Architectures et protocoles de communication pour la collecte des données environnementales

Ateliers Expérimentation et Instrumentation INSU – CNRS

Rahim KACIMI

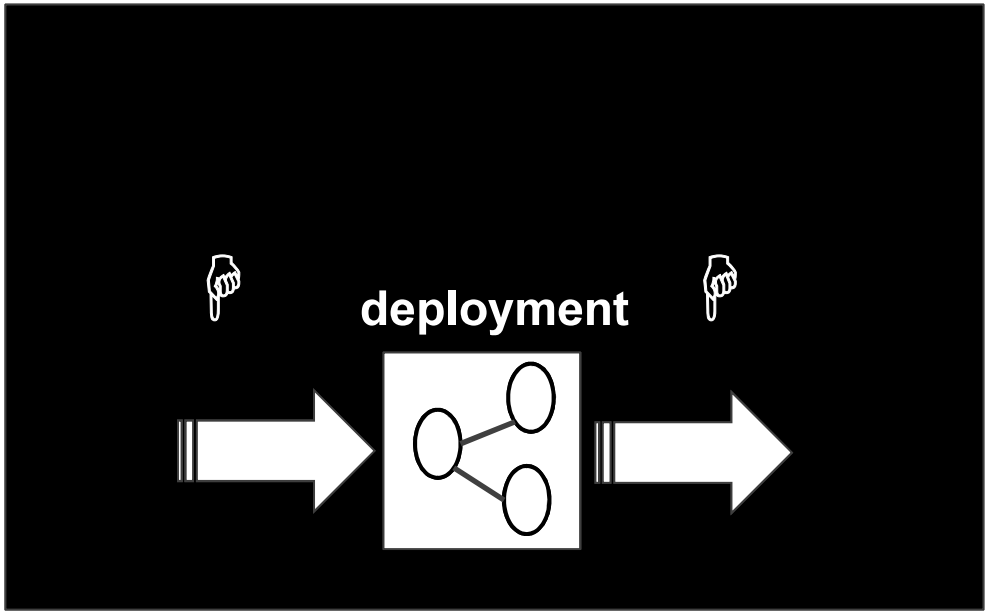
Team identity

issues

Network design
Deployment
Performance analysis
Dimensioning
Inter-networking
Coverage
Scalability

metrics

Packet Delivery Ratio
Latency
Energy efficiency
… QoS



solutions

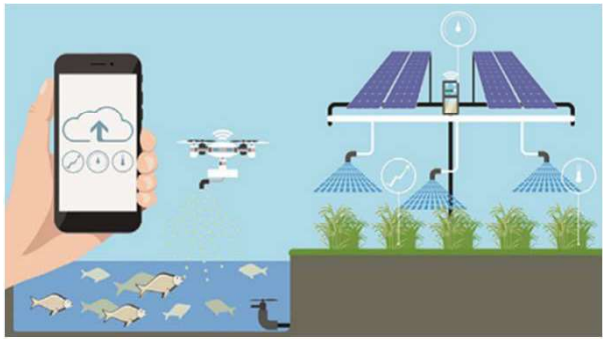
Architectures
Protocols
Algorithms
Mechanisms
Strategies

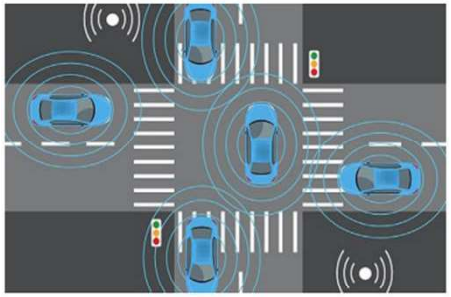
domains

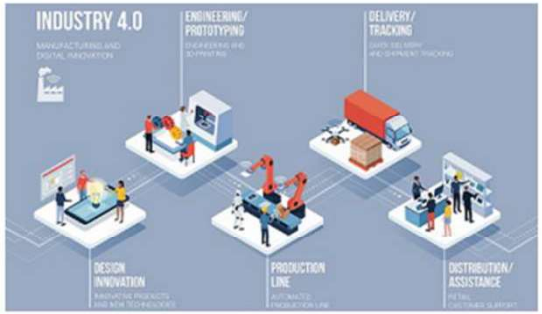
Smart Cities
Environment
Smart grid
*Monitoring**

APPLICATIONS

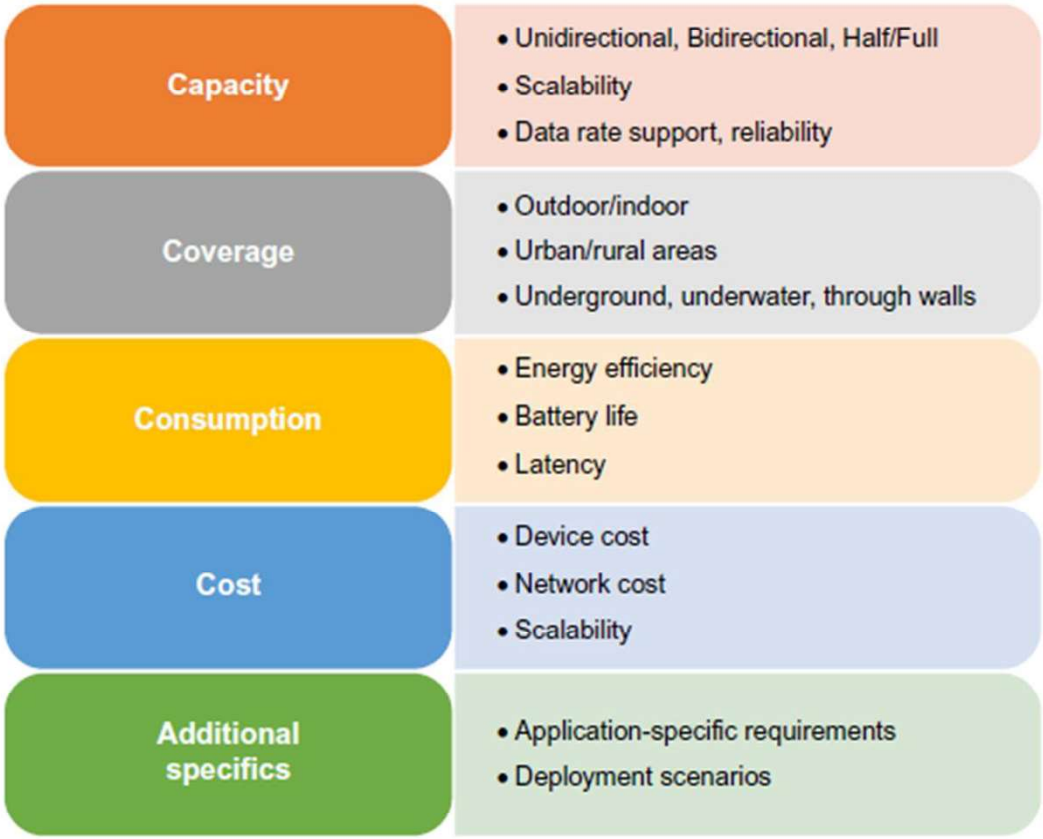
LPWAN Applications







Application requirement priorities and characteristics



Factors Influencing Sensor Network Design

- *Fault Tolerance (Reliability)*
- *Scalability*
- *Production Costs*
- *Hardware Constraints*
- *Sensor Network Topology*
- *Operating Environment (Applications)*
- *Transmission Media*
- *Power Consumption (Lifetime)*

Design considerations

- *Traffic characteristics*
- *Capacity and densification*
- *Energy-efficient operations and low-power sources*
- *Coverage*
- *Localization*
- *Security and privacy*
- *Reduced device hardware complexity*
- *Range of solutions options*
- *Operations, interrelationships, and interworking*

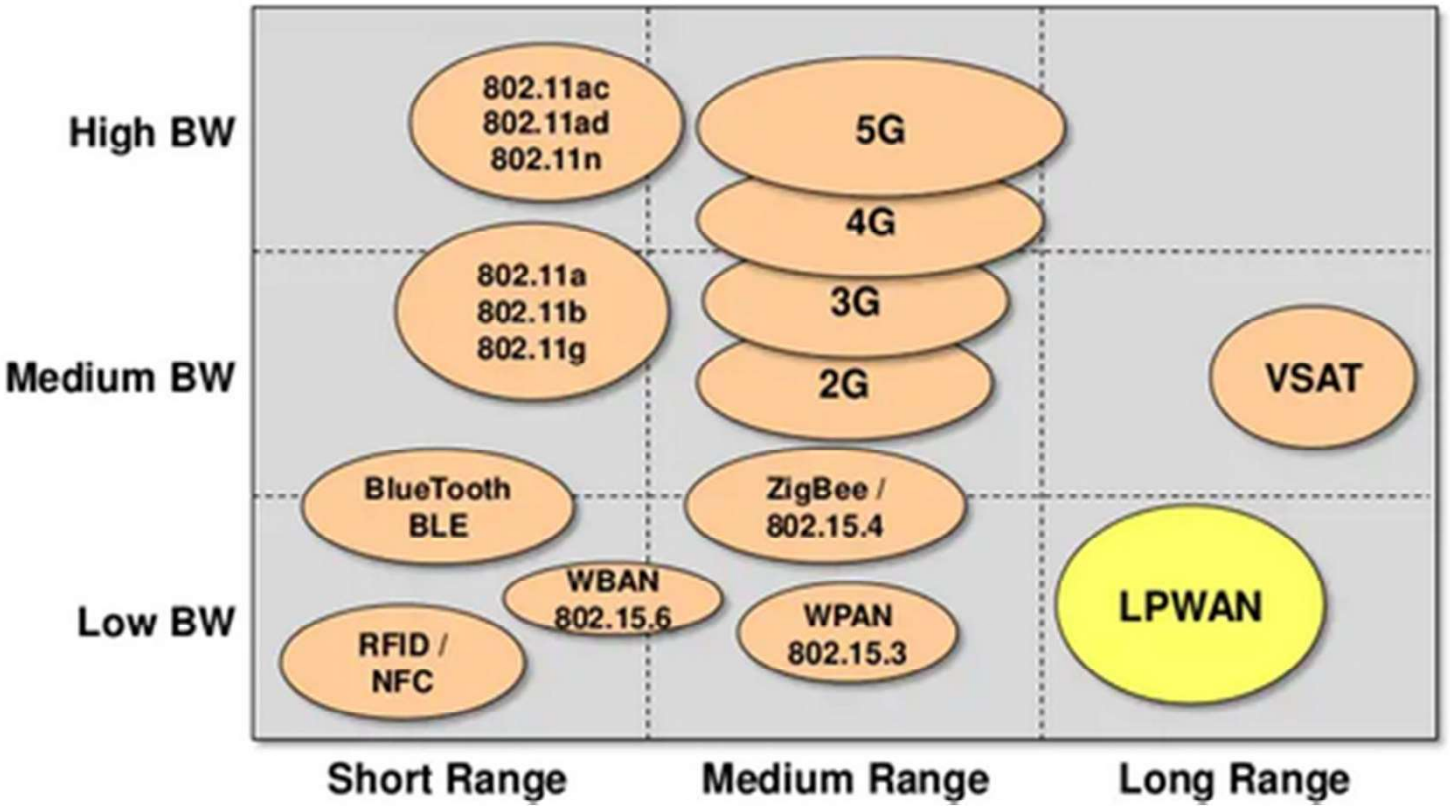
Technologies

Technological context

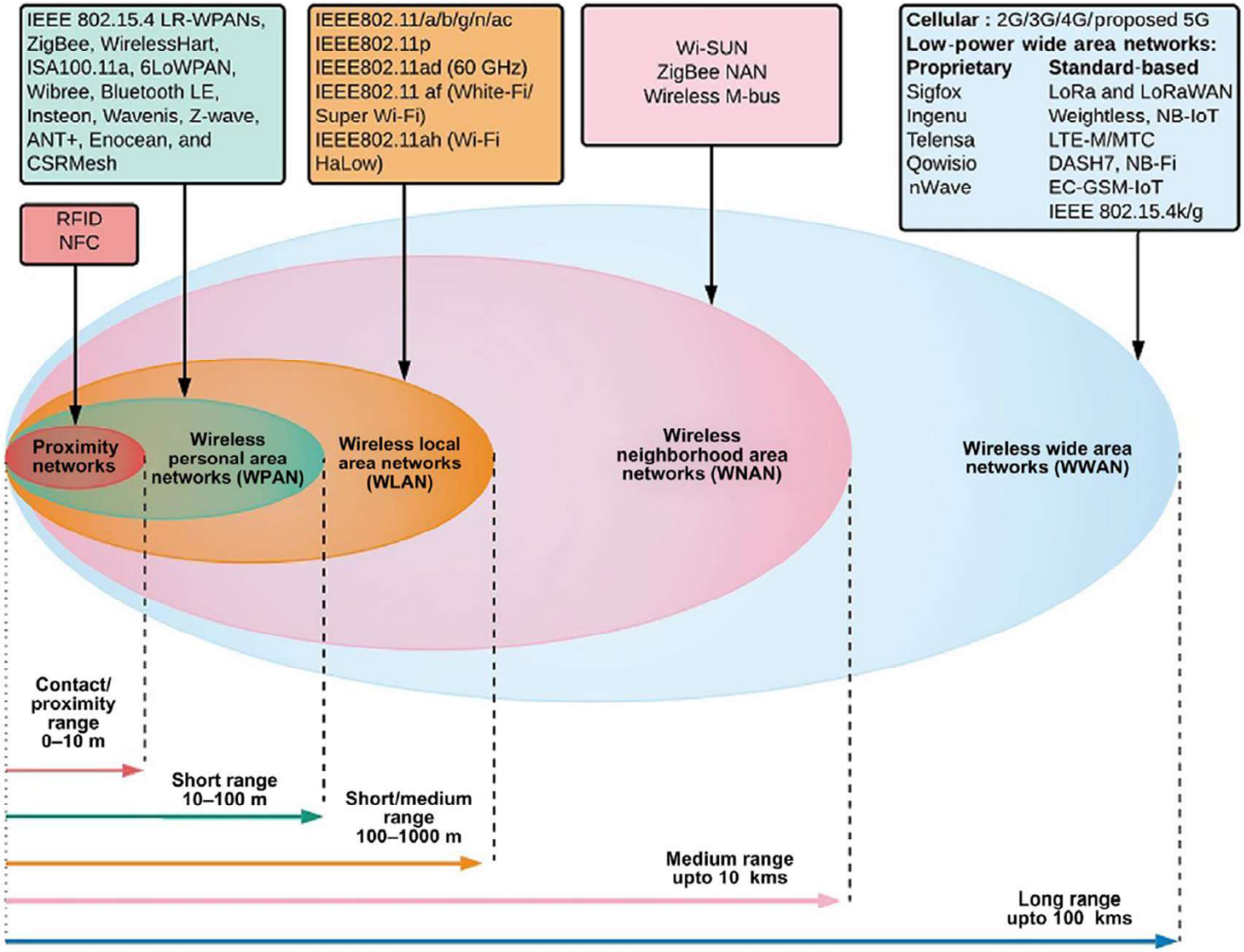
- **WPAN**

- **LPWAN**

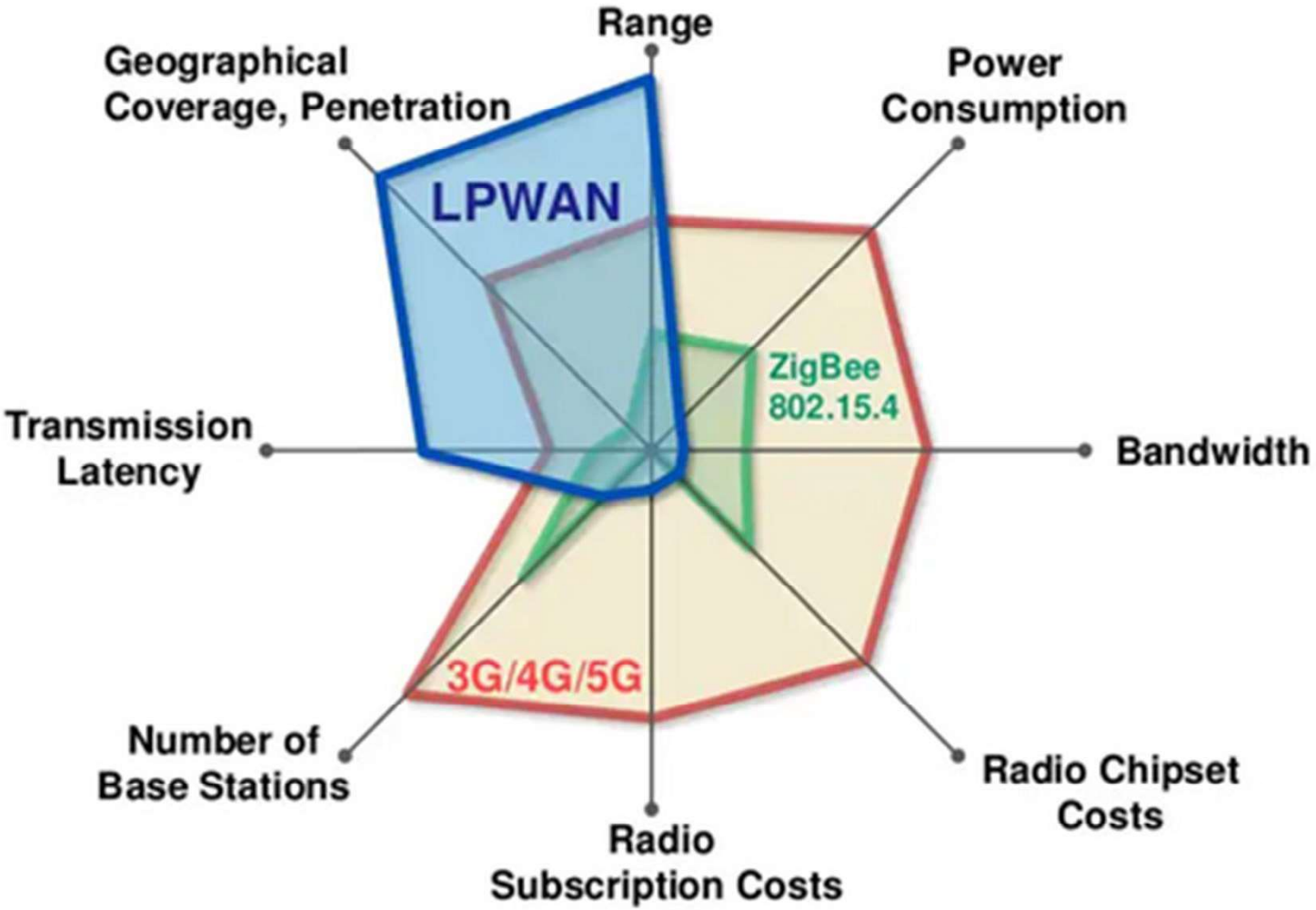
Technological context



Wireless access geographic coverage



Comparison


Range
Geographical
Coverage, Penetration
Power
Consumption
LPWAN
ZigBee
802.15.4
Transmission
Latency
Bandwidth
3G/4G/5G
Number of
Base Stations
Radio Chipset
Costs
Radio
Subscription Costs

Comparison

Technology	802.11ah	WLAN	ZigBee	LTEM	Sigfox & other UNB	LoRa®
Sensitivity	-106 dBm	-92 dBm	-100 dBm	-117 dBm	-126 dBm	-136 dBm
Link Budget	126 dB	112 dB	108 dB	147 dB	146 dB	150 dB
Range (I=Indoor, O=Outdoor)	O: 700m I: 100m	O: 200m I: 30m	O: 150m I: 30m	2km urban 20km rural	2km urban 20km rural	5km urban 15km rural
Data rate	100 kbps	6 Mbps	250 kbps	1 Mbps	600 bps	300 bps to 10 kbps
Tx current consumption	300 mA 20 dBm	350 mA 20 dBm	35 mA 8 dBm	800 mA 30 dBm	120 mA 20 dBm	39 - 124 mA 14 - 20 dBm
Standby current	NC	NC	0.003mA	3.5mA	0.001mA	0.001mA
RX current	50 mA	70 mA	26 mA	50 mA	10mA	14 mA
Battery ife 2000mAh				18 months	90 months	105 months
Localization	no	<1m	no	200m	no	10m
Interference Immunity	moderate	moderate	bad	moderate	bad	good

Proprietary and standards-based solutions

- ***Proprietary technologies***
  - *Sigfox*
  - *Ingenu*
  - *Telensa*
  - *Qowisio*
  - *Nwave*
- ***Standards-based technologies***
  - *LoRa and LoRaWAN*
  - *Weightless*
  - *Narrowband Internet of things*
  - *LTE-M*
  - *DASH7*
  - *NB-Fi*
  - *Enhanced coverage global system for mobile Internet of things (EC-GSM-IoT)*
  - *IEEE 802.15.4k*
  - *IEEE 802.15.4g*

Proprietary and standards-based solutions

	Short-range network			LPWAN			
	BLE	ZigBee	Wi-Fi	LoRa	Sigfox	NB-IoT	LTE Cat-M1
Frequency	2.4 GHz	Sub-GHz/ 2.4 GHz	2.4/5 GHz	Sub-GHz	Sub-GHz	LicensedGSM/LTE bands	Licensed LTE bands
ISM	Yes	Yes	Yes	Yes	Yes	No	No
Range	100–400 m	100 m	50 m	15 km	50 km	15 km	11 km
Data rate	<25 Mbps	250 kbps	600 Mbps	50 kbps	1 kbps	250 kbps	1 Mbps
Power	Low	Low	High	Low	Low	Low	Low

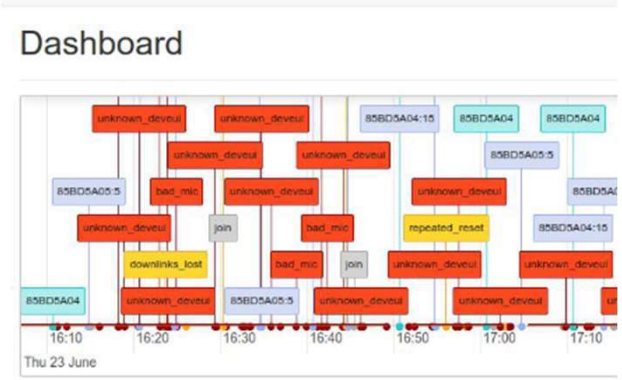
Note: BLE, bluetooth low energy.

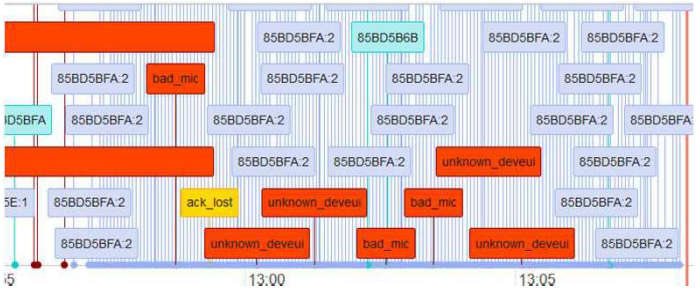
Proprietary and standards-based solutions

	Short-range network			LPWAN			
	BLE	ZigBee	Wi-Fi	LoRa	Sigfox	NB-IoT	LTE Cat-M1
Frequency	2.4 GHz	Sub-GHz/ 2.4 GHz	2.4/5 GHz	Sub-GHz	Sub-GHz	LicensedGSM/LTE bands	Licensed LTE bands
ISM	Yes	Yes	Yes	Yes	Yes	No	No
Range	100–400 m	100 m	50 m	15 km	50 km	15 km	11 km
Data rate	<25 Mbps	250 kbps	600 Mbps	50 kbps	1 kbps	250 kbps	1 Mbps
Power	Low	Low	High	Low	Low	Low	Low

Note: BLE, bluetooth low energy.

/!\ Duty-Cycle
0,1 – 1 %





Implementation factors

LPWAN technology	Coverage	Alliances and standards	Commercial devices availability
LoRa	Private/some countries of Europe, America, Asia, Oceania, and Africa	LoRa Alliance ETSI LTN	Very high
SigFox	Europe, America, Australia, and areas of Africa and Asia	ETSI LTN	Very high
NB-IoT	Europe, North America, Brazil, Argentina, Russia, China, and Oceania	3GPP	High
LTE-CatM	Europe, North America, Brazil, Argentina, Russia, China, and Oceania	3GPP	High
SNOW	–	–	Very low
Weightless	Private	Weightless Special Interest group	Low
Ingenu-RPMA	United States, China, South Africa, and Italy	Wi-SUN Alliance IEEE 802.15.4k,g	Very low
Telensa	–	ETSI LTN	Low
GSM-IoT	Global (GSM coverage)	EC-GSM-IoT Group 3GPP	Low
Wi-SUN	Private	IEEE 802.15.4k	Low
DASH7	Private	DASH7 Alliance	Moderate
IQRF	Private	IQRF Alliance	Low
MIOTY	Private	–	Low

More capabilities!

LPWAN technology	Remote firmware updating score (1 = worst, 5 = best)	Location services score (1 = worst, 5 = best)	IP support	Roaming support
LoRa	2	3	Under research	Under research
SigFox	3	5	Under research	Yes
NB-IoT	3	3	Under research	Under research
LTE-CatM	5	3	Yes	Under research
SNOW	1	2	No	–
Weightless	5	2	No	Yes
Ingenu-RPMA	4	2	Yes	No
Telensa	1	1	No	–
GSM-IoT	1	3	No	Under research
Wi-SUN	5	3	No	Yes
DASH7	5	3	No	Yes
IQRF	5	2	No	Yes
MIOTY	3	1	No	–

LoRa & LoRaWAN

LoRaWAN

- LoRa network
  - is a **LPWAN** (Low Power Wide Area Network) like SigFox,
  - technology acquired by Semtech in 2012,
  - LoRA is mostly a layer 1 (OSI stack) ranging from 169MHz to 1GHz,
  - Mostly known implementation focus on the 433/868MHz (ISM) frequency,
  - Chirp spread spectrum (CSS) modulation (FHSS for ZibBee and BT),
  - enables point to multi-points networks,
  - LoRa modules available (like RFM95W with a 20dBm PA),
  - LoRaWAN is (OSI) uppers layers,
  - Bouygues, Orange and others have deployed LoRaWAN by the end of 2017.

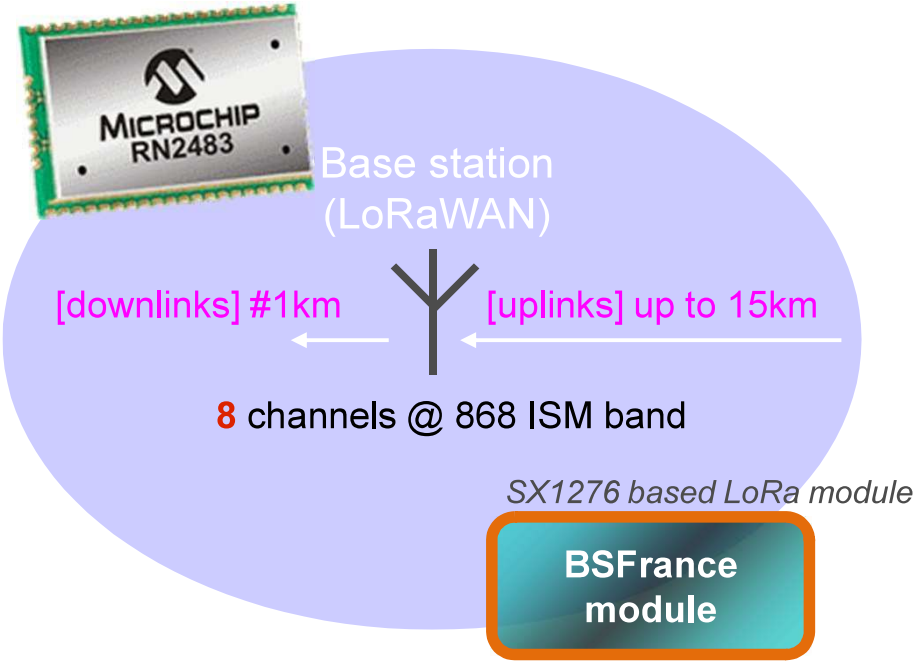
TTN indoor gateway

[2020] Helctec Cube Cell, LoRaWAN arduino compatible board

LoRaWAN

- LoRa network (cont'd)
  - Max. 50kbps,
  - App. payload up to 222 bytes,
  - 125 to 250kHz bandwidth,
  - 1% & 10% duty-cycle @ 868MHz,
  - LoRaWAN server @ base station,
  - LoRaWAN manages data-rate AND power of each end-device, (Adaptative Data Rate –ADR)
  - Allow Private Network

https://www.lora-alliance.org



BSFrance LoRaM3-D L151 / STM32 + OLED + LiPo + SX1276

LoRaWAN Devices

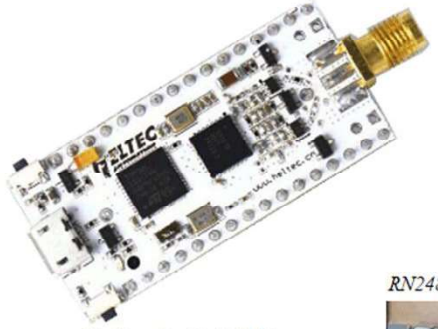
RN2483 - MICROCHIP

Heltec CubeCell LoRaWAN

e.g Ecolab's -80°c fridges

Heltec ESP32 based LoRaWAN

RaspberryPi LoRaWAN HAT
(includes GPS)



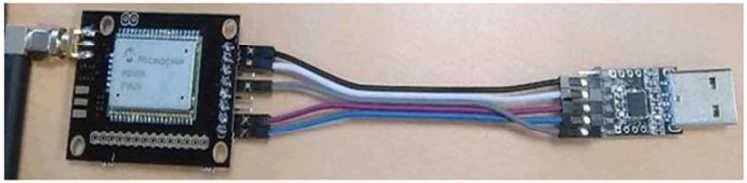
Heltec LoRaWAN

LoRa-E5
(stm32WL55 based)

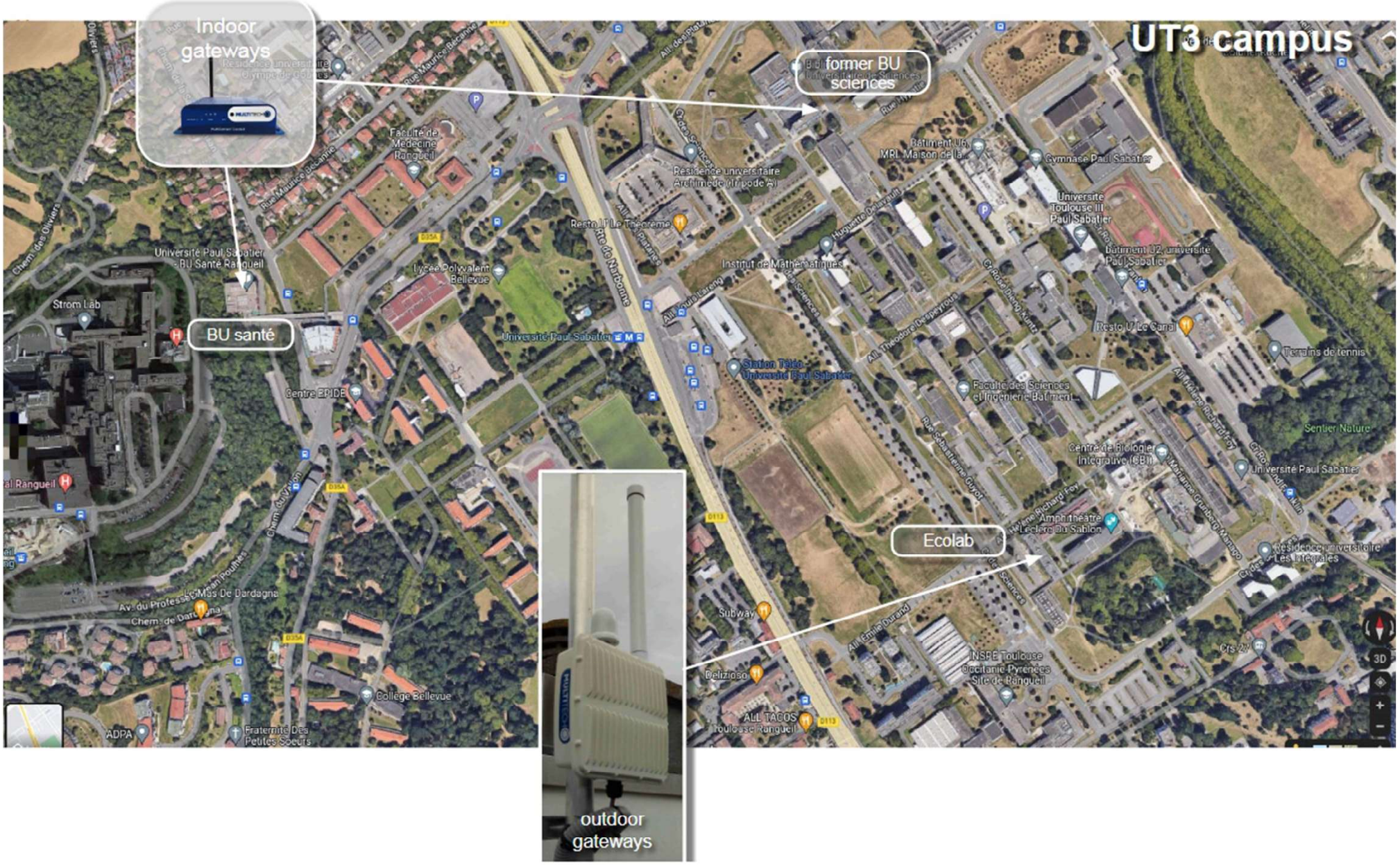
Need help designing your solution ?
ask the LoRaWAN multi labs design team :)
JL.Druilhe, M.Irain, R.Kacimi & F.Thiebolt

RN2483A + breakout-board

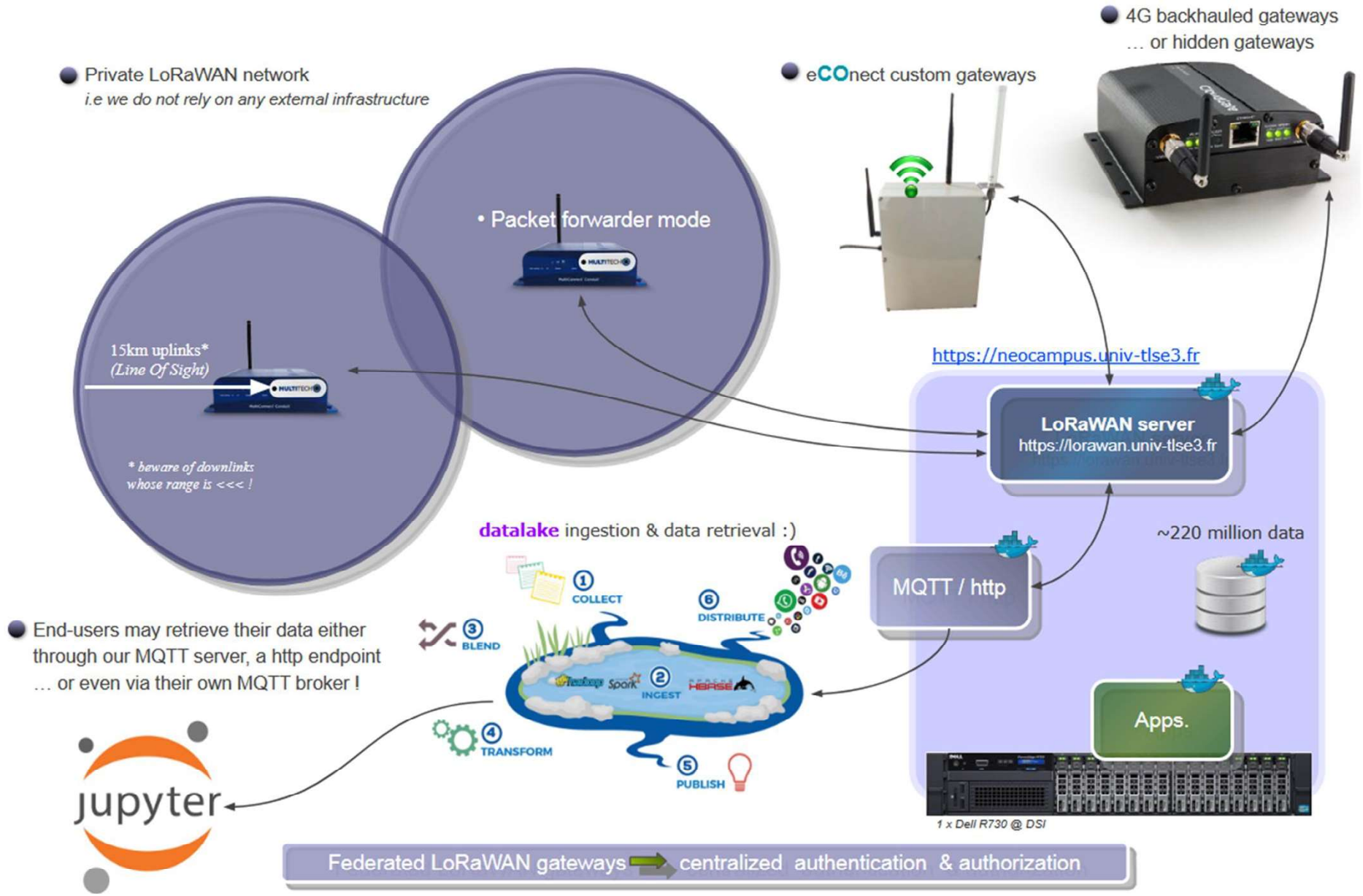
USB to serial adapter



UT3 LoRaWAN Infrastructure

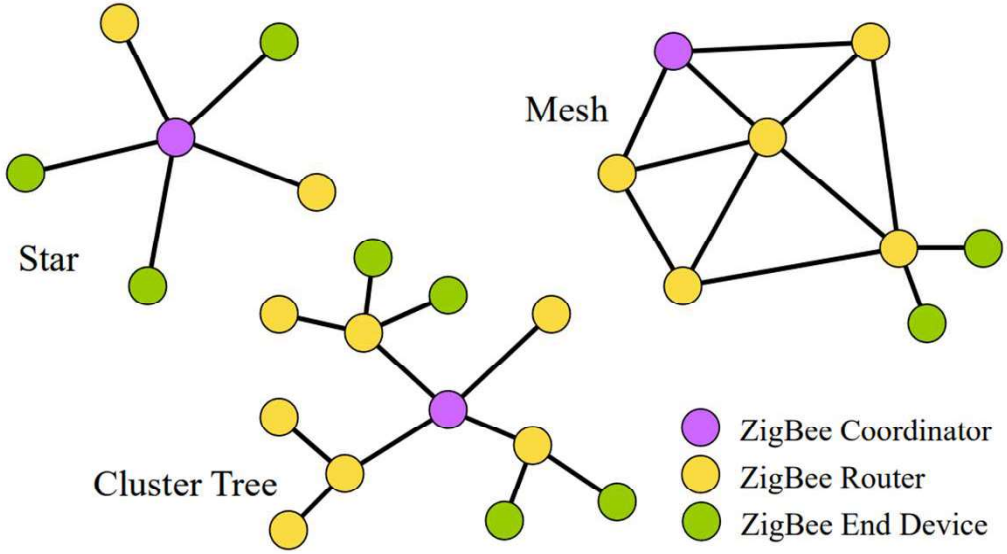


UT3 LoRaWAN Infrastructure



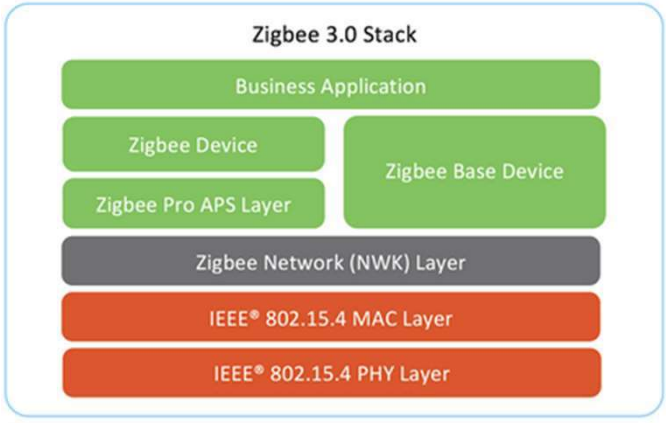
ZigBee

ZigBee



DIGI XBEE 3
ZIGBEE 3.0

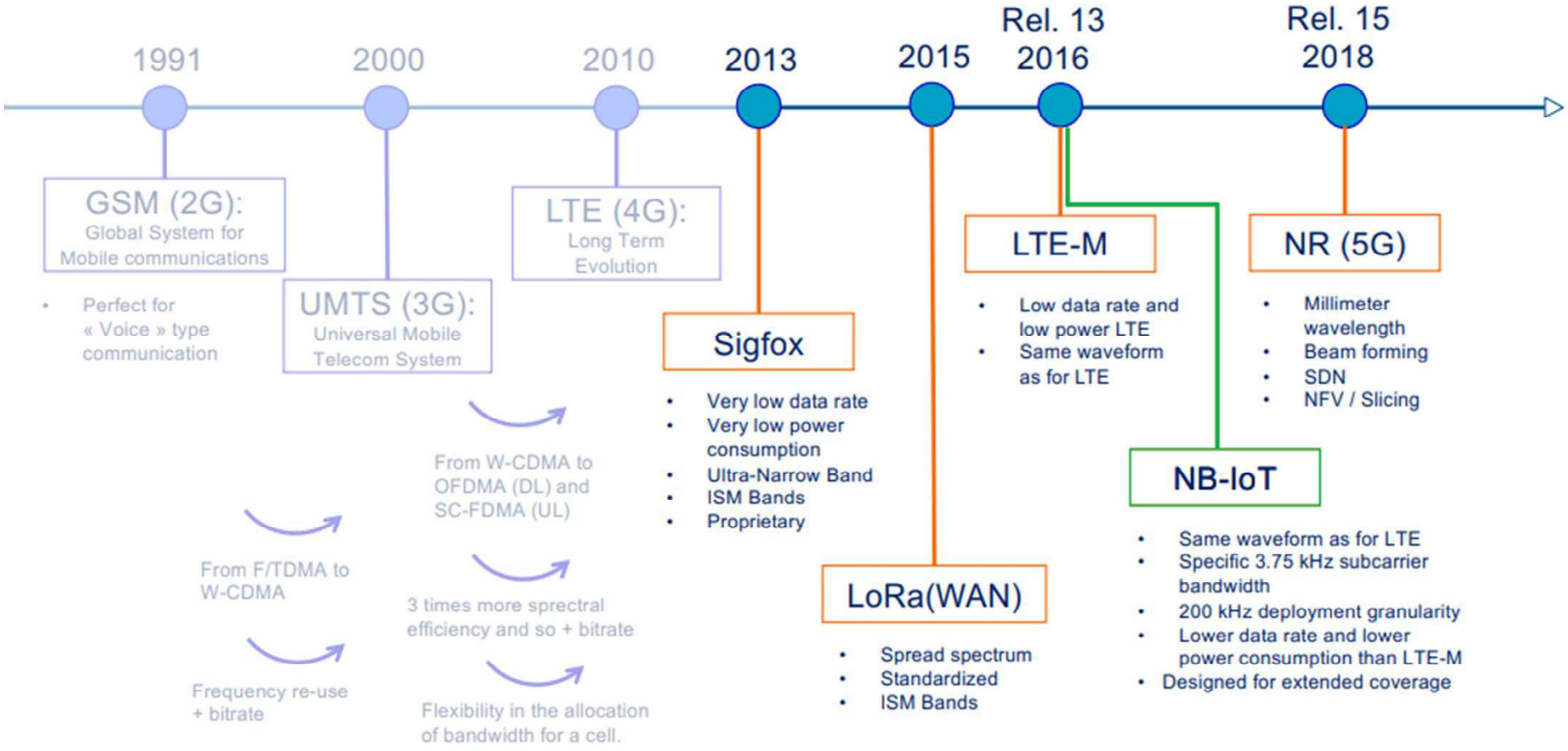
Bande 2.4 GHz
Débit 250 Kbps
Délai 5 ms
Portée ~100-3200 m
Topologie Star, Tree, Mesh



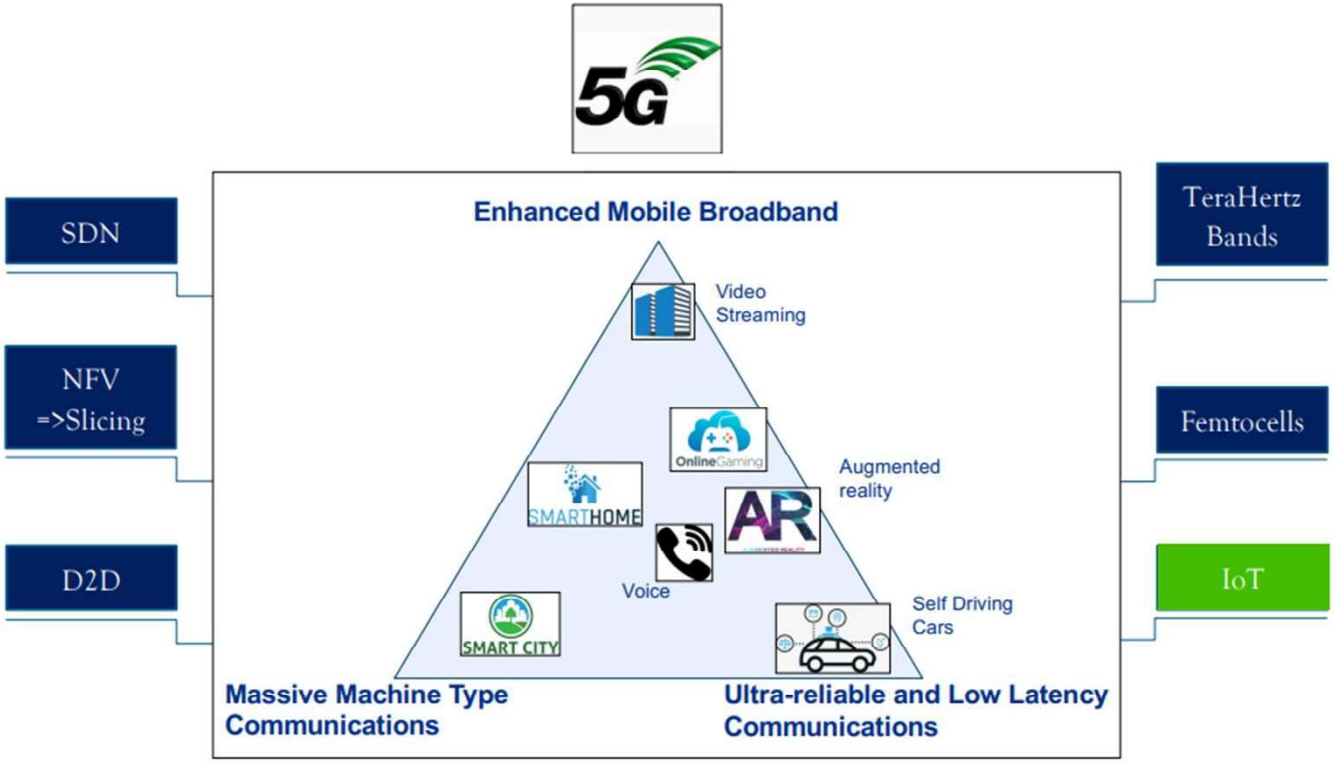
NB-IoT

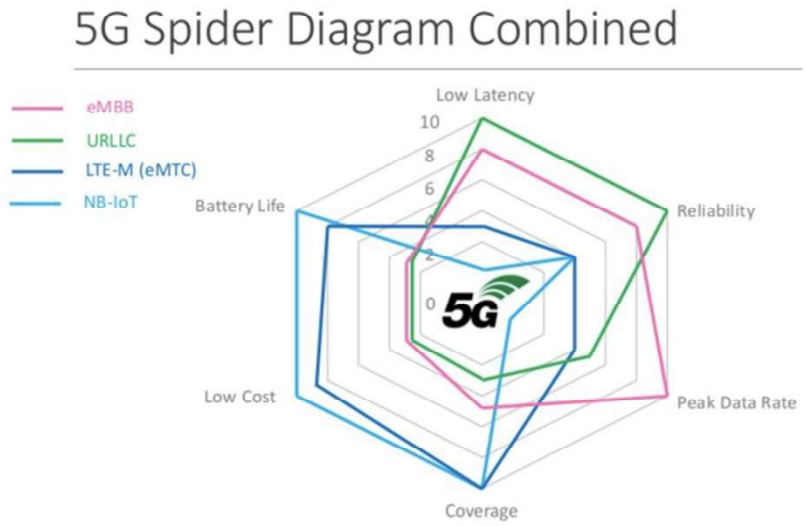
NB-IoT

Cellular Technology Evolution



IoT in 5G

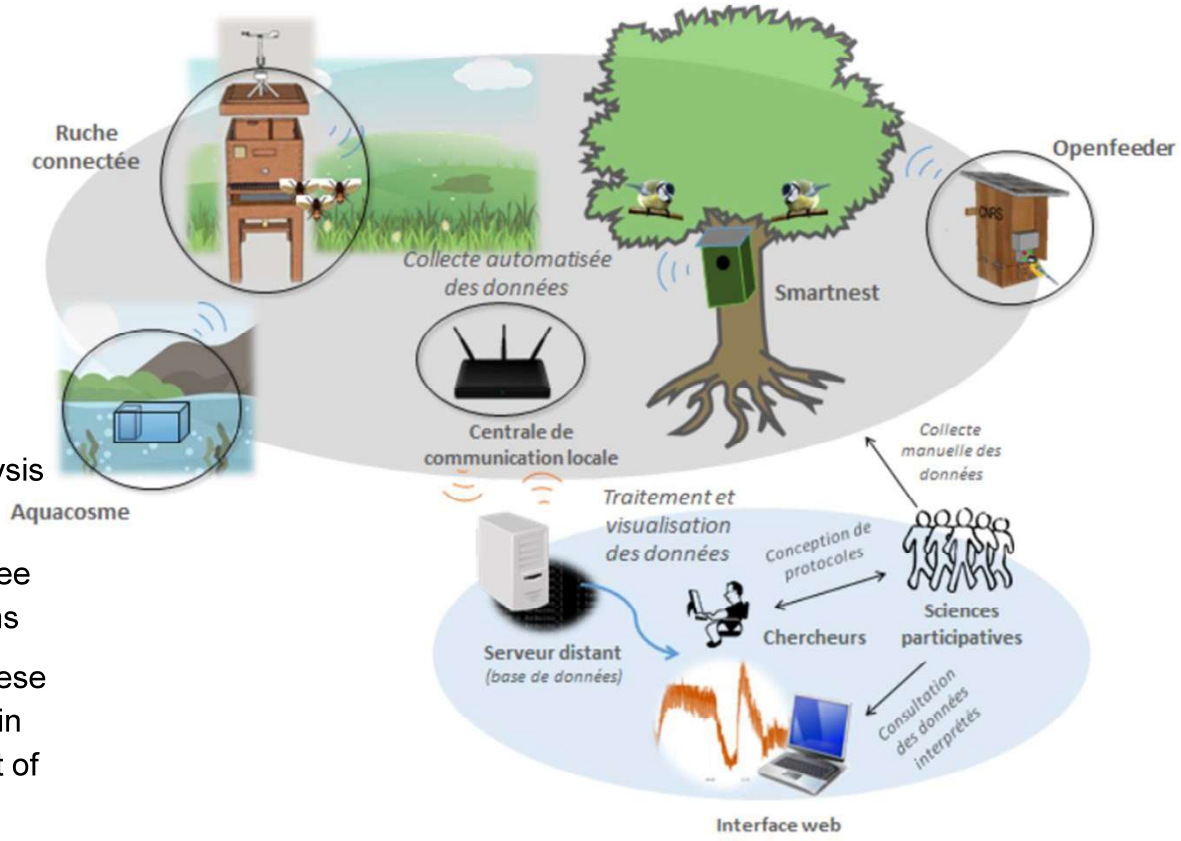




Examples

Example 1: ECOnect project

Data communication and Data processing architecture



econect.cnrs.fr

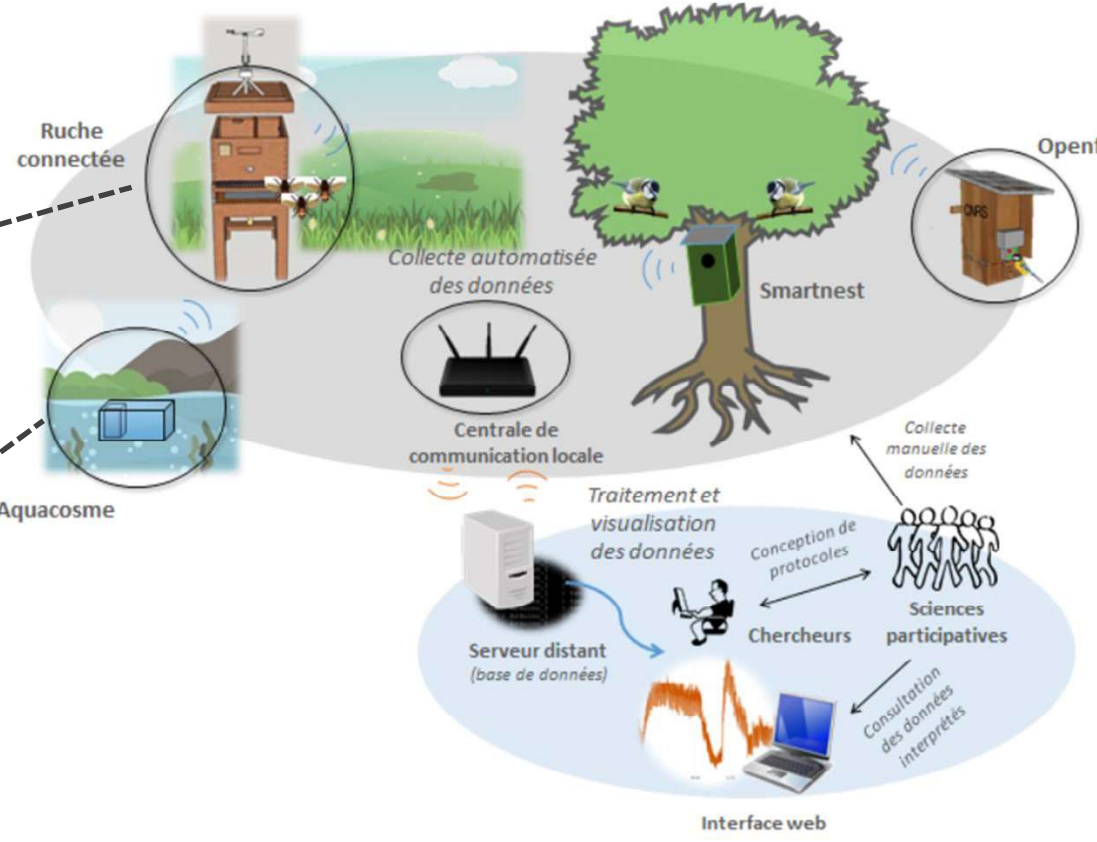
- Develop an architecture for collection, transfer and analysis of environmental data
- Apply this architecture to three environment sentinel systems
- Evaluate the relevance of these sentinel systems to assess, in an integrative way, the effect of anthropogenic pressures

« Développement de systèmes sentinelles de l'environnement, connectés, pour mieux comprendre la dégradation des cours d'eau, le déclin des abeilles et des oiseaux »

Contact : Arnaud Elger, LEFE

Example 1: ECOnect project

❖ Data communication and Data processing architecture



✓ **Abeille domestique**

- Dynamique de la colonie
- Comportement et cognition

✓ **Microcosme aquatique**

- Physico-chimie de l'eau
- Fonctions écologiques

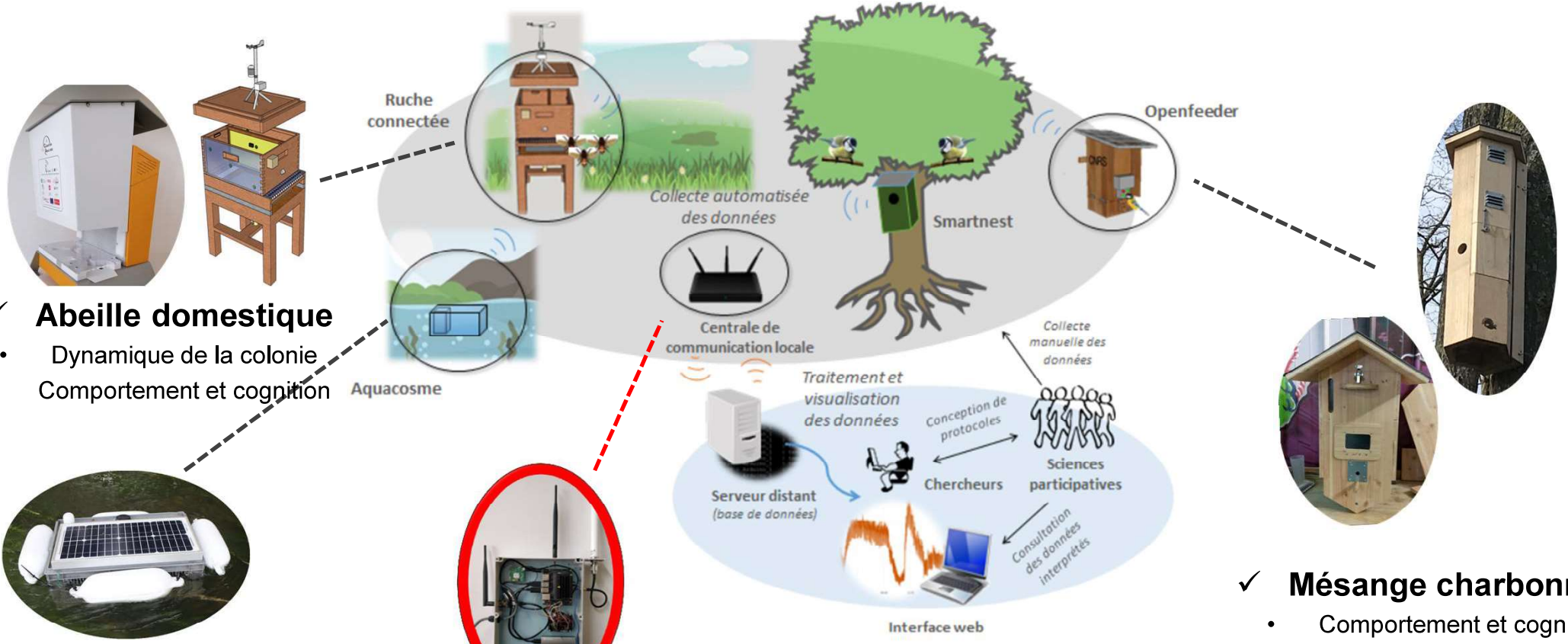
✓ **Mésange charbonnière**

- Comportement et cognition
- Succès reproducteur

Example 1: ECOnect project

econect

Data communication and Data processing architecture



✓ **Abeille domestique**

- Dynamique de la colonie
- Comportement et cognition

✓ **Microcosme aquatique**

- Physico-chimie de l'eau
- Fonctions écologiques

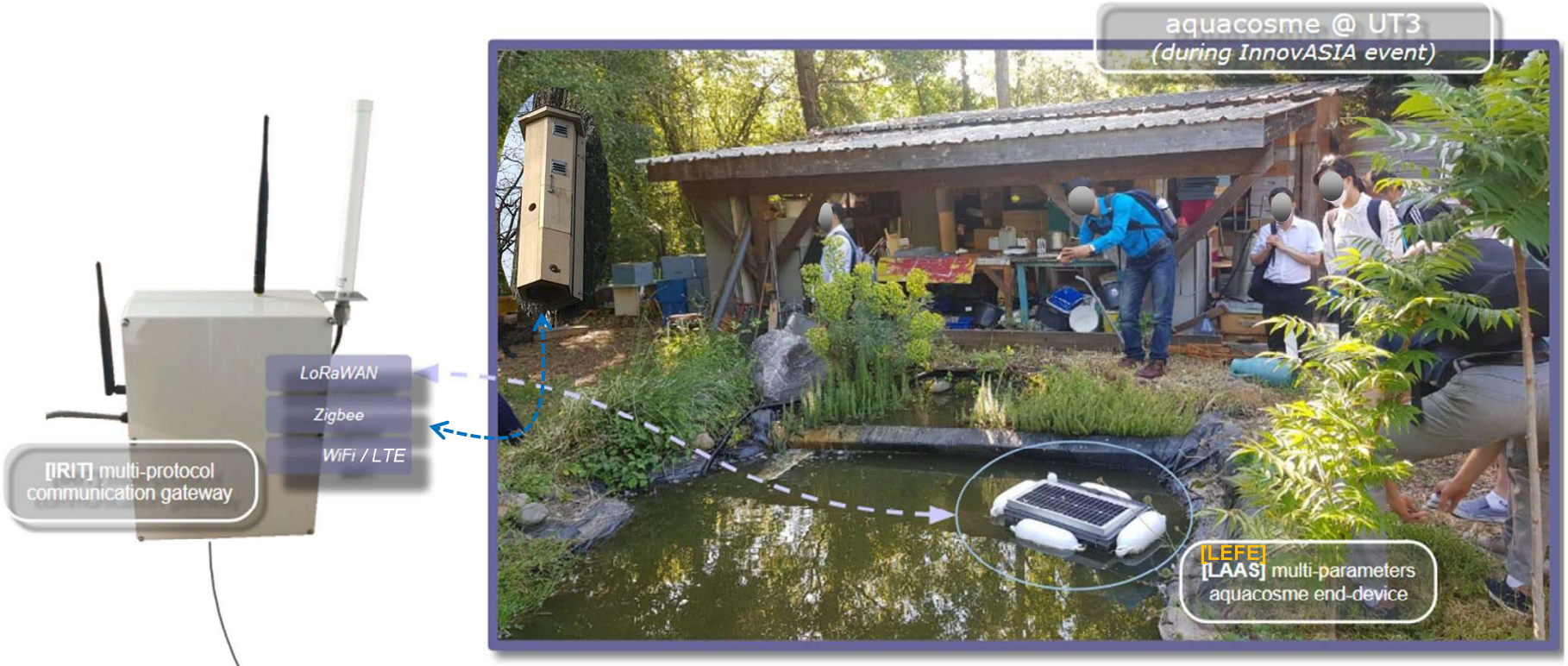
Centrale de communication
Multi-techno
ZigBee, LoRaWAN, LTE

✓ **Mésange charbonnière**

- Comportement et cognition
- Succès reproducteur

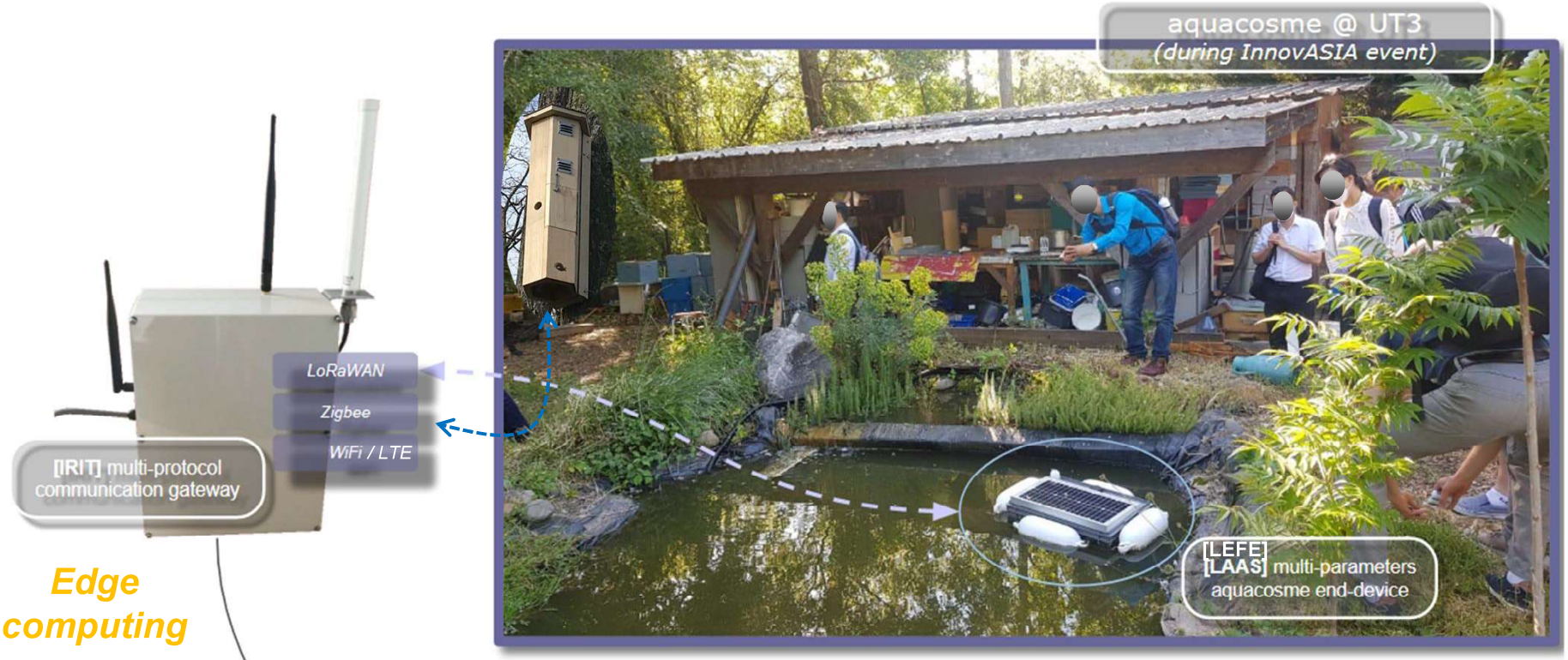
Example 1: ECOnect project

LoRaWAN-enabled sentinel

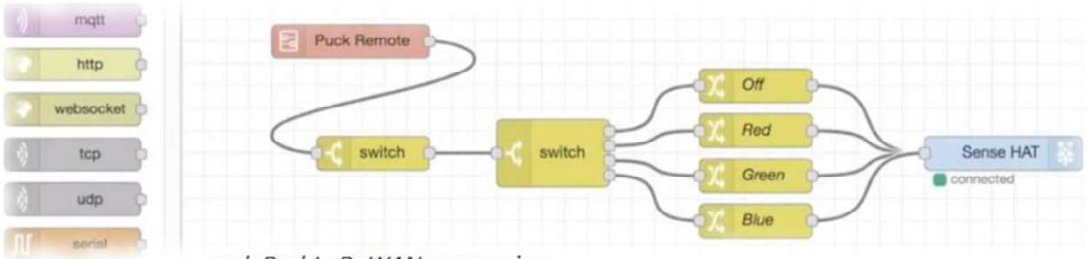


nodeRed LoRaWAN processing

Example 1: ECOnect project



Edge computing



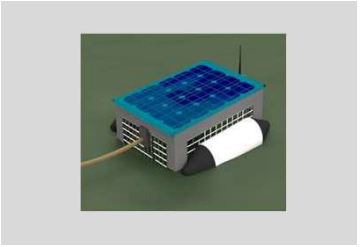
nodeRed LoRaWAN processing

Node-RED

Visual IoT Programming tool

Example 1: ECOnect project

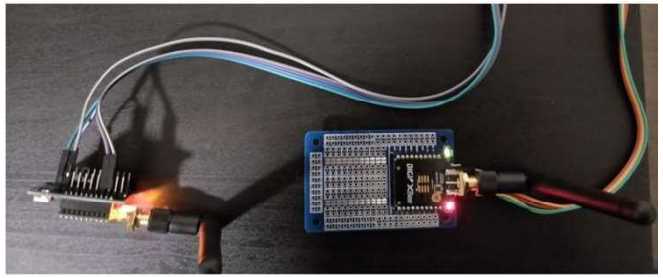
- **Data communication and Data processing architecture**



Example 1: ECOnect project

ZigBee-enabled sentinel

Nichoir Connecté [SETE Moulis]



tests à 115m, 300m, 1100m
Débit support 250 kbps
Image ~50Ko en 10s

ZigBee®

Example 2: Indoor Air Quality monitoring

Interreg Sudoe 3SqAir
https://3sqair.com

https://greenme.fr

https://catie.fr

LoRaWAN server
https://lorawan.univ-tlse3.fr

Frames processing

mongoDB.
influxdb

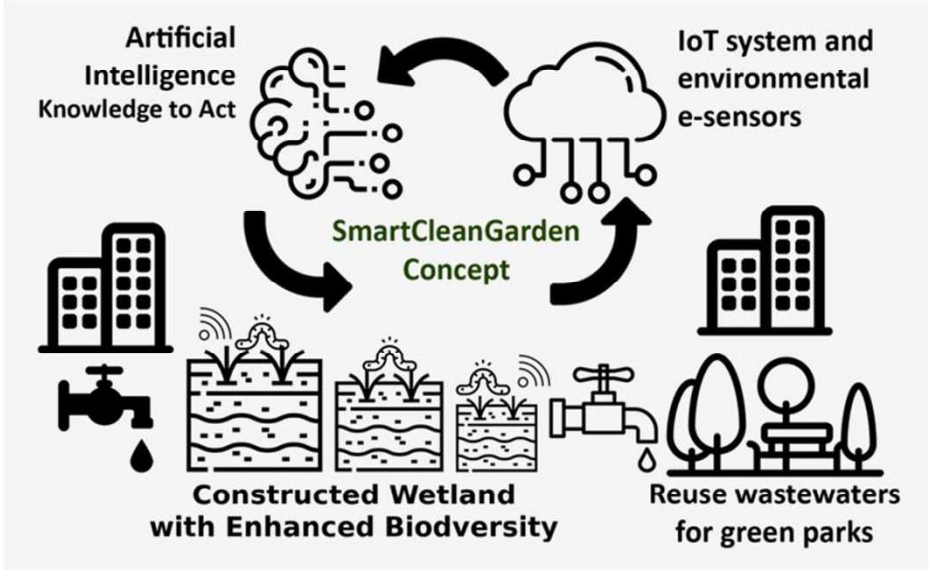
IAQ computations

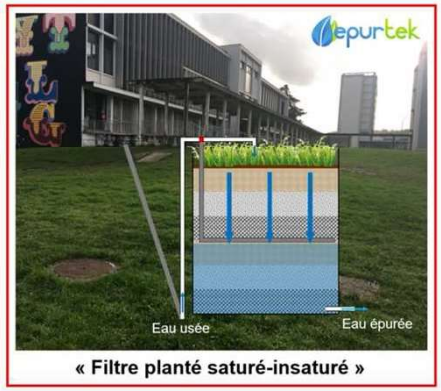
Grafana

Example 3: Filter

smartcleangarden.org
www.transnet-sudoe.eu

«Optimization of planted filters by increased biodiversity»



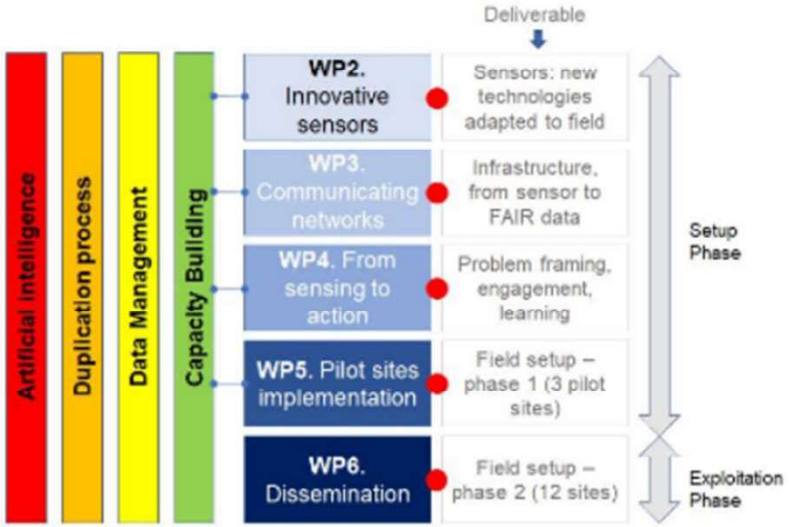


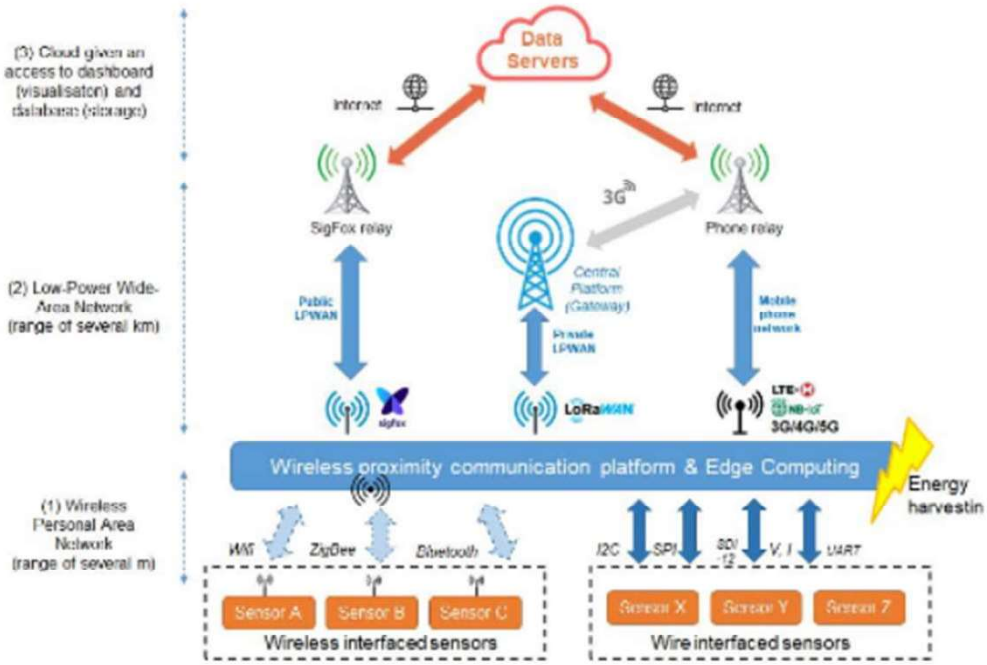
« Filtre planté saturé-insaturé »

Contact : Magali Gerino, LEFE

Example 4: Terra Forma

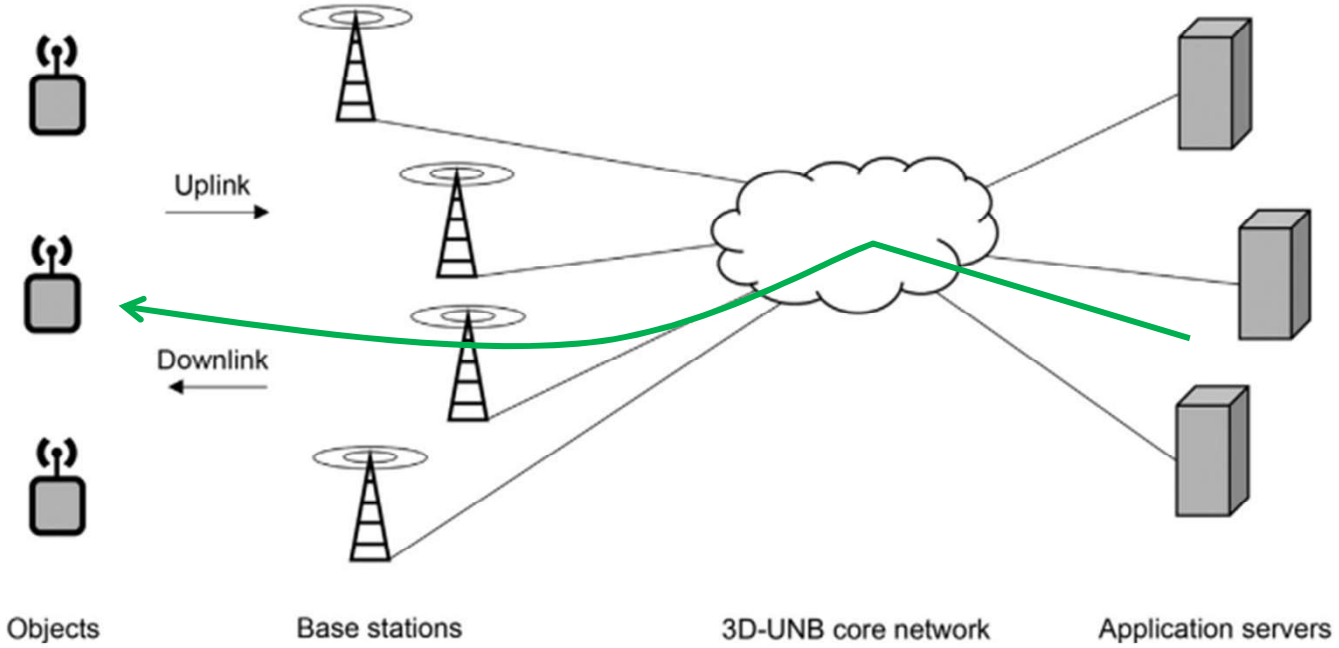
- **TRL: 6 to 8**
- **15 sites**





Open issues

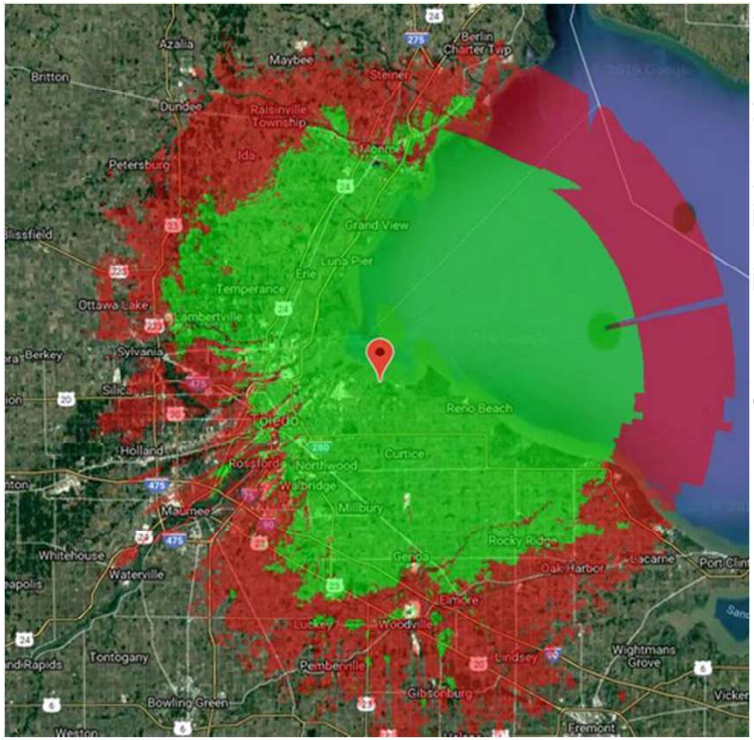
The downlink limitation



Mainly needed for remote configuration and firmware upgrade.

Densification & coverage

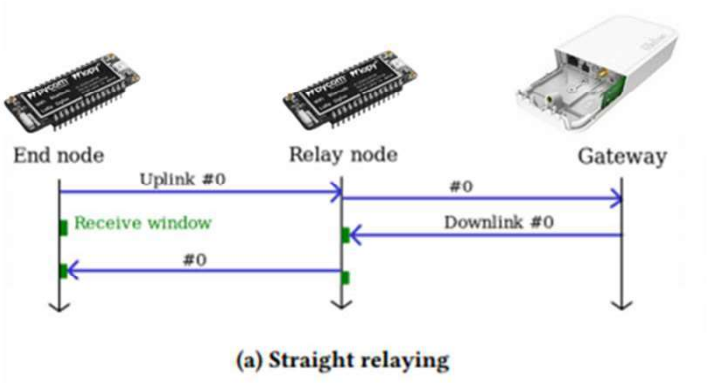
- **Controversial issue**



Source: The Things Network

- **Simple Idea !**

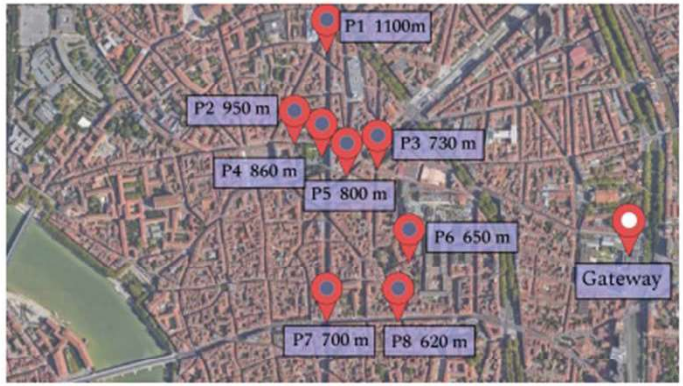
Relaying !



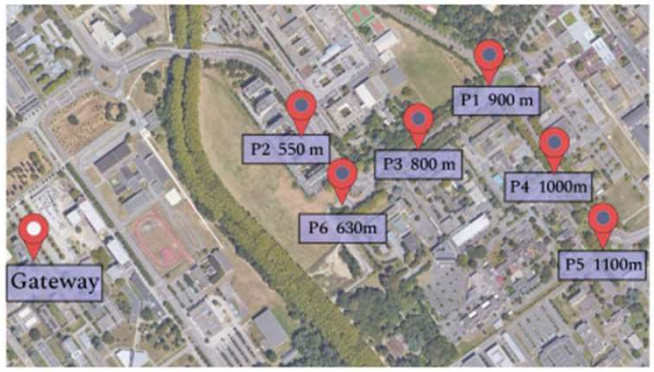
(a) Straight relaying

Densification & coverage

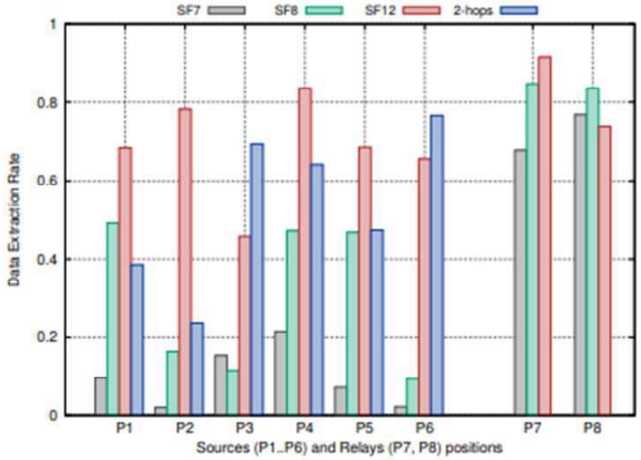
Data Extraction Rate



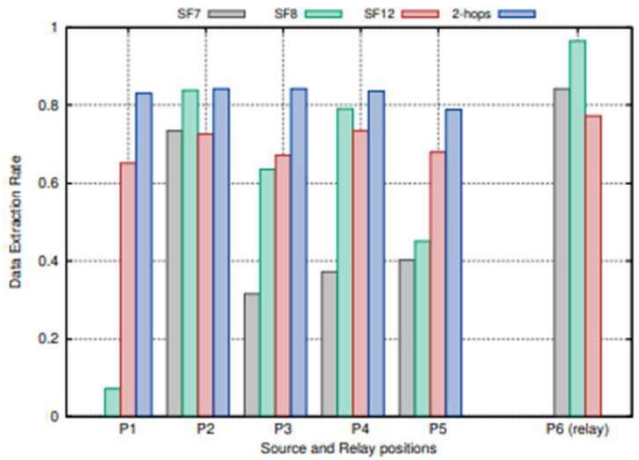
(a) City center of Toulouse, representative of dense urban environment.



(b) Suburb of Toulouse, IRIT-UT3, a typical suburban area allowing LoS conditions but not being full clear field.



(a) Urban area. Relays are located at $P7$ and $P8$. $P8$ relays $P6$ and $P3$ while $P7$ relays the others.



(b) Suburban area. Relay is located at $P6$.

[*] E. Lumet, A. Le Floch, R. Kacimi, M. Lihoreau, and A.-L. Beylot. "LoRaWAN Relaying : Push the Cell Boundaries"
In : 24th Inter-national Conference on Modeling, Analysis and Simulation of Wireless and Mobile Systems (MSWIM'21), ACM, Alicante, 2021.

Thank you!

- **Contact**

Rahim.Kacimi@irit.fr