Applications, Sciences et Technologies de l'Internet des Objets

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Internet des Objets - *Internet of Things*

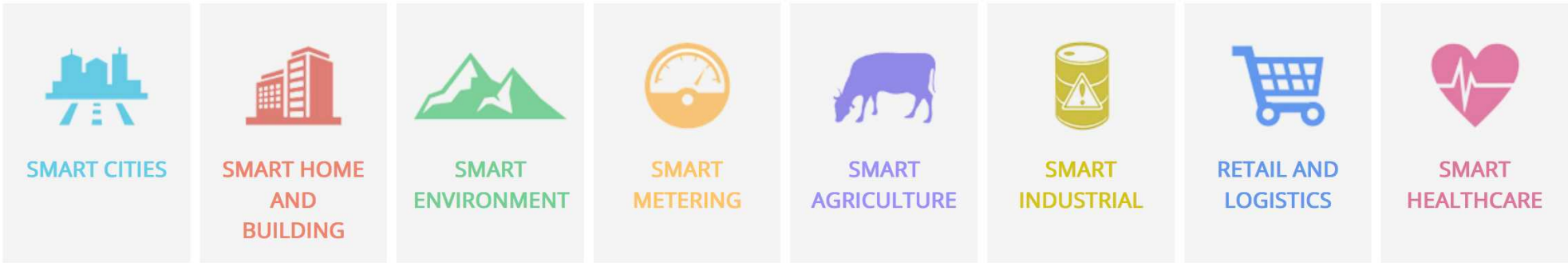
Gartner : 20 milliards d'objets en 2020

95 % des nouveaux objets électroniques sont connectables à Internet.

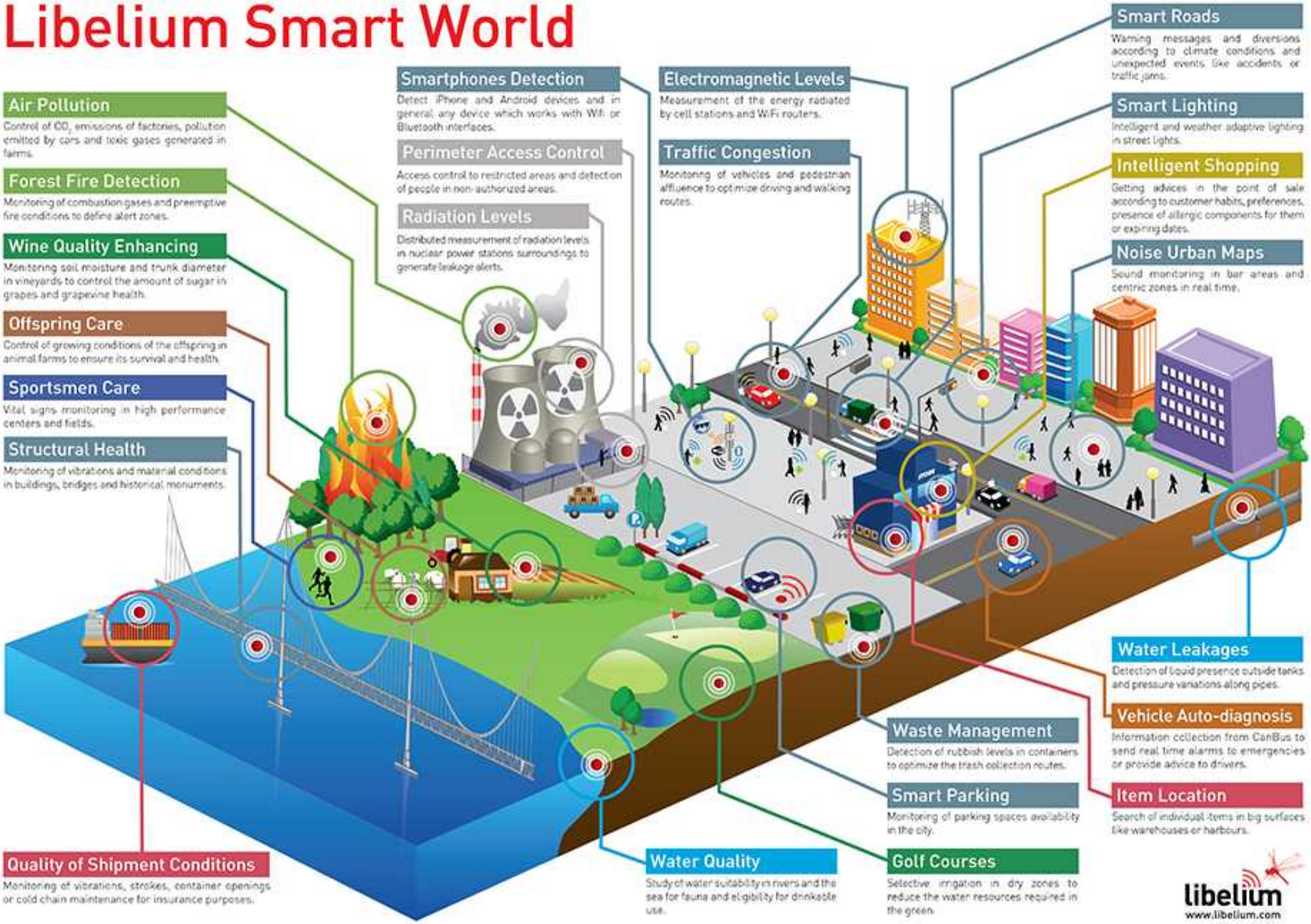
IoT small range : Smart Home, Smart Office

IoT medium range : Smart Building

IoT long range : Smart City, Smart Grid, Smart Agriculture, …



Libelium Smart World



Air Pollution
Control of CO_2 emissions of factories, pollution emitted by cars and toxic gases generated in farms.

Forest Fire Detection
Monitoring of combustion gases and preemptive fire conditions to define alert zones.

Wine Quality Enhancing
Monitoring soil moisture and trunk diameter in vineyards to control the amount of sugar in grapes and grapevine health.

Offspring Care
Control of growing conditions of the offspring in animal farms to ensure its survival and health.

Sportsmen Care
Vital signs monitoring in high performance centers and fields.

Structural Health
Monitoring of vibrations and material conditions in buildings, bridges and historical monuments.

Quality of Shipment Conditions
Monitoring of vibrations, strokes, container openings or cold chain maintenance for insurance purposes.

Smartphones Detection
Detect iPhone and Android devices and in general any device which works with Wifi or Bluetooth interfaces.

Perimeter Access Control
Access control to restricted areas and detection of people in non-authorized areas.

Radiation Levels
Distributed measurement of radiation levels in nuclear power stations surroundings to generate leakage alerts.

Electromagnetic Levels
Measurement of the energy radiated by cell stations and WiFi routers.

Traffic Congestion
Monitoring of vehicles and pedestrian affluence to optimize driving and walking routes.

Water Quality
Study of water suitability in rivers and the sea for fauna and eligibility for drinkable use.

Smart Roads
Warning messages and diversions according to climate conditions and unexpected events like accidents or traffic jams.

Smart Lighting
Intelligent and weather adaptive lighting in street lights.

Intelligent Shopping
Getting advices in the point of sale according to customer habits, preferences, presence of allergic components for them or expiring dates.

Noise Urban Maps
Sound monitoring in bar areas and centric zones in real time.

Water Leakages
Detection of liquid presence outside tanks and pressure variations along pipes.

Vehicle Auto-diagnosis
Information collection from CanBus to send real time alarms to emergencies or provide advice to drivers.

Waste Management
Detection of rubbish levels in containers to optimize the trash collection routes.

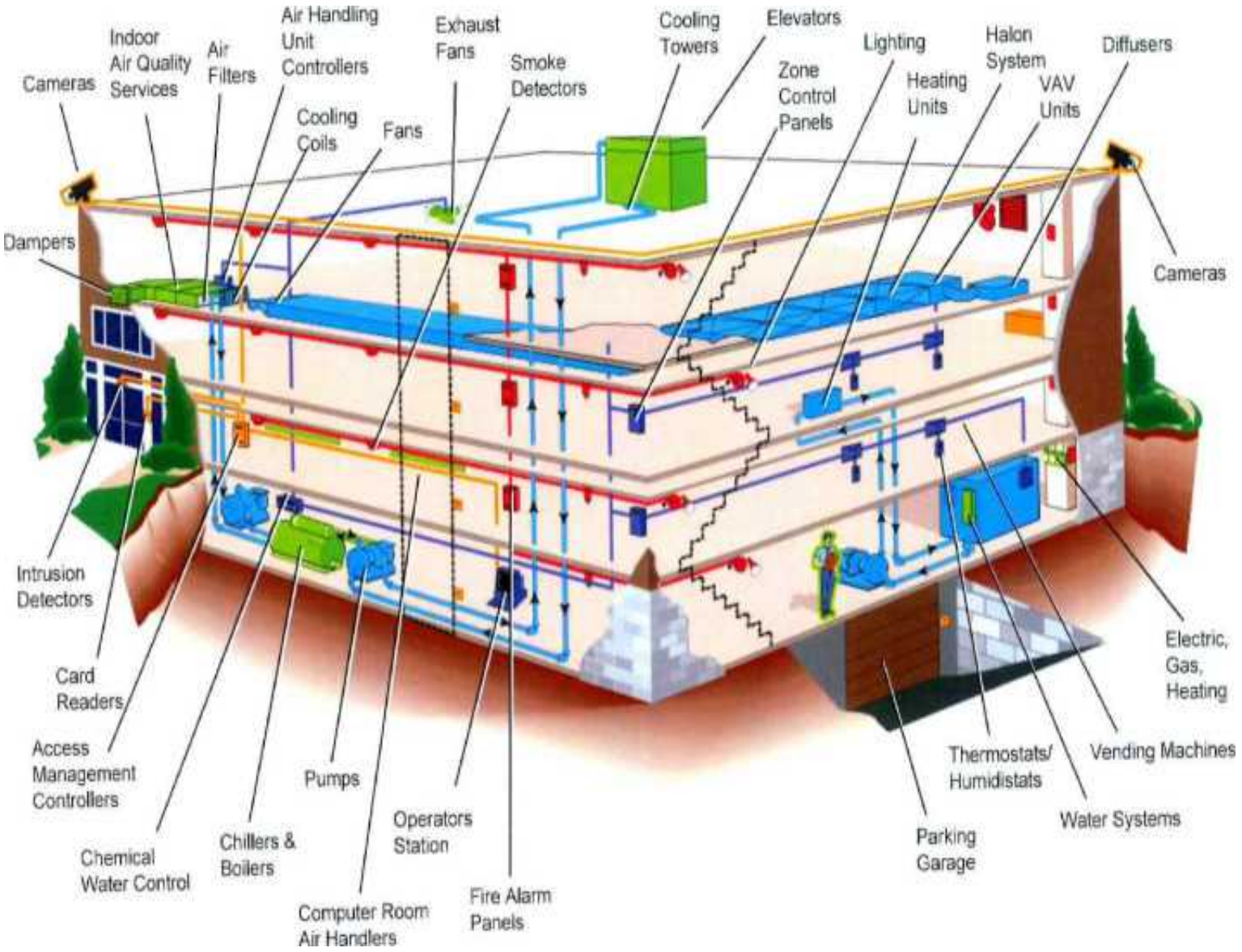
Smart Parking
Monitoring of parking spaces availability in the city.

Item Location
Search of individual items in big surfaces like warehouses or harbours.

Golf Courses
Selective irrigation in dry zones to reduce the water resources required in the green.

libelium
www.libelium.com

Building Automation



Smart Metering

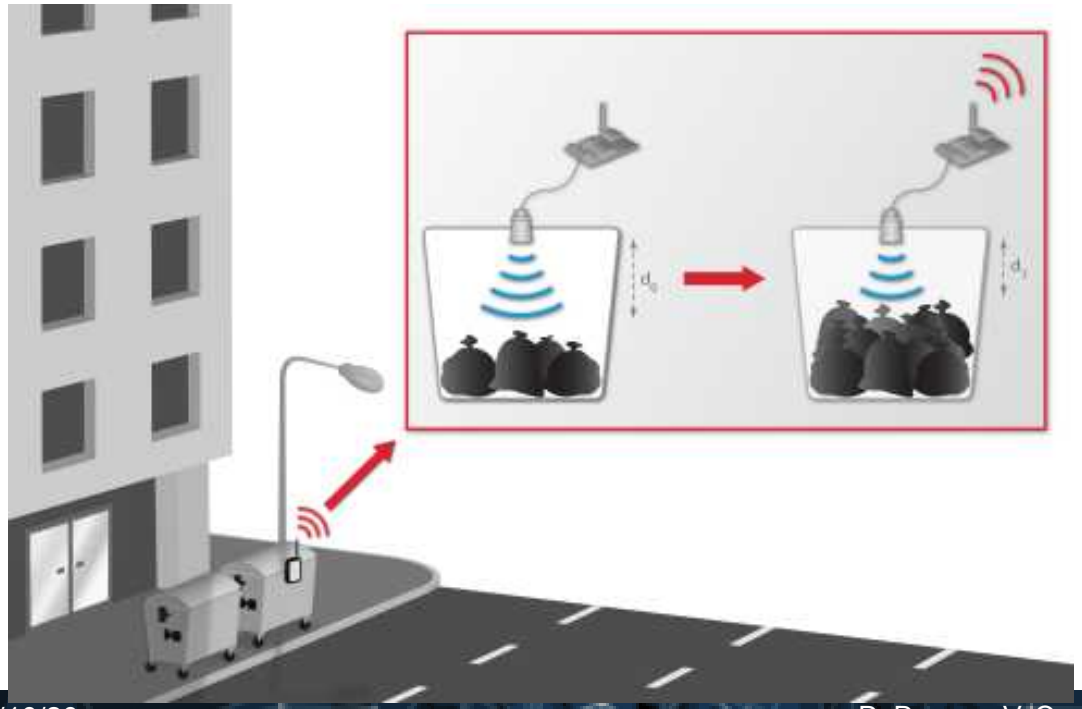
- Utilities
  - Gas, Water, Electricity, Steam
- Market
  - Status : 88,2M SM installed in 2017
  - Forecast : 588M installations between 2018 and 2022
- Applications
  - Suivi en « temps réel »
  - Détection de fuite
  - Economie
  - Ajustement production-consommation (Smart grid)
  - Fraude
- *Remark : Deep Indoor communications*

Smart Grid

- Consommation d'énergie
  - Anticiper en temps réel la demande globale pour gérer la production glob
  - Auto-consommation au niveau d'un quartier, d'une résidence
- Production d'énergie
  - Panneaux solaires, Eoliennes, ...
    - Individuel, Toit d'immeuble, Collectivité, Ferme, ...

Gestion des déchets

- Collecte optimisée
- Paiement au volume

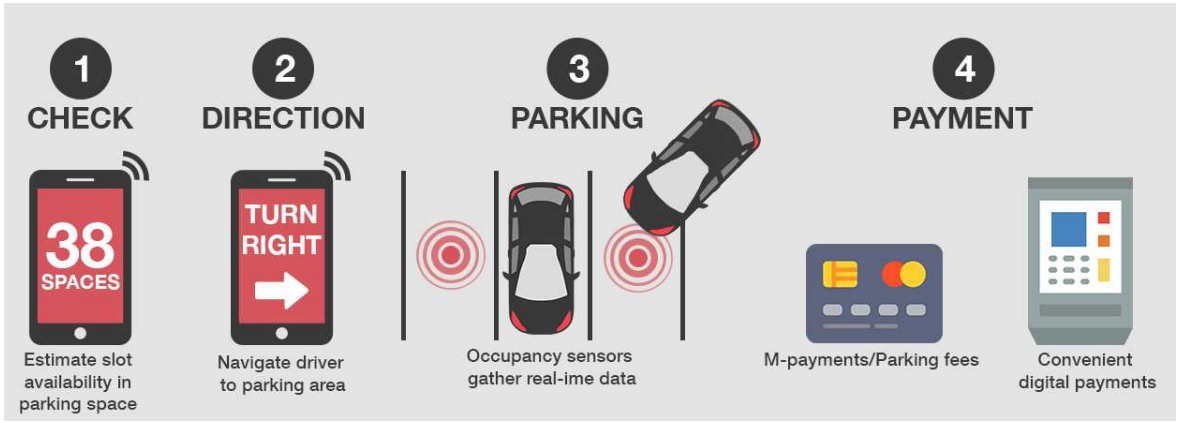


Smart Parking

- Applications
  - Aide au guidage des automobilistes
    vers les places libres
  - Aide à la recherche des places handicapé libres
  - Détection des infractions (places handicapés, livraisons, …)
  - Paiement à la minute

  - A smart parking solution can reduce a 43% the time spent looking for parking, a 30% the miles traveled with a vehicle searching for a parking, the 8% of the traffic volume and the 40% of green house gas emissions.

Smart Parking



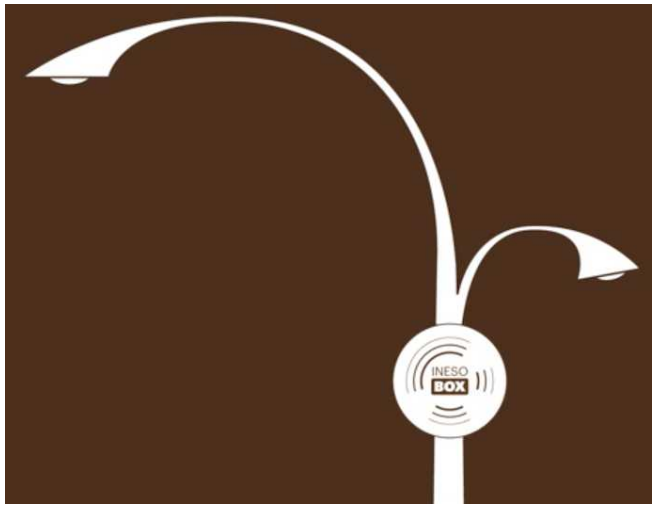
Colas

Suivi de flotte

- Véhicules, conteneurs ...
  - Optimisation
  - Conduite dangereuse
  - Fraude
  - Vol
  - Urgence
    - Couplage avec les feux de trafic

Smart Urban Lighting

- Eclairage urbain
  - 40 % de la facture d'électricité des villes
  - 1900 milliard de kg de CO_2 (4 fois les émission de la France)
- Contrôle individuel des lampadaires urbains
  - 1 sur 2,
  - gradation (LED),
  - présence,
  - « précède moi »
  - « je suis en panne » (maintenance)
  - ...



Sécurité

- Bâtiments
  - Bureau, Hall, Communs
  - Isolé : Cave, Hangar, Parking souterrain
- Applications
  - Présence/Intrusion
  - Incendie
  - Radiation
  - Panic Button (travailleur isolé)
- Risques naturelles
  - Nilomètre
  - Nivomètre
  - Mouvement de terrain
- Risques industriels
  - Radiation
  - Pollution des eaux

Air Quality

- Facts
  - Air pollution generate 8.2 million deaths per year in the world
  - Estimated cost : 68 to 97 G€/year (for France)
- Measurements
  - Fixed/mobile air quality stations
  - Flying stations

Pigeons wearing wireless pollution-monitoring devices will report back via Twitter
 - Picture credits Plume Labs
https://www.linkedin.com/pulse/when-pigeons-tweet-birds-iot-harald-naumann

Air Quality

- Particules (PM), VOC, CO2, NO2, …

  - Forecast : Particle sensors market will reach $1.2B in 2023, with 300Munits (all applications included)

Risk management

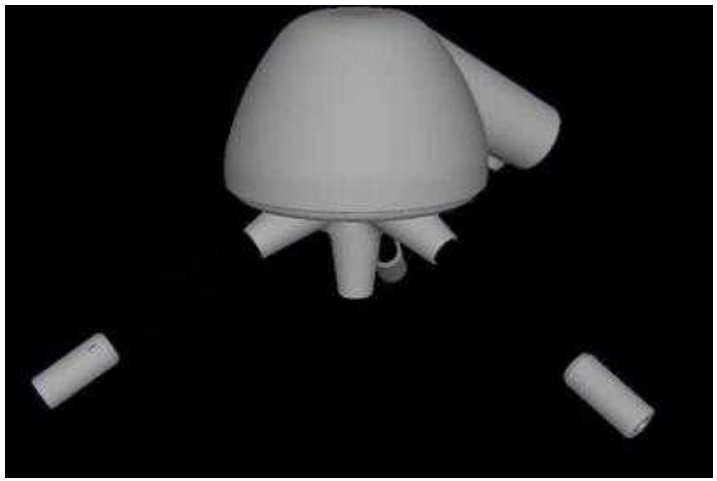
- Risks
  - Floods, Snowslide, Landslide ...
- Measurements
  - River level, Motion detection ...

https://air.imag.fr/index.php/IRock

https://twitter.com/decentlab/status/731042251665747968

Nuisances sonores

- Faits
  - Un coût sur la santé du bruit des transports s'élevant à 11,5 milliards d'euros par an en France, dont 89% induit par le trafic routier (*)
- Applications
  - Traffic routier
  - Lutte anti-fétard



Capteur sonore Bruitparif

* http://www.bruit.fr/cout-social-du-bruit-en-france-57-milliards-deuros.html

Distributeurs automatiques

- Niveaux de remplissage des compartiments
- Pics d'activité
- Remontées des anomalies

Personnes fragiles

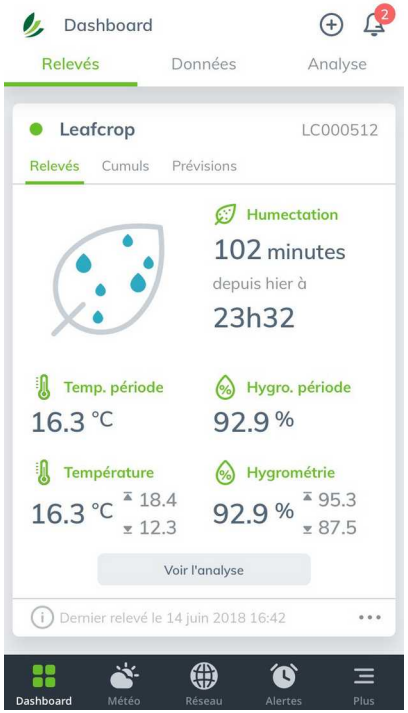
- Services à domicile (santé, repas, ménage)
  - Badgeuse (Suivi)
- Activités
  - *Montres connectées*
  - *Panic button*
  - Mouvement (chute)
  - Consommation fluide

Lysbox du CG Loiret

Agriculture de Précision

- Greenhouses, Open fields, Beehives, …
- Water distribution, Temperature, Ice, Air humidity, Soil moisure, Light, Acidity, ...

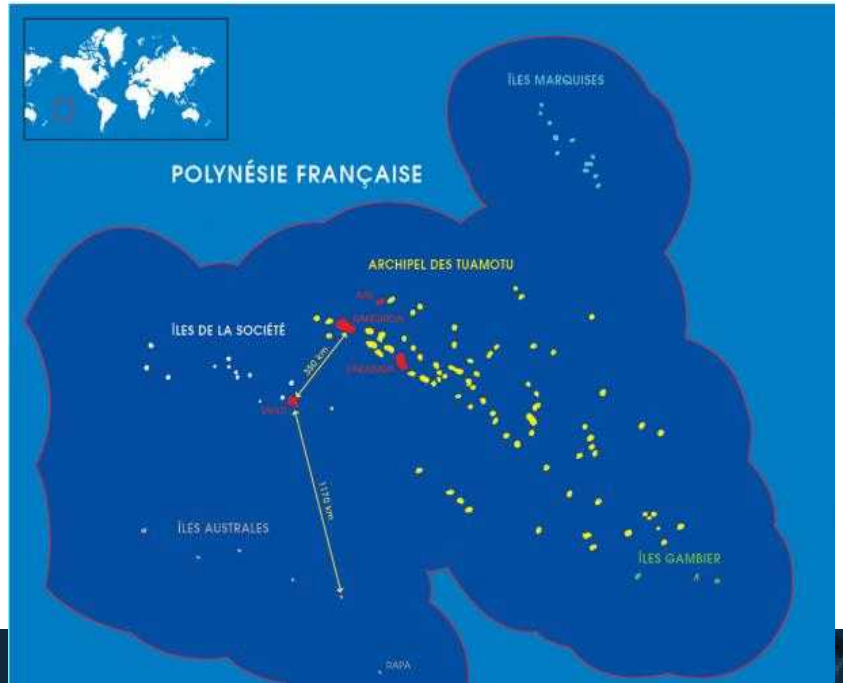
http://sencrop.com/fr/produits/anemometre-connecte/



The Internet of Isolated Things

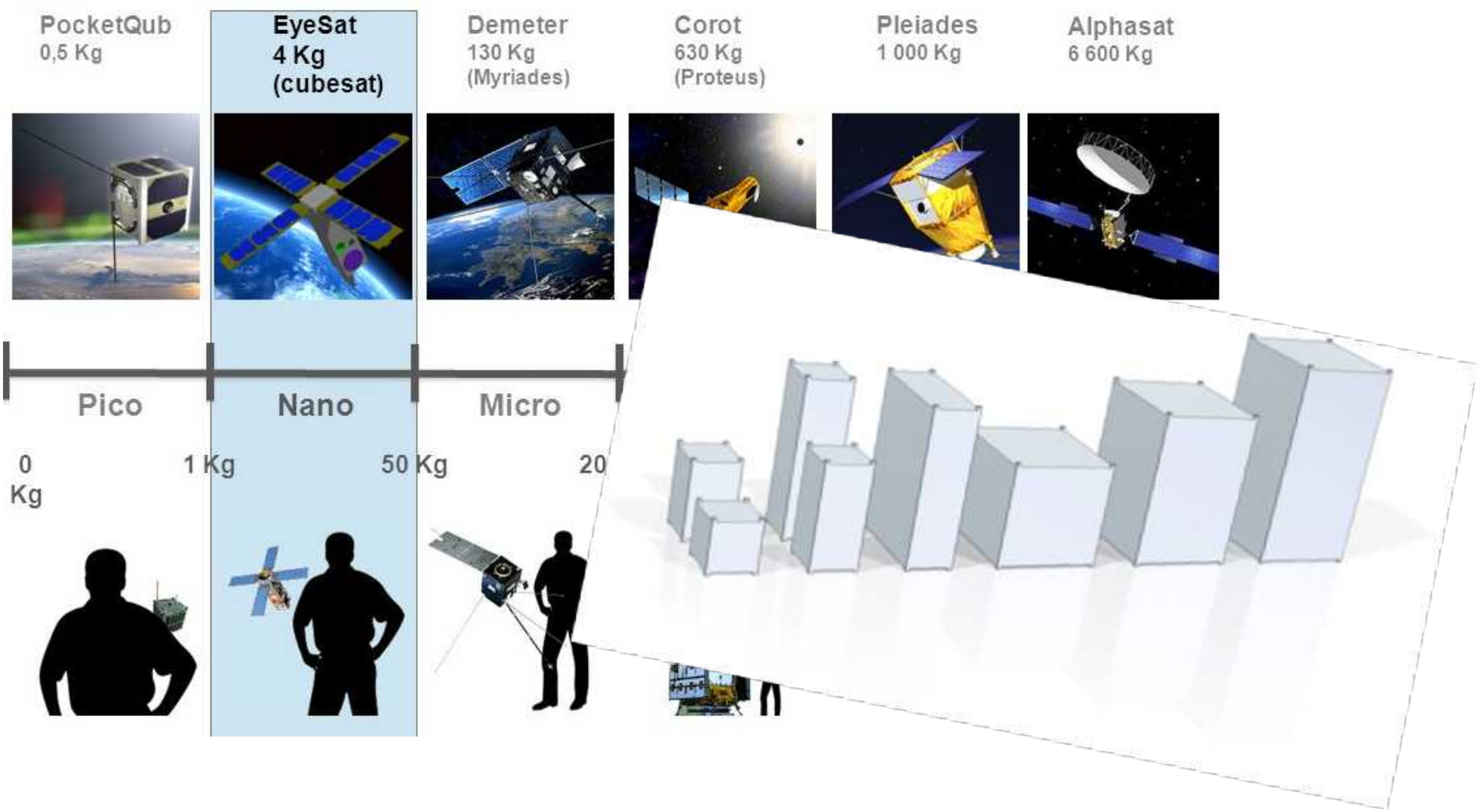
IoT networks cover only a few part of the Earth (*Orbi*)

Deserts, oceans, pole regions, unpopulated areas are “not” connected to the global web



New Space & Cubsats

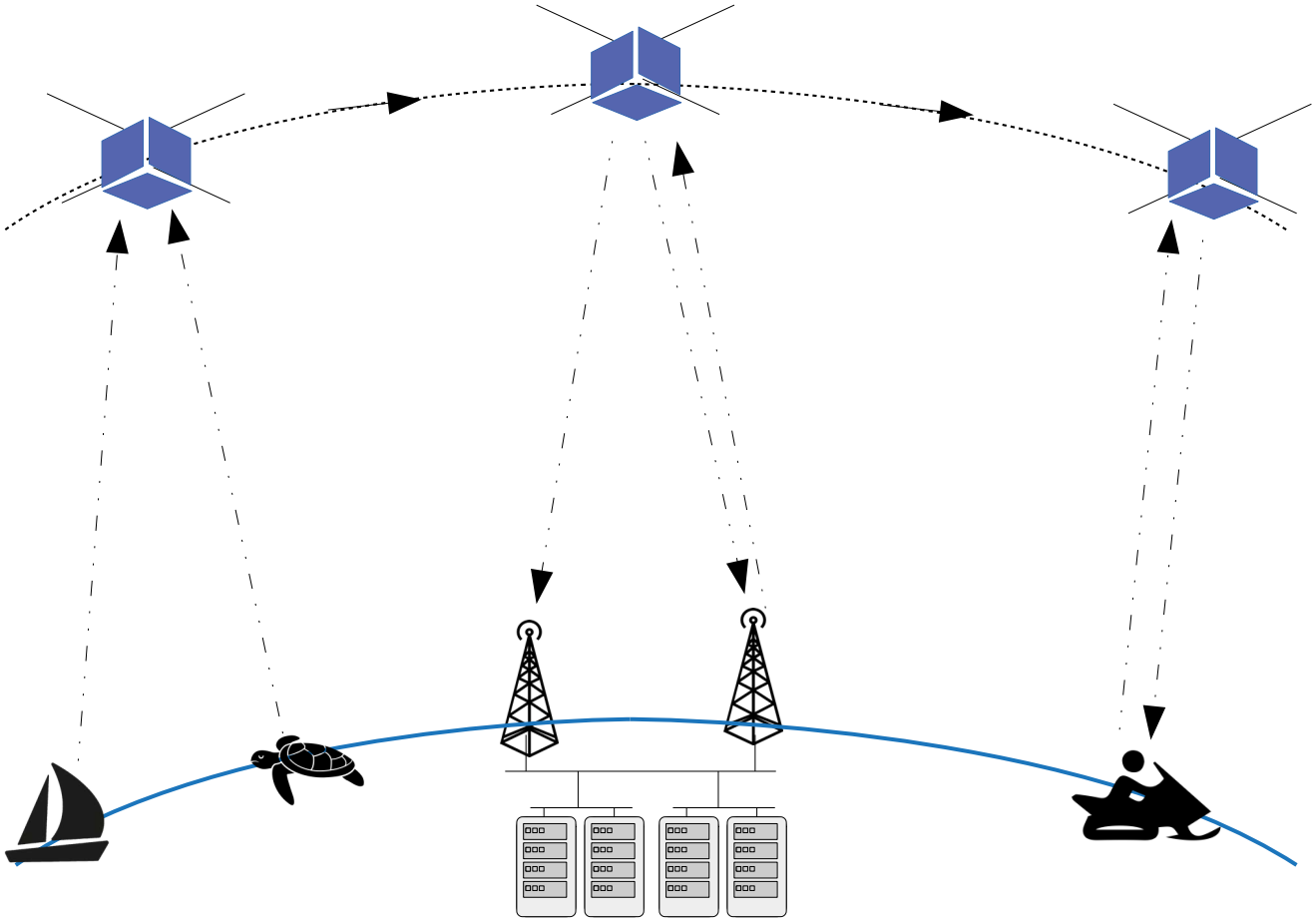
- Agile and “affortable” LEO satellites



Sat-IoT

Projet ThingSat

Constellation de nano-satellites servant de « mules »
des messages reçus du sol

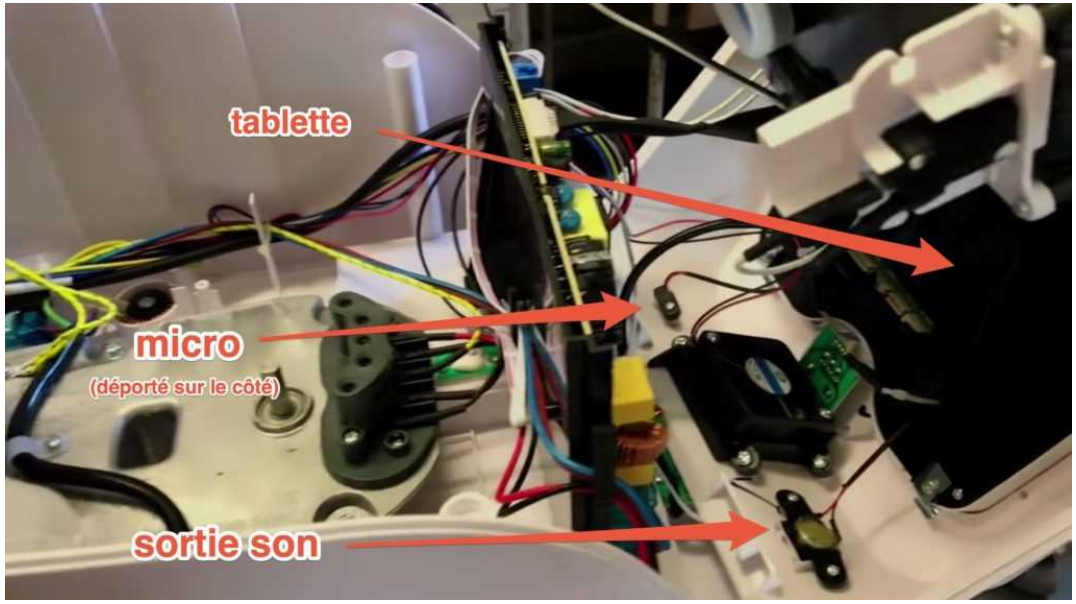


Cyber-sécurité et Vie privée

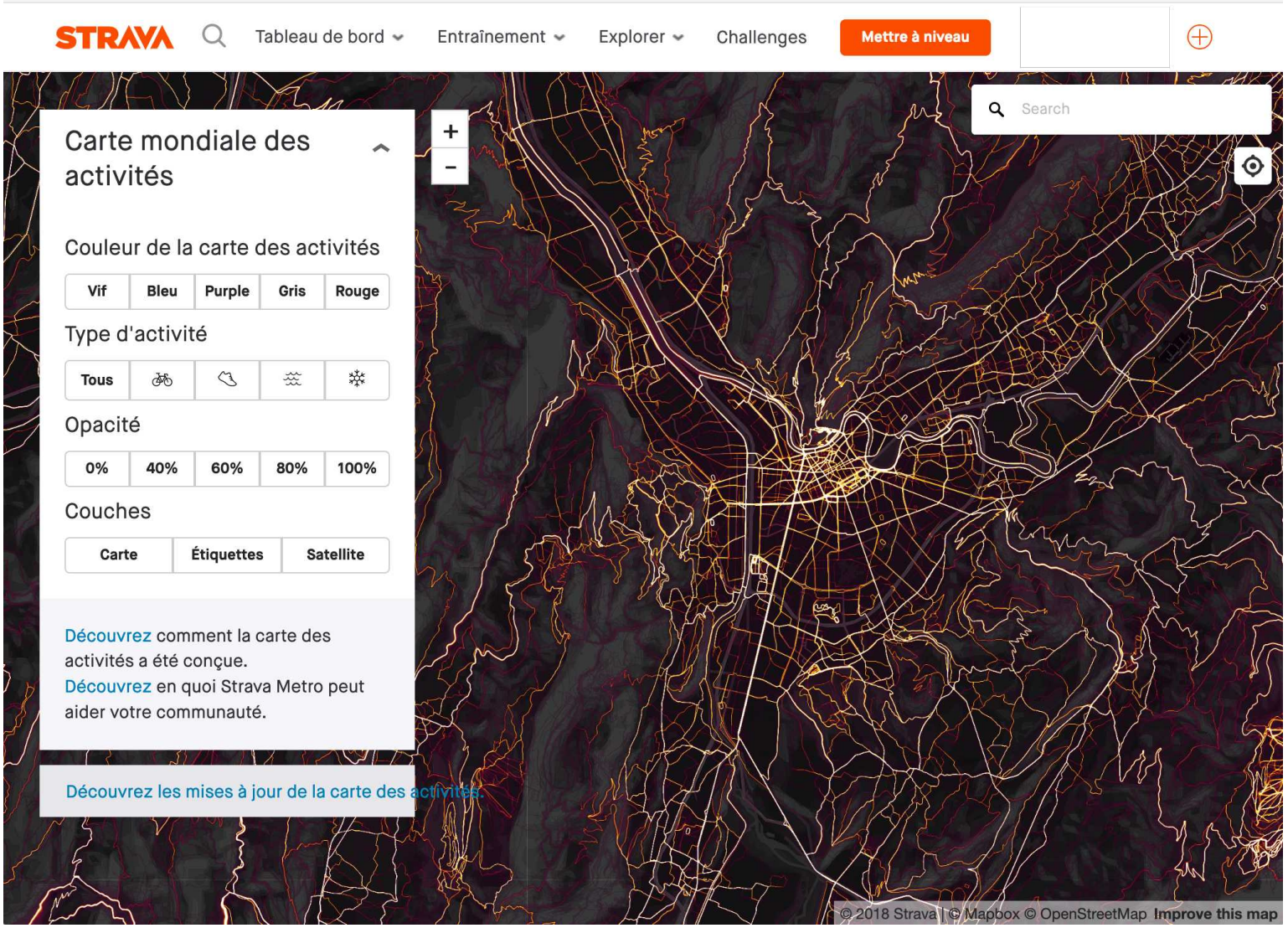
- Objet connecté
  - Brèche dans la sécurité (maison, entreprise)
  - Conception du logiciel en urgence (TTM)
    - *Unsecure By Design* vs *Security By Design*
- Surveillance des faits et gestes des usagers
  - « note sociale » de la RPC
    - 150 millions de caméras + reconnaissance faciale
  - Compteurs intelligents
  - Montres & co connectées
    - Bonus assurance (privée)
    - Waze, Nest, Fitbit (rachetés par Google)

LIDL Monsieur Cuisine Connect

- Alexis Viguié (@Siphonay), Adrien Albisetti (@Sinuso)
- Présence d'une tablette Android 6 (obsolète en 2019) avec un micro



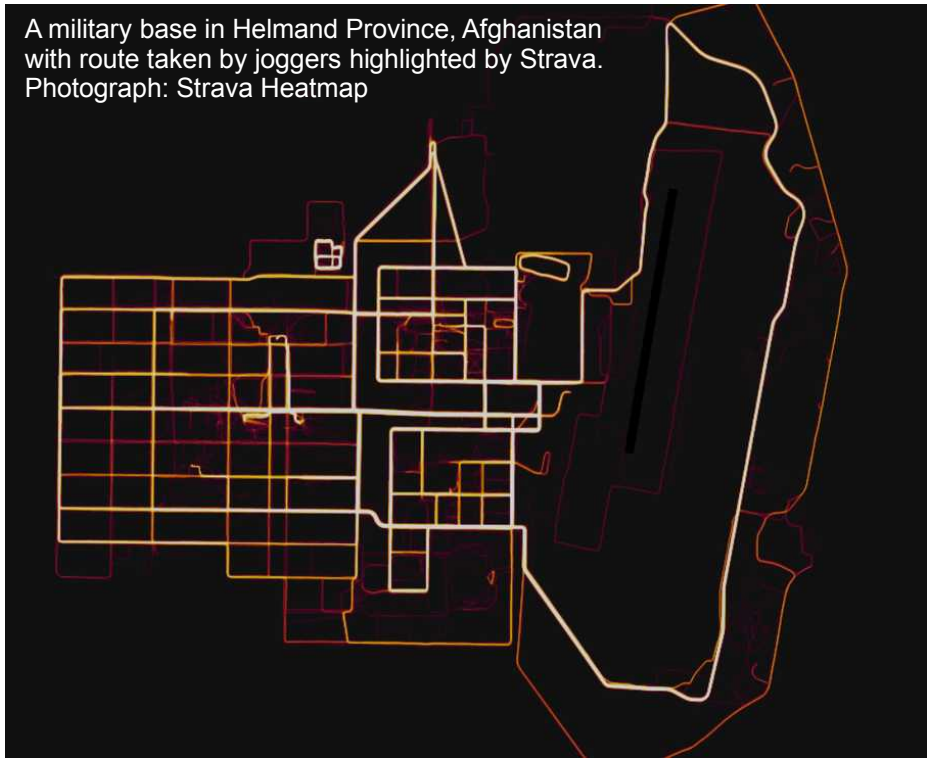
Strava
Carte mondiale des activités



https://www.strava.com/heatmap#11.68/5.66491/45.18139/hot/all

Strava
Carte mondiale des activités

- parcours des sportifs du dimanche
- athlètes qui participent au marathon de Paris
- militaires en entraînements quotidiens (bases sensibles et parfois secrètes en Syrie, Afghanistan, Niger).



GPS/GNSS

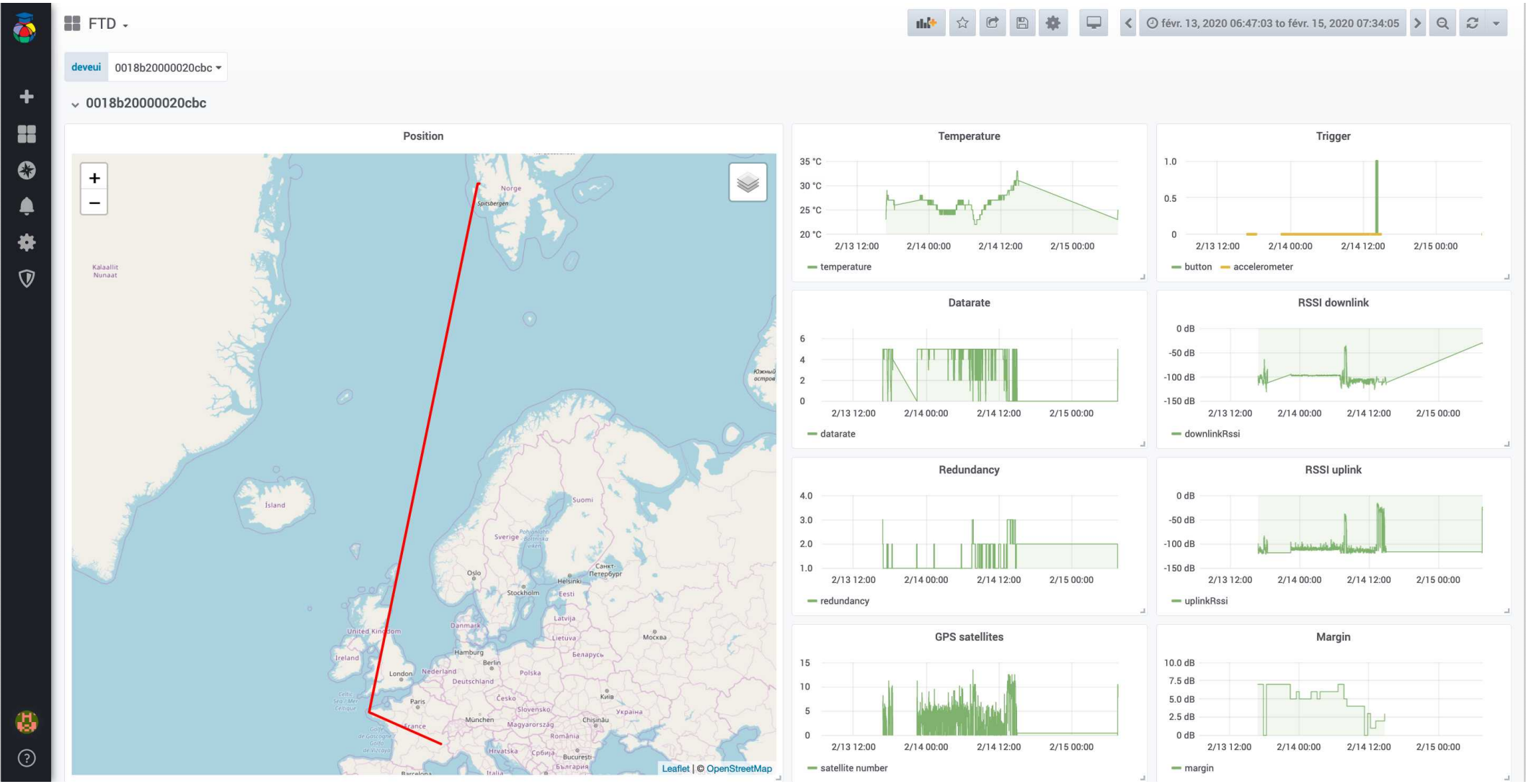
- GNSS
  - Fournit position et temps UTC des/aux objets)
  - Dépendance de plus en plus forte
- Attaques
  - Par bouillage
  - Par leurrage

https://www.anfr.fr/controle-des-frequences/brouillages/les-brouilleurs-dondes/les-brouilleurs-gps/

Exemple d’attaque GPS

- Moscou, Syrie, Corée du Nord ...
- Aéroport de Nantes
- Détournement du yacht White Rose

Exemple d’attaque GPS



Architecture d'un système IoT

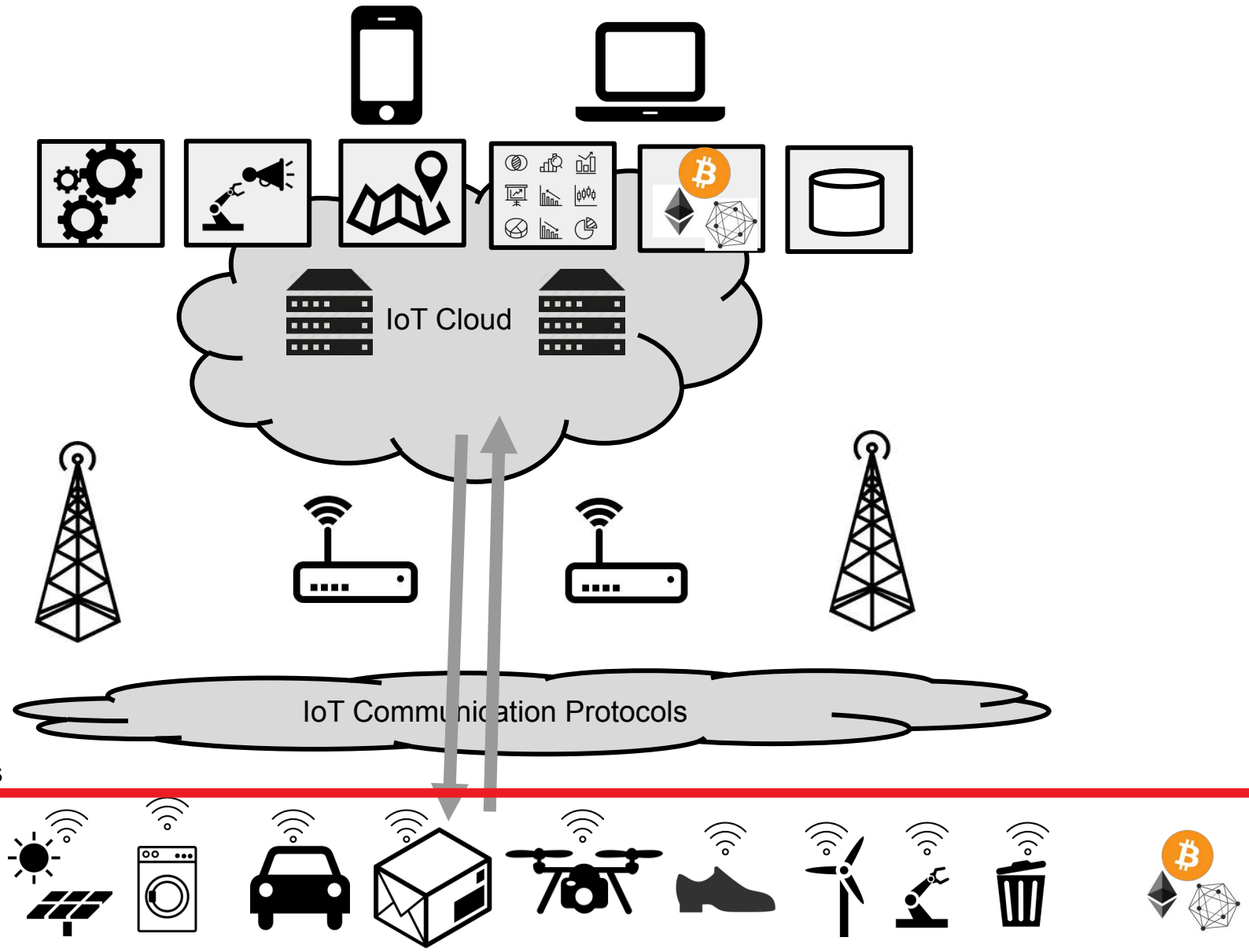
IoT Applications

Cloud infrastructure
(public, private)

Fog/Edge Computing

Communications
- wired/wireless
- IP / No IP
- licensed/free bands

Connected Things
(sensors & actuators)



LPWAN Communication Technologies

Low-Power and Long Range WAN

The 3C : Cost, Current, Coverage

LoRa/LoRaWAN

Sigfox

NB-IoT and LTE-M (3GPP)

covers most of the (previous) IoT use cases

Low-Power and Long Range WAN

Example: Elsys ELT2 (LoRa endpoint with temperature sensor)

- Battery lifetime from **6** to **18** years (**1 temp. msg/hour**)

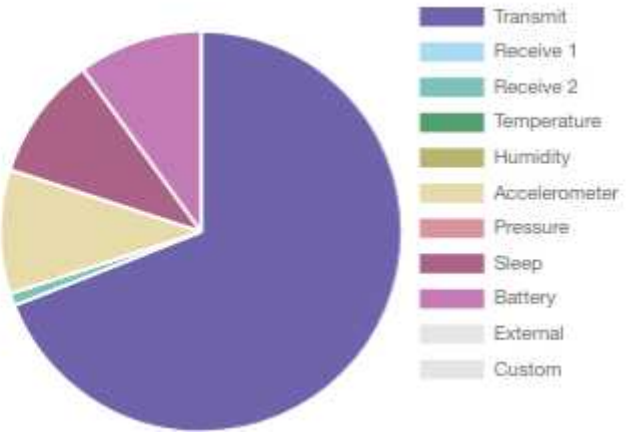
Sample time	Sensor	Battery capacity	Battery performance
3600	ELT2 HP	2700	80
Seconds	Select Elsys sensor	Capacity(mAh)	Performance(%)

Spreading factor

○ SF7 ○ SF8 ○ SF9 ○ SF10 ○ SF11 ◉ SF12

Result:

The battery will last for **6.2** years*. The sensor will draw **40**uA and **351**mAh in one year.



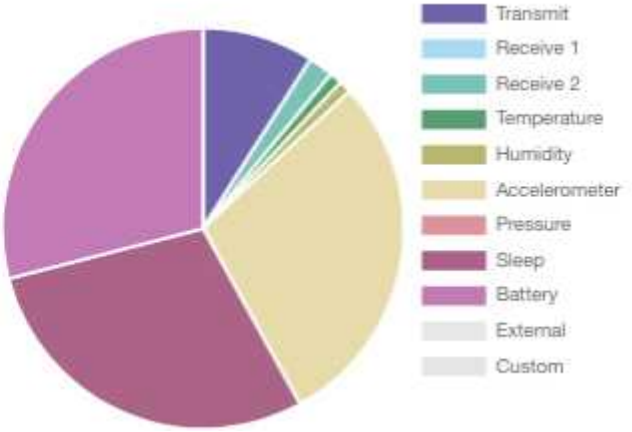
Sample time	Sensor	Battery capacity	Battery performance
3600	ELT2 HP	2700	80
Seconds	Select Elsys sensor	Capacity(mAh)	Performance(%)

Spreading factor

◉ SF7 ○ SF8 ○ SF9 ○ SF10 ○ SF11 ○ SF12

Result:

The battery will last for **18** years*. The sensor will draw **14**uA and **120**mAh in one year.



Low-Power and **Long Range** WAN

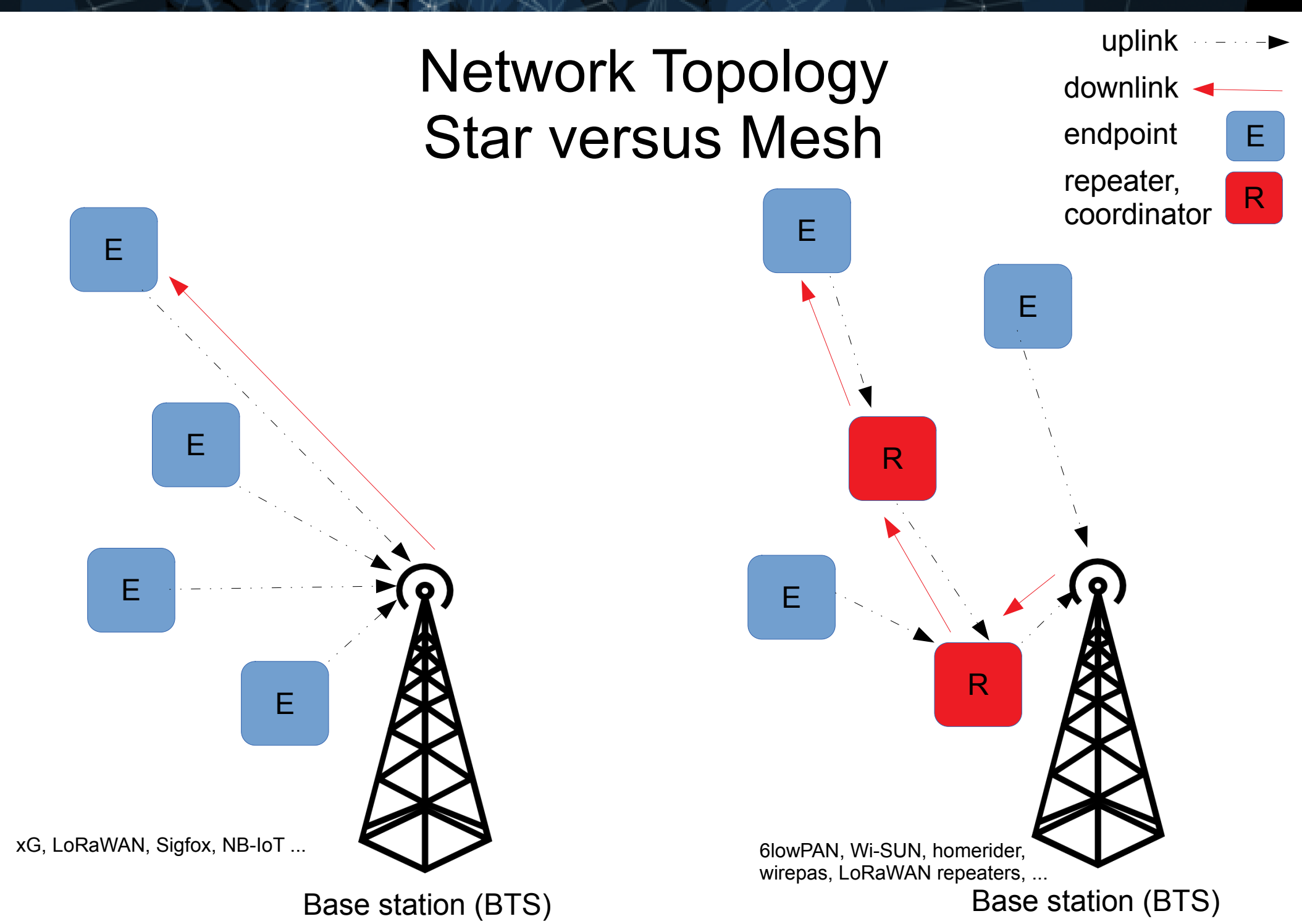
Example: Elsys ELT2 (LoRa endpoint with temperature sensor)

- Mont-Blanc → Strasbourg 300 kms (Eclipse IoT Days 2018)

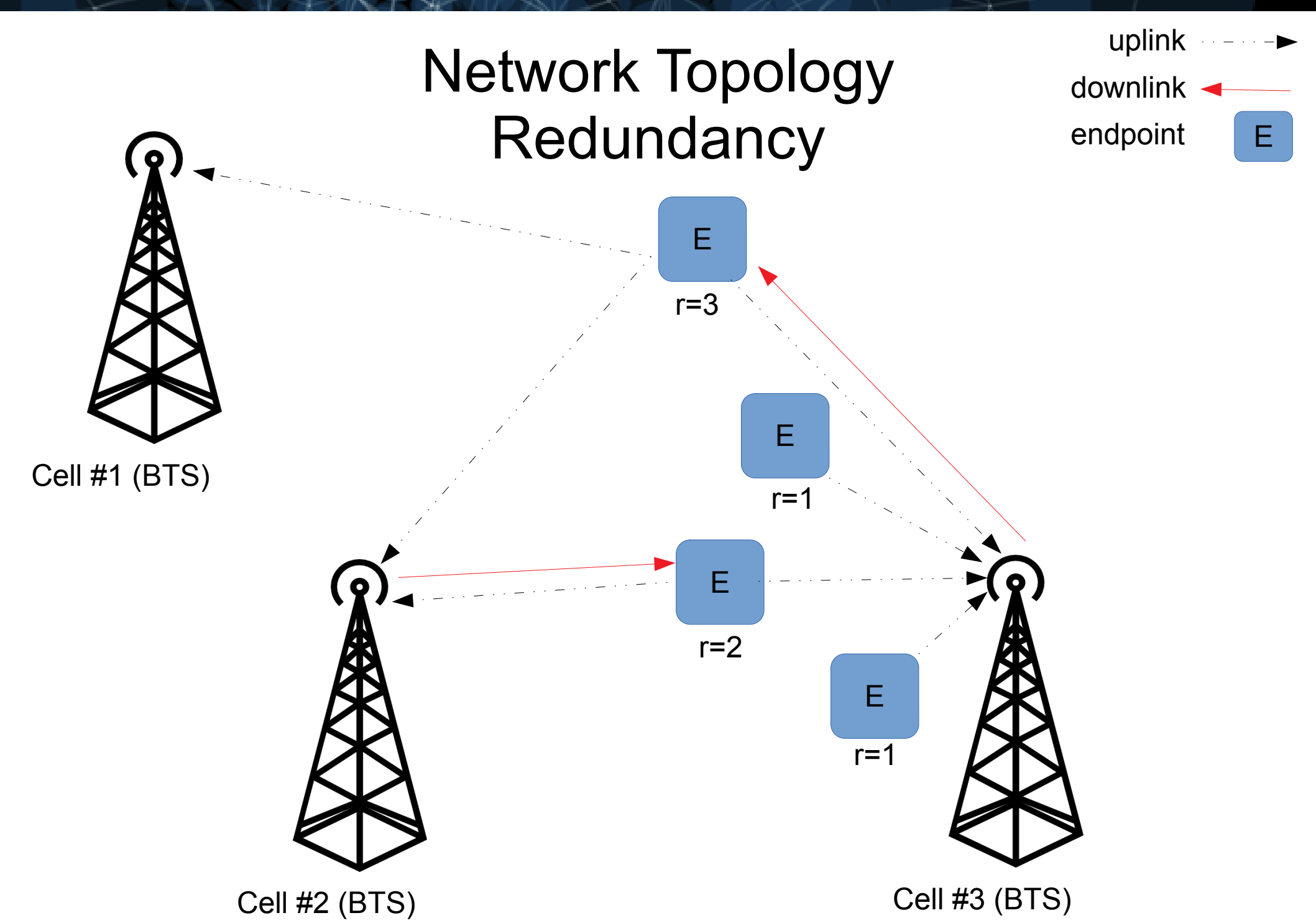
IoT Wireless Communication Ranges

- Proximity
  - RFID (NFC)
- Short
  - RFID (HF, UHF EPC Global) *no battery*
  - Wifi, Bluetooth Low Energy
  - Zigbee, Zwave
  - enOcean *energy scavenging*
  - Rfxcom433, Thread
- Medium
  - WMBus
- Long
  - SMS/2G/3G/4G, HAM
  - Sigfox (UNB), LoRa, *Weightless*, LTE-M, NB-IoT
- Ultra-long
  - Iridium, Argos, LPGAN (Sat-IoT)

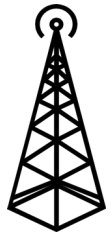
Network Topology
Star versus Mesh



Network Topology Redundancy



Base Stations (Gateways)



- LoRa (200-2000€, 10 W)

LTE BTS 234G (>100K€, >10KW)

Pico Base Stations

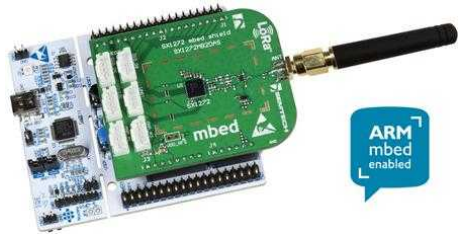
- Home, deep-indoor and building automation
  - Target price 50-100 euros / gateway
- One mile
- « Mono-channel »
  - Pycom, ESP32, Archos Picowan (SX1276)
- « Multi-channel » (LoRa SX1308)
  - Picocell, Murata, ...

Gateway PicoWAN Archos

Sigfox Access Station Micro

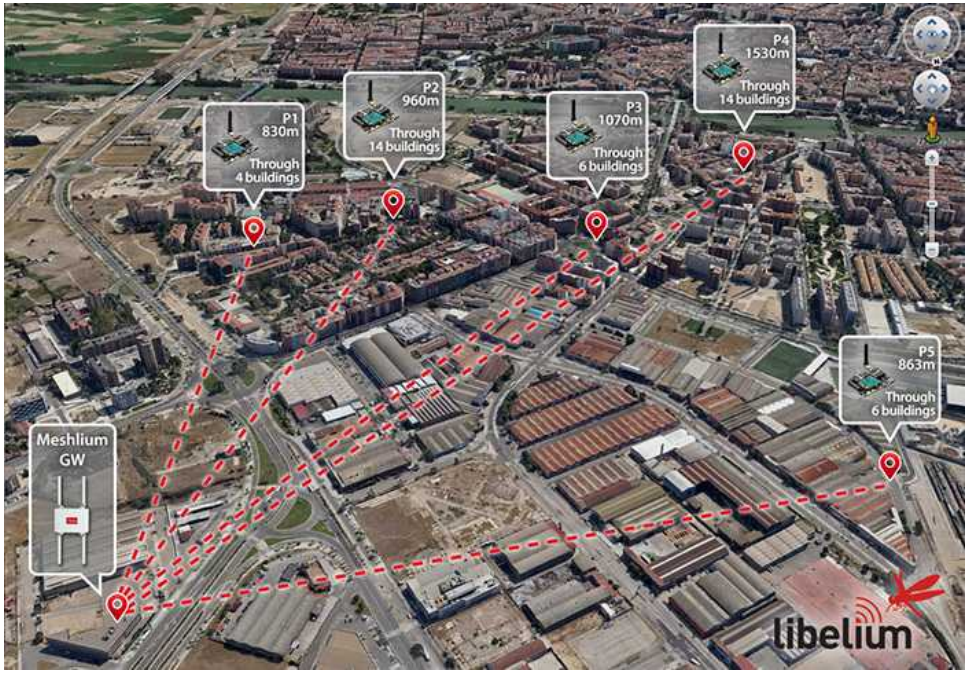
Endpoints

- Development kits
  - For rapid prototyping purpose
    - C/C++, µPython, Javascript, Lua, ...
- Modules
  - Bare metal
    - Firmware should include the program
      and the radio stack (open-source or licensed)
  - Modem
    - Pre-certified
    - Require a host µC
    - Mono-protocol, Multi-protocol (Sigfox, LoRa)
- End products
    - Certified (ETSI, FCC, ...)
    - Ready to use after personnalization
      - AES Keys, factory default parameters



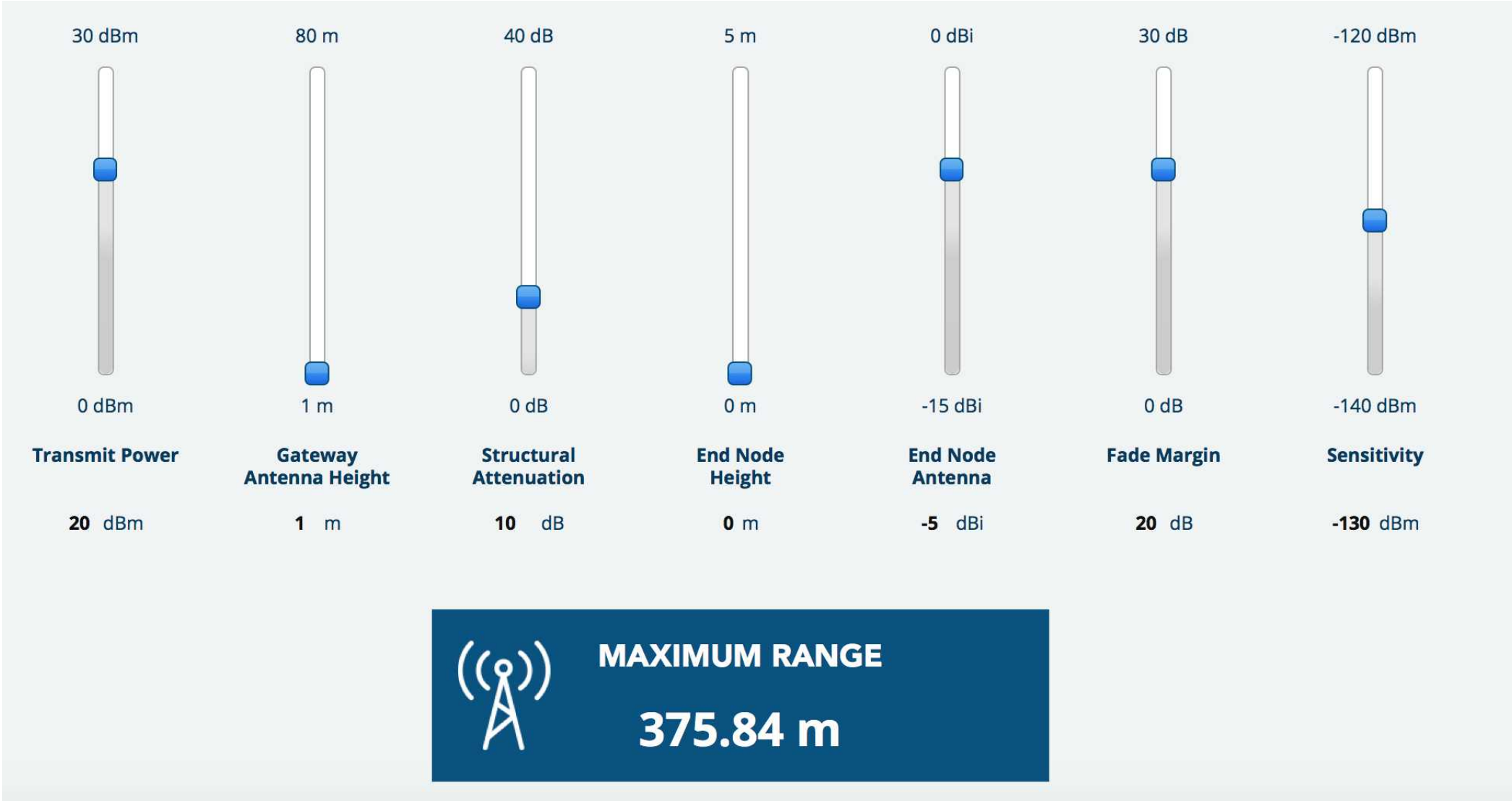
Range and Coverage
Line Of Sight

- 22km (13.6 miles) in LOS links
- up to 2km (1.2miles) in NLOS links in (Paris) urban environment (going through buildings).



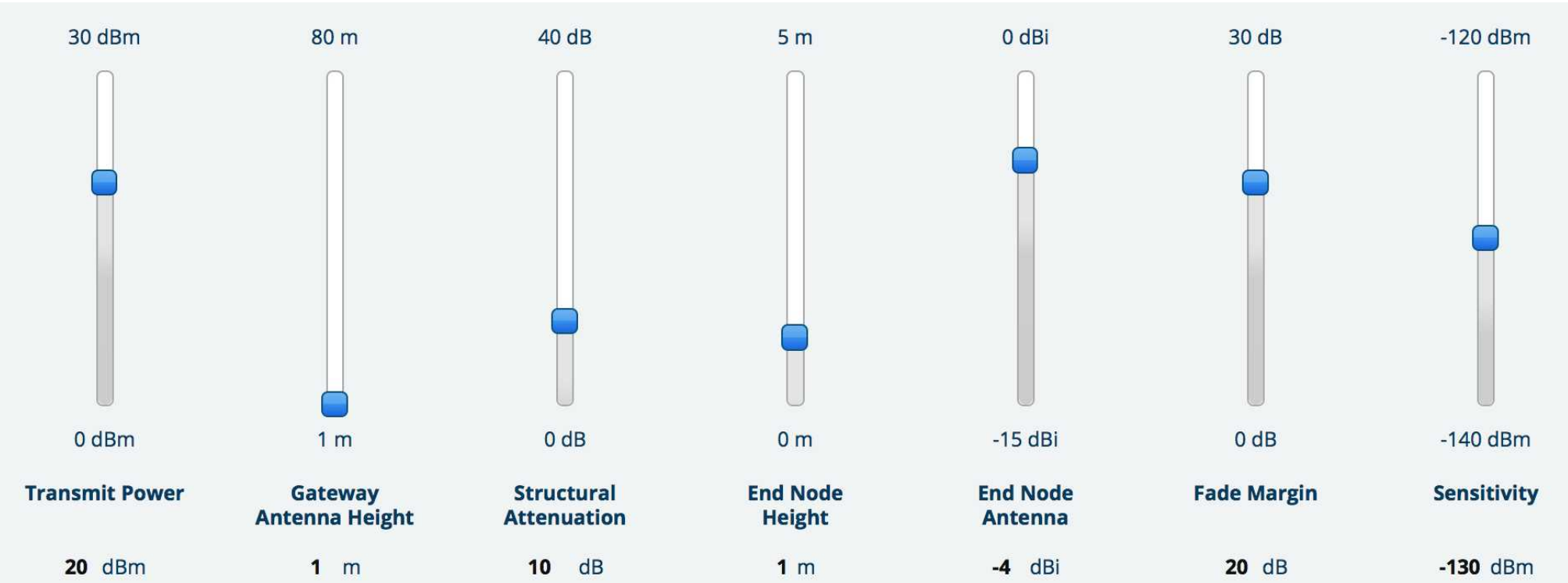
Source : Libelium waspmote_technical_guide.pdf
https://en.wikipedia.org/wiki/Line-of-sight_propagation

Range : LOS vs NLOS
1m ← → 0m



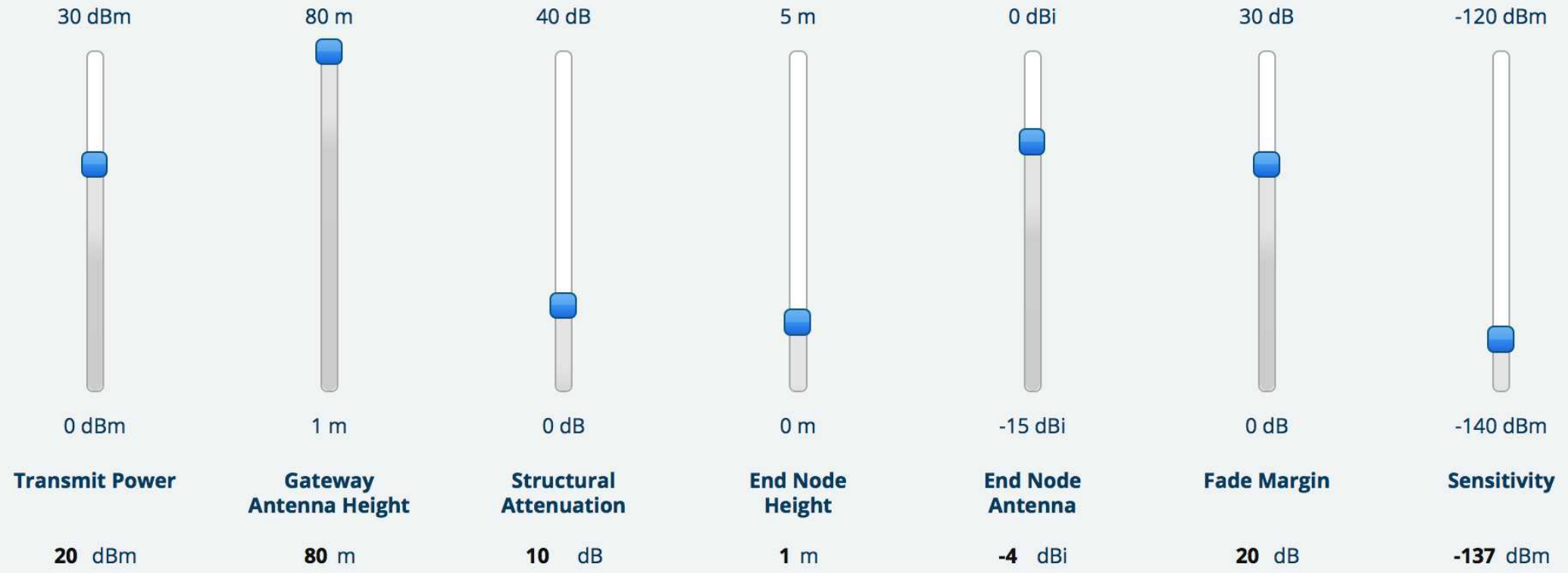
Source : http://www.link-labs.com/walop/

Range : LOS vs NLOS
1m ← → 1m



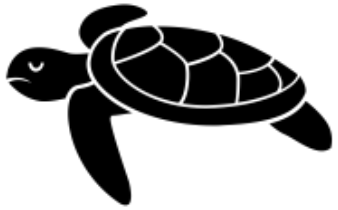
Source : http://www.link-labs.com/walop/

Range : LOS vs NLOS
80m ← → 1m

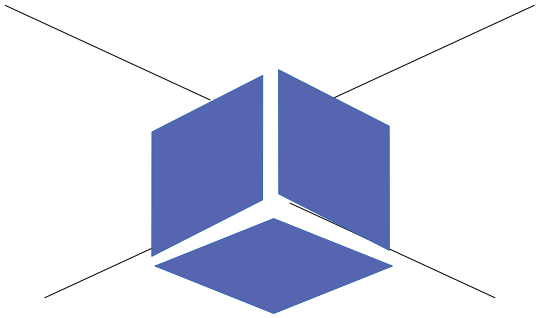


Source : http://www.link-labs.com/walop/

Range : LOS vs NLOS
0 m ← → 500 000 m (LEO)



?



Projet
ThingSat

Preliminary radio tests
LoRa in the Near Space

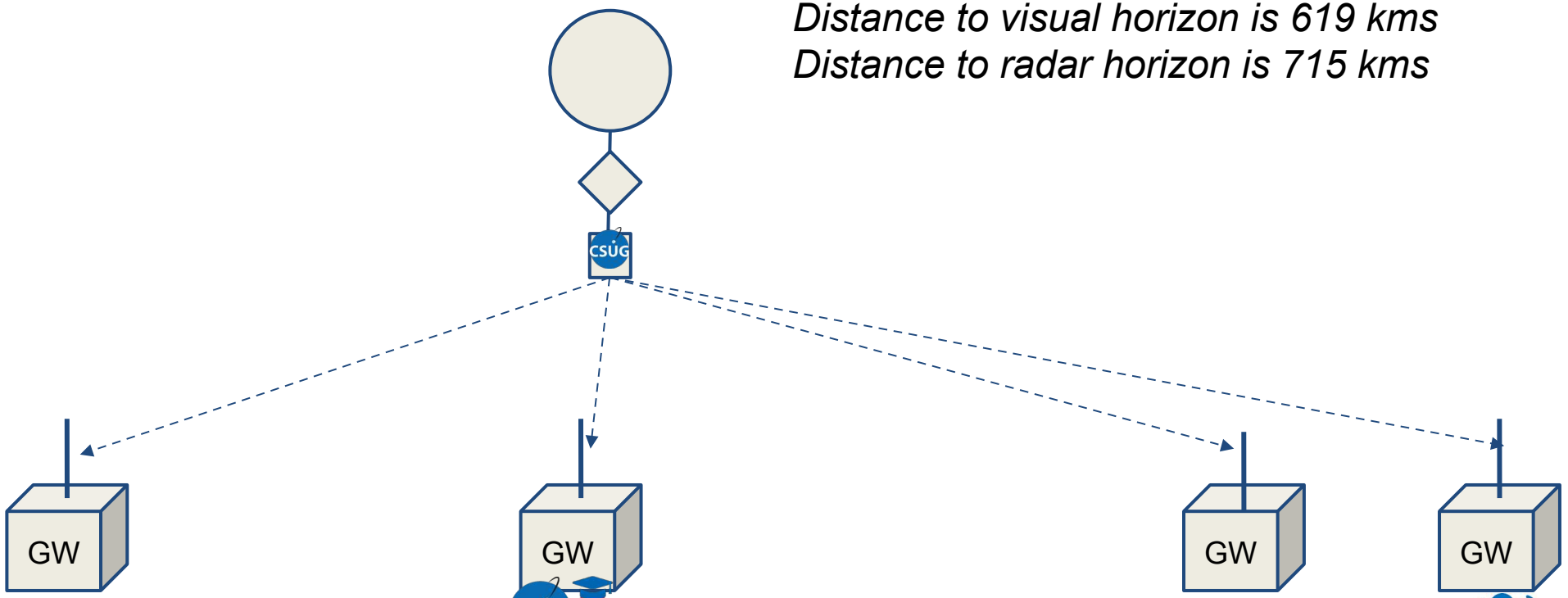
Goal

- Benckmarking LoRa™ modulation link margin and distance per LoRa radio parameters (TxPower, SF and BW)

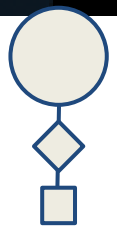
How

- EP into a sounding balloon (up to 30000 meters of altitude)

Distance to visual horizon is 619 kms
Distance to radar horizon is 715 kms



Preliminary radio tests
LoRa in the Near Space



Our endpoint

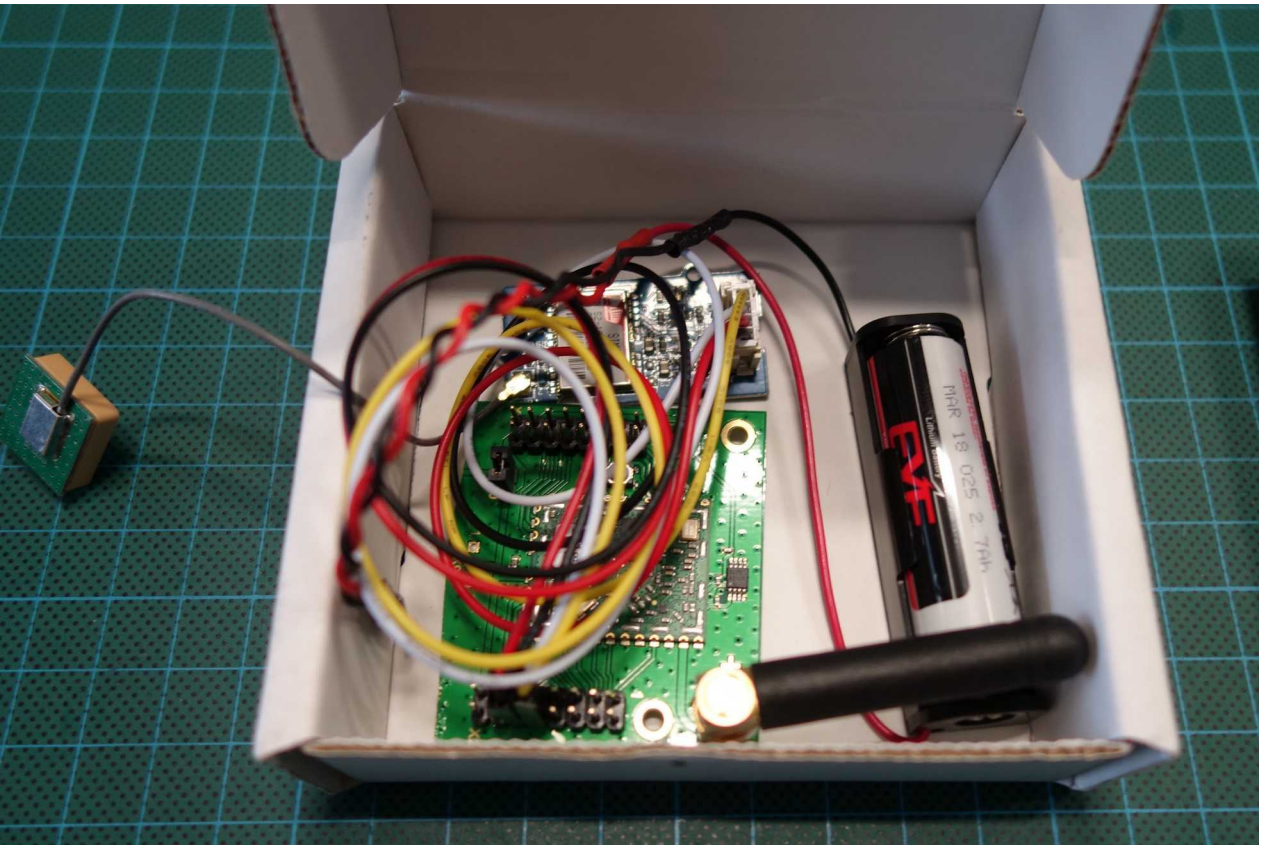
- *Off-the-Shelves* board (STM32+SX1272+GPS)
  - RIOT OS
  - ADR is off. Transmit frames with various combinaisons of SF (7 .. 12) and TxPower (2 .. 19)
  - SF, TxPower, Temperature, GPS (latitude, longitude, altitude)
- Registration on multiple LoRaWAN Networks
  - Orange LiveObject (5500 gateways with/without TDOA in France)
  - The Thing Network (+4700 gateways in Europe)
  - CampusIoT (1 mobile gateway in a car roof top)
- Live tracking with NodeRED (GPS, TDOA)

Max link budget = **157** dB

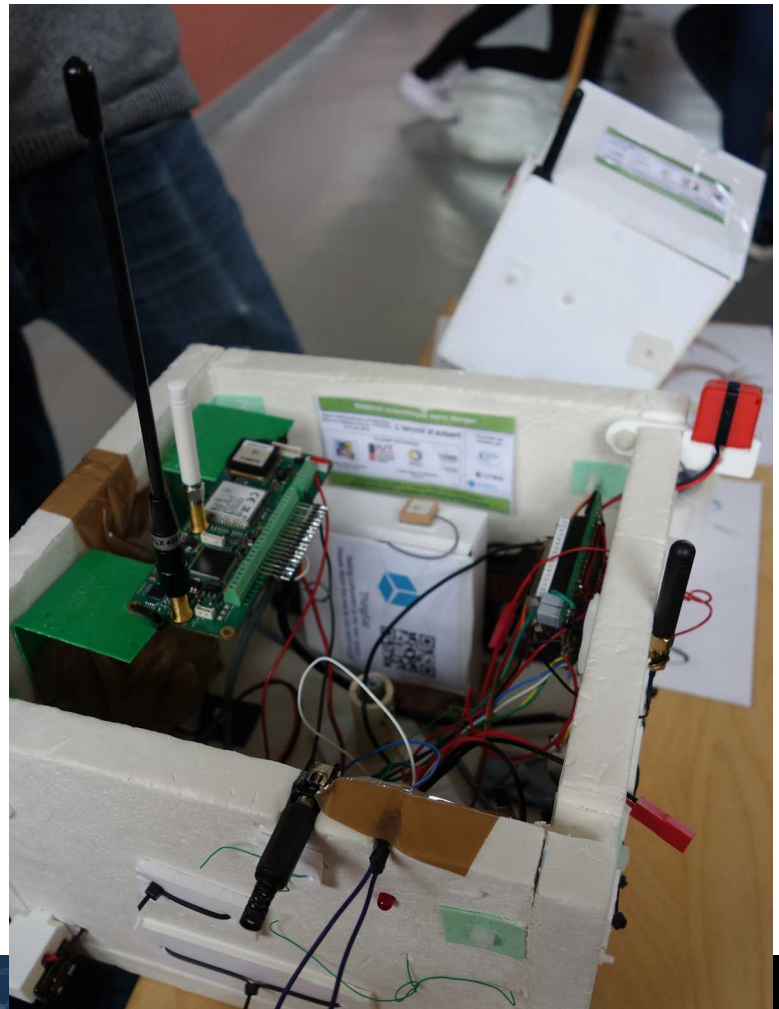
Flight #1
“L’envol d’Albert”, May 9th, 2019

Planète Sciences
IUT Valence, Lycée Triboulet (Roman/Isère), Collège XX

80 grams



1800 grams max

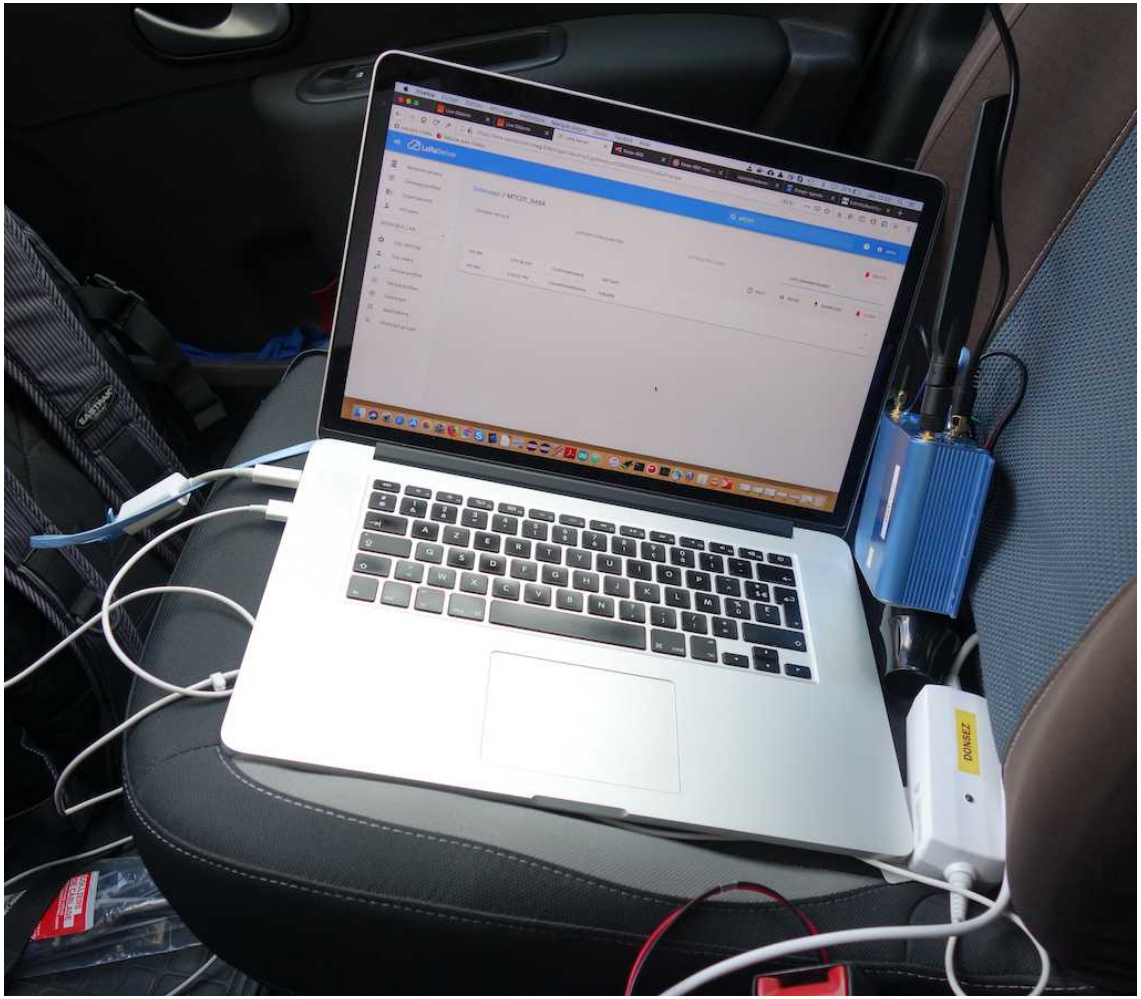


Flight #1
“L’envol d’Albert”, May 9th, 2019

Valence (26) → 140 kms (2h30) → Méolans-Revel (04) à 2200m alt.
Weather conditions: cloudy

Flight #1
“L’envol d’Albert”, May 9th, 2019

LoRa Sniffer Car



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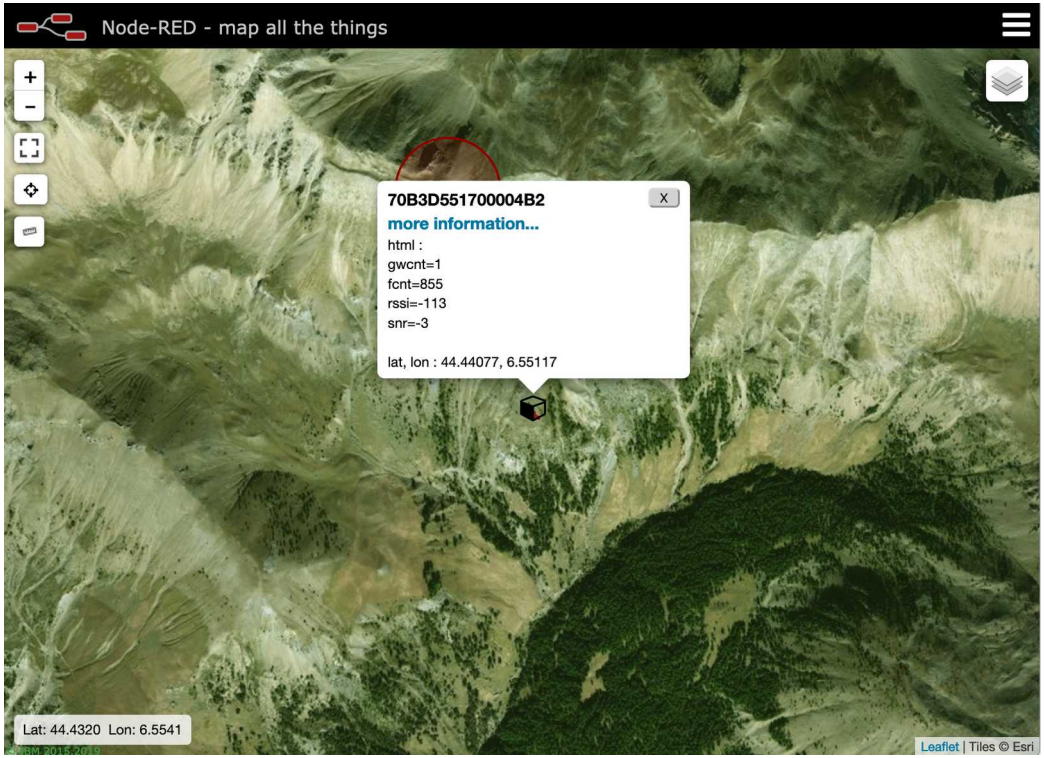
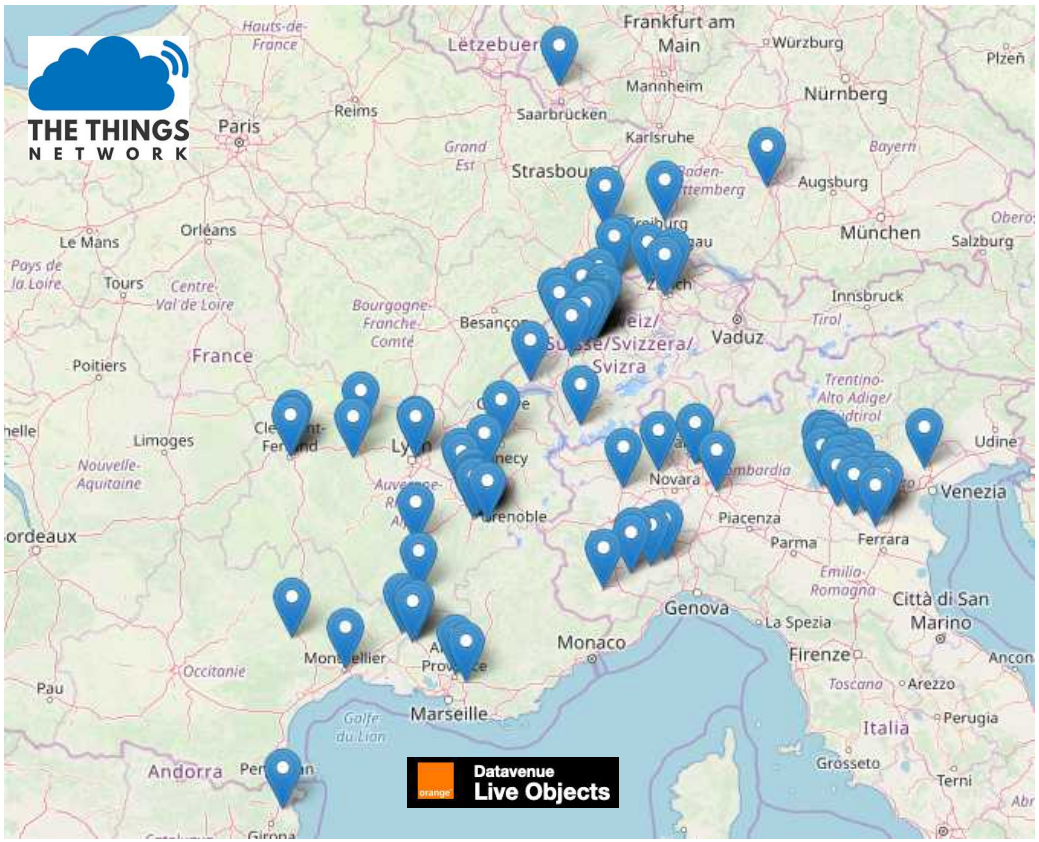
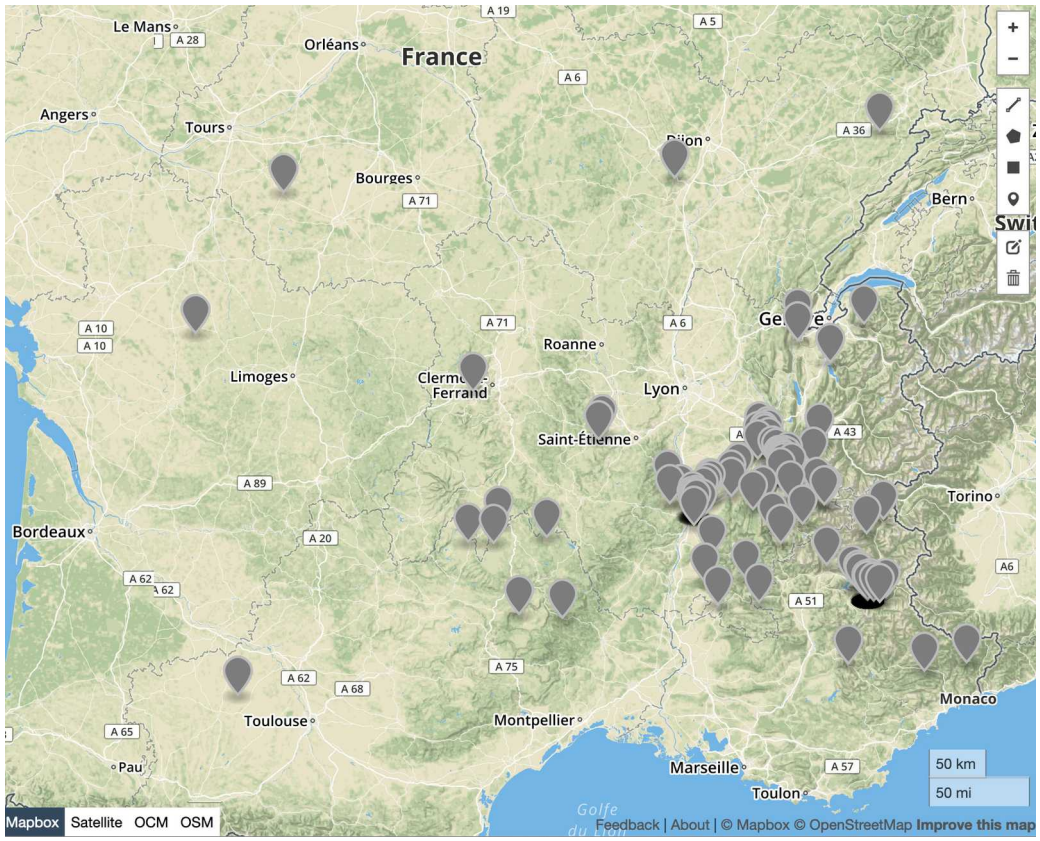


LoRa in the Near Space
Preliminary results of flight #1

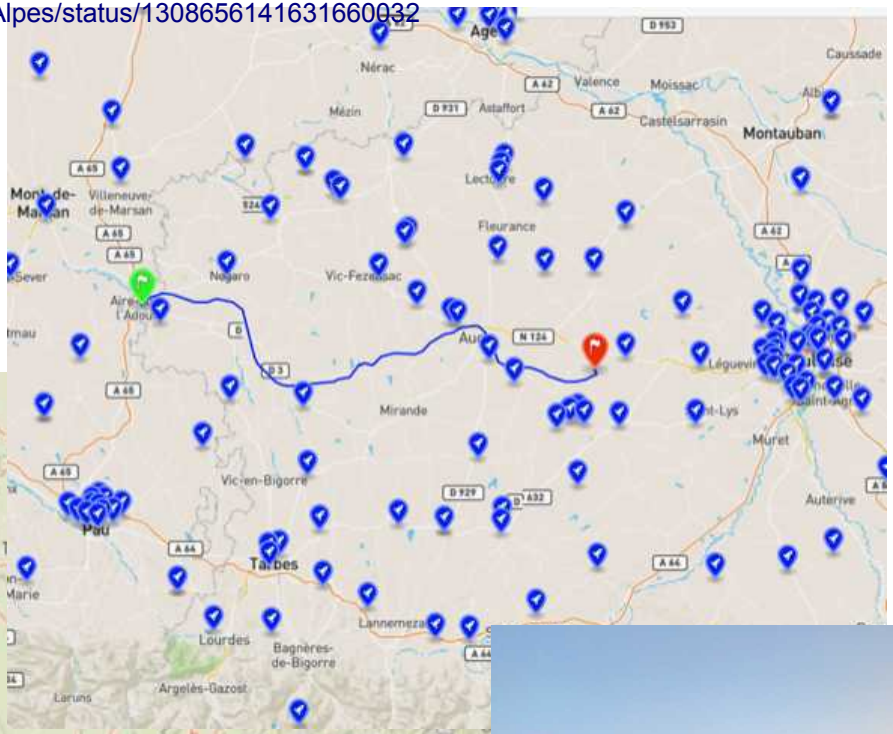
Distance, RSSI/SNR, Packet Error Ratio (per SF and per Tx Power)
UNDER ANALYSIS (550 kms on TTN, 400 kms with Orange LiveObject)





Flight #2 2020
Aire-sur-l'Adour (CNES)

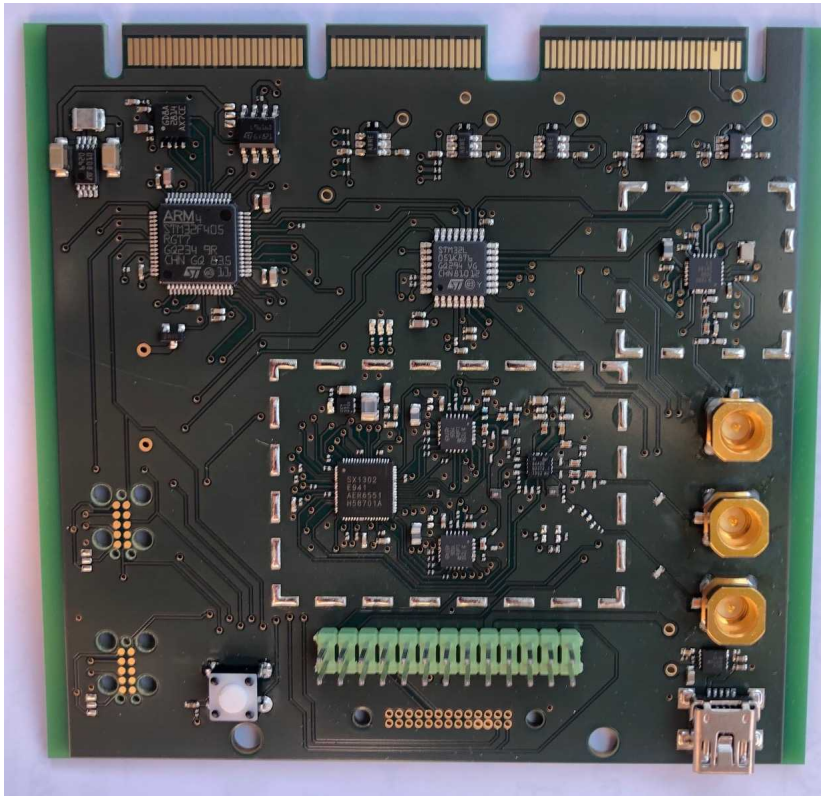
https://twitter.com/CampusIoT/status/1308685481086005249
https://twitter.com/CSUG_Alpes/status/1308656141631660032

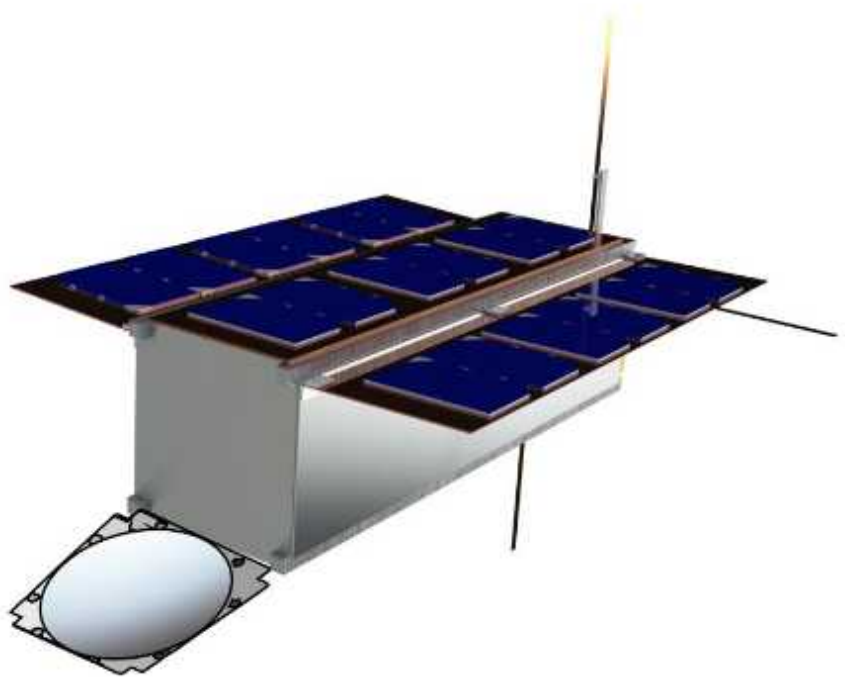


700 kms
SF12,BW125,Tx14

ThingSat

- Expérimentation de communication LoRa LPGAN depuis et vers un cubesat
- Mise en orbite LEO héliosynchrone en Juin 2021





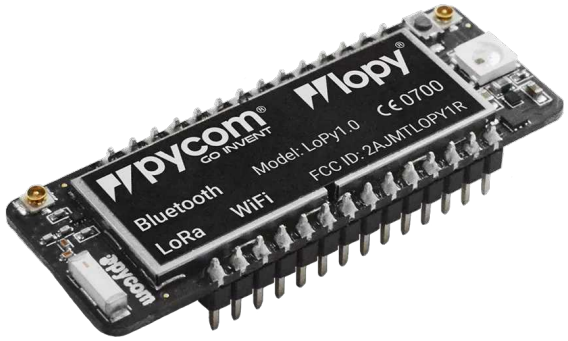
Comment apprendre l'IoT ?

- Une peu de théorie
  - Maths (géométrie, statistique …)
  - Physique (Onde, énergie, électronique, thermique, ...)
  - Informatique (algo, traitement de données, dataviz …)
- Pratique : Learn-By-Doing
  - Kit pédagogique (abordable)
  - Prototypage d'idée d'objets connectés

Kit(s) pédagogique(s)

- 1 gateway LoRaWAN chez vous

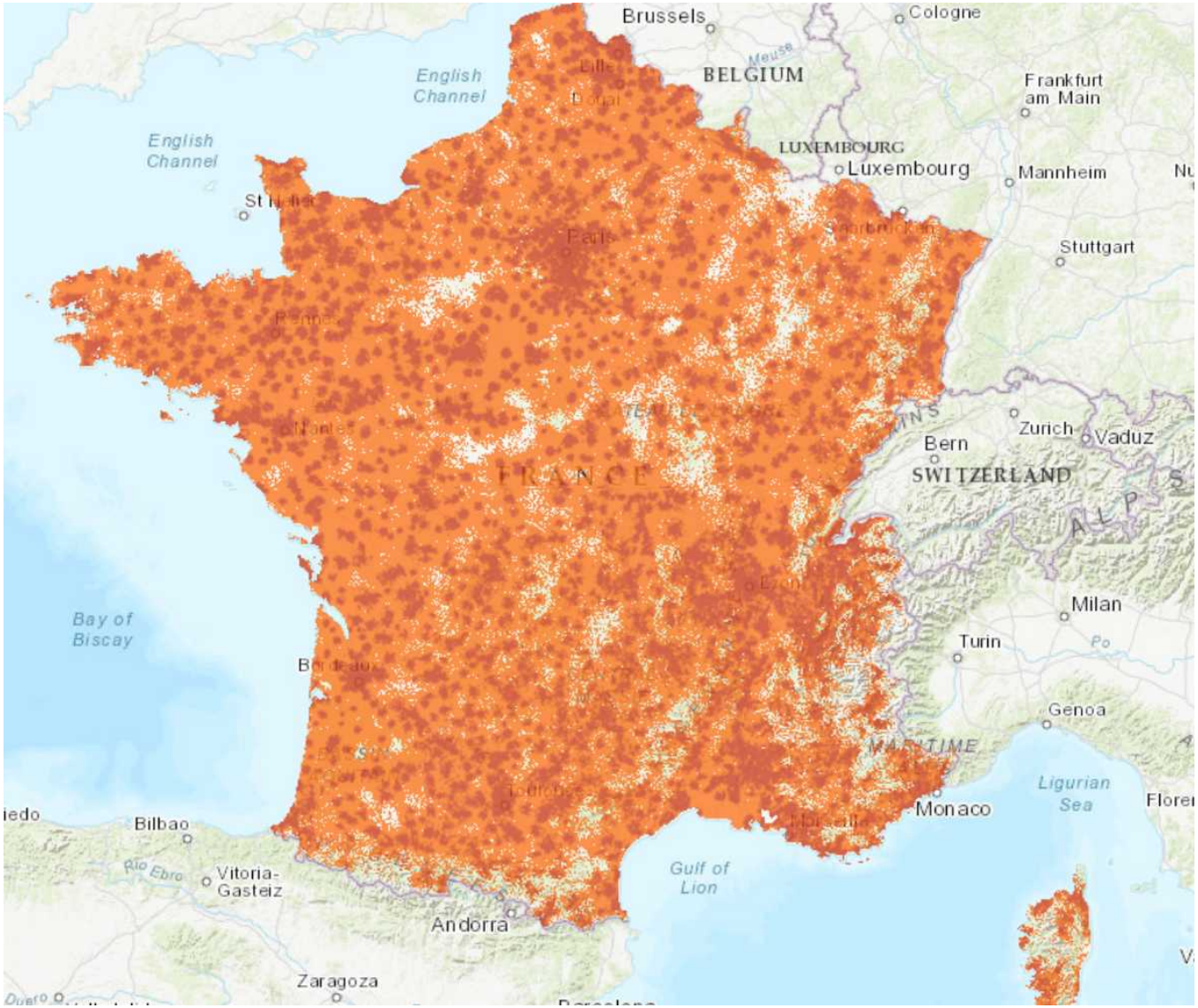
- Cartes de découverte et de prototypage
  - Programmation : C/C++, Python, Javascript



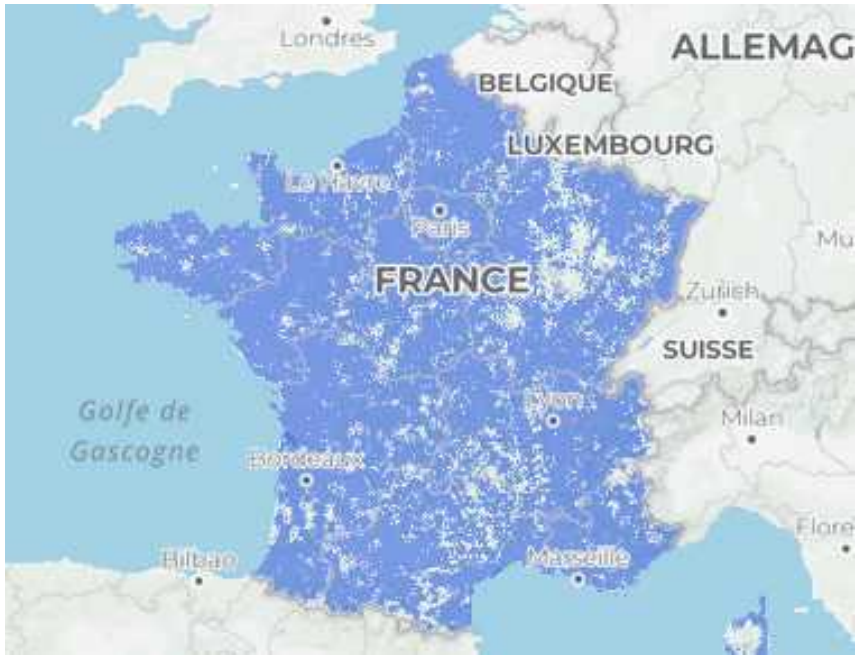
Opérateurs LoRaWAN

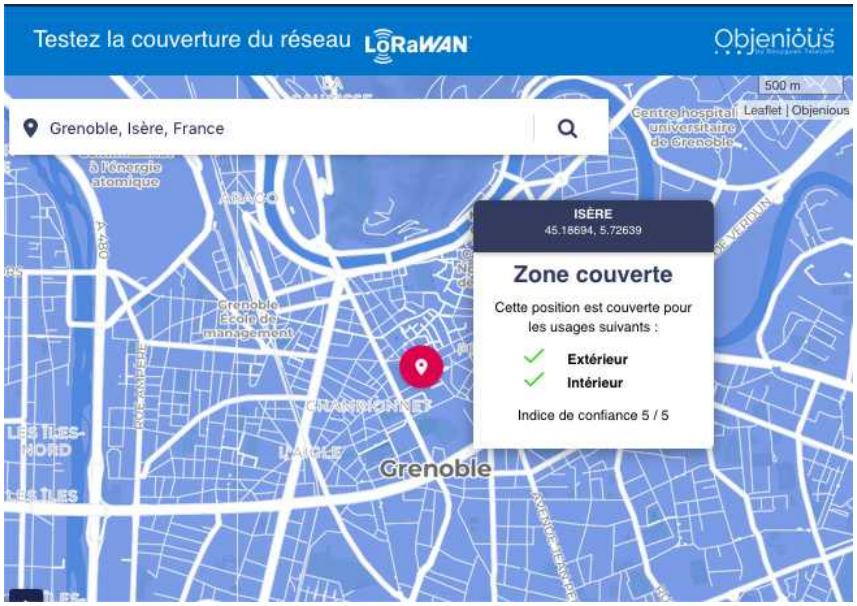
- Réseaux privés (on premise)
  - Open-source : TTS, Chirpstack
  - Licenced : Actility, Orbiwyse, Resiot, Loriot, TTN industries ...
- Opérateurs Réseaux privés (on cloud)
  - Actility, Orbiwyse, Resiot, TTN industries ...
- Opérateurs Réseaux Communautaires
  - TTN (TheThingNetwork)
- Opérateurs Réseaux publiques
  - Orange, Objenious, ~~La Poste~~, Swisscom …
    - Extension réseau pour deep-indoor
- Opérateurs Réseaux Publics Non LoRaWAN
  - Archos Picowan
- Opérateurs réseaux Privés non LoRaWAN (legacy)

Exemple : Orange LiveObject LoRaWAN coverage (~5000 BTS)



Exemple : Objenious LoRaWAN coverage (~5000 BTS)





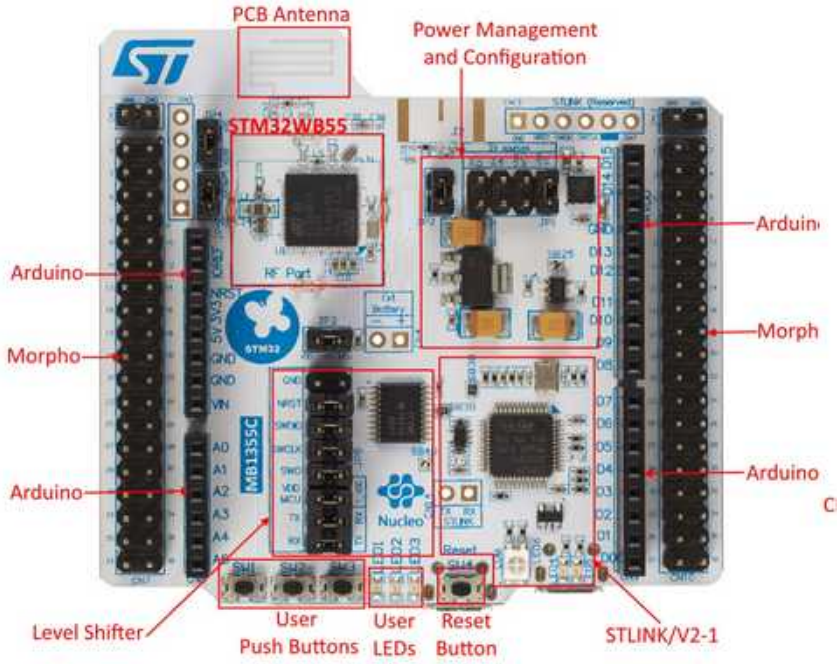
Réseaux (NetId) publics/privés LoRaWAN @Grenoble

Septembre 2019

STM32Python

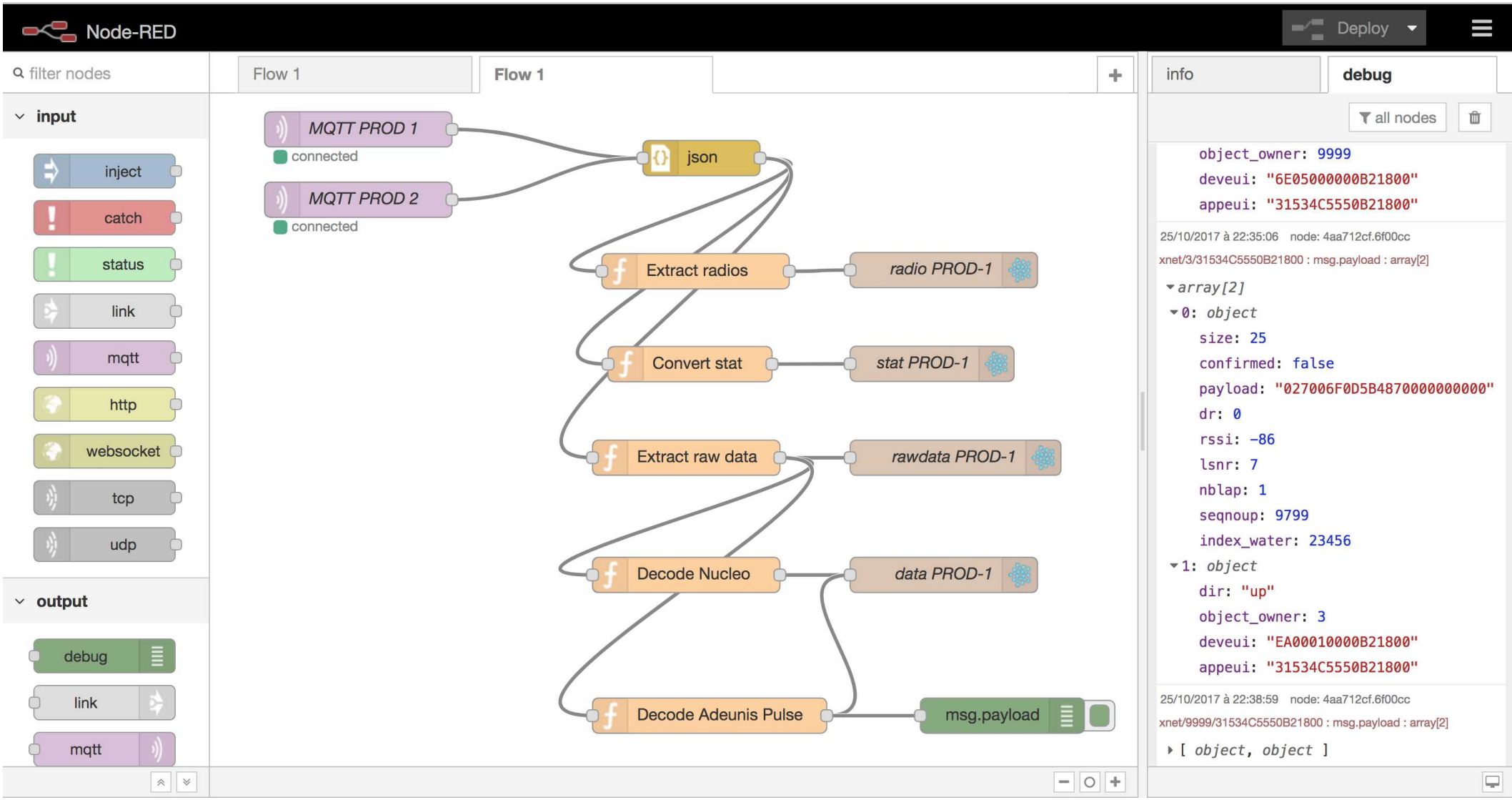
https://stm32python.gitlab.io/fr/

- Kit pratique pour l'apprentissage de l'IoT en SNT

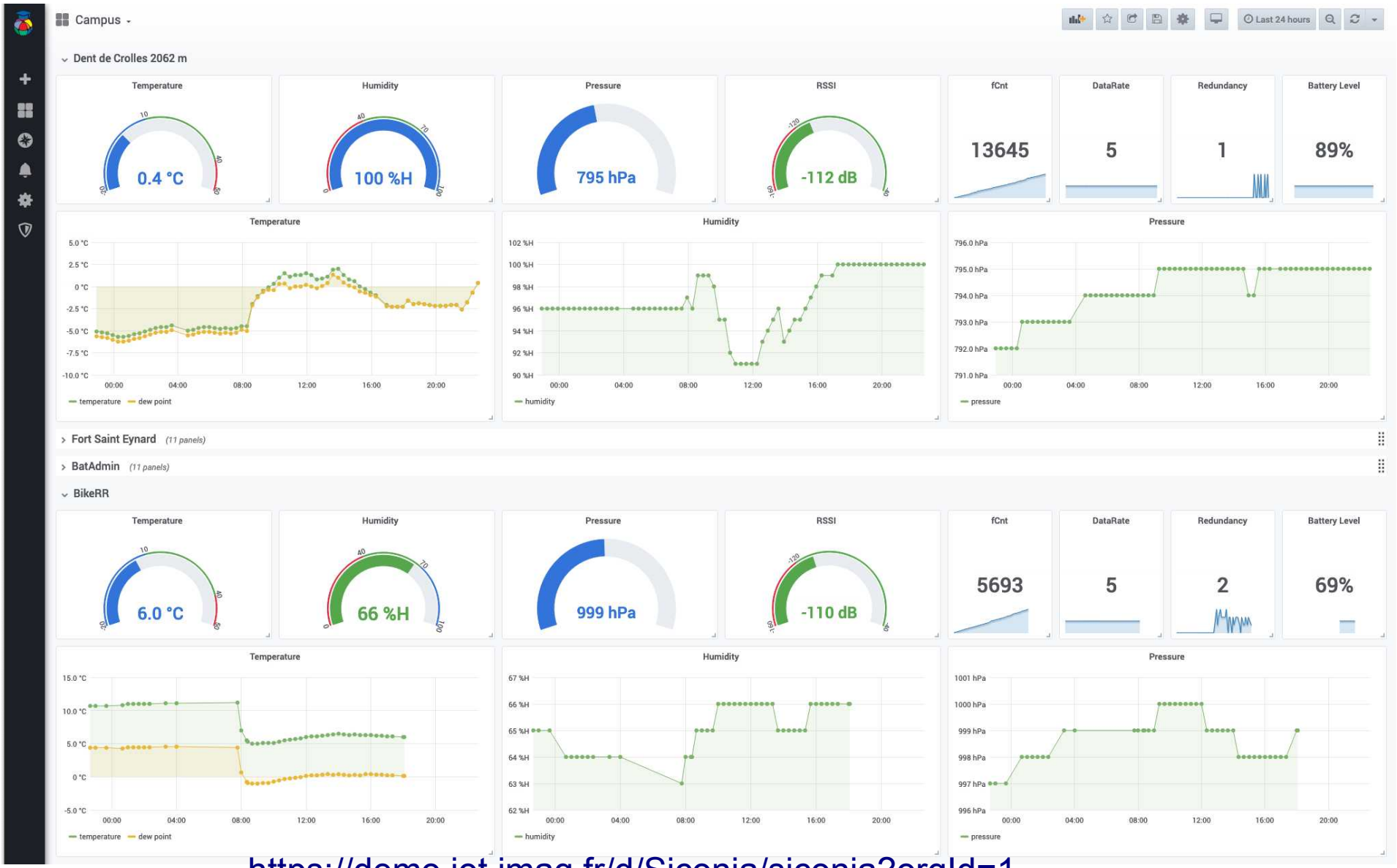


Traitement de données

Programmation graphique ...



Visualisation



https://demo.iot.imag.fr/d/Siconia/siconia?orgId=1

Conclusion

- IoT is the 3rd wave of the Internet
- IoT involves all the STEM
- IoT can be teached with Learn-By-Doing
- IoT HW ressources (devkit) are affortable
- IoT SW ressources are free and open

Visit github.com/CampusIoT