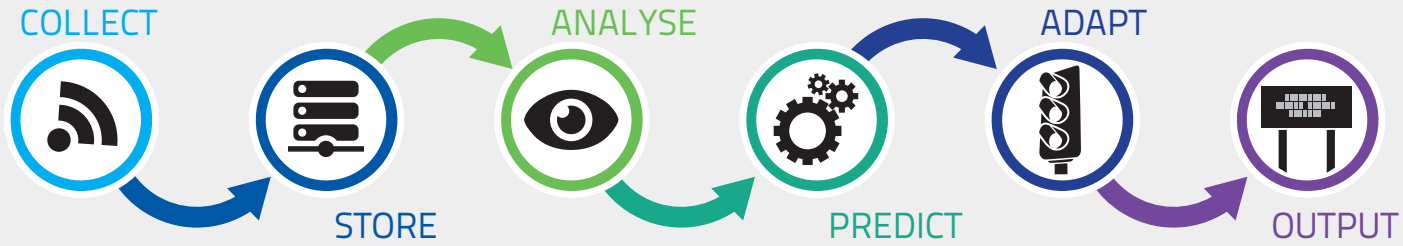
Visit: www.smartcambridge.org

http://opendata.cambridgeshireinsight.org.uk

Intelligent City Platform

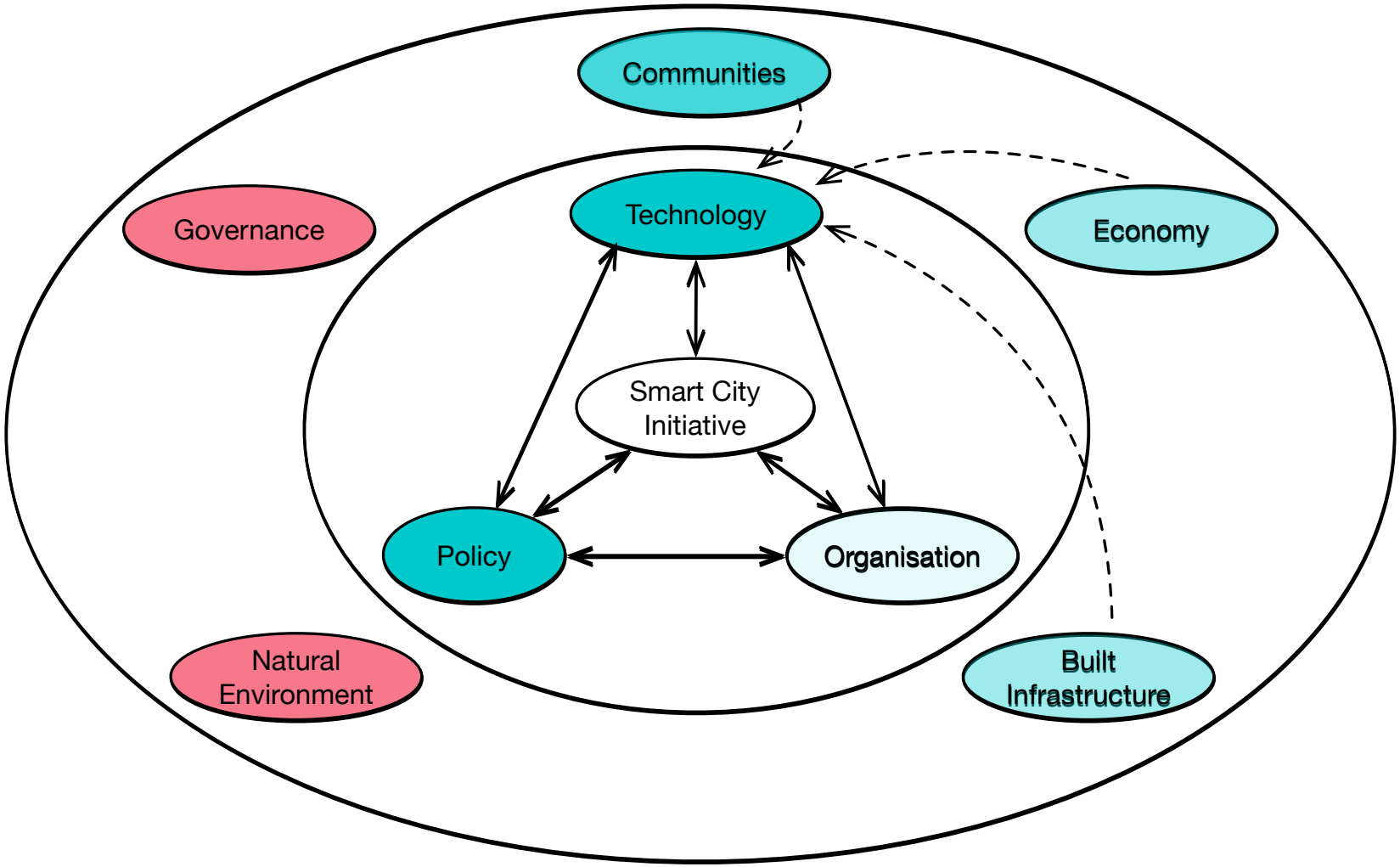
The process for developing the iCP and using the data



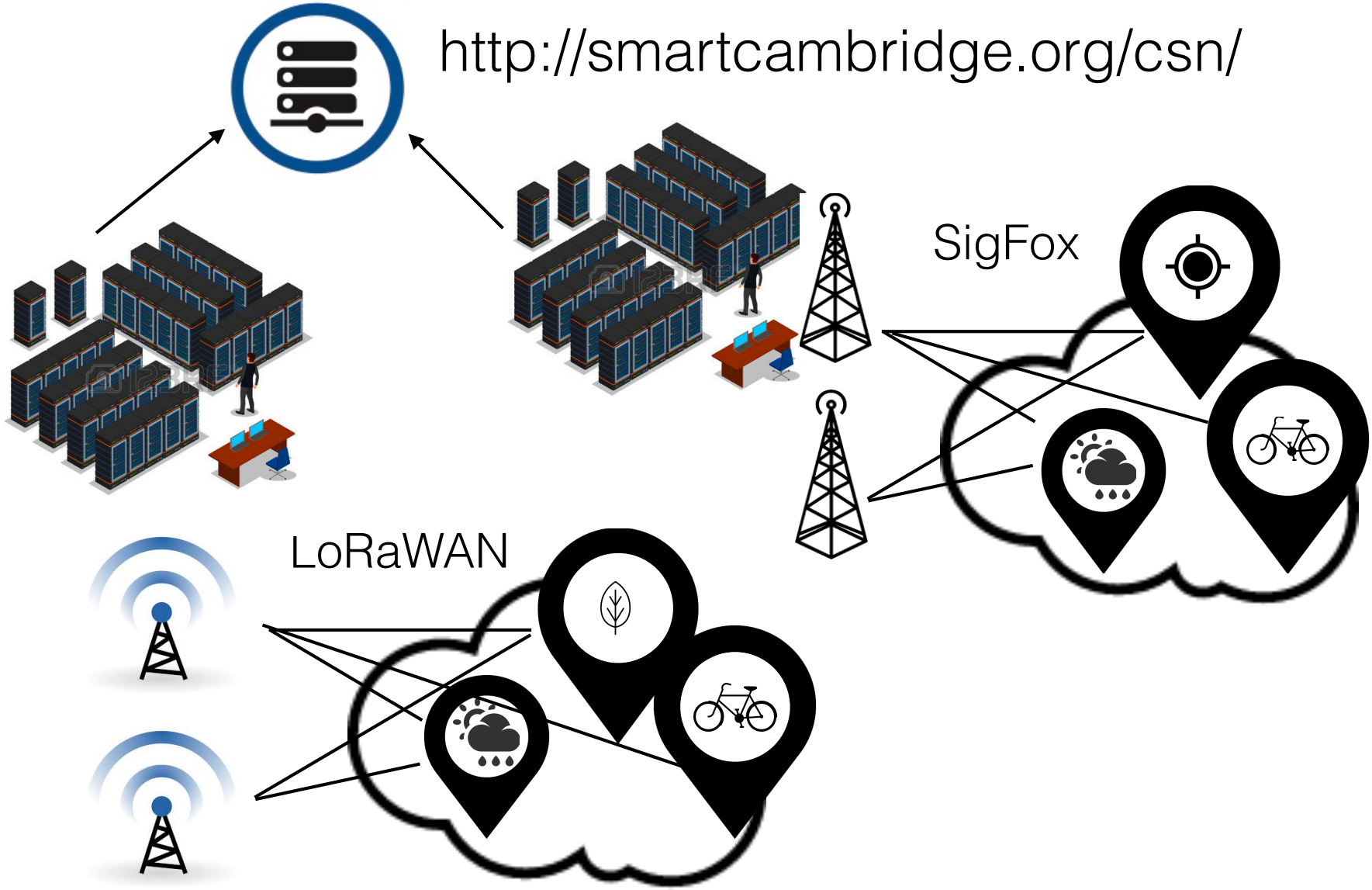
Expected impact

- Improve experience of people living, travelling and working in and around the city
- Develop mobile apps to help the traveller plan their journey
- Data will be open (#hackathons)

Towards a Community Architecture for a Smart City



IoT Network Infrastructure

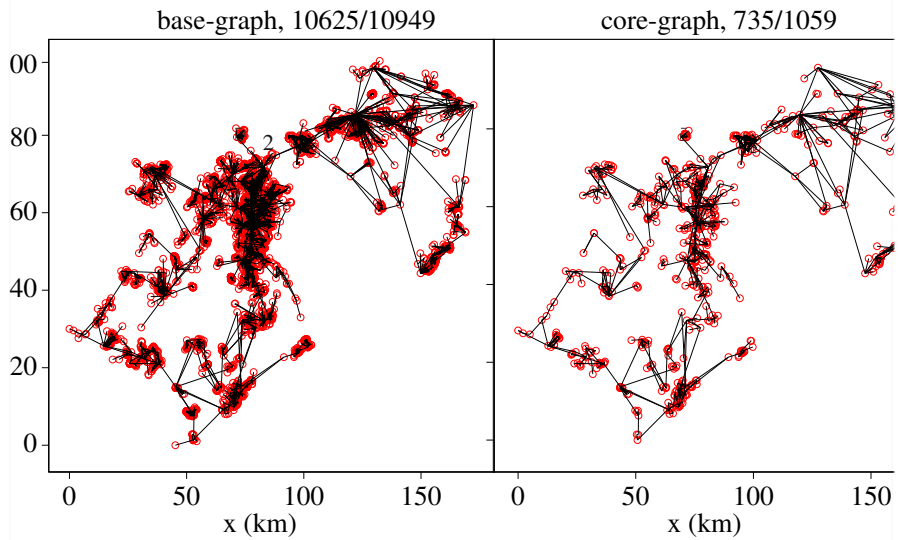


Network Models

- LoRaWAN: Community built or private network service.
- SigFox: Subscription based network service - they say. In practice is public institution - private

A bottom-up smart city infrastructure

- Smart city as an organic integration of systems and services.
- Core of super nodes and based point to multipoint nodes.

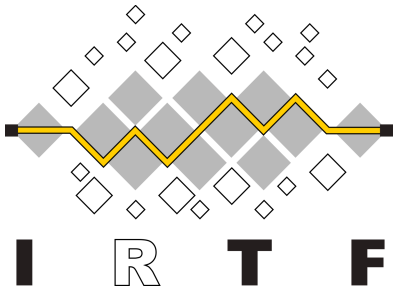


ure 1. Base and core graphs of the Catalunya zone. Axis are in

	nodes/links	degree
base-graph	10,625/10,949	1/2.06/476
core-graph	735/1,059	1/2.88/30

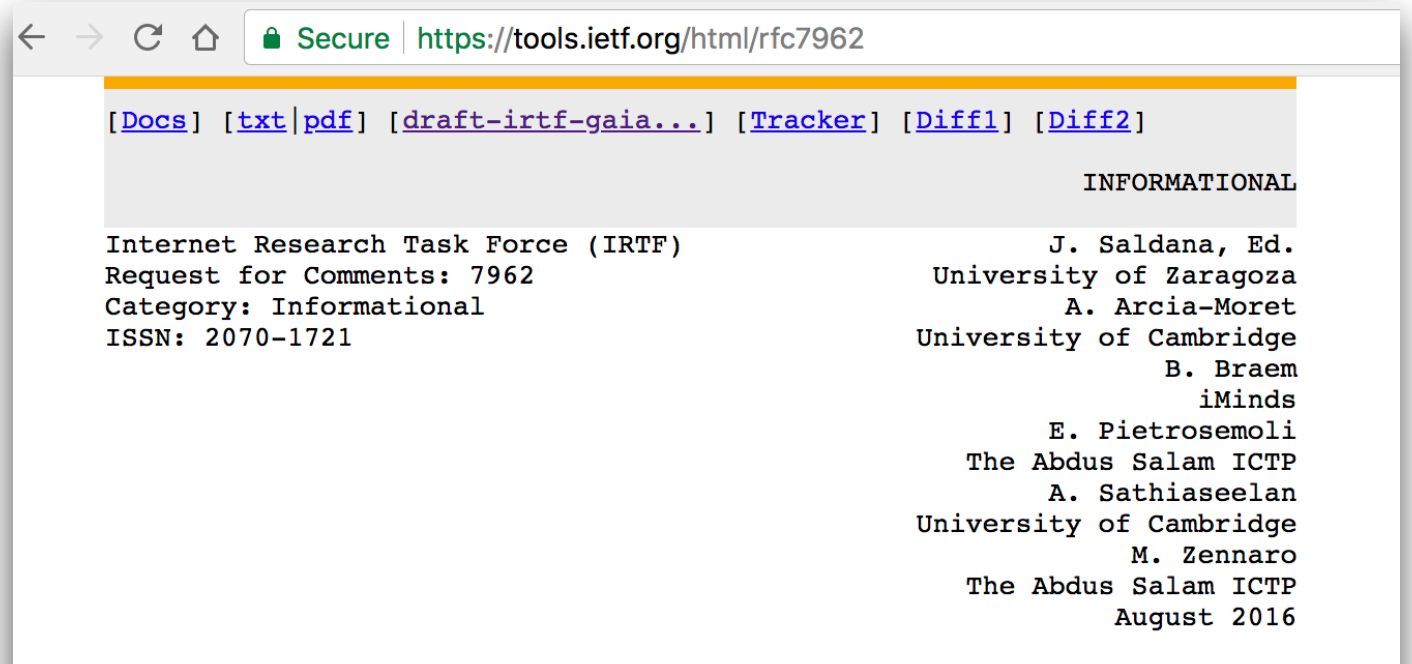
Table II
SUMMARY OF CATALUNYA GRAPHS. NODE DEGREE GIVEN AS MIN/MEAN/MAX.

D. Vega, L. Cerdà-Alabern, L. Navarro, and R. Meseguer, "Topology patterns of a community network: Guifi.net,"


I R T F


I E T F®

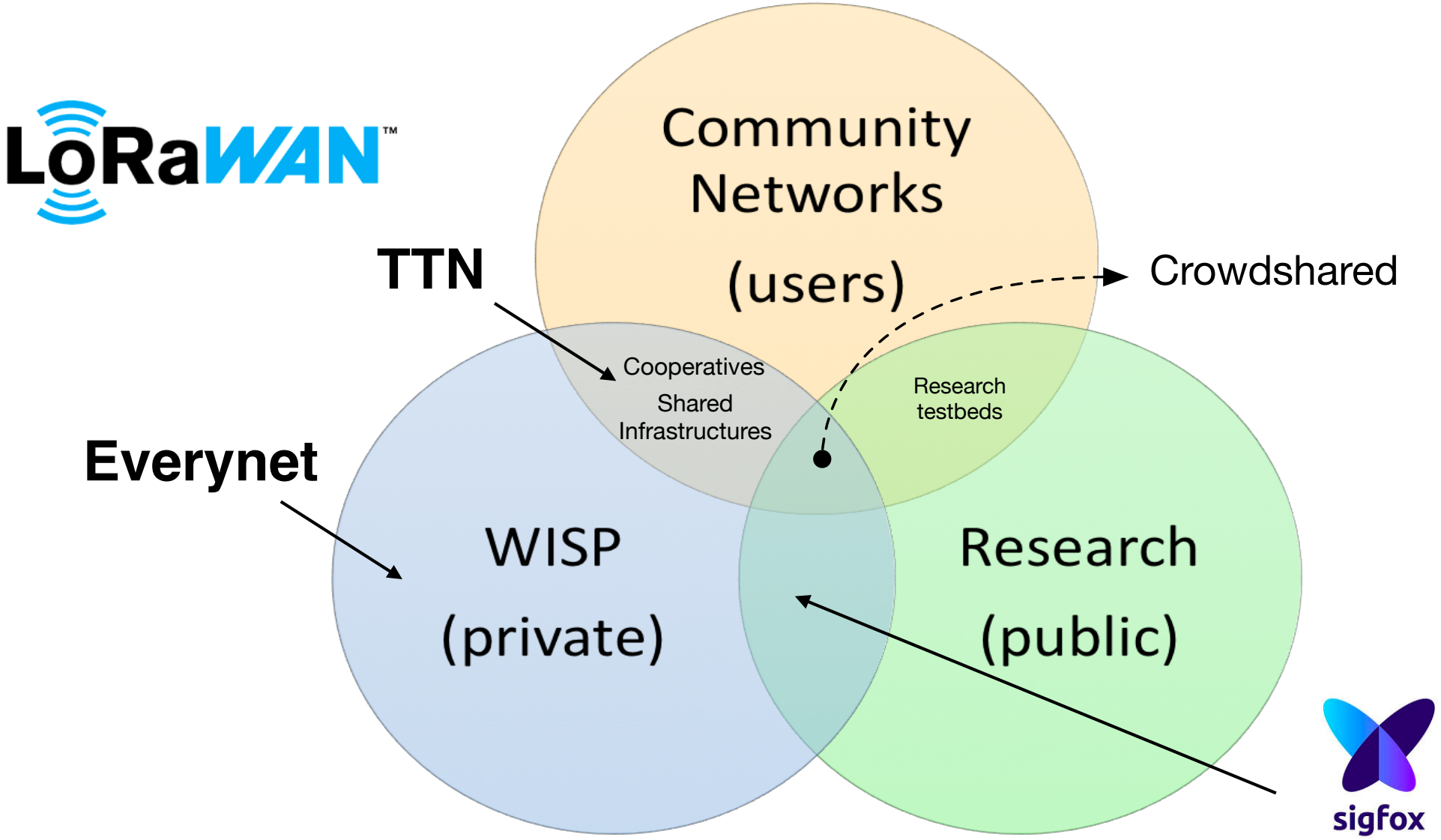
RFC 7962


Secure
https://tools.ietf.org/html/rfc7962
[Docs] [txt|pdf] [draft-irtf-gaia...] [Tracker] [Diff1] [Diff2]
INFORMATIONAL
Internet Research Task Force (IRTF)
Request for Comments: 7962
Category: Informational
ISSN: 2070-1721
J. Saldana, Ed.
University of Zaragoza
A. Arcia-Moret
University of Cambridge
B. Braem
iMinds
E. Pietrosemoli
The Abdus Salam ICTP
A. Sathiaseelan
University of Cambridge
M. Zennaro
The Abdus Salam ICTP
August 2016

Taxonomy of AN

	Promoter	Goals / Motivation	Administration	Technologies	Typical Scenarios
Community Networks	Community	Reduce hurdles Serve underserved areas Grant net	**Distributed**	Wi Fi (**unlicensed**) Optical	Urban **Rural**
WISPs	Companies	Serve **underserved areas** Reduce CAPEX	Centralised	Wi-Fi (unlicensed)	Rural
Shared Infrastructure	Communities + Private	Reduce CAPEX for operators Lower OPEX foroperators	Distributed	Wi-Fi (unlicensed) Optical	Rural (dev regions)
Crowdshared	Community + Public + Private	Massively share connectivity and resources	Distributed	Wireless (unlicensed)	Urban Rural
Testbed for research	Research Entity / Community Network	Research Extend CNs	Centralised may become distributed	Wired Wireless (unlicensed)	Urban Rural

Classifying Alternative Networks



LoRaWAN load

- Home temperature and humidity (+30)
- Development boards
- 16 projects aggregating 50+ devices

SigFox and LoRaWAN operate in the same band

- What are the odds for these two technologies to interfere with each other?
- There has to be a spectrum management strategy in place if we would like to use it in commons
- In practice, interference will be difficult to prevent

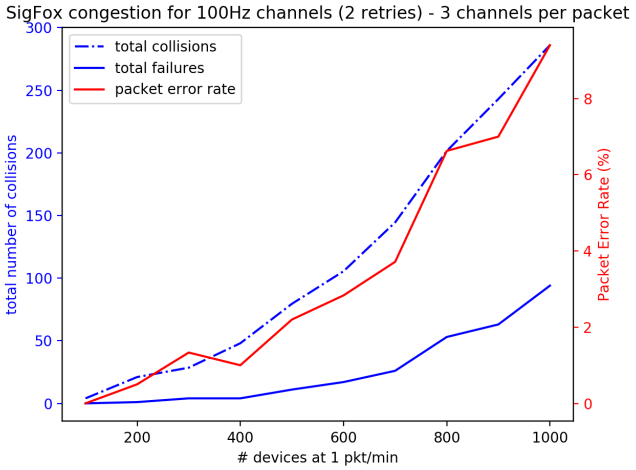
Perspective on Interference

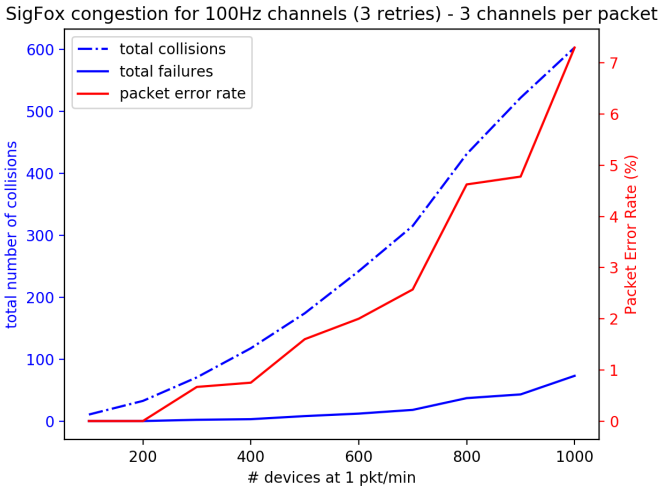
Perspective on Interference

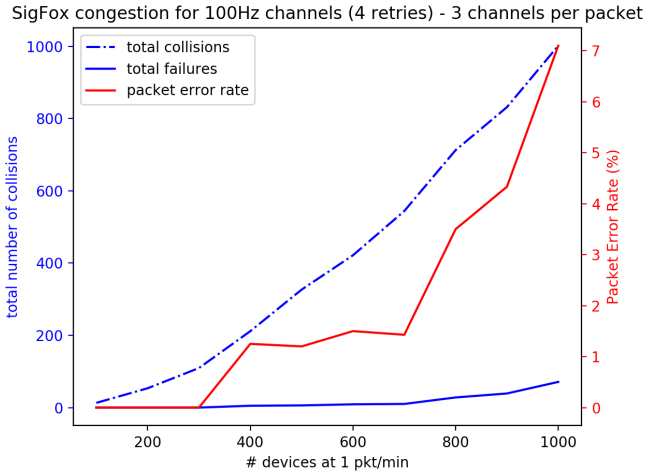
SigFox simulation setup:

- Chunk of 200KHz
- Channel bandwidth 100Hz
- 1000 devices transmitting over 6000 slots (10ms each)
- 3 Transmissions per packet
- Collision if packets overlap (no side channel effect)
- Random transmission of 12 Byte packets (uplink only)

Simulation Results (1/2)



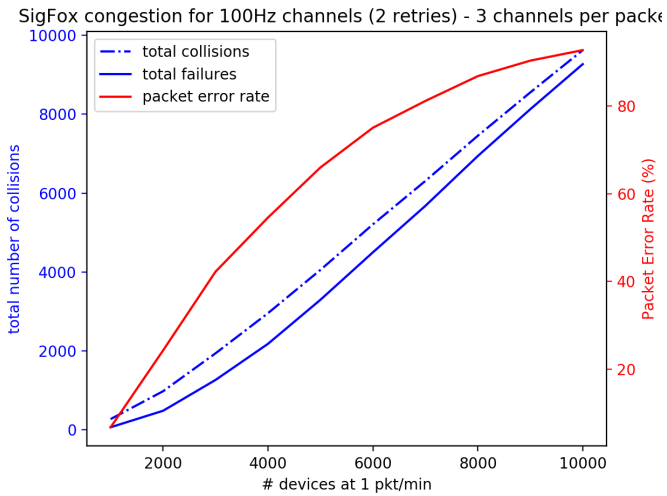


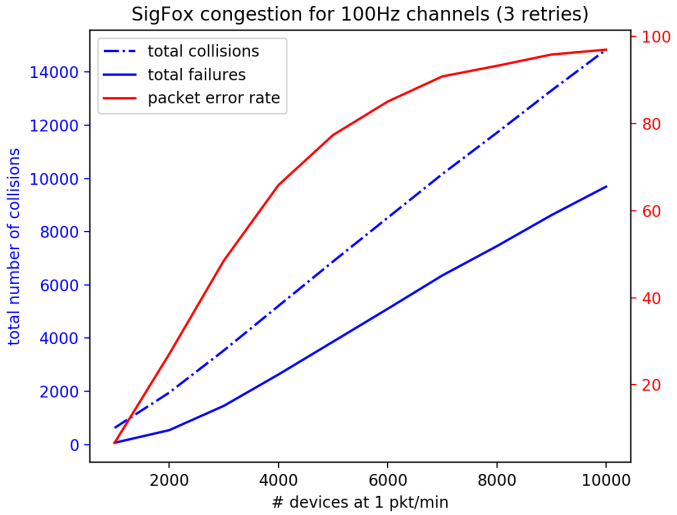


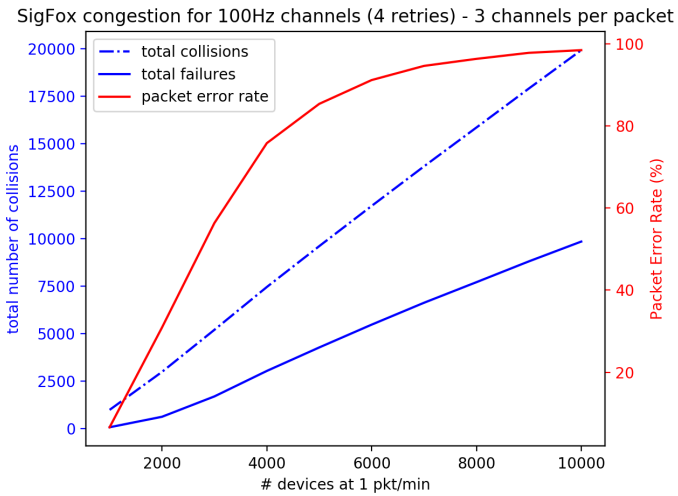
From left to right, we increase the number of retransmissions

Number of failed transmissions under 10% up to 1000 dev

Simulation Results (2/2)







For 4K msgs:

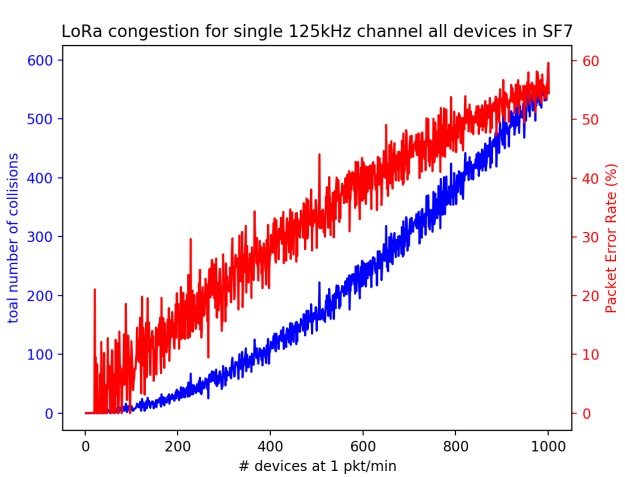
~2K success	**~2K sucs**	**~2.5K sucs**
Congestion	Congestion	Congestion
3K collisions	5.8K collisions	7.5K collisions
1.5 collisions/success	2.9 c/suc	3 c/suc

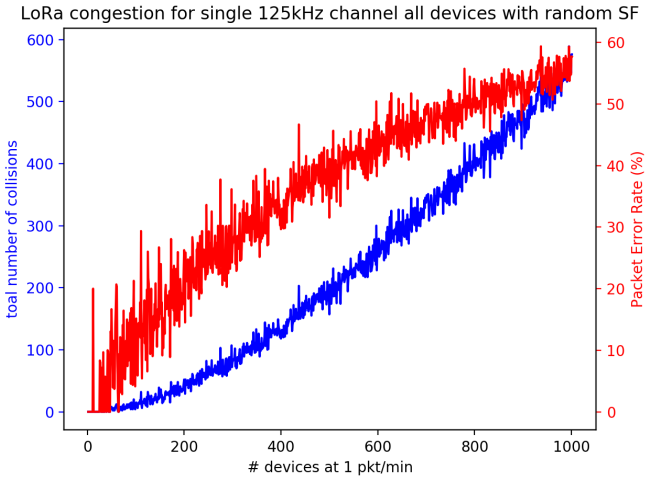
Perspective on Interference

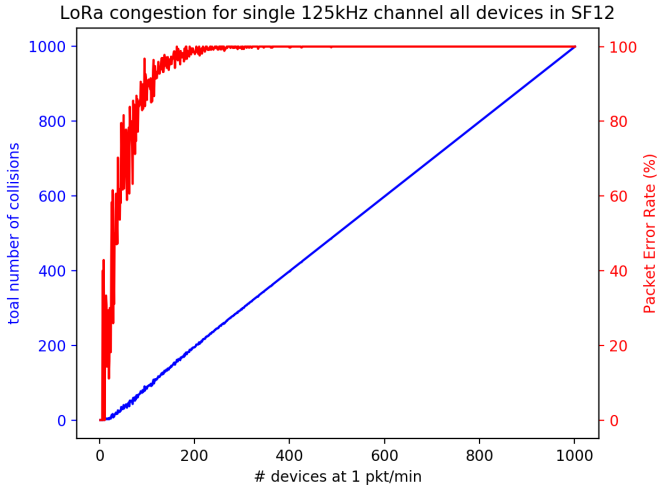
LoRaWAN simulation setup:

- Attempt to access the same channel at different times during 1 min (6000 intervals of 10 ms)
- Single channel of 125kHz
- Random transmission of 25 Byte packets (uplink only)
- From SF7 (21 ms) to SF12 (628 ms)
- Collision if transmissions overlap (no side channel effect)

Simulation Results



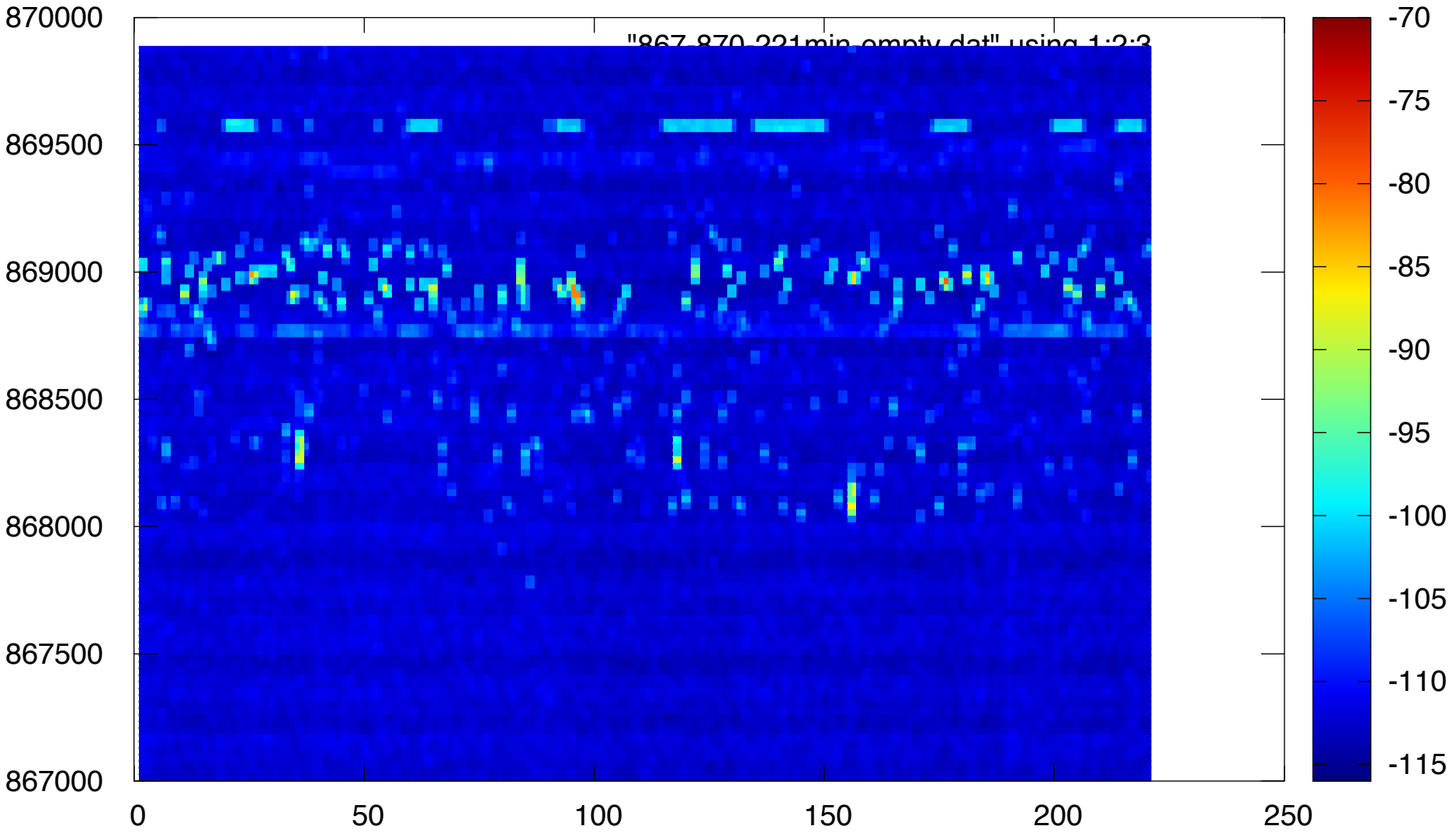




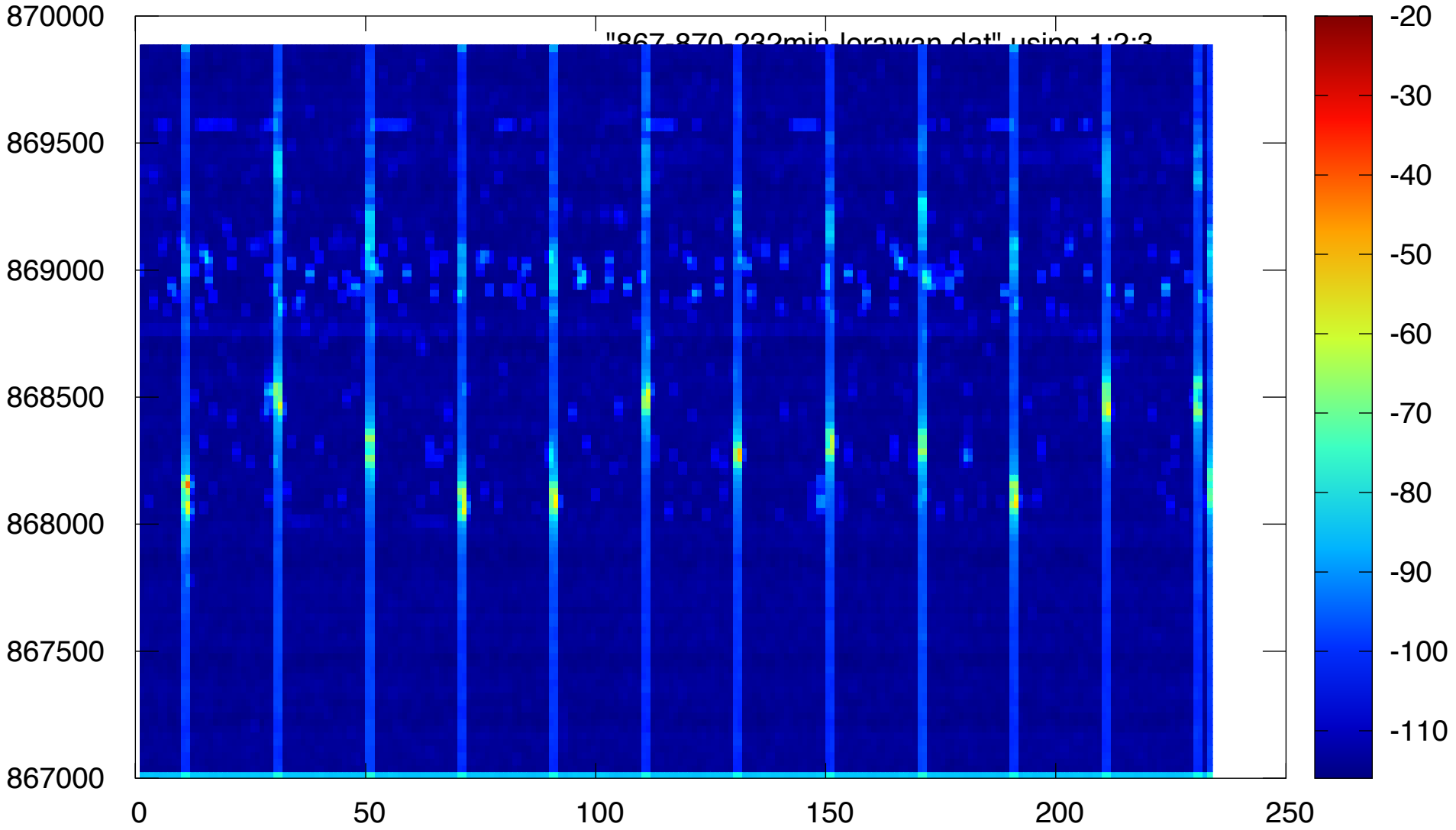
A primer on Interference

LoRaWAN/SigFox deployment

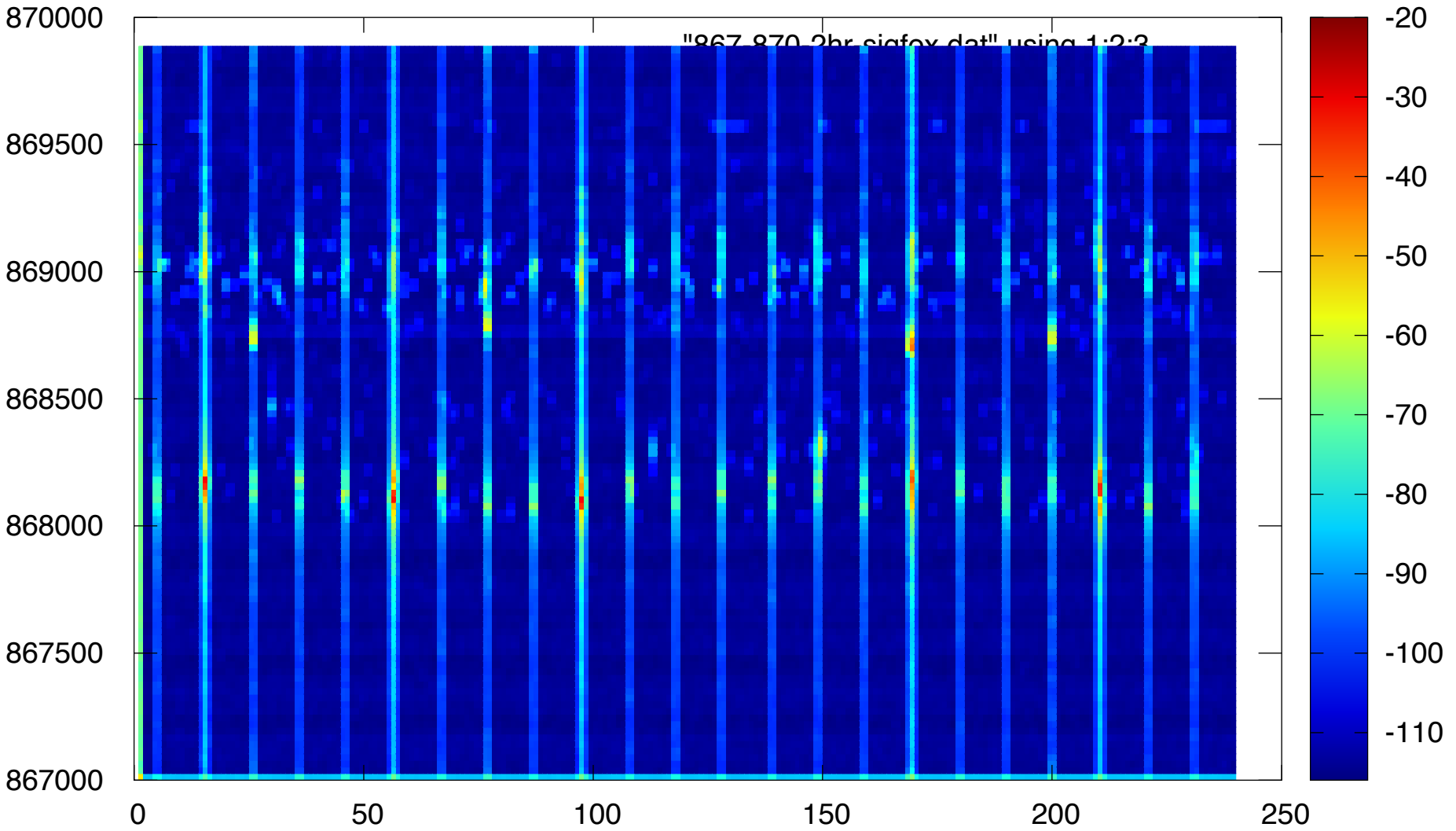
Spectrum 9:30am to 11:30am Fri 4/5/18



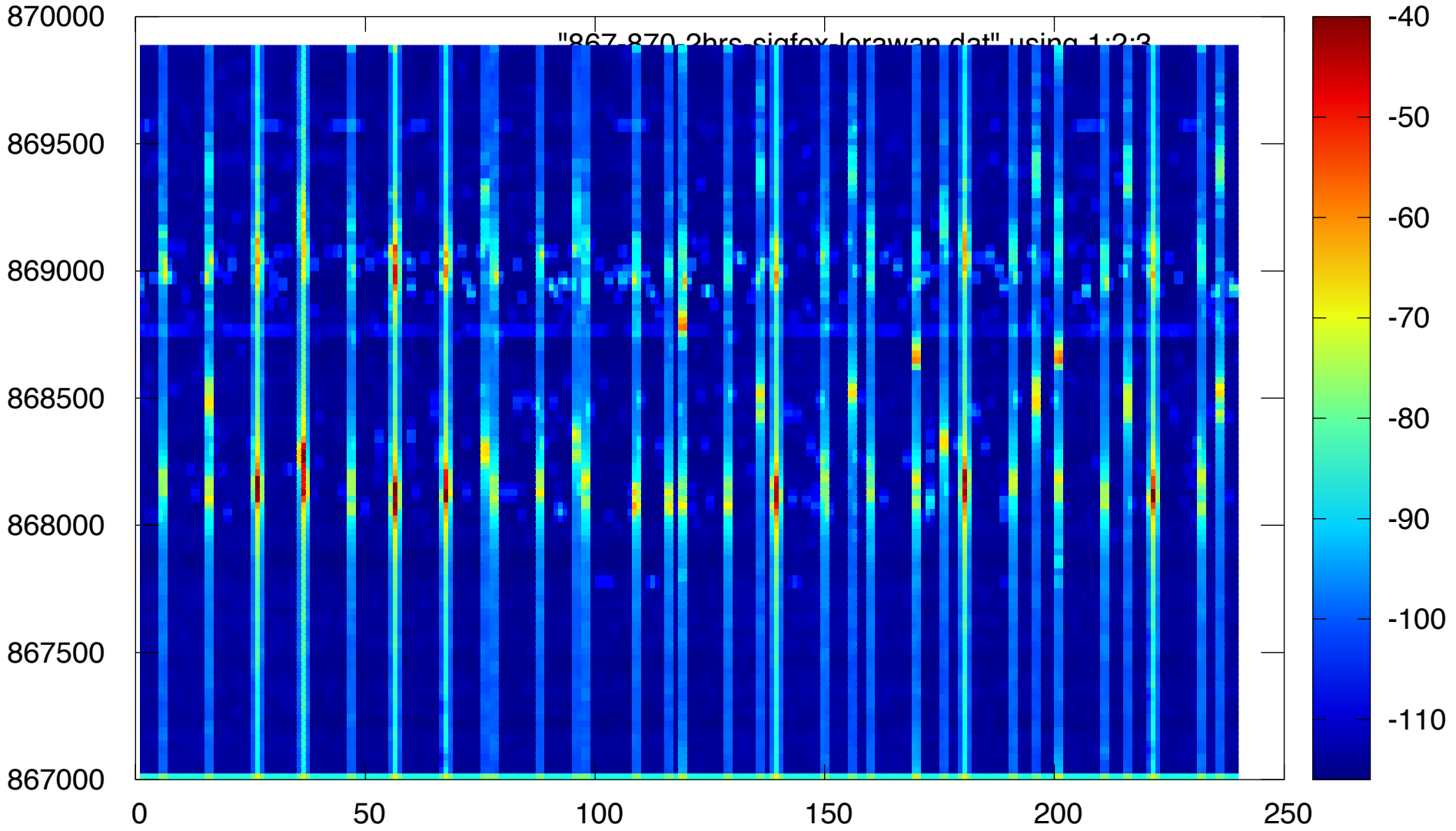
Only LoRaWAN



Only SigFox

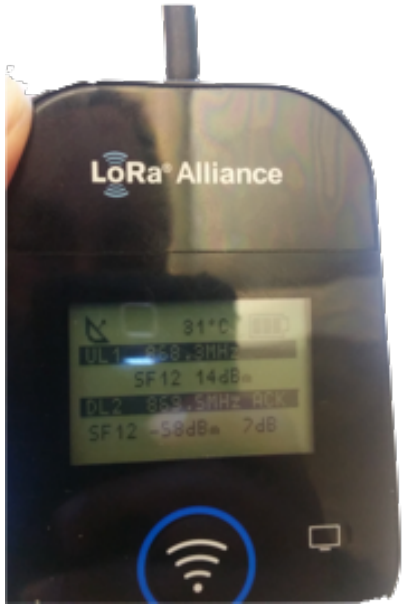

"867-870_2hr_sigfox.dat" using 1:2:3
870000
869500
869000
868500
868000
867500
867000
0
50
100
150
200
250
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110

2 Hrs Monitoring
SigFox vs LoRaWAN

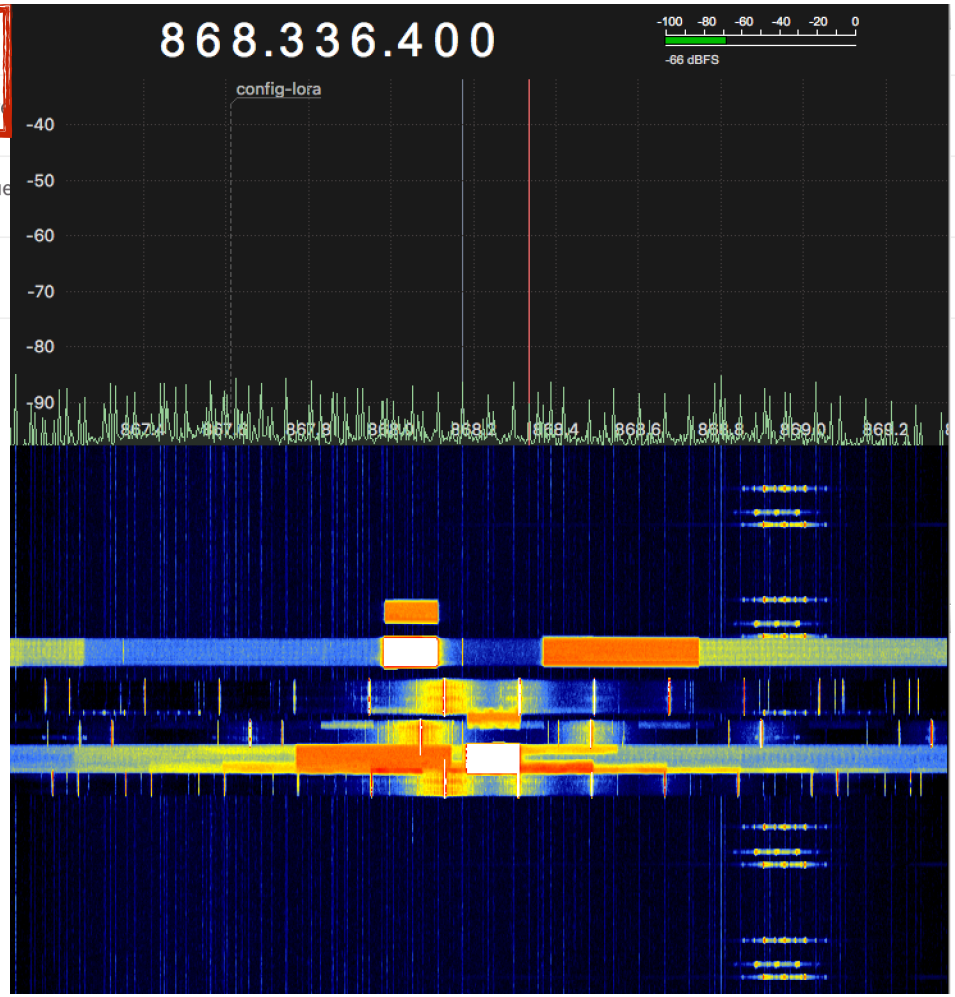


Interference LoRaWAN and SigFox

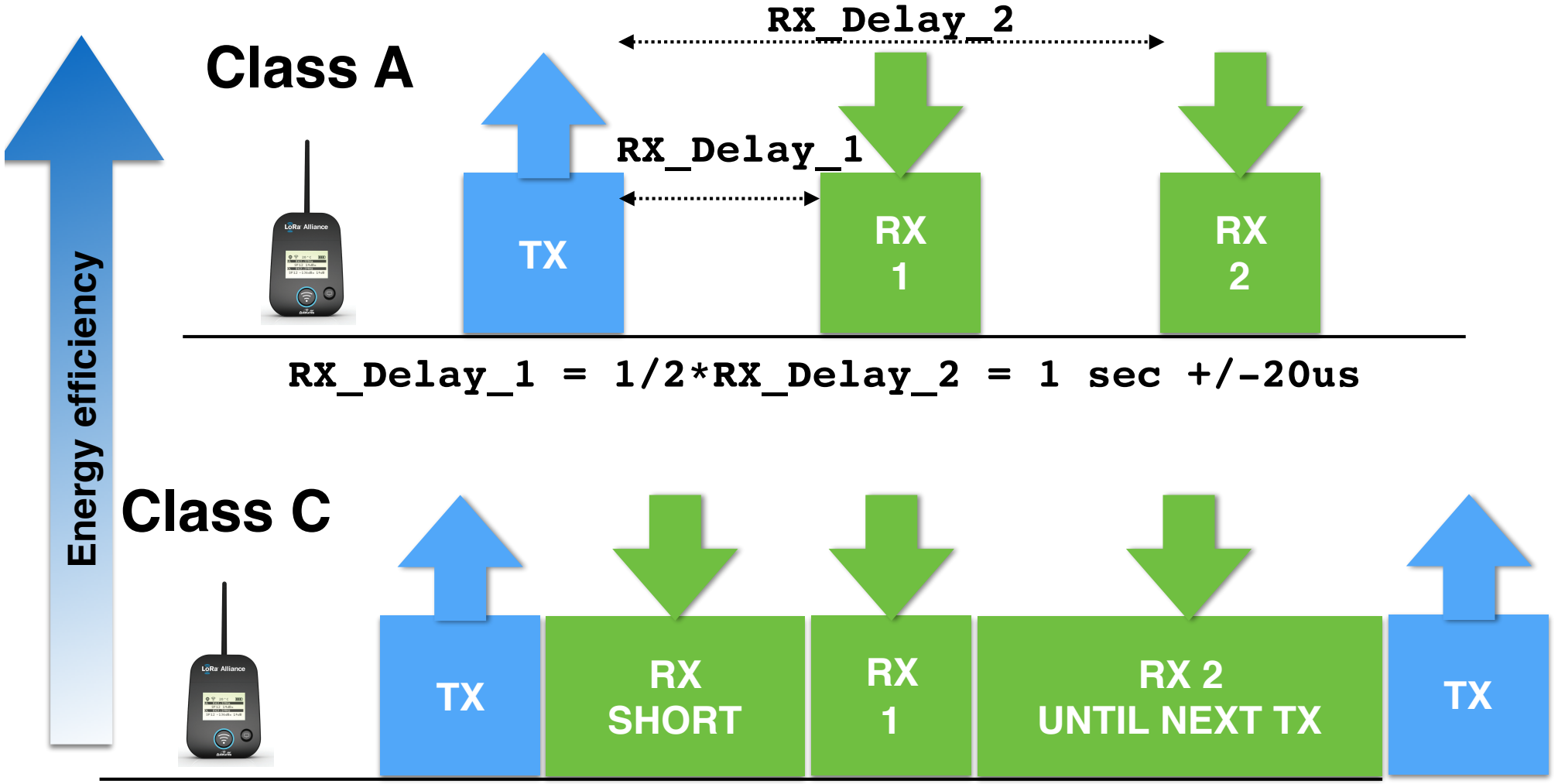
✗	18:28:36 02/05/2018	application	↓	Requesting downlink message failed due to application error: ApplicationError(u"KeyError('result',)",). Please check application availability.
✗	18:28:35 02/05/2018	application	↑	Sending 'uplink' message failed due to application error: ApplicationError(u"KeyError('result',)",). Please check application availability
✓	18:28:35 02/05/2018	core	↑	Uplink message duplicate
🔔	18:28:35 02/05/2018	core	↑	Uplink message with repeated counter r
✗	18:28:31 02/05/2018	application	↑	Sending 'post_uplink' message failed due
✓	18:28:30 02/05/2018	core	↓	Downlink message sent.
✓	18:28:30 02/05/2018	core	↓	Downlink message prepared to send.



sigfox

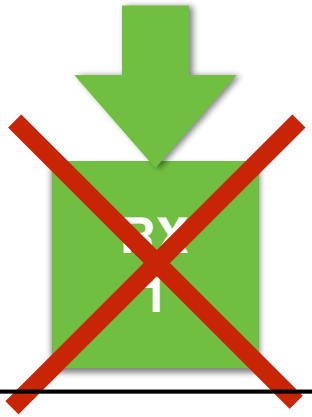


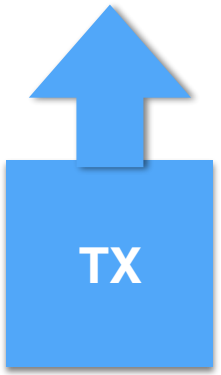
Detail on the interference



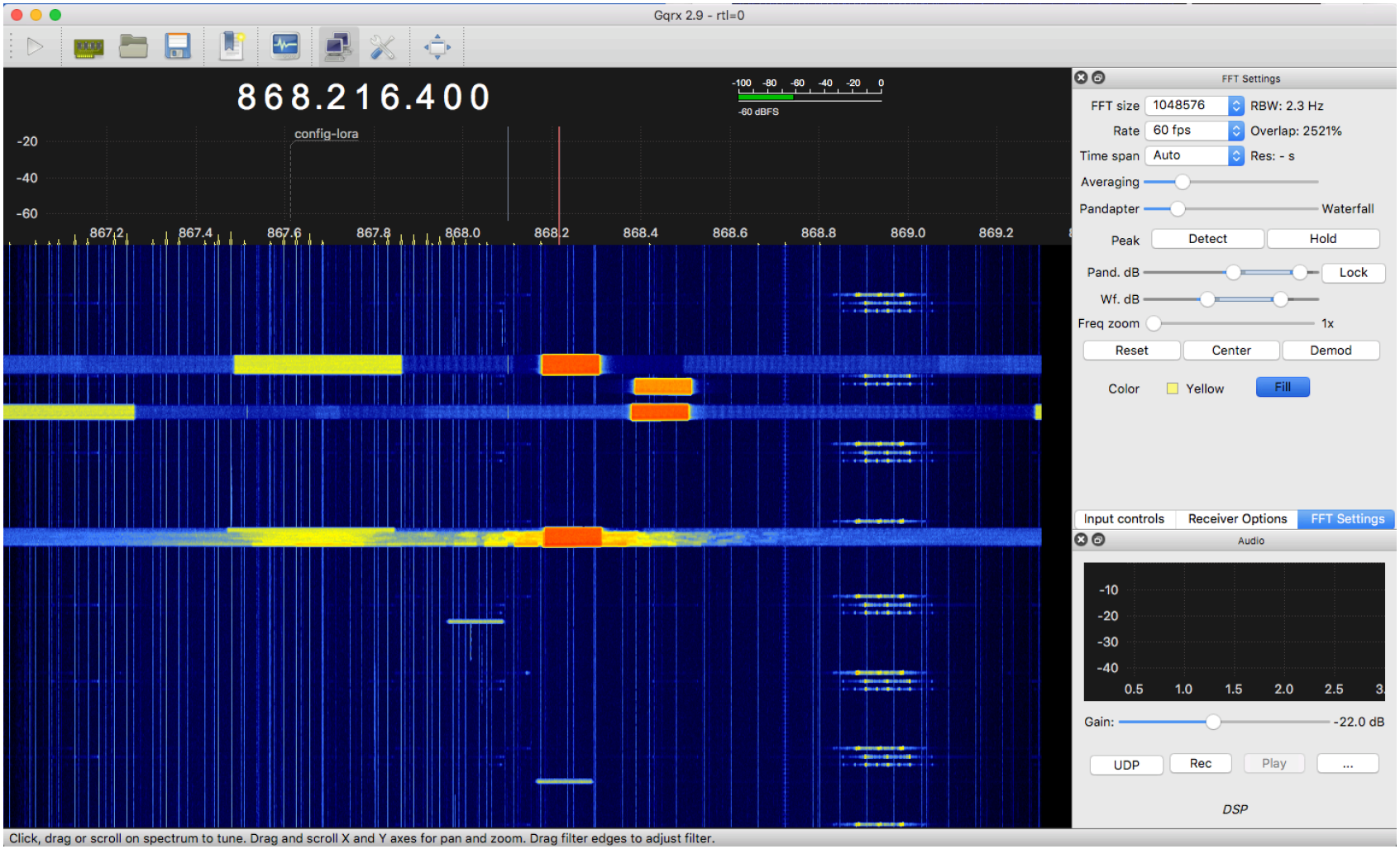
What happened

Class A
With ACK

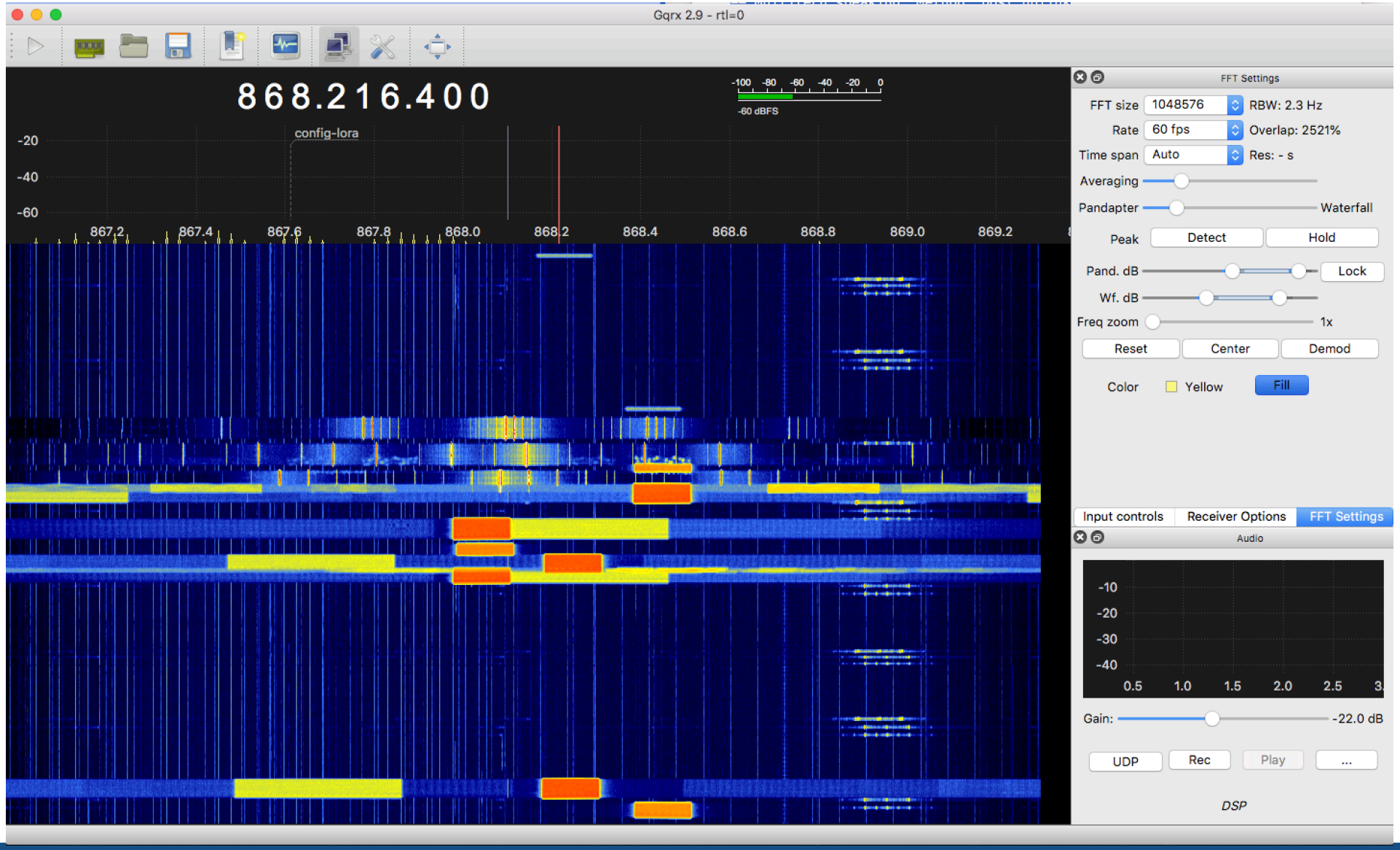




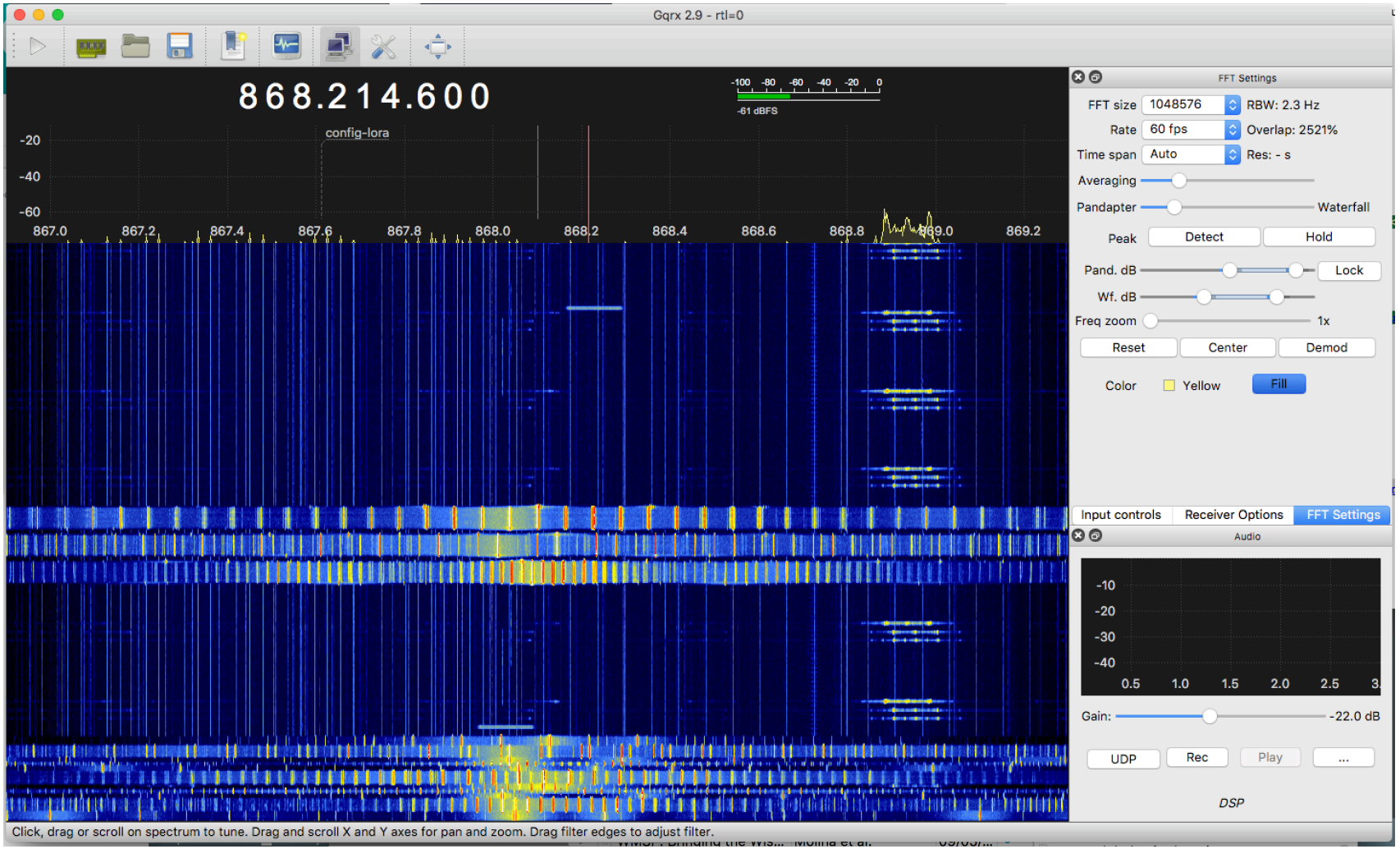
Two LoRaWAN devices: interference (worse case scenario)



Two LoRaWAN devices: interference (most congested scenario)



Interference between two SigFox devices



Testing Everynet Network

upload more samples
download place
delete

001-adeunis-everynet

Total number of samples	93
Total distance	7.81 **km**
Total number of frequencies	8
Range of frequencies	[474-515] **MHz**
Minimum power	-255 **dBm**
Maximum power	0 **dBm**
Average power	-235.7 **dBm**
Standard deviation of power	14.7 **dBm**

Edit place

35 minutes ago

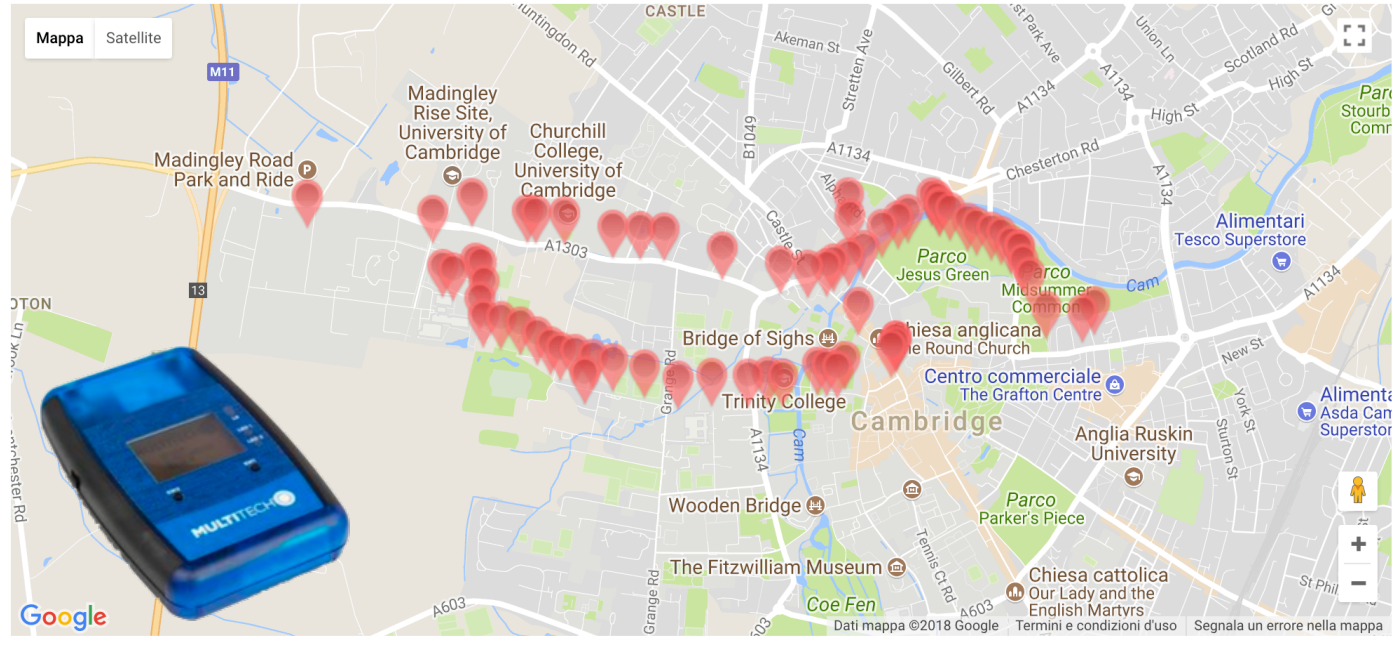
upload more samples
download place
delete

008-multitech-everynet

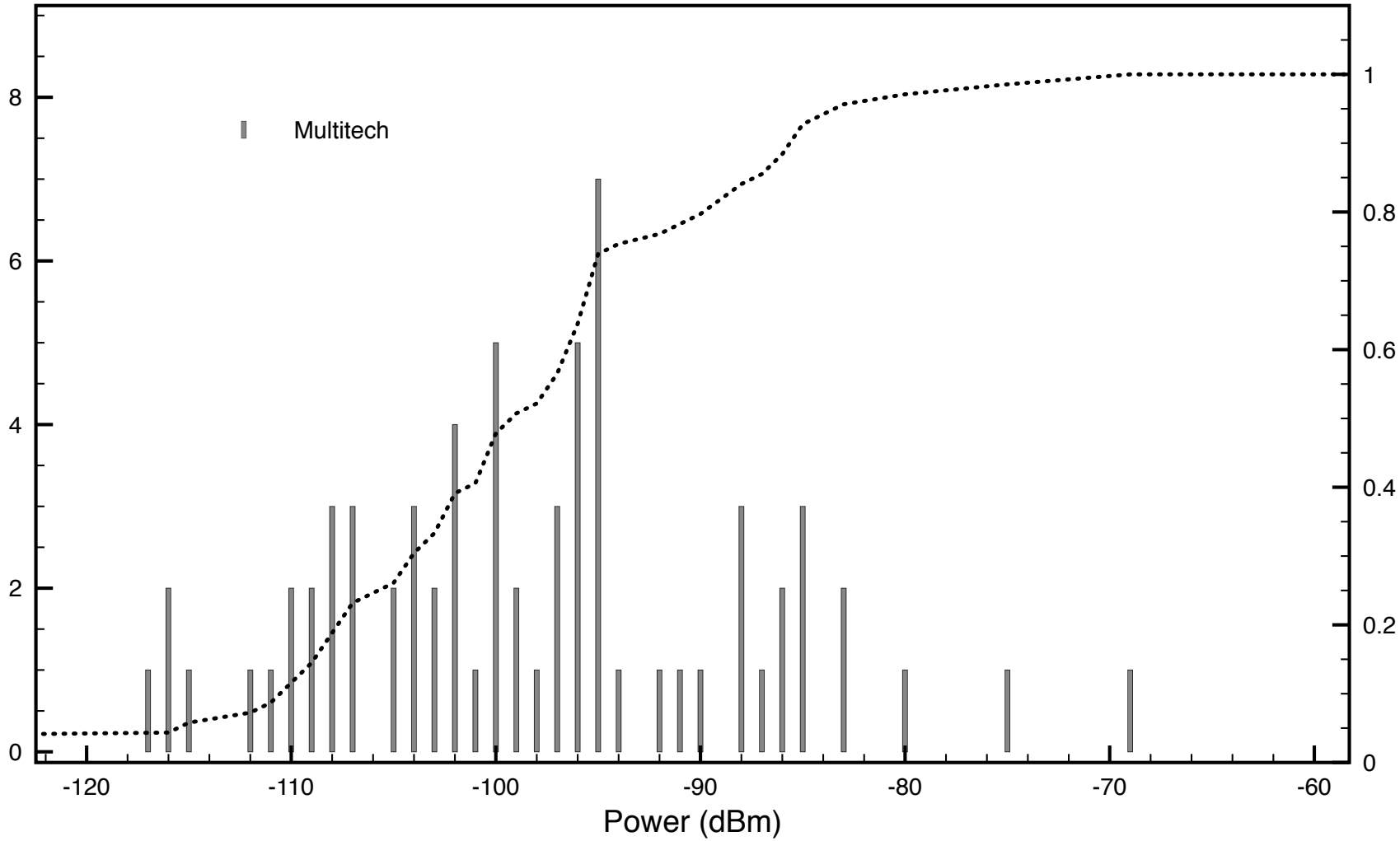
Total number of samples	69
Total distance	12.25 **km**
Total number of frequencies	8
Range of frequencies	[474-515] **MHz**
Minimum power	-255 **dBm**
Maximum power	-69 **dBm**
Average power	-235.4 **dBm**
Standard deviation of power	1.2 **dBm**

Edit place

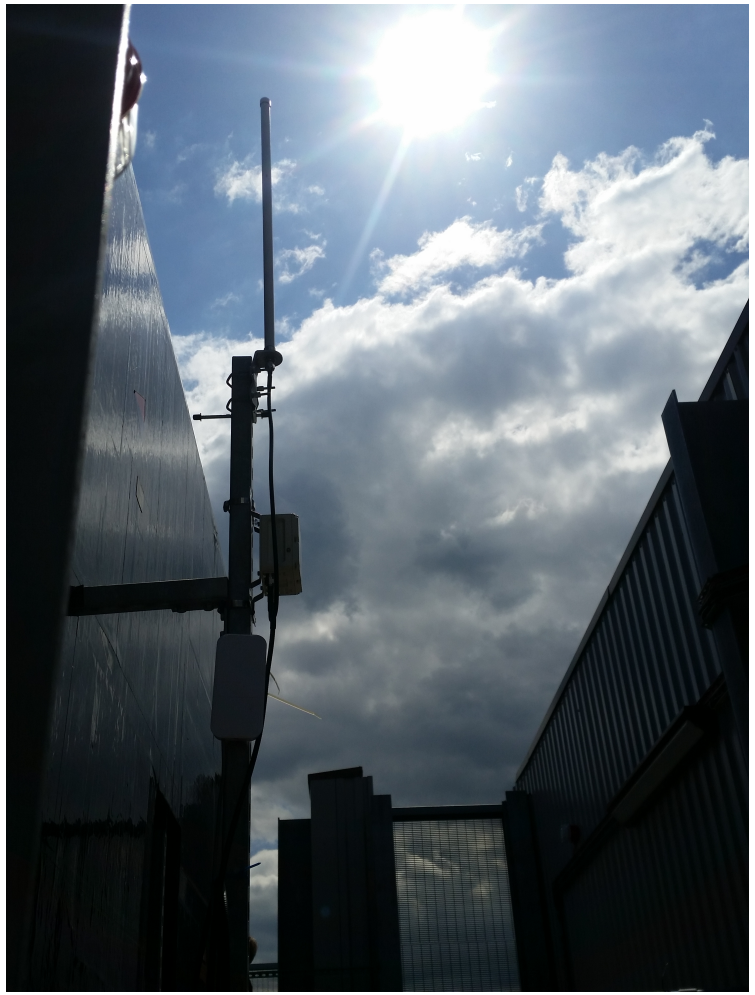
an hour ago



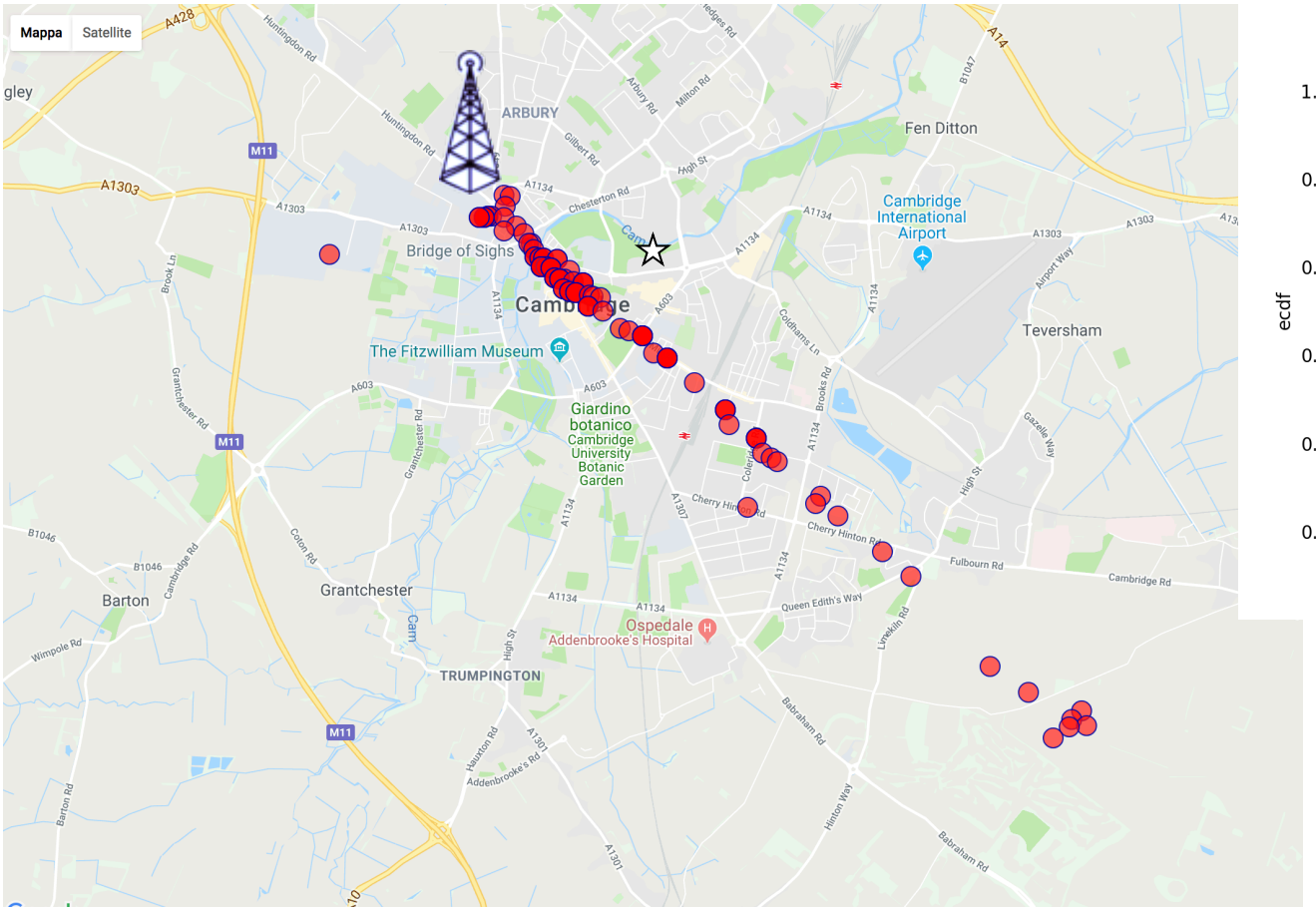
Power Distribution

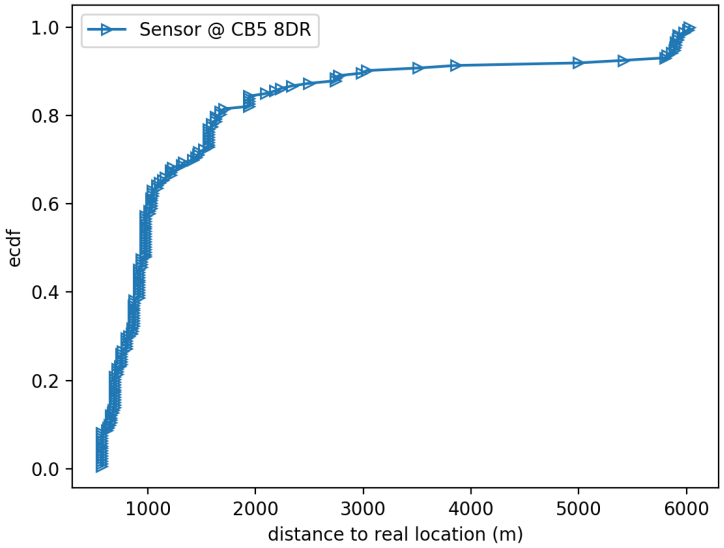


SigFox Deployment

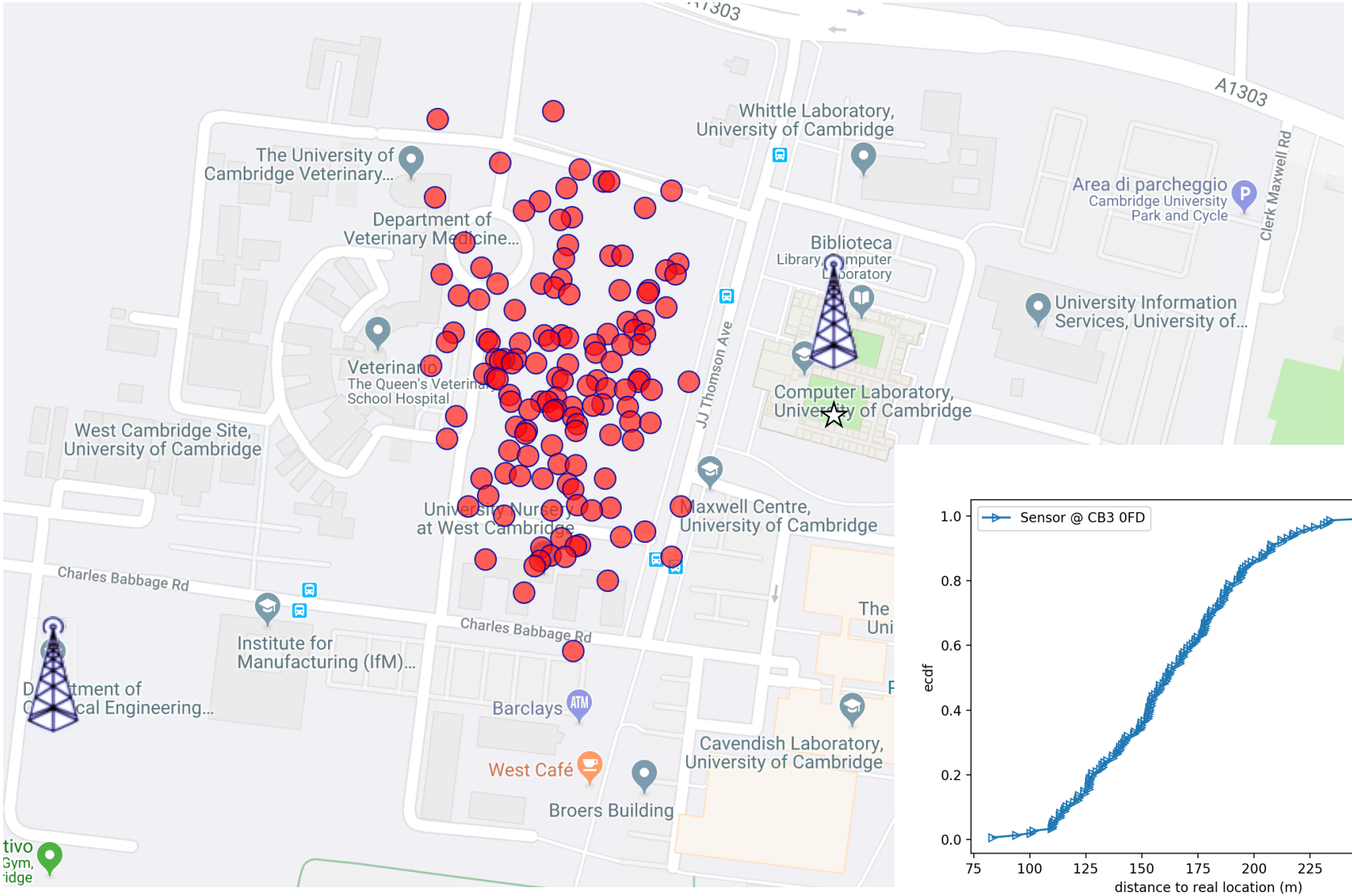


SigFox Geolocation Service

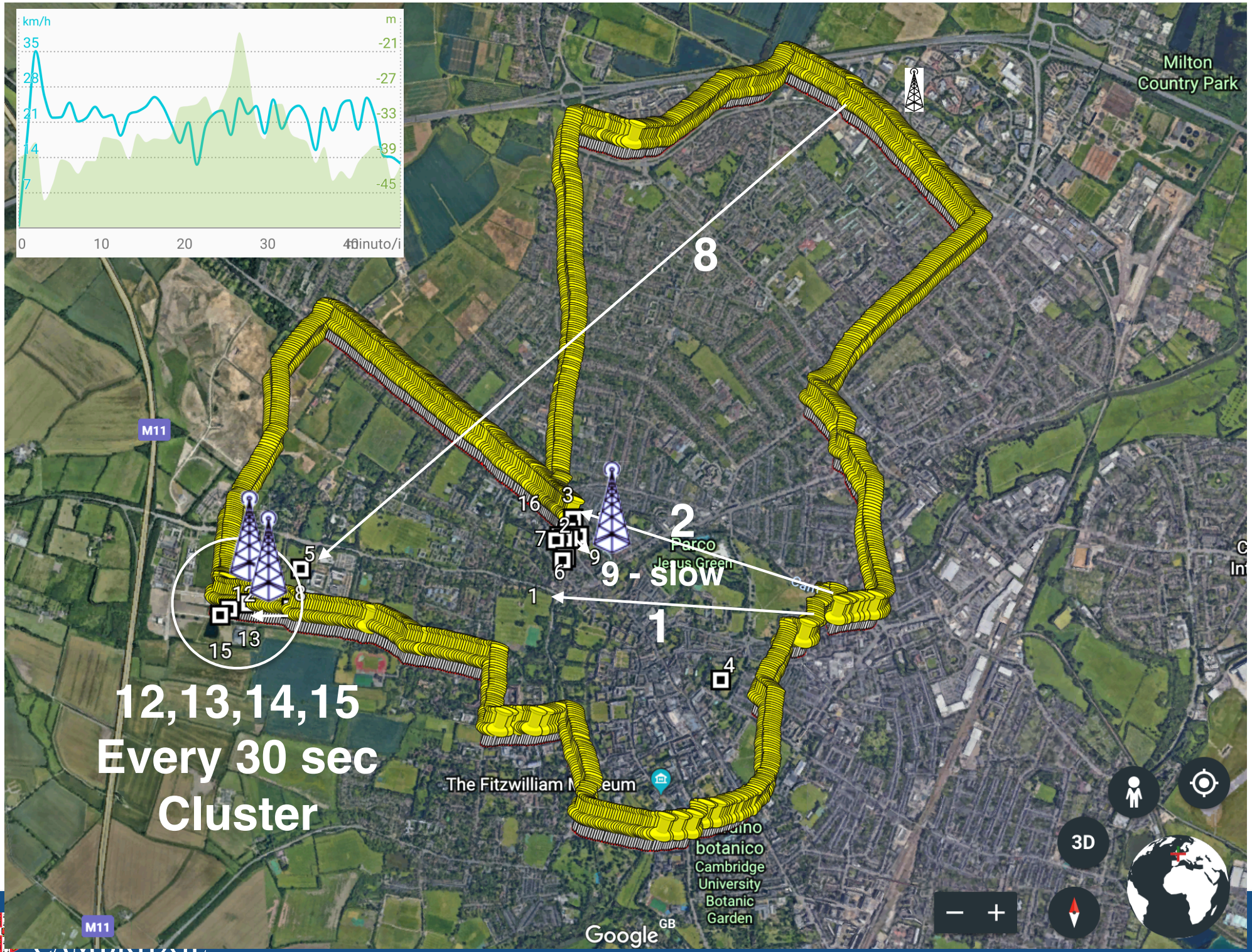


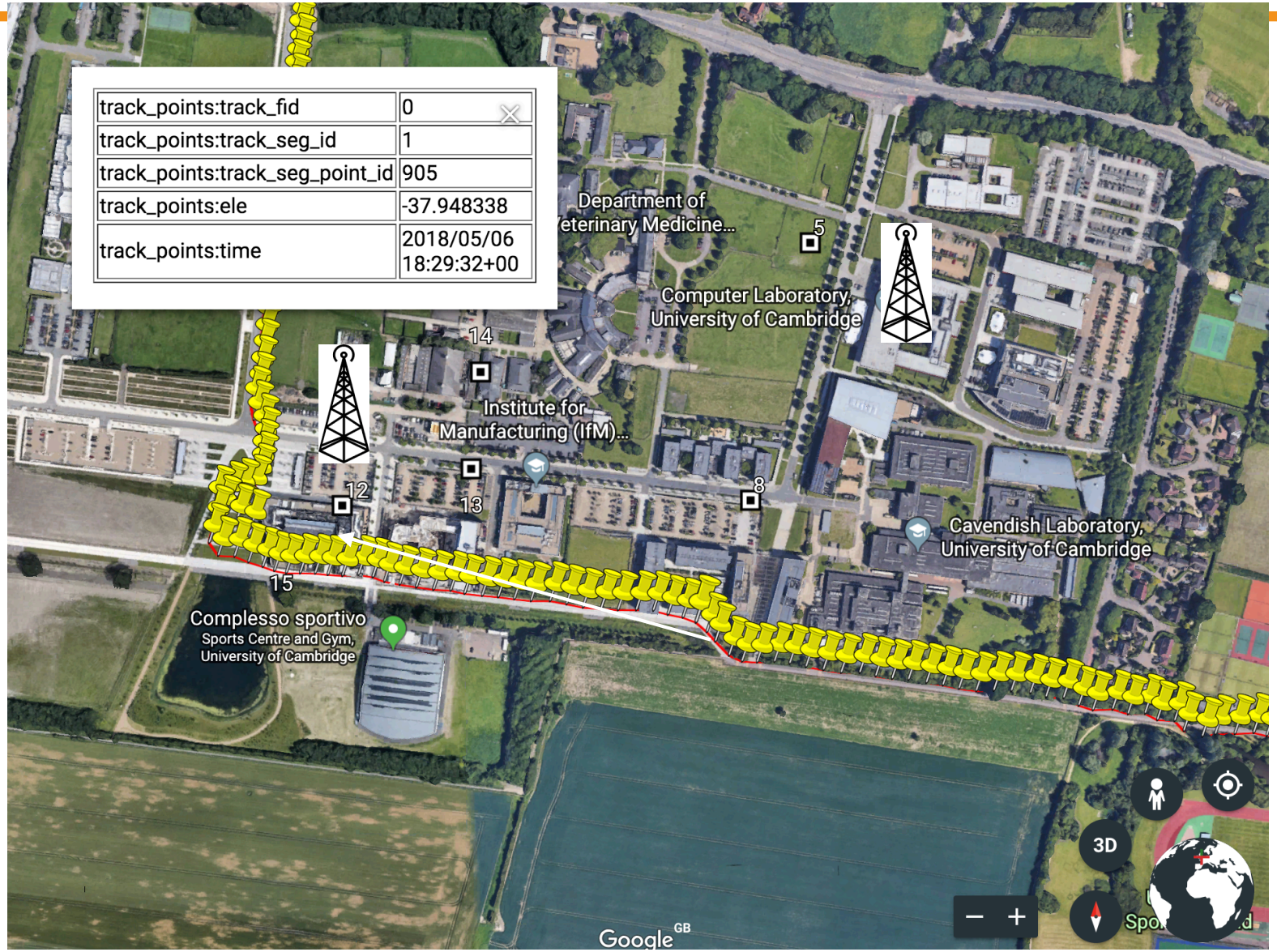


SigFox Geolocation Service



Mobility on SigFox only


km/h
m
35
28
21
14
7
-21
-27
-33
-39
-45
0
10
20
30
40
minuto/i
Milton
Country Park
8
2
9 - slow
1
12,13,14,15
Every 30 sec
Cluster
M11
M11
Parco
Jesus Green
The Fitzwilliam Museum
botanico
Cambridge
University
Botanic
Garden
Google
GB
3D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track_points:ele -37.948338
track_points:time 2018/05/06 18:29:32+00
Department of
eterinary Medicine...
5
Computer Laboratory,
University of Cambridge
14
Institute for
Manufacturing (IfM)...
12
13
8
Cavendish Laboratory,
University of Cambridge
15
Complesso sportivo
Sports Centre and Gym,
University of Cambridge
3D
Google GB

Mobility on SigFox and LoRaWAN

LoRaWAN / Everynet

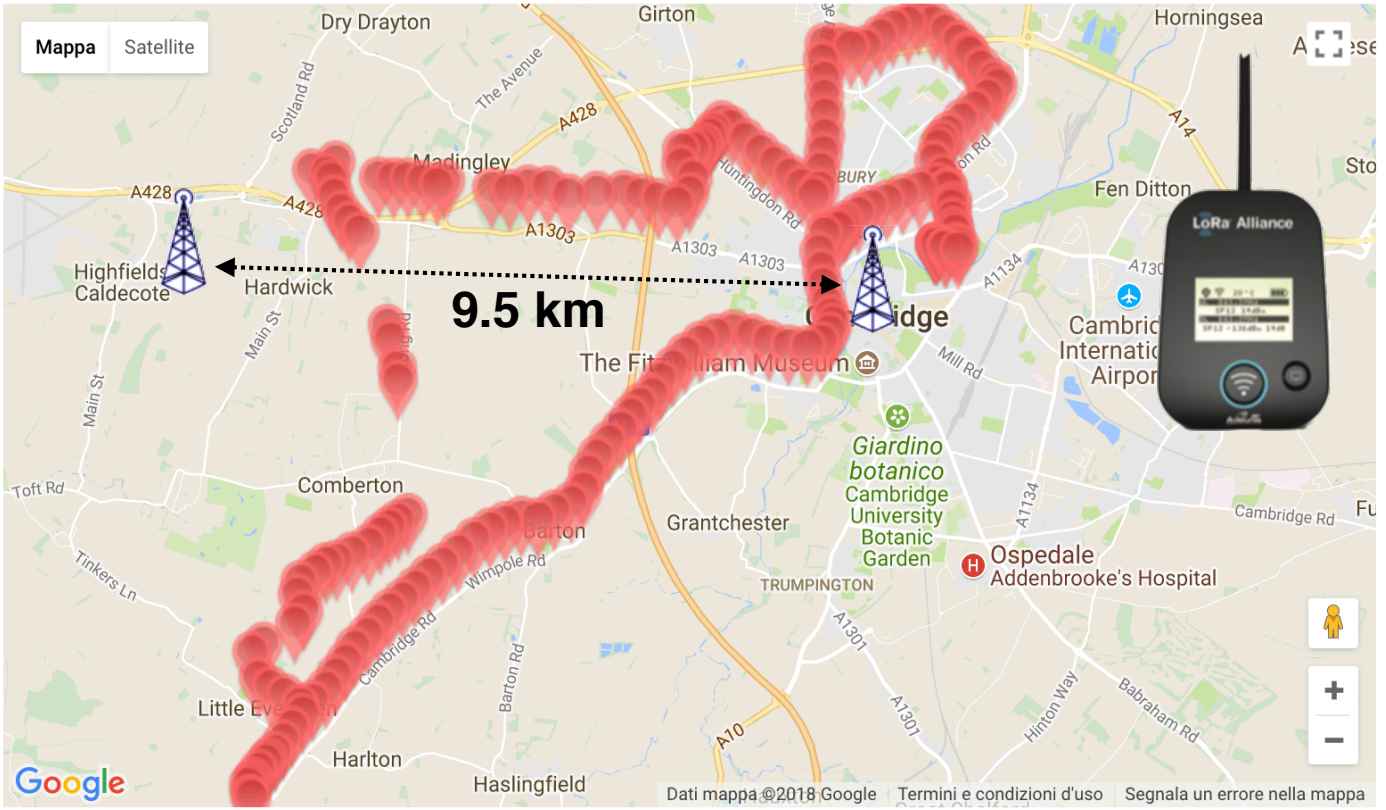
upload more samples
download place
delete

lorawan-everynet-sun-6-5-18

Total number of samples	181
Total distance	46.83 **km**
Total number of frequencies	8
Range of frequencies	[474-515] **MHz**
Minimum power	-255 **dBm**
Maximum power	0 **dBm**
Average power	-240.7 **dBm**
Standard deviation of power	14.1 **dBm**

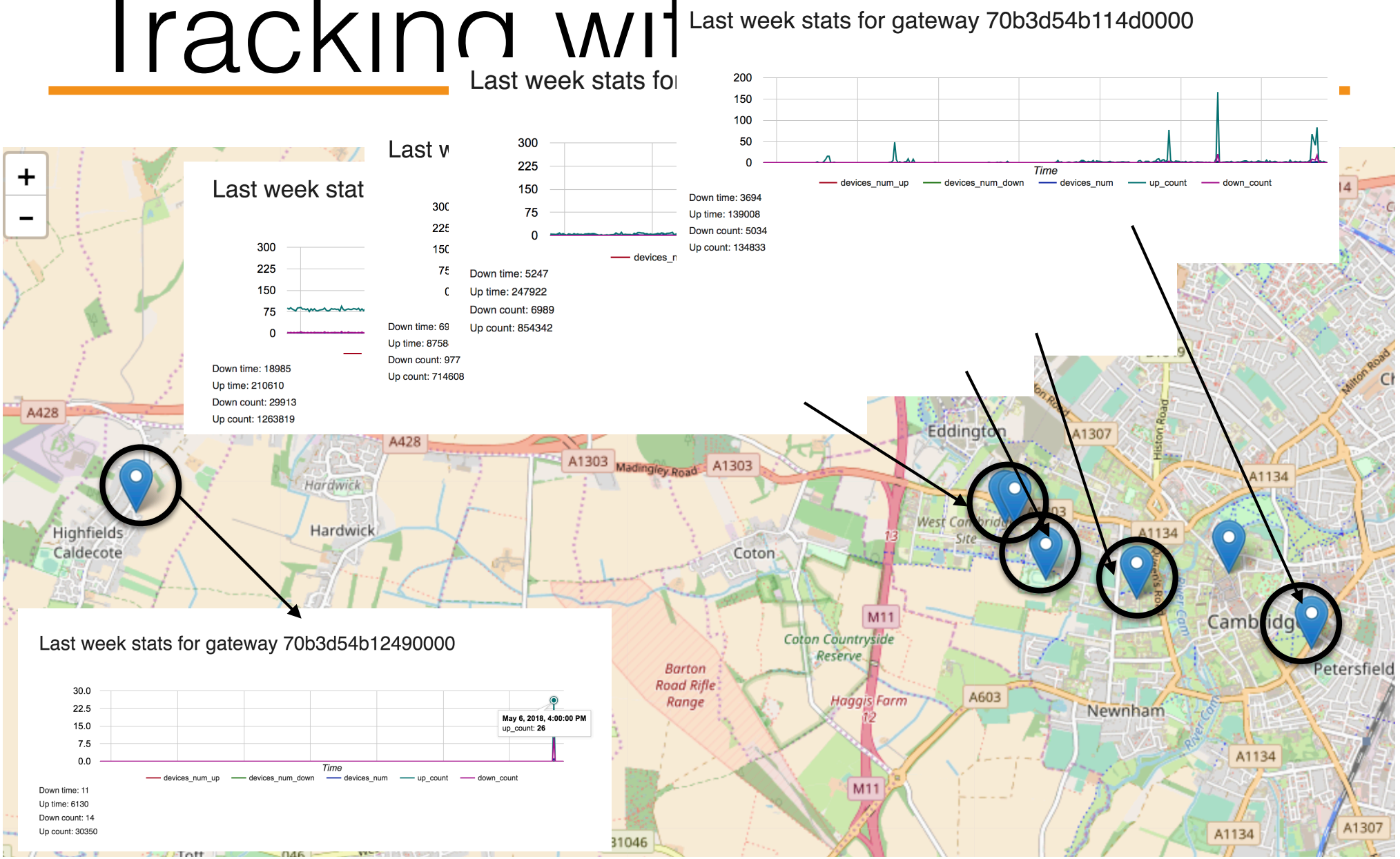
Edit place

a few seconds ago

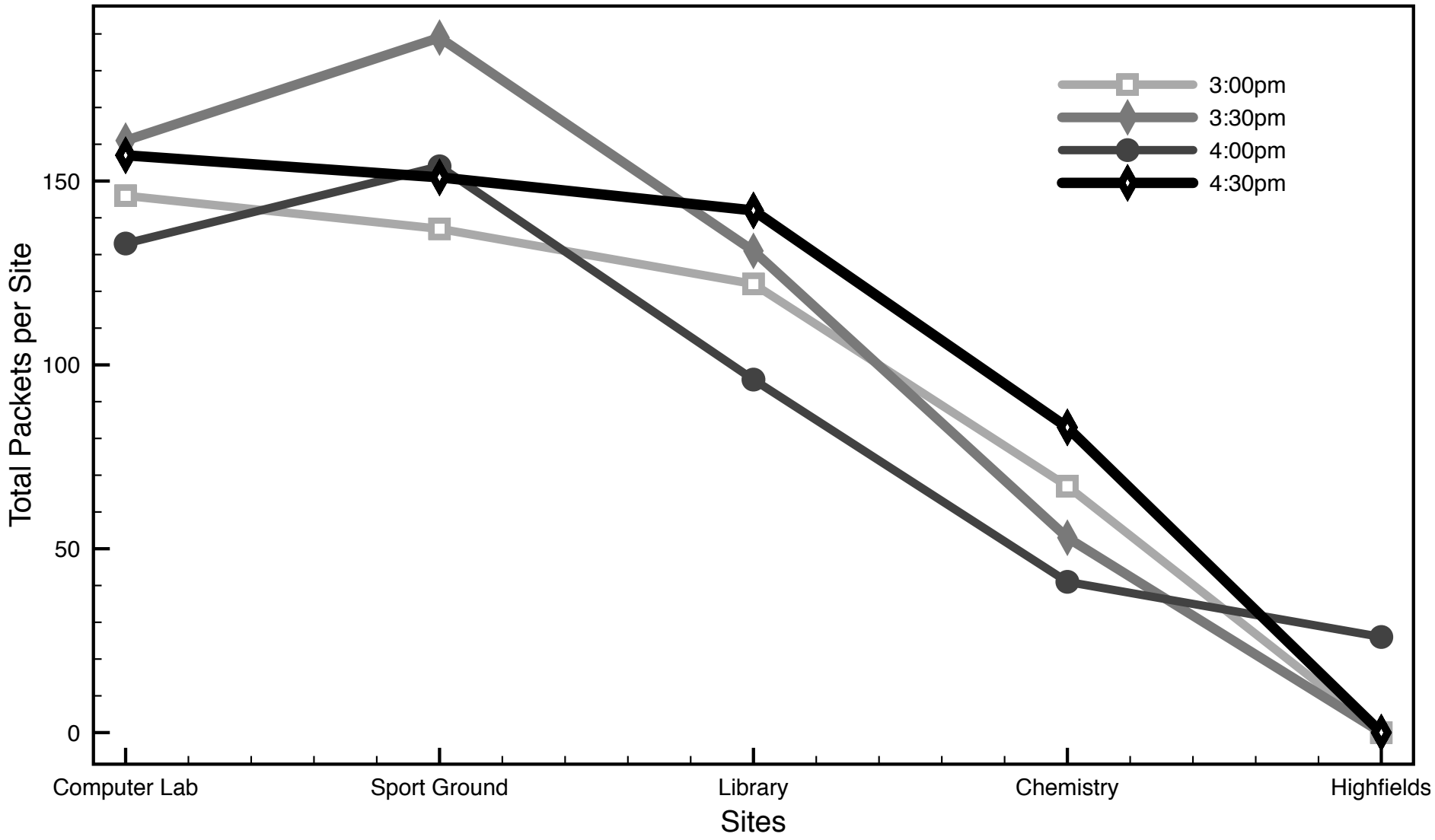


80% packets received

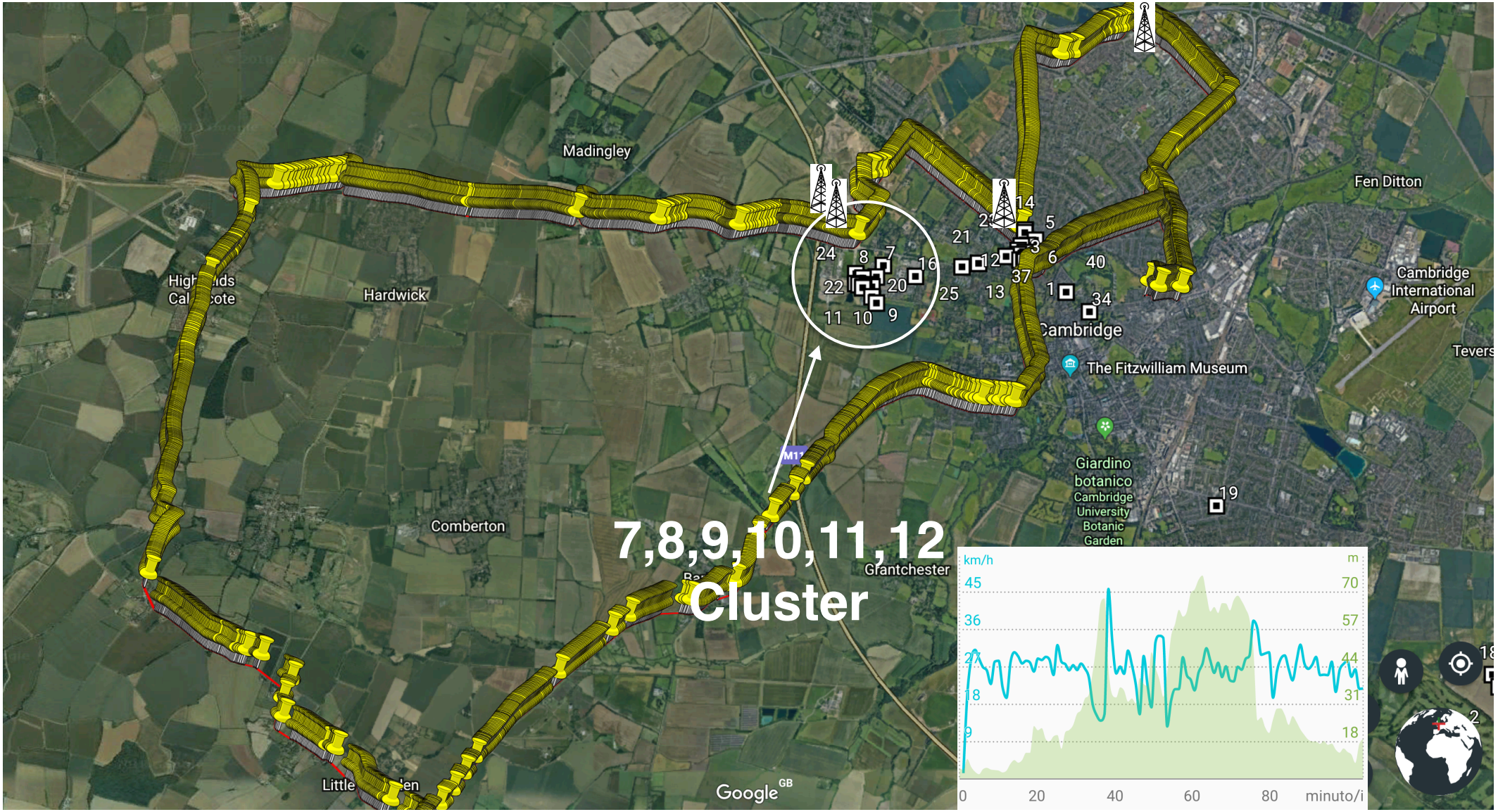
Tracking wit



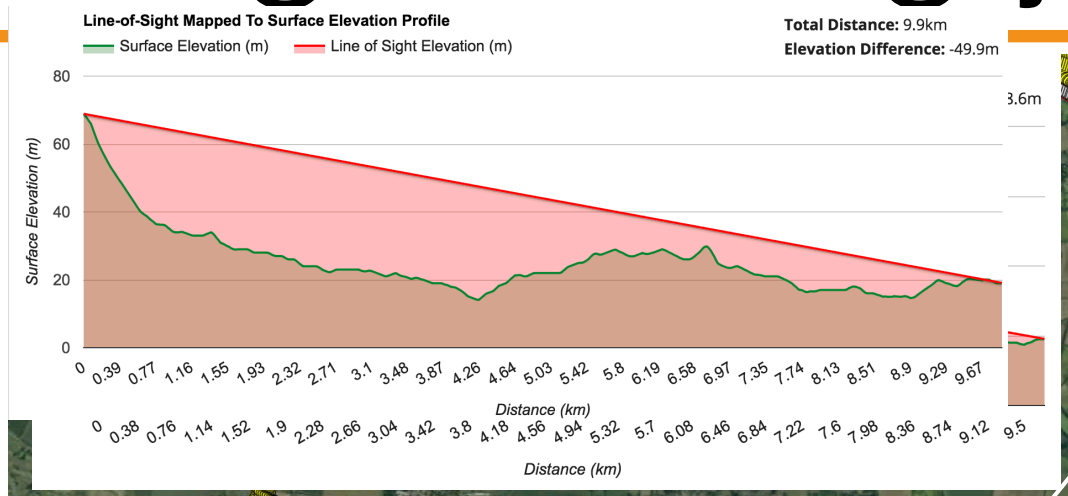
LoRaWAN load per Site



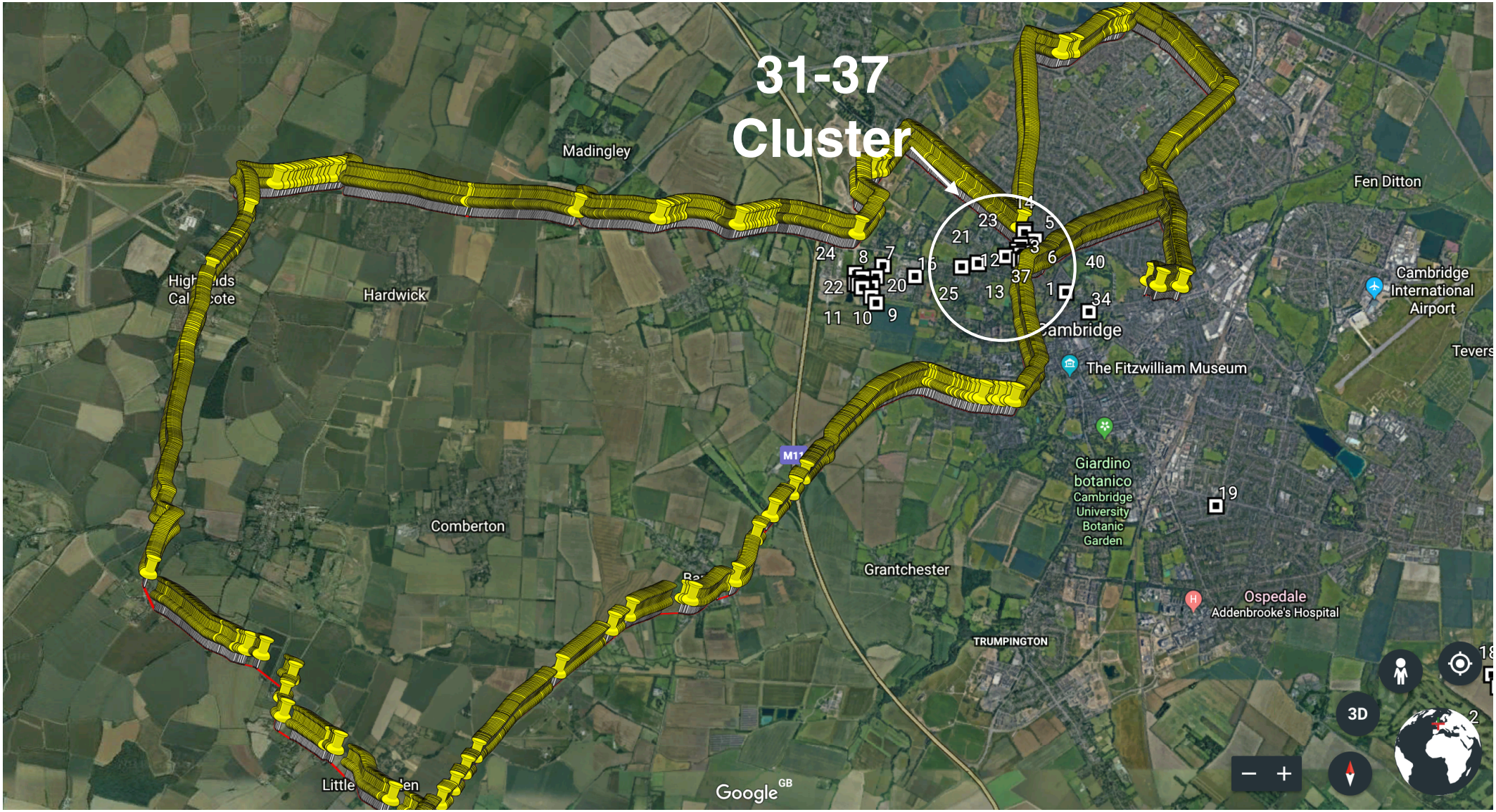
SigFox long journey



SigFox long journey

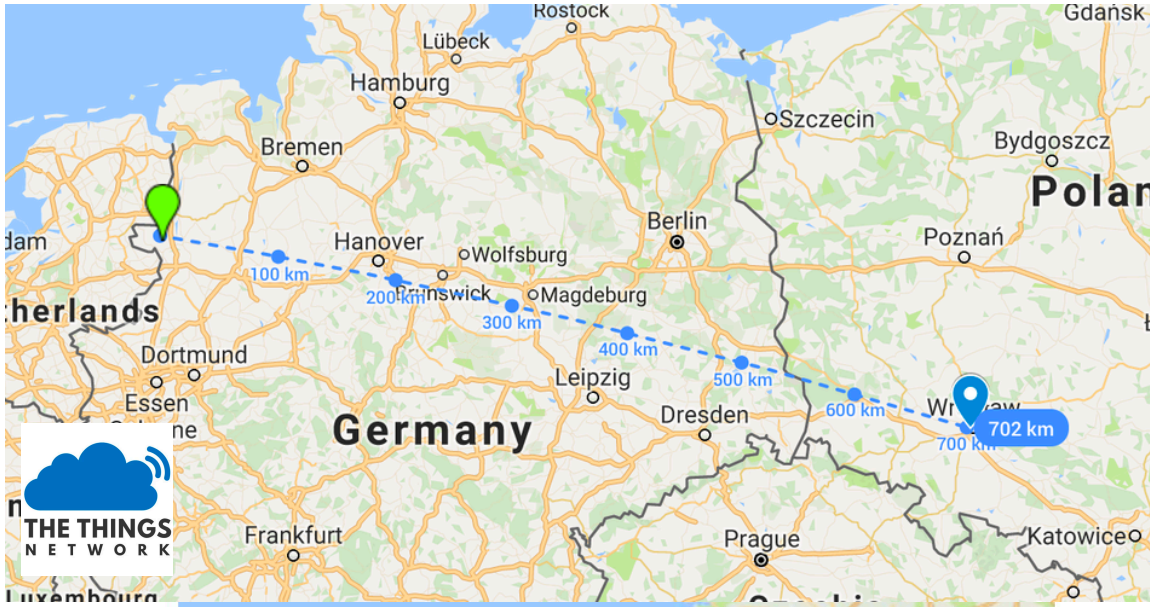


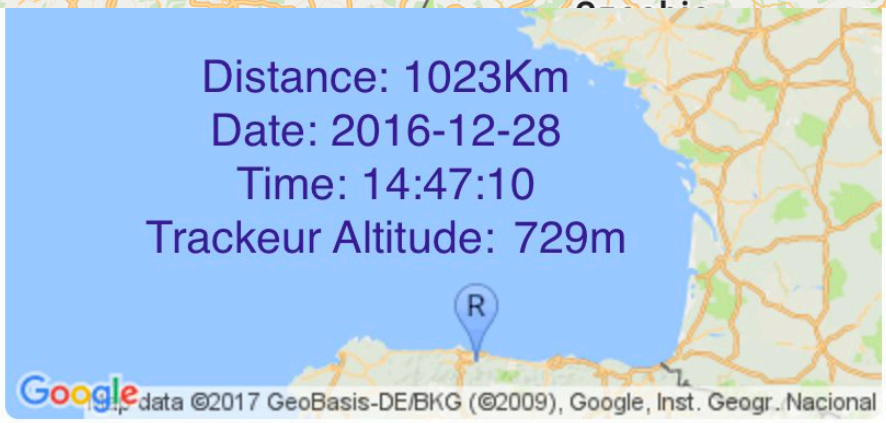
SigFox long journey



Challenging the limits

Challenging the limits



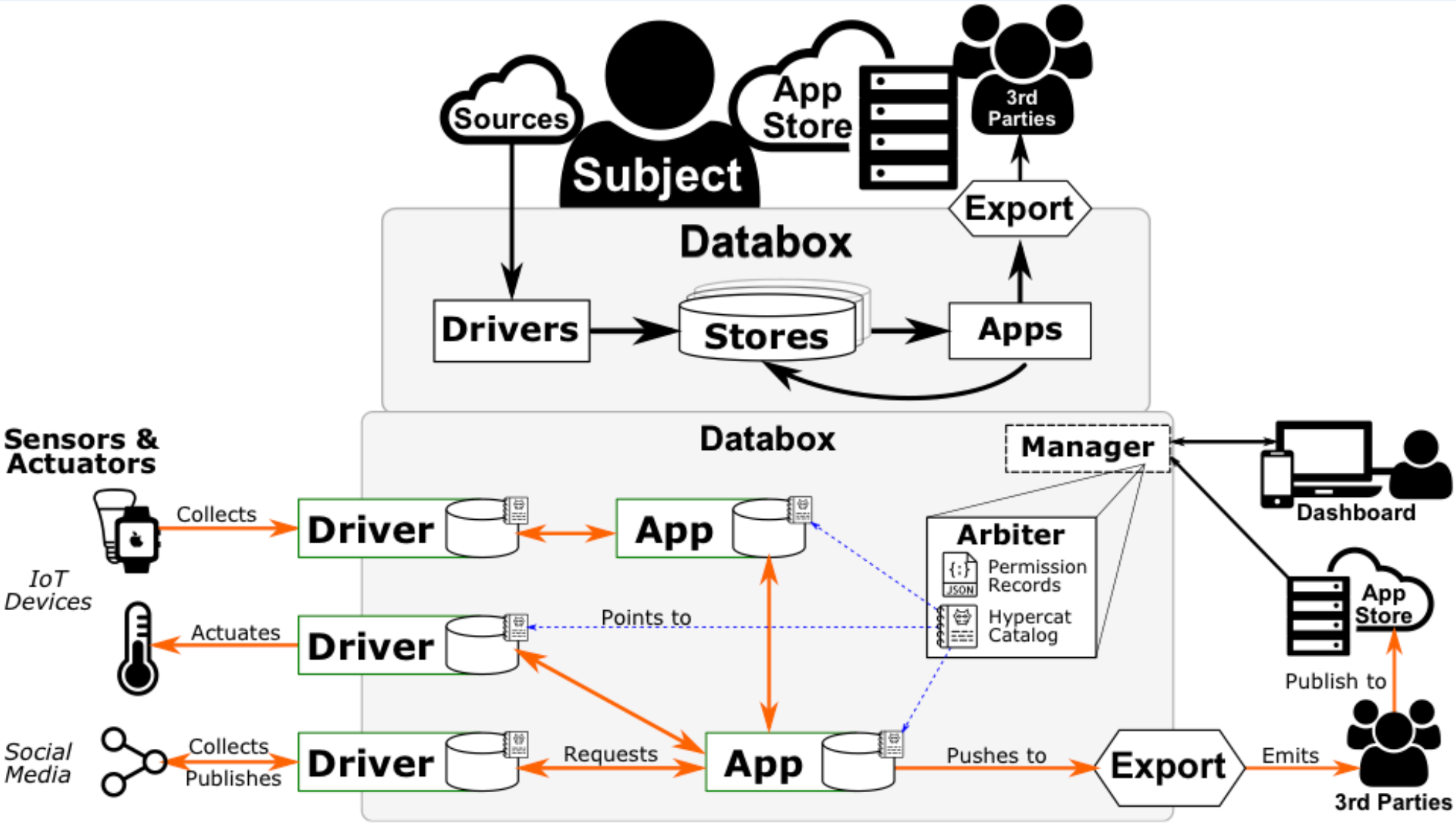


LoRaWAN world record
702 Km

SigFox world record
1023 Km

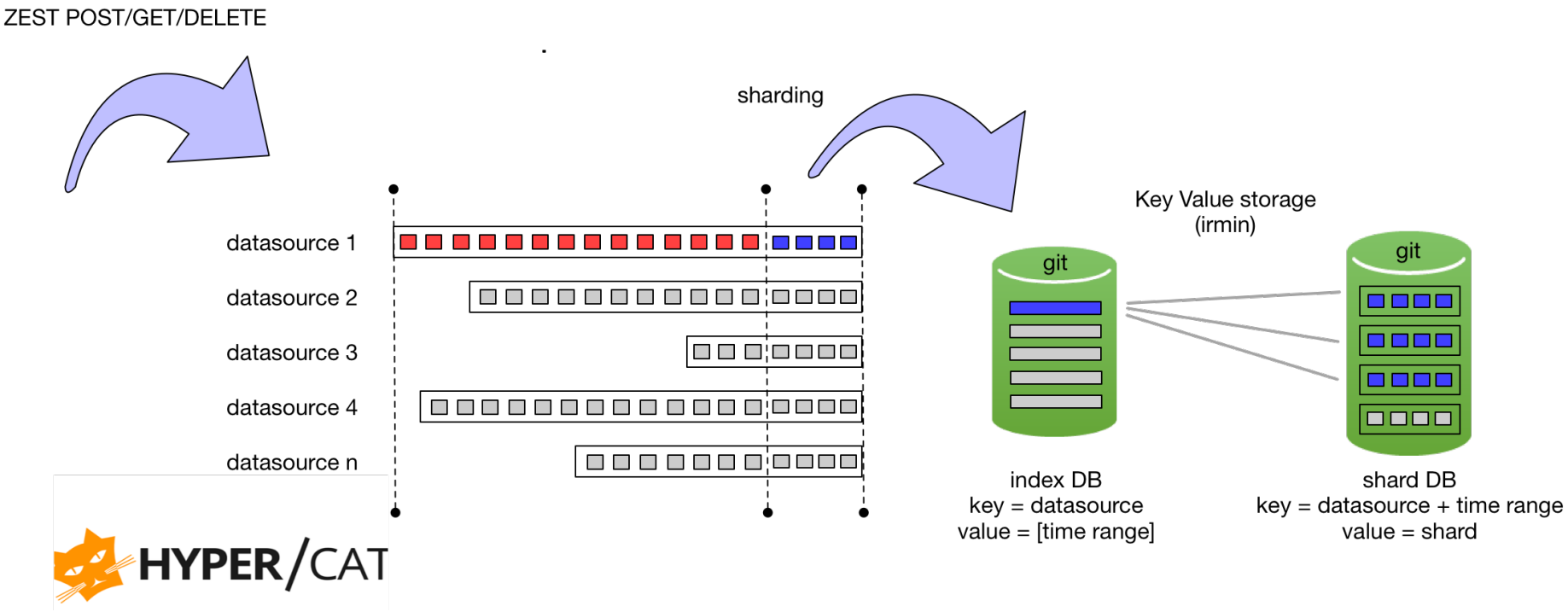
Databox

Databox Architecture



Time-series with GIT flavour

Implementing a time series database over git



Download ZestDB

https://github.com/me-box/zestdb

Key takeaways

- We're in early stage of building an LPWAN infrastructure in Cambridge. We're constantly assessing the deployment process as it exhibits patterns of an AND.
- Simulations suggest that there is a potential for interference and although it is not urgent, there should be a monitoring strategy in place (as to adapt the network).
- It seems like we urgently need a way to enforce coexistence between LoRaWAN and SigFox.
- Presumably SigFox service require more density in BSs and so far geolocation report service is not adequate.

Thank you!

Questions?