Protocoles Réseaux pour l'IoT

Des protocoles pour longue et courte distance

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CPE LYON — LIVE AND DISCOVER

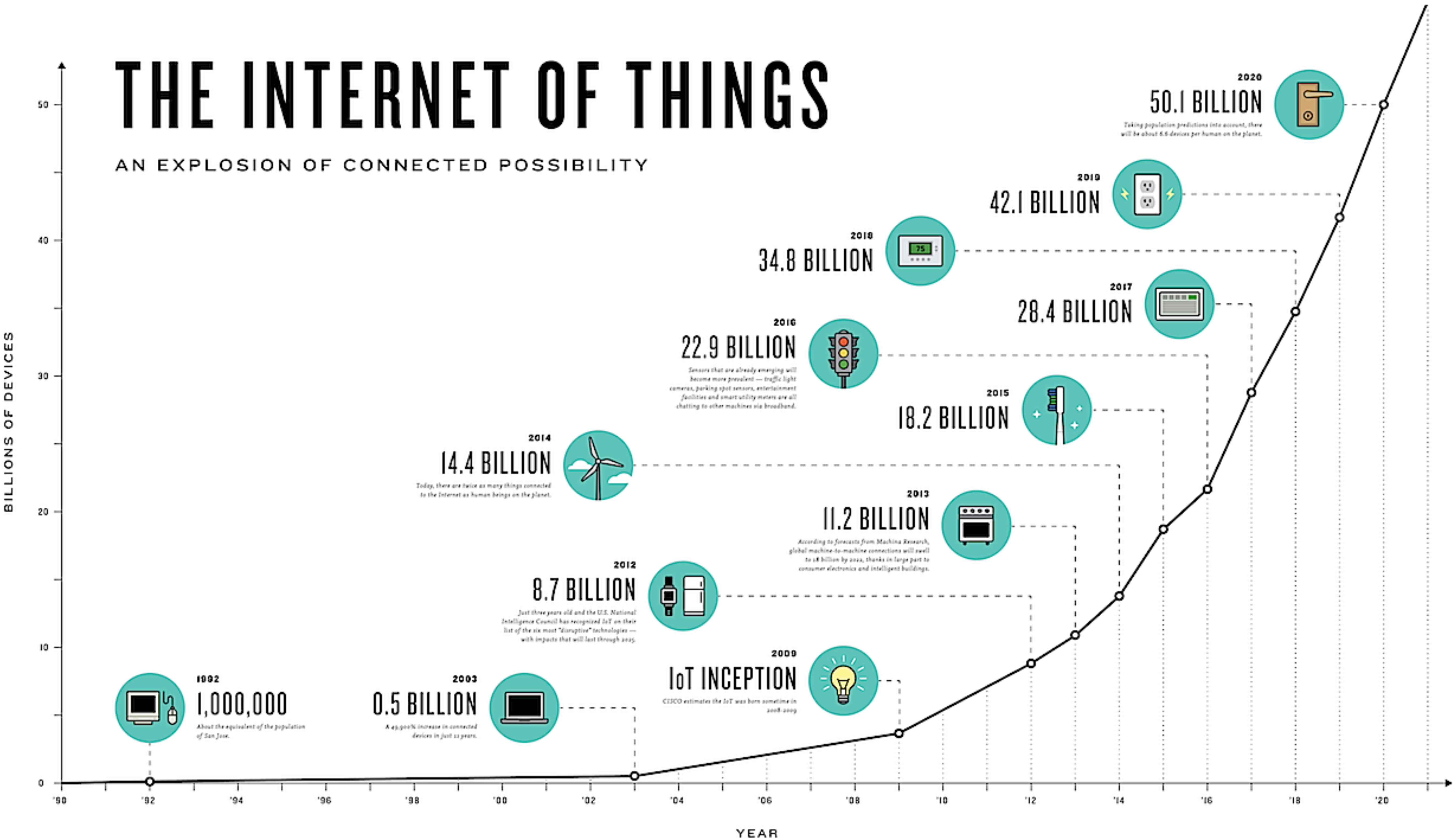
Université de Lyon — établissement associé

Plan

1. La connectivité des objets
2. WPAN
3. LPWAN
4. EN PRATIQUE : RF SUB-1GHz

LA CONNECTIVITÉ DES OBJETS

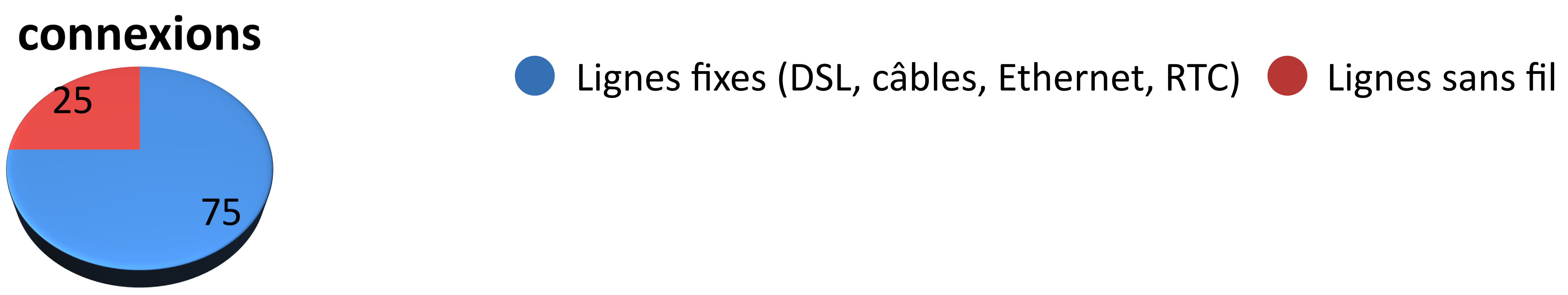
01


THE INTERNET OF THINGS
AN EXPLOSION OF CONNECTED POSSIBILITY
1992
1,000,000
About the equivalent of the population of San Jose.
2003
0.5 BILLION
A 49,900% increase in connected devices in just 11 years.
2009
IoT INCEPTION
CISCO estimates the IoT was born sometime in 2008-2009
2012
8.7 BILLION
Just three years old and the U.S. National Intelligence Council has recognized IoT on their list of the six most "disruptive" technologies — with impacts that will last through 2025.
2013
11.2 BILLION
According to forecasts from Machina Research, global machine-to-machine connections will swell to 18 billion by 2022, thanks in large part to consumer electronics and intelligent buildings.
2014
14.4 BILLION
Today, there are twice as many things connected to the Internet as human beings on the planet.
2015
18.2 BILLION
2016
22.9 BILLION
Sensors that are already emerging will become more prevalent — traffic light cameras, parking spot sensors, entertainment facilities and smart utility meters are all chatting to other machines via broadband.
2017
28.4 BILLION
2018
34.8 BILLION
2019
42.1 BILLION
2020
50.1 BILLION
Taking population predictions into account, there will be about 6.6 devices per human on the planet.
BILLIONS OF DEVICES
0
10
20
30
40
50
'90
'92
'94
'96
'98
'00
'02
'04
'06
'08
'10
'12
'14
'16
'18
'20
YEAR

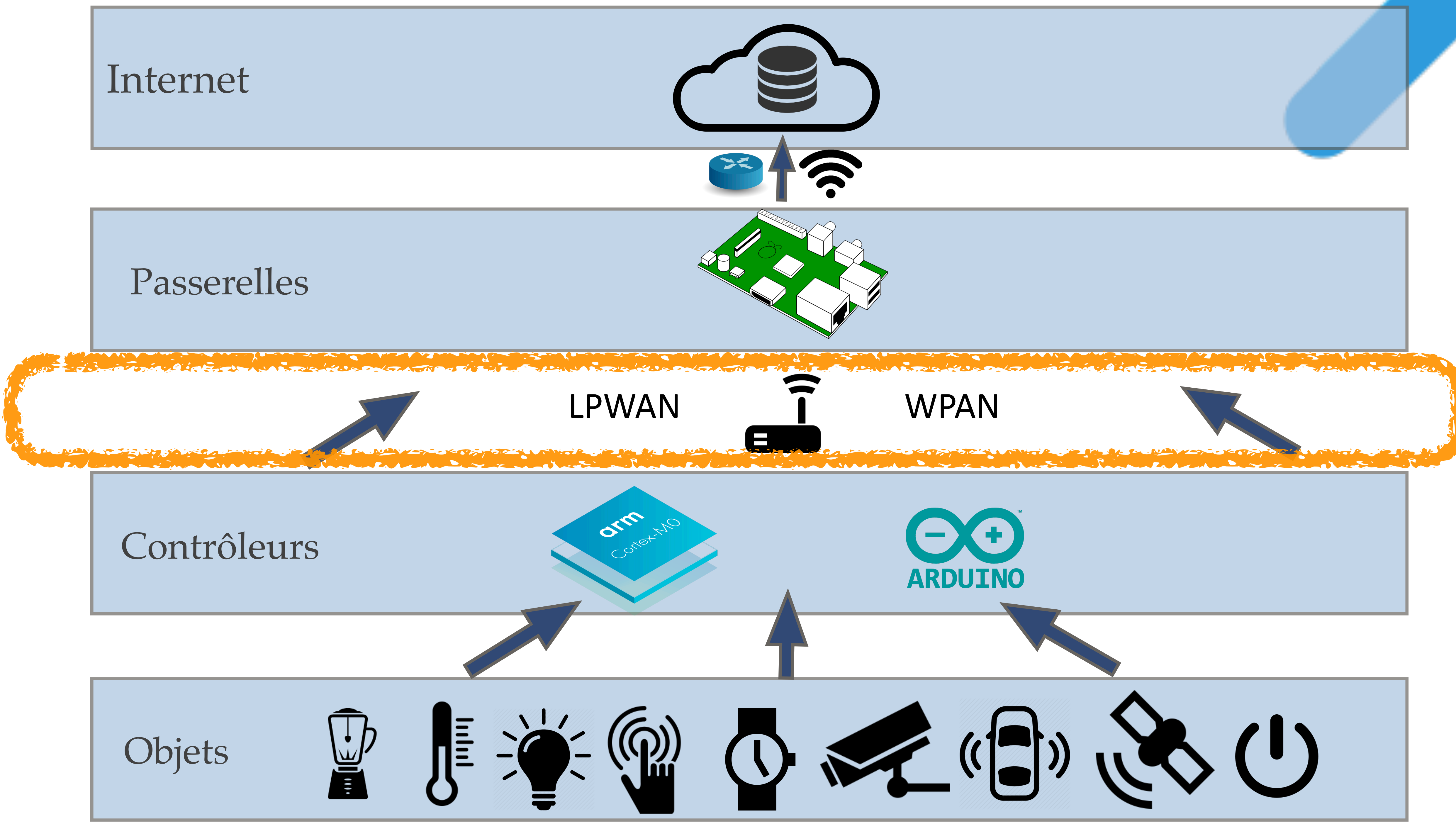
LA CONNECTIVITÉ

Grâce à l’Internet des objets, l’industrie devrait accélérer la connexion de ses systèmes aux réseaux numériques

En 2017, le marché de l’IoT devrait générer 13 millions de connexions fixes et sans fil supplémentaires portant le total à 66 millions de lignes dans le monde (source ABI Research)



LA CONNECTIVITÉ: WPAN - LPWAN

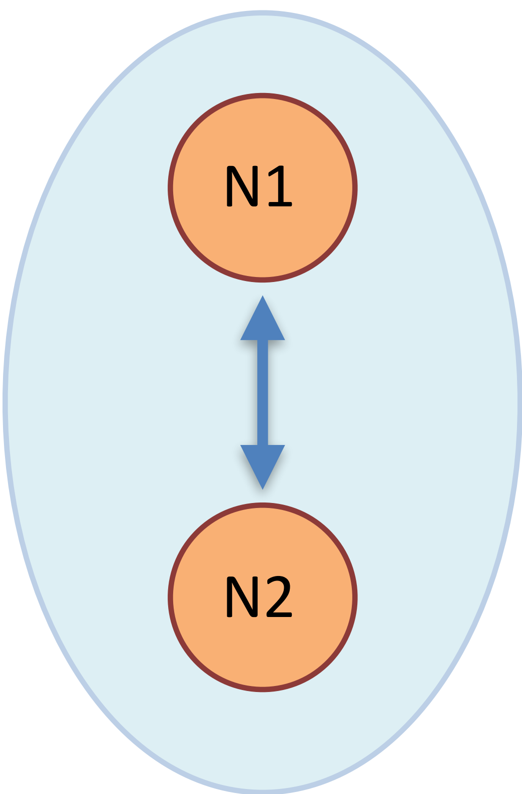


Comment concevoir mon réseaux ?

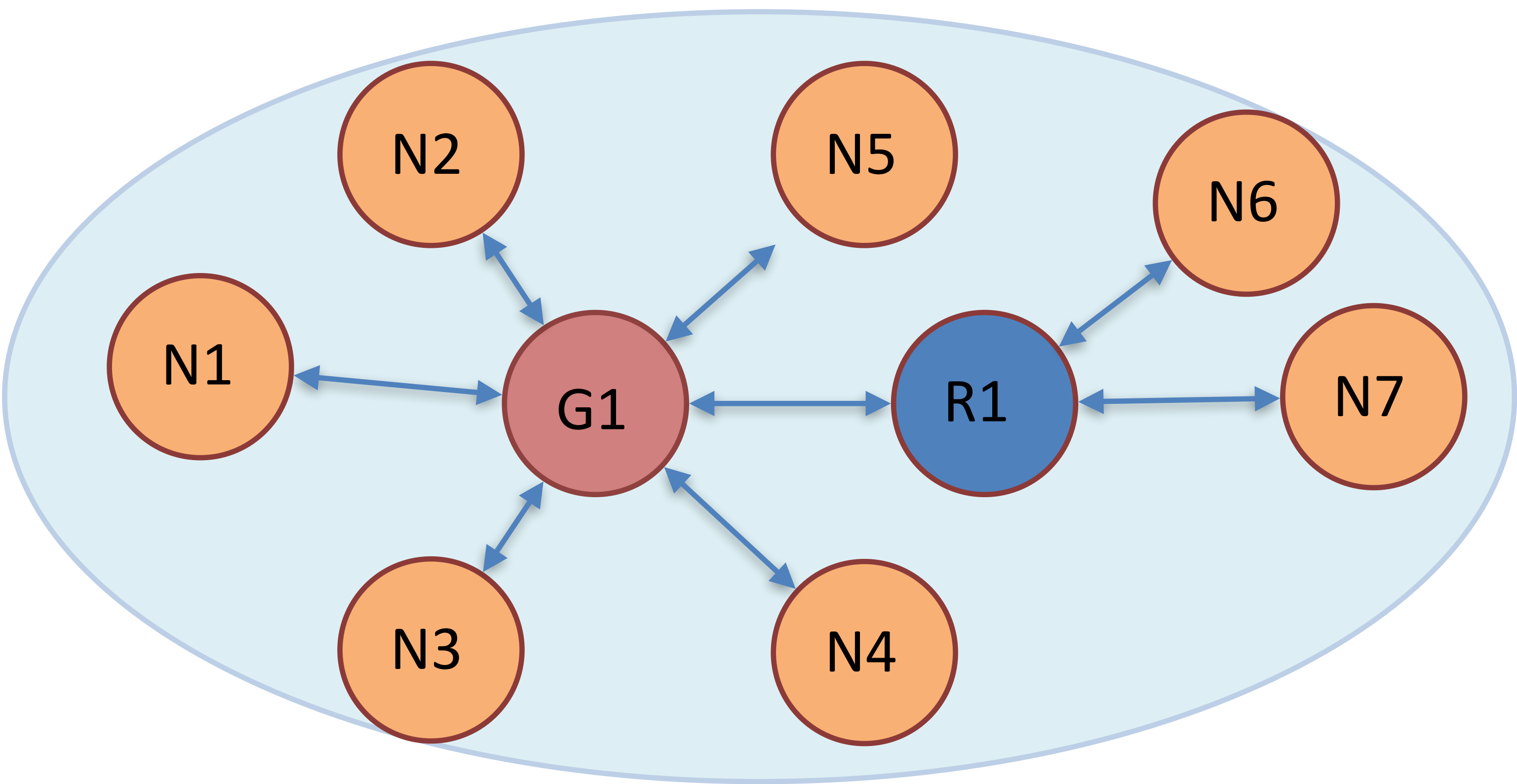
- Combien de noeuds dans mon réseaux sans fils ?
- À quelle distance seront les noeuds ?
- Est-il nécéssaire une basse consommation d’énergie ?
- Il y t’il besoin de s’aligner à des standards ?

QUELLE TOPOLOGIE POUR MON RÉSEAU ?

- Pair à pair (p2p)
  - ✓ Unidirectionnel
  - ✓ Bidirectionnel

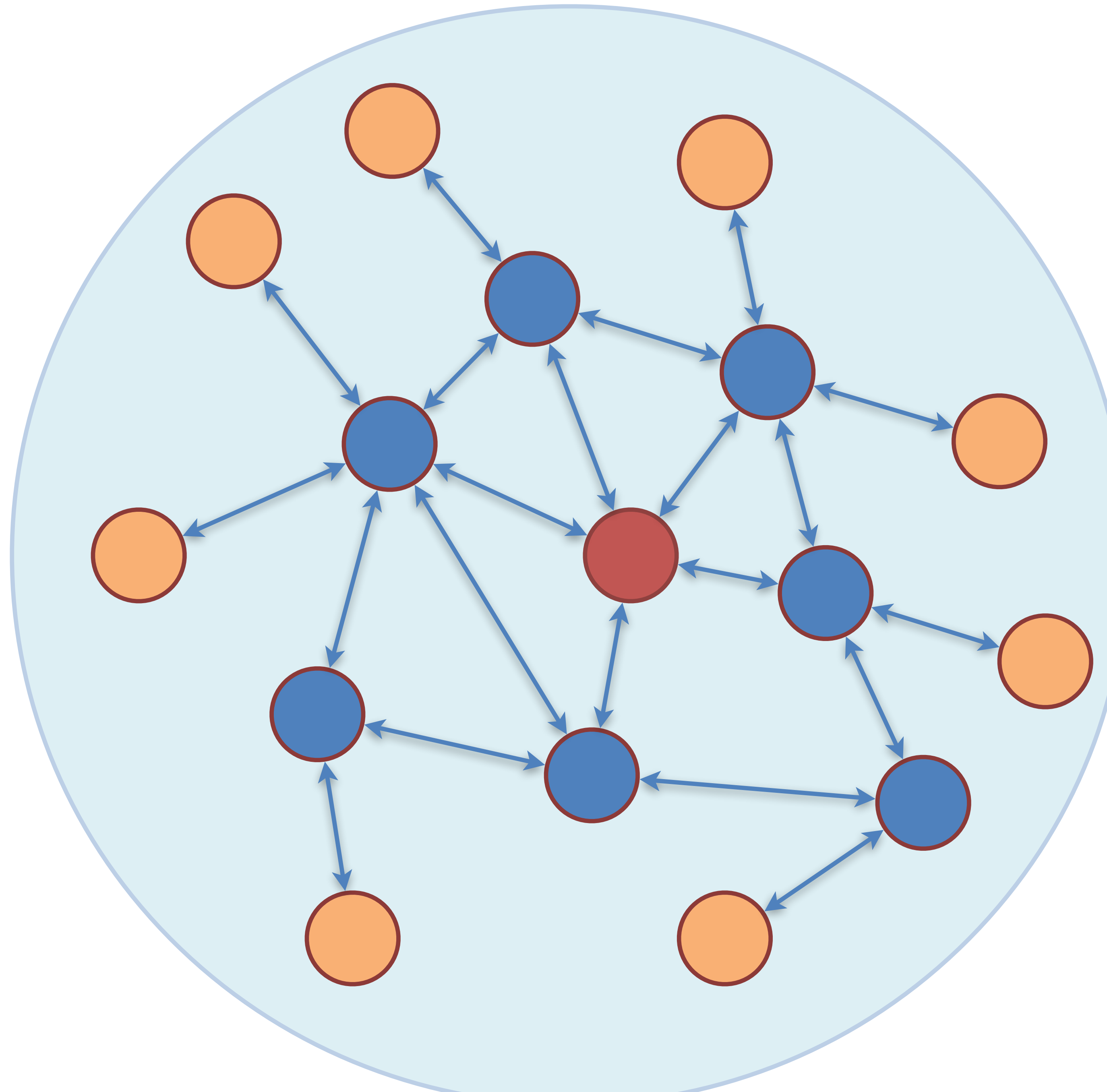


- Étoile (star)
  - ✓ Point d'accès (Gateway)
  - ✓ Répéteurs
  - ✓ Centralisé



QUELLE TOPOLOGIE POUR MON RÉSEAUX ?

- Maillé (mesh)
  - ✓ Coordinateur
    - Démarre le réseau
    - Route paquets
    - Contrôle sécurité
    - Associe routeurs et dispositif final
  - ✓ Routeur
    - Route paquets
    - Associe routeurs et dispositifs finaux
  - ✓ Dispositif final
    - En mode sleep
    - Batterie
    - Ne route pas



QUELLE DISTANCE DE PROPAGATION ?

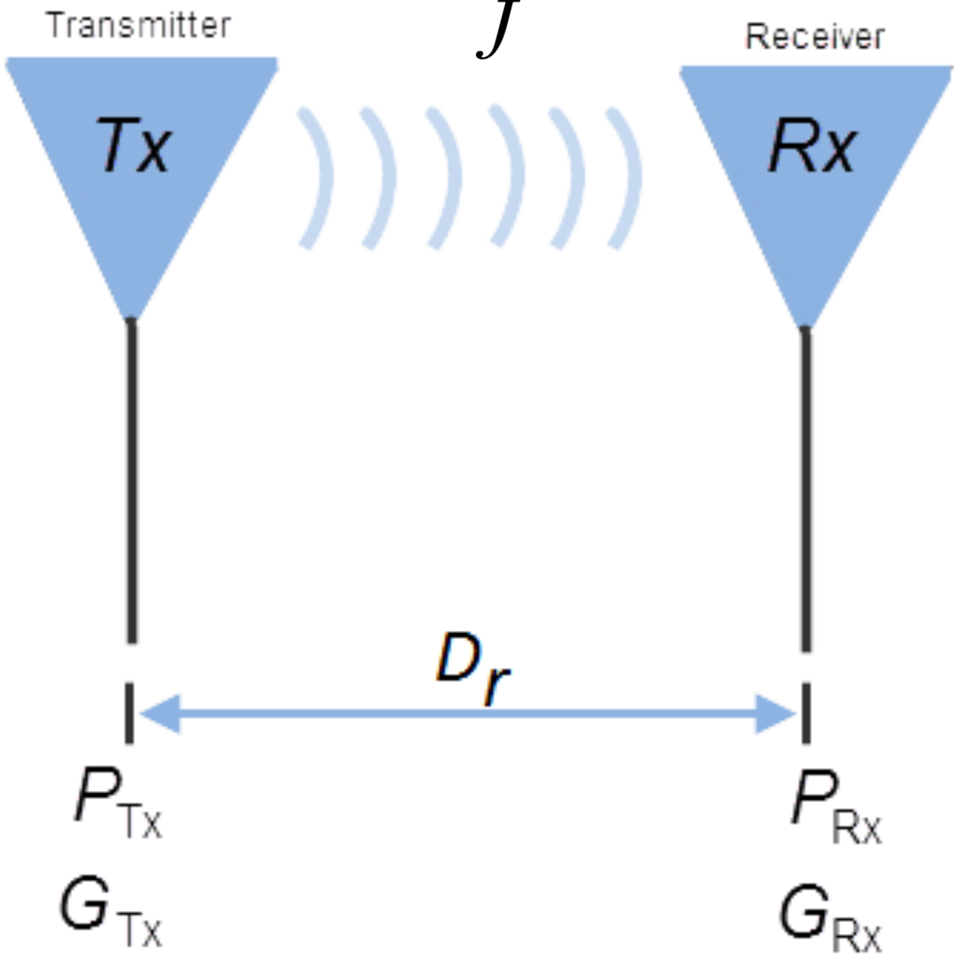
- La distance entre les noeuds de transmission (Tx) et celui récepteur (Rx) est déterminé par l'équation de Friis'

$$P_r = P_t + G_t + G_r + 20\log\left(\frac{\lambda}{4\pi}\right) - 20\log d$$

$$\lambda = \frac{c}{f}$$

$$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2}$$

$$d = \frac{\lambda}{4\pi}\sqrt{\frac{P_t G_t G_r}{P_r}}$$



DISTANCE: DANS LA PRATIQUE

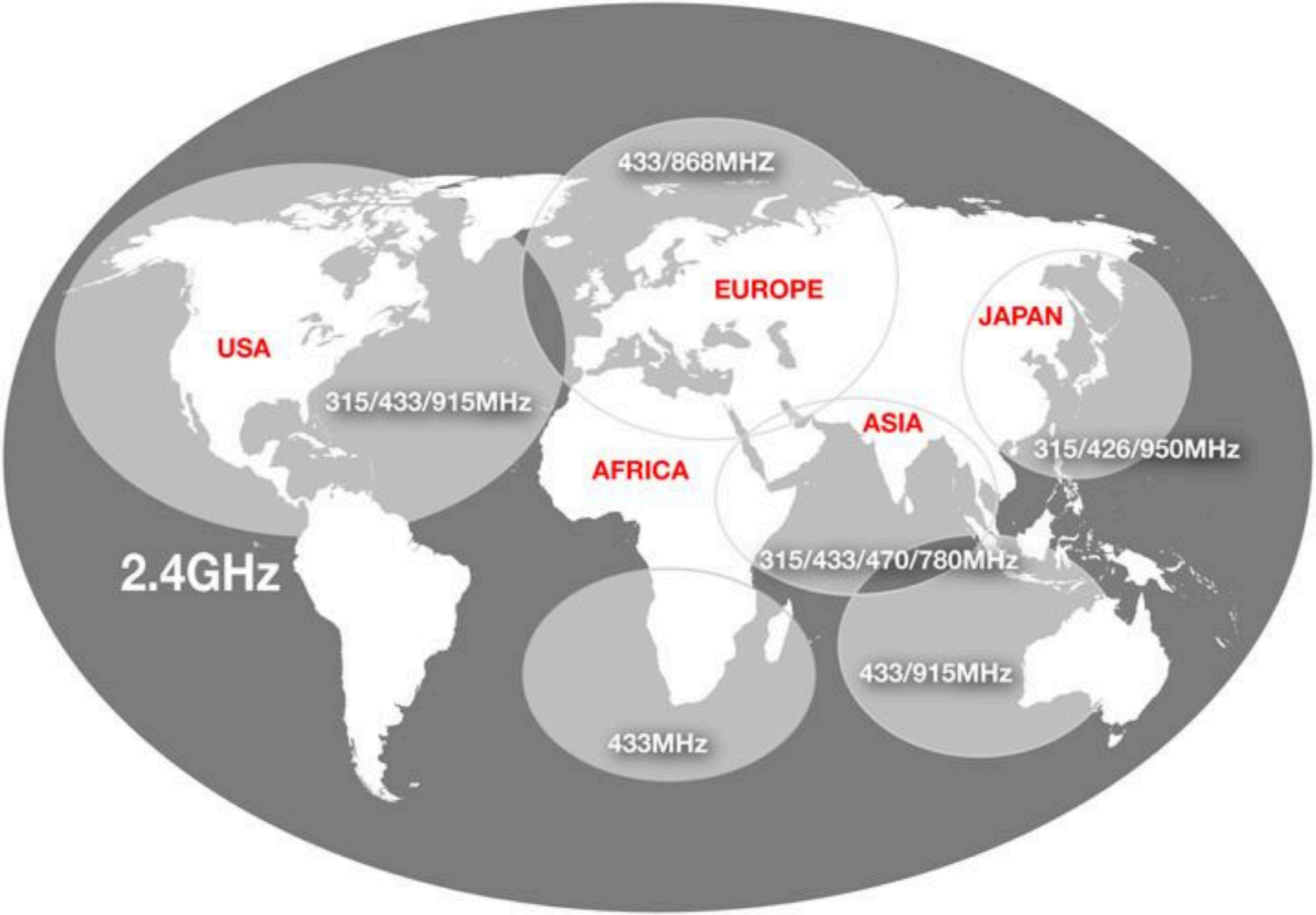
- Antenne : gain
- Sensibilité : puissance minimale d’entrée
- Environnement avec interférences ?
- Puissance de sortie ?
- Environnement (en vue, obstacles, réflexions, …)

- En général:
  - ✓ 6dB de gain de plus -> double distance
  - ✓ Double fréquence -> distance divisée par 2

ECONOMISER DE L'ENERGIE

- ✦ Utiliser le réseau le moins possible
  - ✓ Envoyer des données seulement si c'est nécéssaire, et le minimum.
  - ✓ Utiliser le plus haut débit
- ✦ Utiliser le courant le plus bas possible
  - ✓ Le moins de voltage sans dégrader la transmission
- ✦ Utiliser le mode sleep

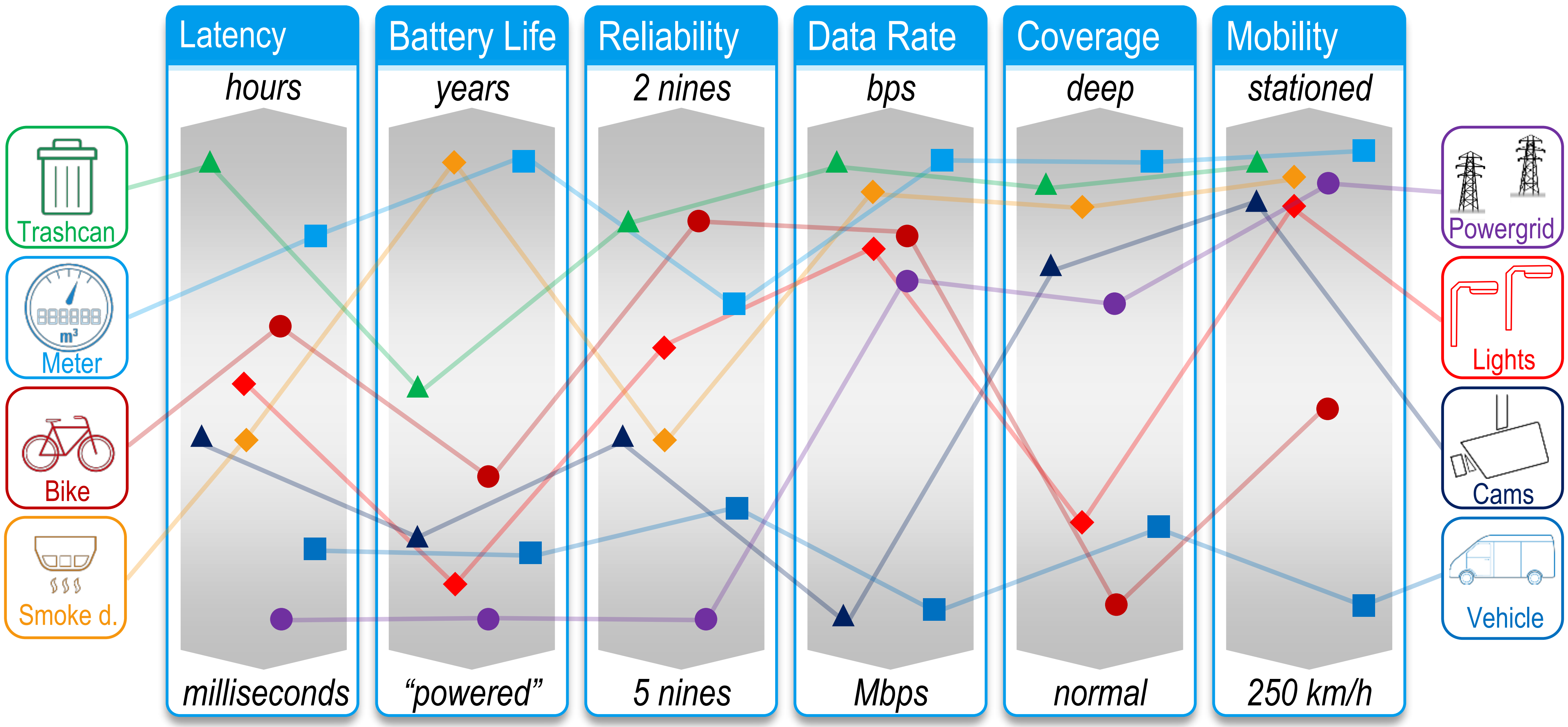
DES STANDARDS À RESPECTER ?



Tendances technologiques dans l'IoT

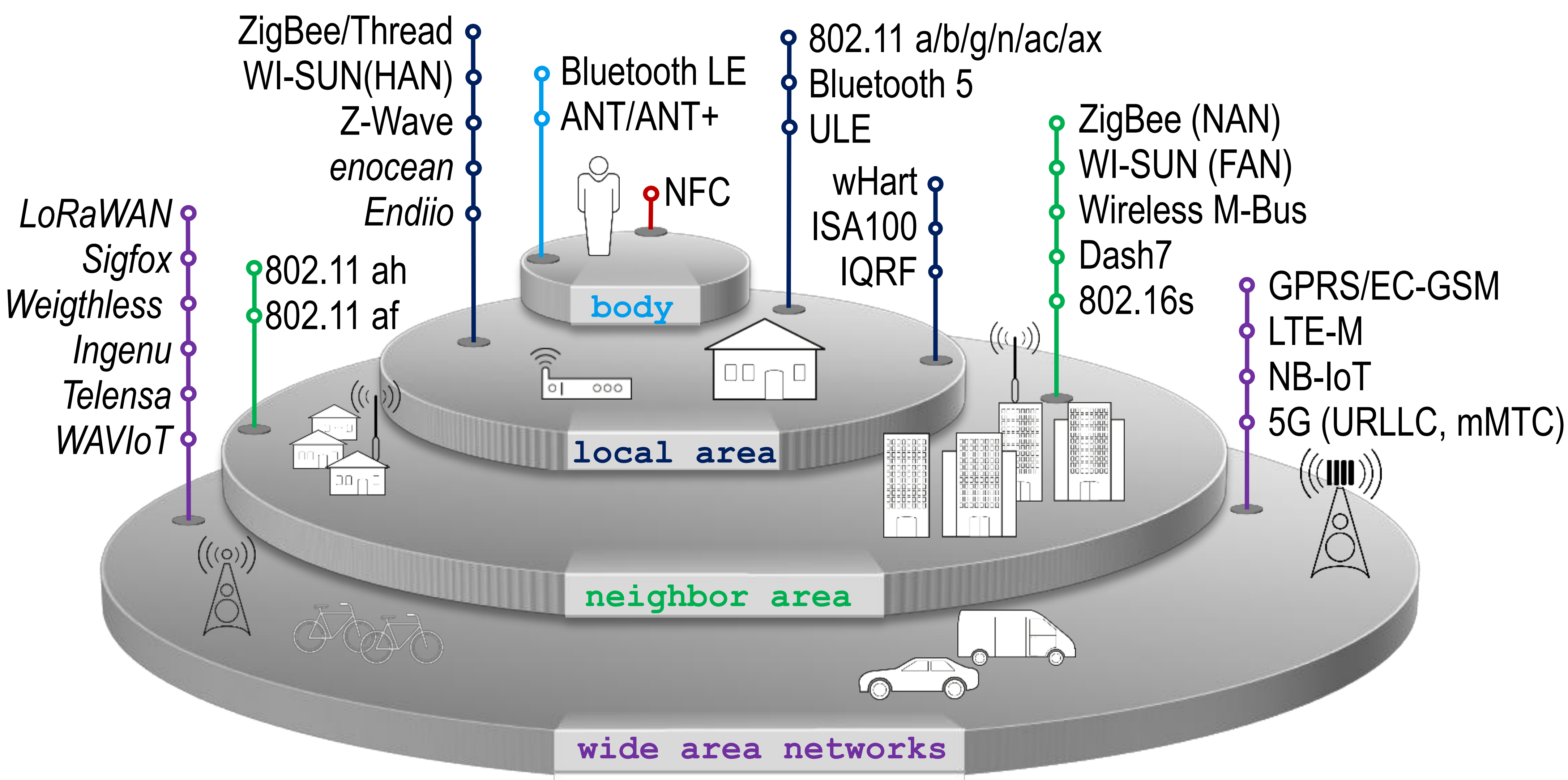
Quelle technologie utiliser ?

Define your requirements



"Everything that will benefit from being connected will be connected"
Ericsson, 2010

A plethora of radio technologies



All product names, logos, and brands are property of their respective owners

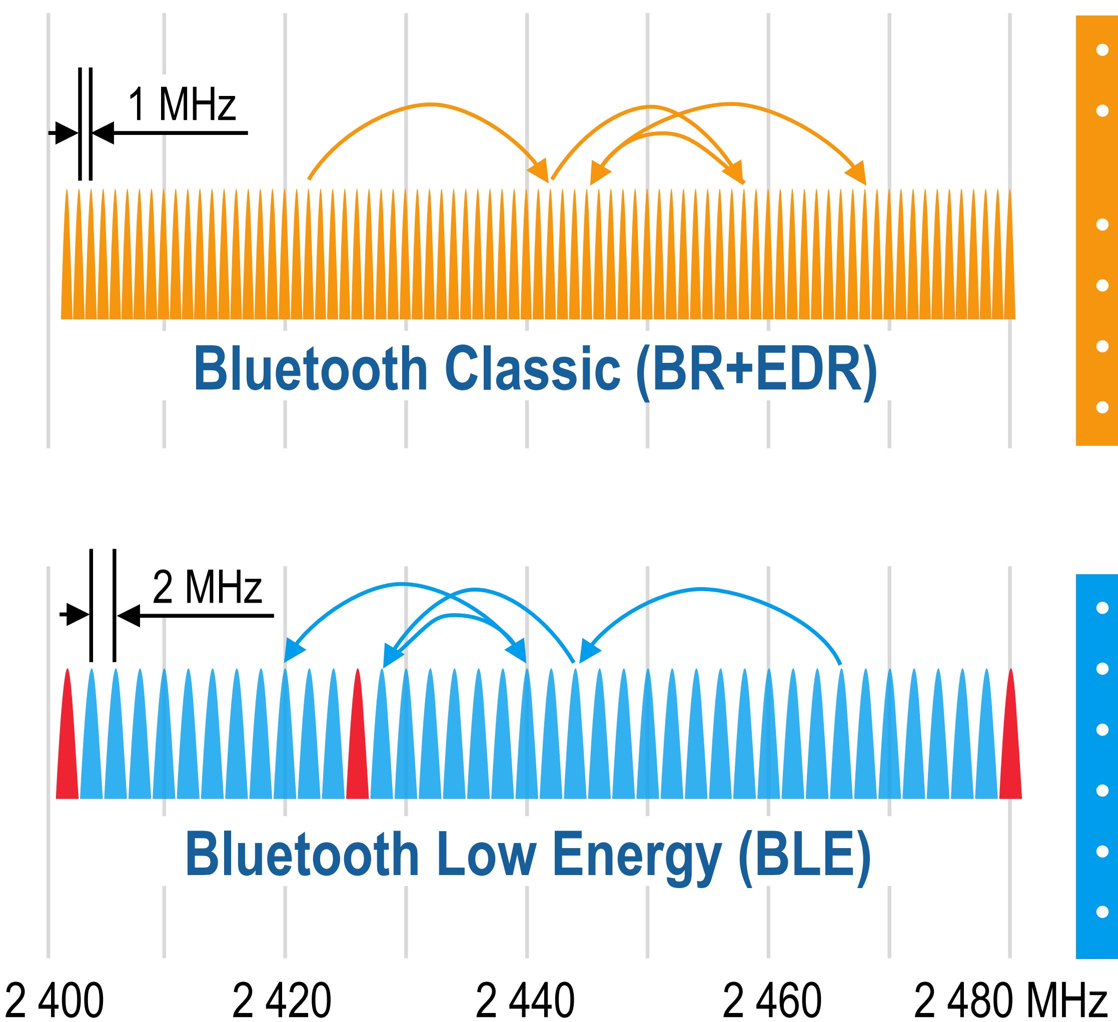
WPAN

02

Some Bluetooth History

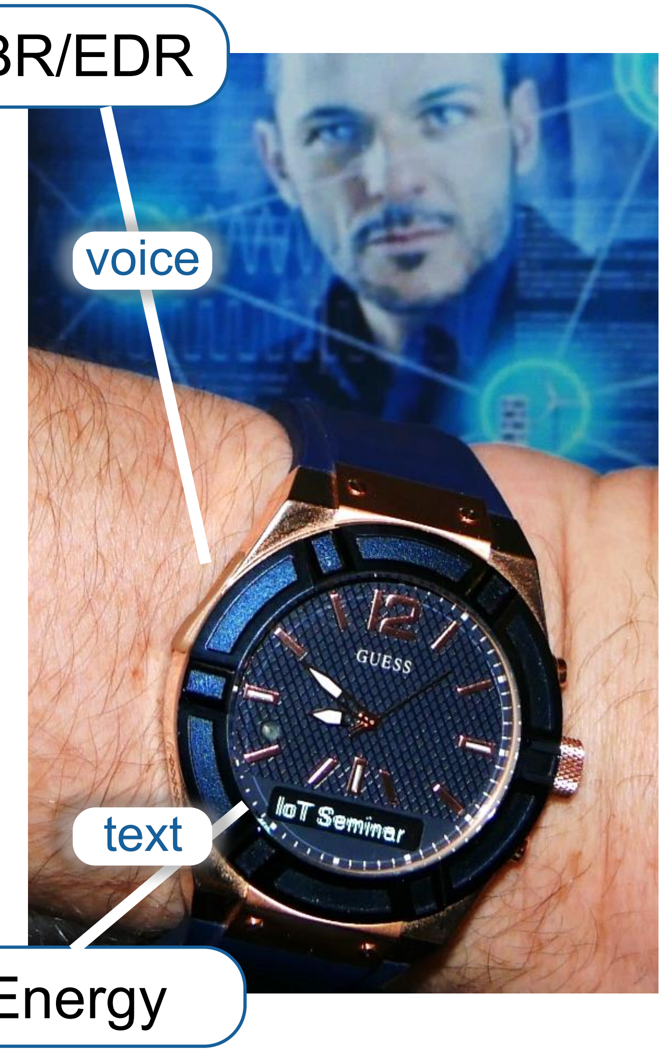
The idea for the Bluetooth name came from Jim Kardach of Intel, who was reading a historical novel about Vikings and King Harald Blåtand at the time. (Courtesy: Intel Free Press)

Bluetooth Basic and Low Energy



- 2.4 GHz ISM band
- 1 Msymbol/s using GFSK modulation
  EDR: data modulation π/4-DQPSK / 8DPSK
- 79 channels on 1 MHz spacing
- Frequency hopping (1600 hops/s)
- Voice support
- FEC

- 2.4 GHz ISM band
- 1 Msymbol/s using GFSK modulation
- 40 channels on 2 MHz spacing
- 3 advertising channels
- Frequency hopping (37 channels)
- CRC



Bluetooth IoT Features

Gateway
Connecting devices directly to the cloud

02/16

Speed
100% improvement for low latency apps

12/16 5.0

Mesh
building mesh by using relay nodes

07/17

Range
4x range to cover a smart home or office

12/16 5.0

Broadcast
Extended capabilities of advertising channel

12/16 5.0

WiFi

- Initially created by the National Cash Register

50% of **all IP traffic in 2021**, will be Wi-Fi, 30% will be wired, and 20% will be mobile.

42% in 2016

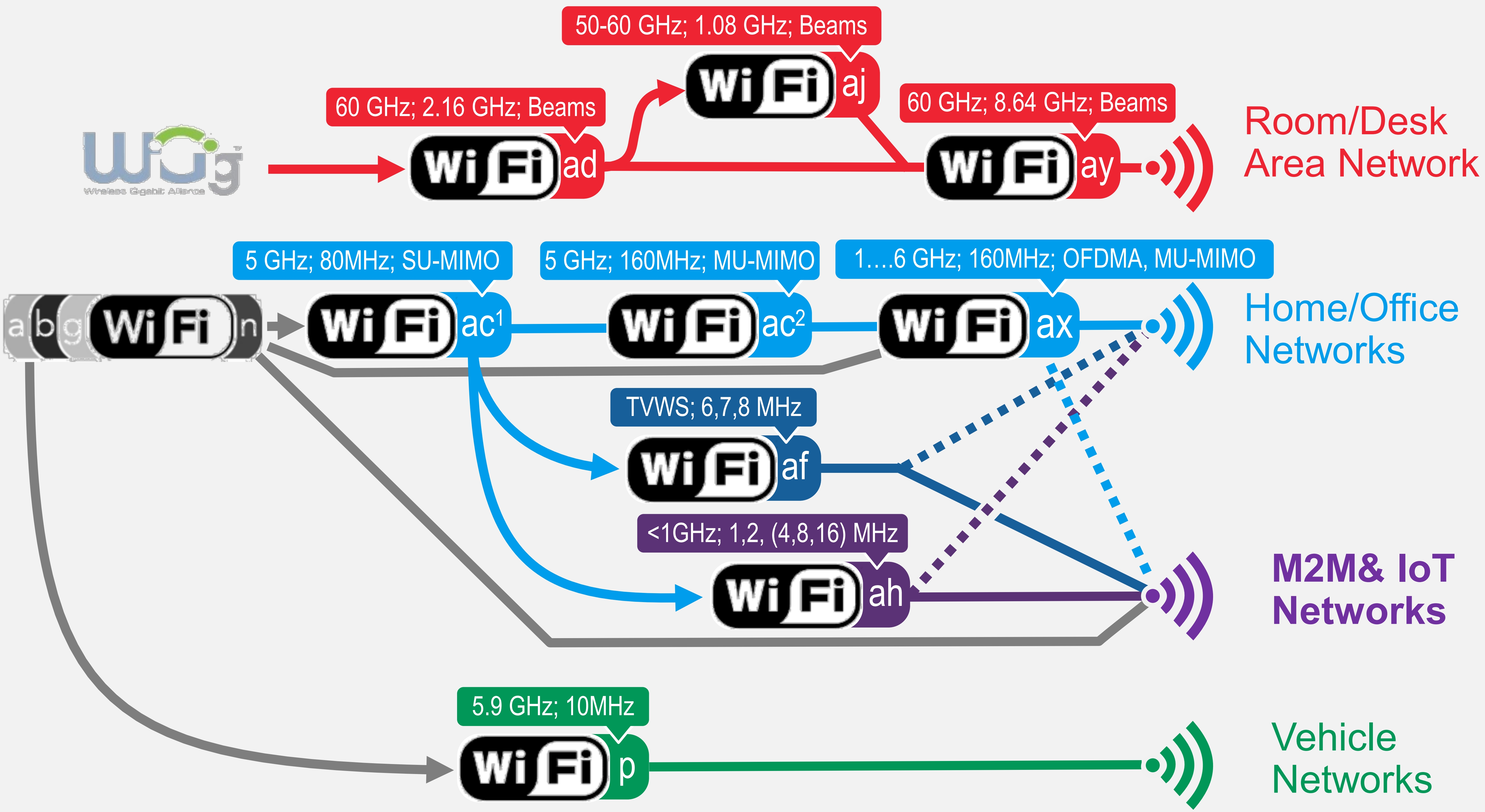
6fold grow of **Wi-Fi homespots** from 85.1 million in 2016 to 526.2 million **by 2021**.

63% of total mobile data traffic will be **offloaded through Wi-Fi or femtocell in 2021**.

60% in 2016

Source: Cisco VNI | March 2017

Wireless alphabet soupe



WiFi HaLow (802.11ah)

- “New technology will extend Wi-Fi® solutions for the Internet of Things” Wi-Fi Alliance (Jan.2016)

Long range operation	Low power consumption	Large number of devices per access point	High throughput compared to e.g. ZigBee	Greenfield operation

Sensor Networks

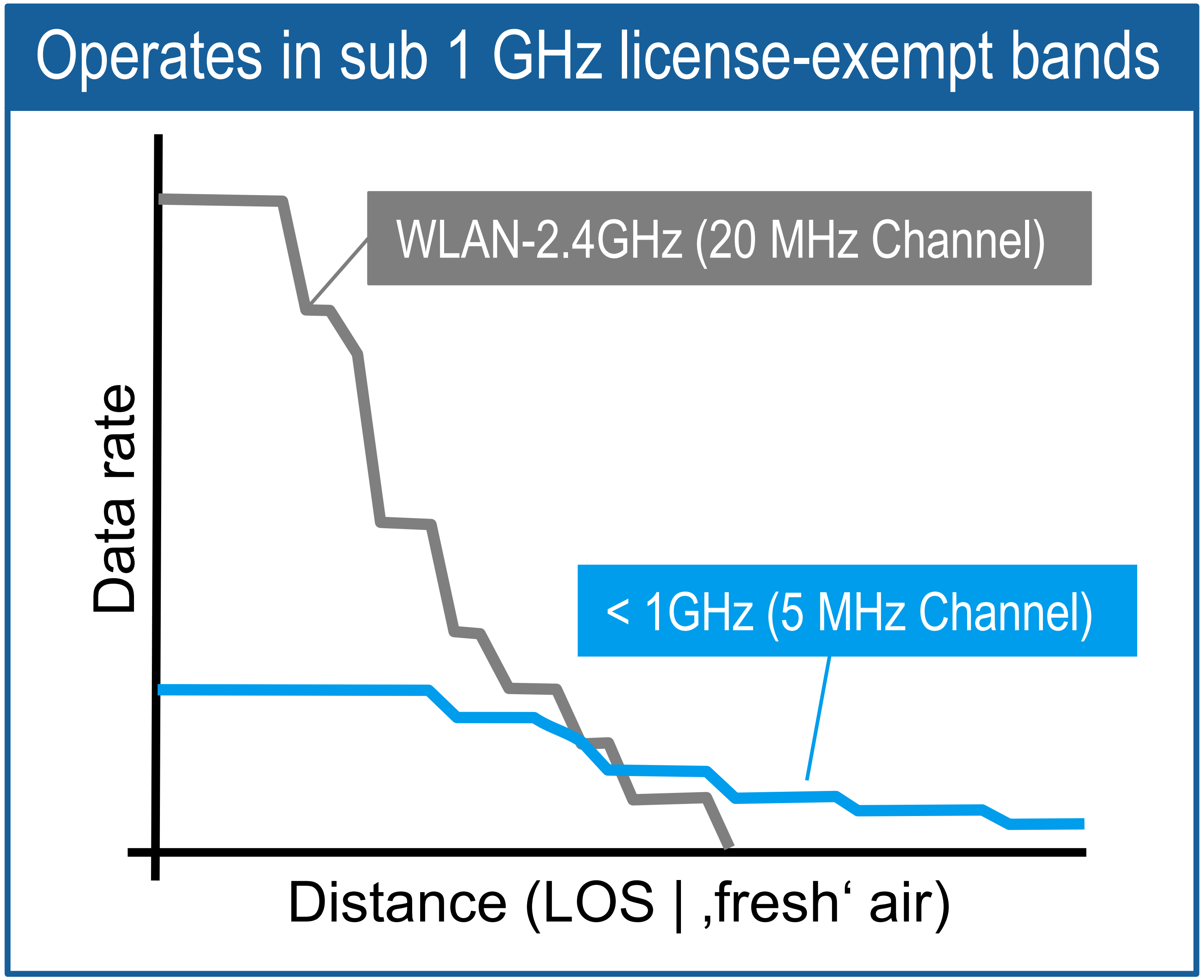
Home Security

Wearables

Range extension

Smart Metering

Long range, low speed, low power WiFi 802.11h



802.11ax Requirements and Applications

- Enhance operation in 2.4 AND 5 GHz bands; backward compatible and coexist with legacy 802.11 devices in the same band (11n/11ac)
- Increase average throughput per station in dense deployment scenarios
- Covering indoor AND outdoor scenarios
- Improve power efficiency of the stations

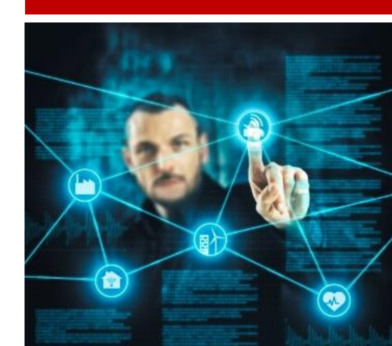
Large Office

Stadium

Mall/Airport

Apartments

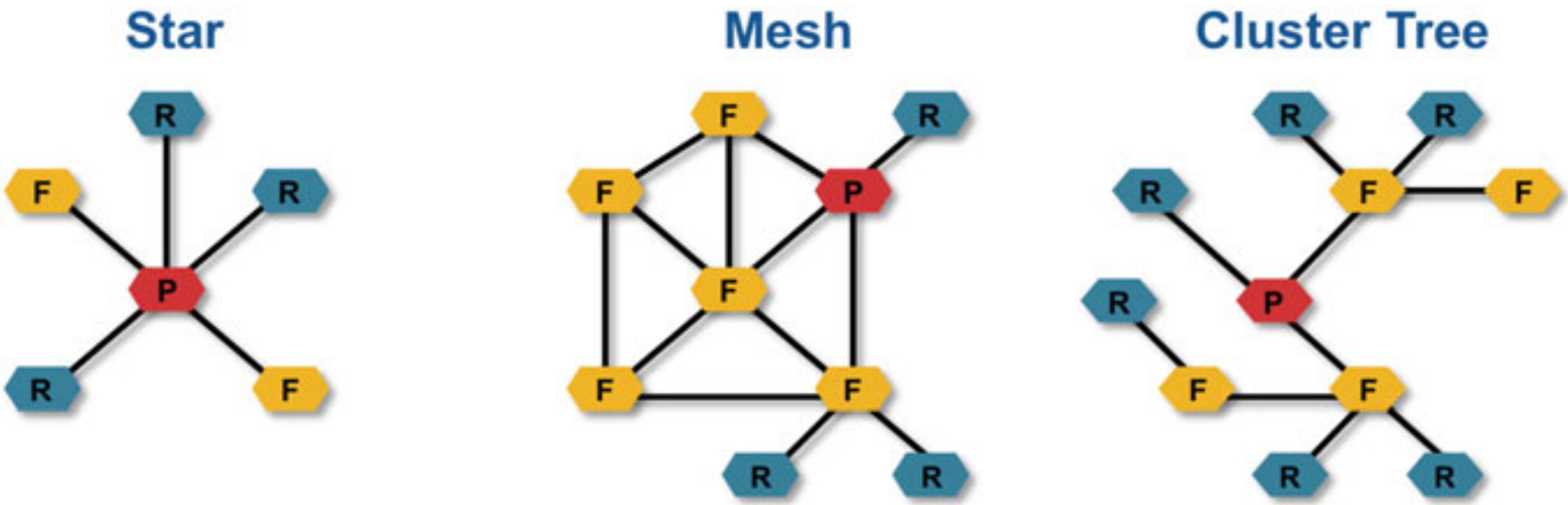
IoT



802.15.4 - for smart home, smart buildings and more

ZigBee	THREAD 6LoWPAN	ISA 100	WirelessHART
ZigBee - Protocol	Protocol (e.g. CoAP)	ISA Protocol	HART: Protocol
ZigBee - Transport	UDP/TCP	UDP	HART: TCP like
ZigBee - Networking	6LoWPAN, DTLS, Distance Vector Routing	6LoWPAN	HART Addressing/Routing
802.15.4 MAC	802.15.4 MAC	Upper data link ISA100 802.15.4 MAC	HART TDMA - hoping
IEEE 802.15.4 2.4 GHz ◆ O-PQSK	**IEEE 802.15.4 2.4 GHz ◆ O-PQSK**	**IEEE 802.15.4 2.4 GHz ◆ O-PQSK**	**IEEE 802.15.4 2.4 GHz ◆ O-PQSK**

802.15.4 Topologies



- RFD: Reduced Fonction Device
- FFD: Full-Function Device

LPWAN

03

Low Power, Low Data Communication

Then: People sending messages

Now: Machine driven wireless

LPWAN Addresses Technology Gap

2G 3G 4G LTE

Traditional Cellular

Low battery life
High Cost
MNO controlled

LoRa

NB-IoT

Sigfox

LPWAN

Long Range
Low data rates
Long battery life

Wi Fi

802.15.4

Local Area Network

Short Range
Low battery life

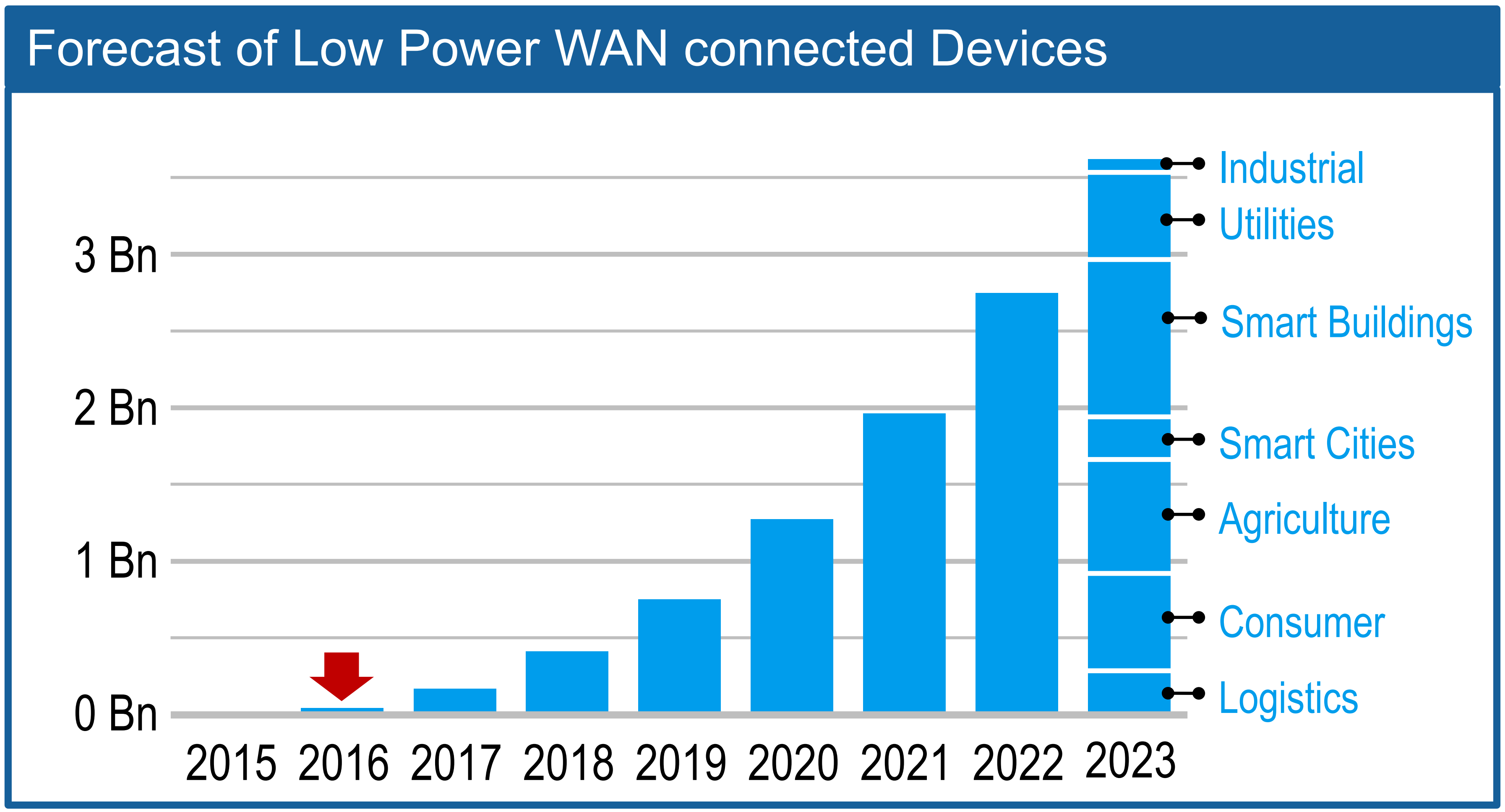
Short range
Medium battery life

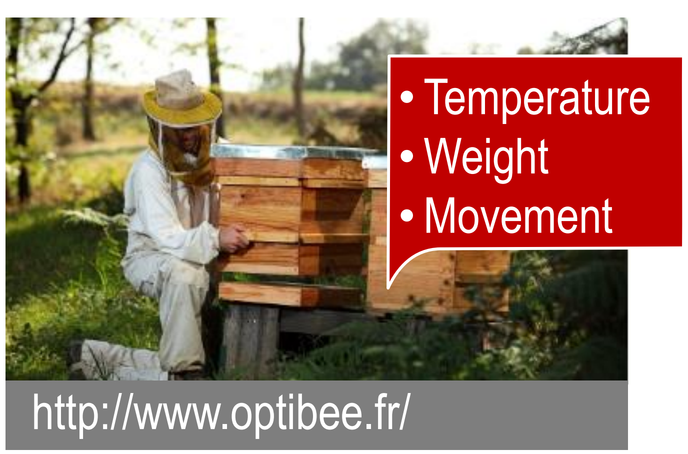
Bluetooth

Personal Area Network

Short Range
Medium battery life

Low-power wide-area networks (LP-WAN) will enable applications which sense literally Everything Everywhere Anytime





3GPP addresses the LPWA market especially with LTE-M/NB-IoT

LTE (Cat-1bis …Cat-4)

- Native LTE (TDD/FDD)
- Full bandwidth of up to 20 MHz
- Seamless mobility
- High data rate

LTE-M (Cat-M1/2)

- In-band LTE (TDD/FDD)
- Reduced bandwidth (1.4/5 MHz)
- Half-duplex optional
- Limited mobility
- Data rate of up to 1 Mbps
- Indoor coverage
- VoLTE support

NB-IoT (Cat-NB1/2)

- In-band, guard-band, standalone LTE (FDD only)
- Narrowband of 180 kHz
- Half-duplex only
- Nomadic mobility (reconnection)
- Low data rate (< 100 kbps)
- Deep coverage

eNB-IoT (Rel. 14) power consumption, positioning, mobility and more

Data rate improvements

- New UE category NB2 with max UL and max DL TBS of 2536 bits, optional support of two HARQ with TBS of 1352/1800 bits (UL/DL)

1 Mill devices per km^2

- Both anchor and up to 15 non-anchor carriers can be used for paging and for random access procedure

Mobility

- Connected mode mobility realized by RRC connection re-establishment triggered by radio link failure (RLF)
- AS Release Assistance Indication

New Power Class

- New power class of 14 dBm to support coin-cell battery operation e.g. for wearables with relaxed MCL of 155 dB

Device positioning

- E-CID support
- OTDOA support based of specific narrowband positioning reference signal (NPRS)
- Measurements in idle mode

Group messaging/updates

- Adoption of Rel.13 Single Cell point-to-Multipoint (SC-PTM) feature with an maximum TBS value for NPDSCH of 2536 bits in idle mode

feMTC (Rel. 14) power consumption, positioning, VoLTE and more

Data rate improvements

- Max uplink TBS of 2984 bits (M1)
- 10 DL HARQ processes
- HARQ-ACK Bundling in HF-FDD
- Faster frequency retuning (guard period of less than 2 symbols)

New UE Category

- New UE category (M2) with max TBS of 4008/6968 bits (UL/DL) and optionally support of 5 MHz (wideband) for PDSCH/PUSCH
- M2 device can operate as M1

Mobility

- Mobility in connected mode
- Intra-frequency and inter-frequency measurements (RSRP/RSRQ) in CE mode

VoLTE support

- Optimized parameter for VoLTE like new PUSCH repletion factors, restricted modulation schemes (QPSK) and adjusted scheduling delays

Device positioning

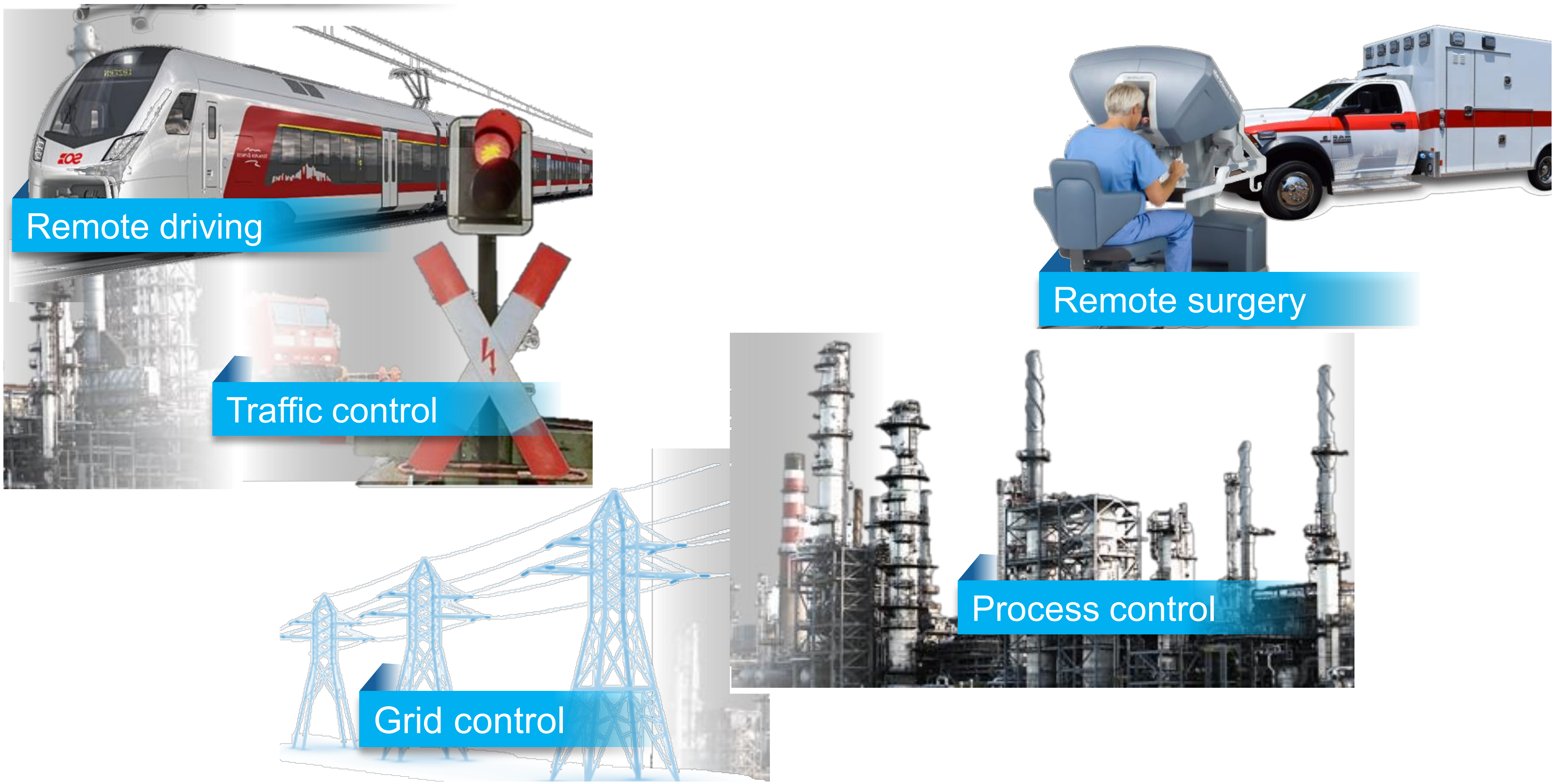
- E-CID support
- OTDOA support based on positioning reference signal (PRS) adapted for LTE-M (e.g. frequency hopping support, long cycles)

Group messaging/updates

- Adoption of Rel.13 Single Cell point-to-Multipoint (SC-PTM) feature
- Supported only in idle on 1.4 or 5 MHz

LTE-M

But, can we connect already everything? What about ....?



"***Everything*** **that will benefit from being connected will be connected"**

Ericsson, 2010

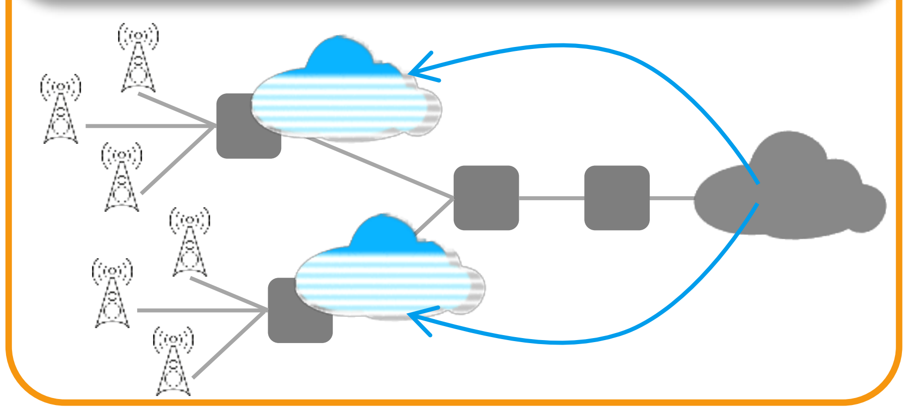
Low latency communication

Proximity

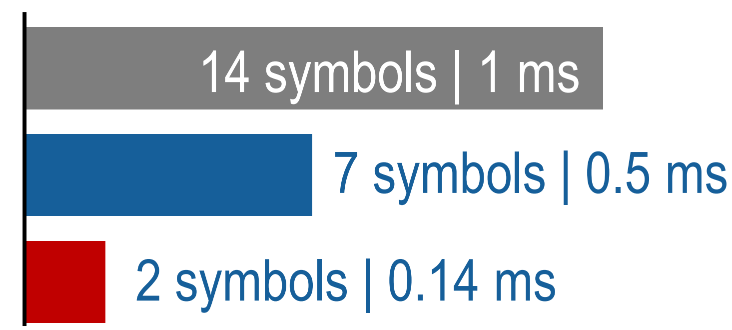
Reduce signaling

Improve speed

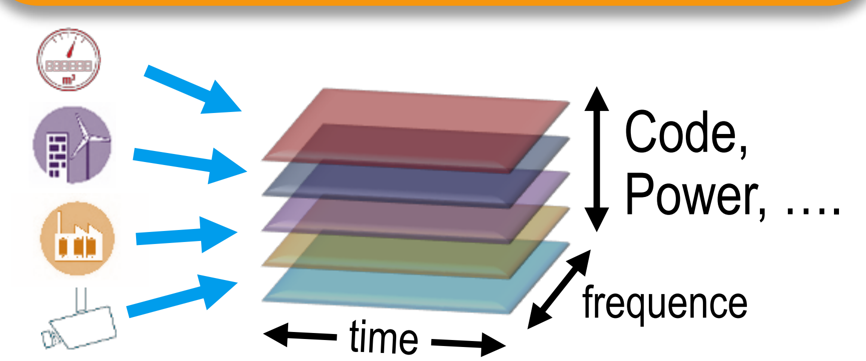
Mobile Edge Computing



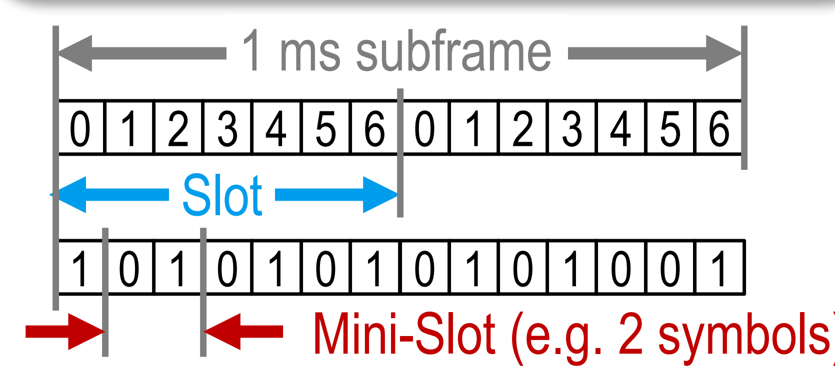
Short TTI



Grant free access



Mini slots



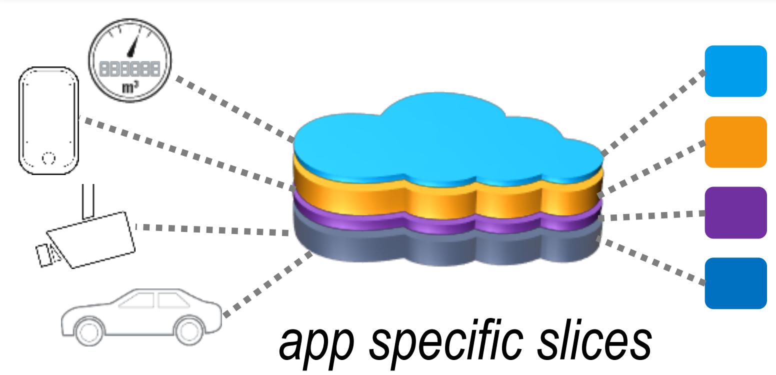
Highly Reliable Communication

Separate network

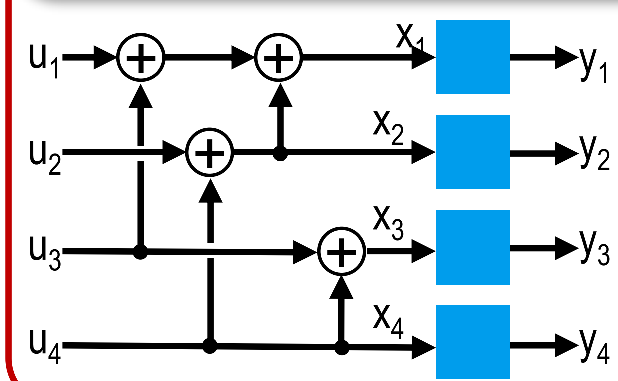
Reduce error rate

Diversity

Network Virtualization

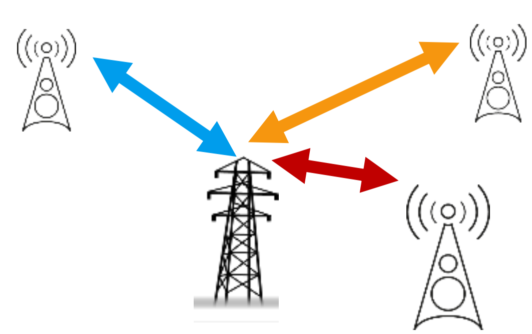


Robust coding



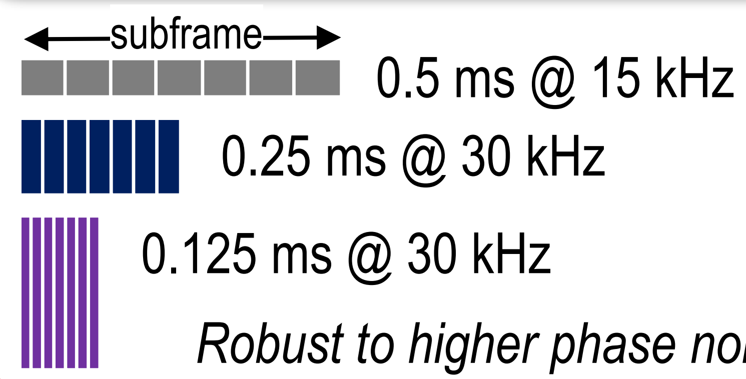
Polar code for short packets

Coordinated multipoint comm.



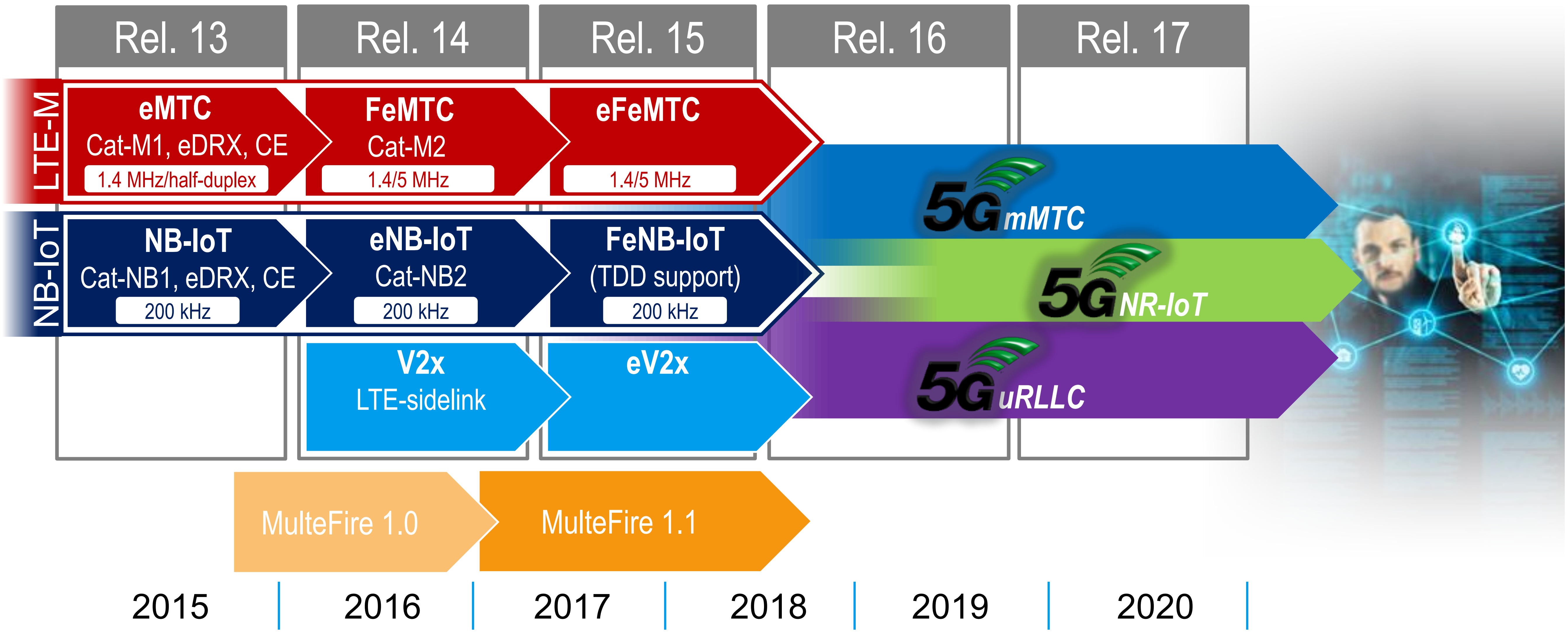
Diversity in frequency and space

Higher sub-carrier spacing



Robust to higher phase noise

On the road to 5G, we are just starting !

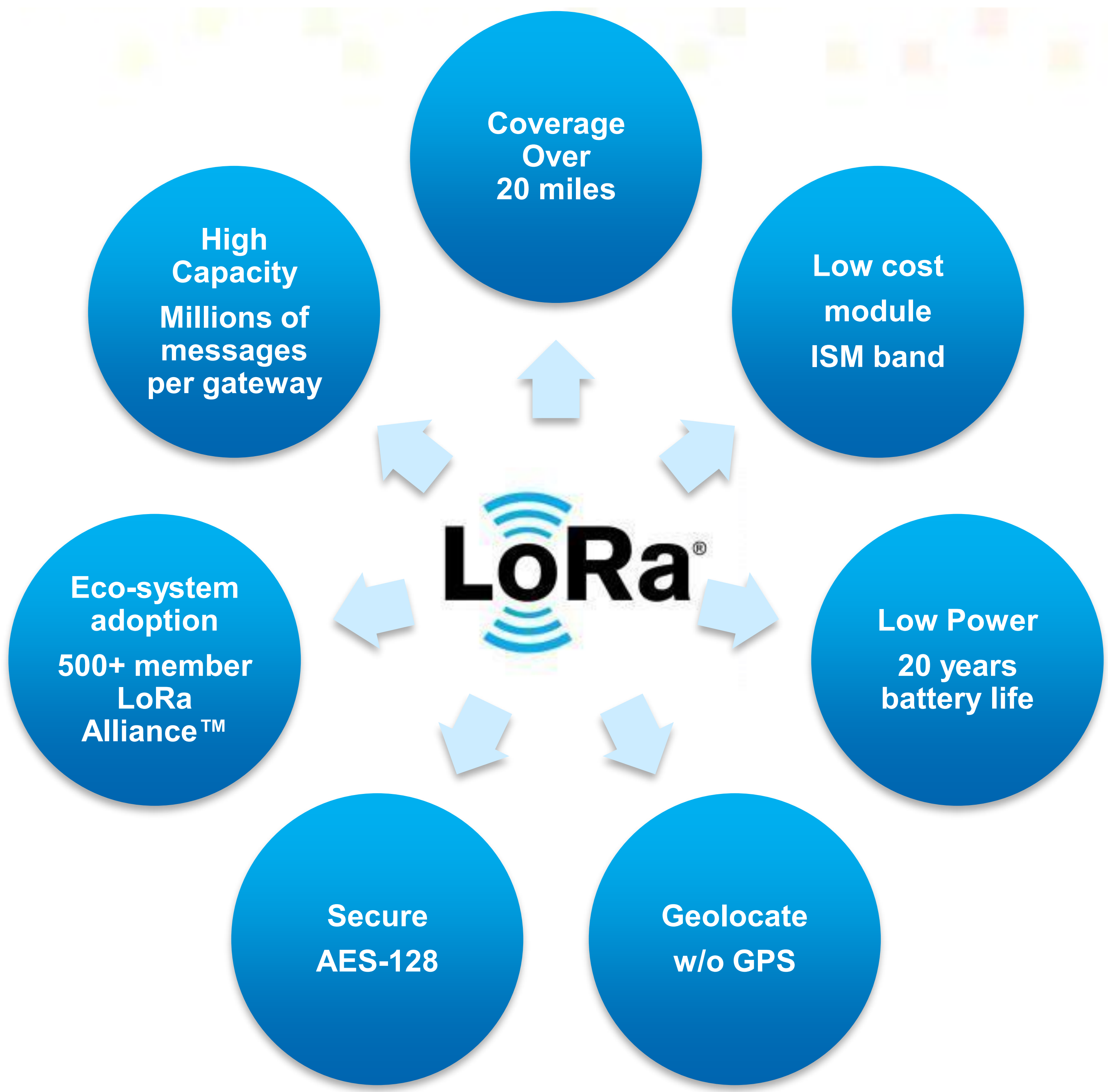


LP-WAN technologies in ISM/ SDR bands shaking the market

	sigfox	LoRaWAN	INGENU simply genius	WEIGHTLESS-N	WEIGHTLESS-W	WEIGHTLESS-P
Technique	Ultra Narrow Band (UNB)	Chirp Spread Spectrum	DSSS RPMA	Ultra Narrow Band (UNB)	DSSS	Narrow Band (NB)
Modulation	UL: DBPSK DL: GFSK	Frequency Chirps	UL:DBPSK DL:DBPSK	UL:DBPSK DL: -	16-QAM…. DBPSK	GMSK, QPSK
Channel BW (UpLink)	ETSI: 100 Hz FCC: 600 Hz	125 kHz 250 kHz 500 kHz	1 MHz	200 Hz	6/7/8 MHz	12.5 kHz
Band	ISM/SDR < 1 GHz	ISM/SDR < 1 GHz	ISM/SDR 2.4 GHz	ISM/SDR < 1 GHz	TV white space 470-790 MHz	ISM/SDR < 1 GHz
Driver	sigfox	SEMTECH	INGENU simply genius	nwave	neul	M2COMM

LoRa

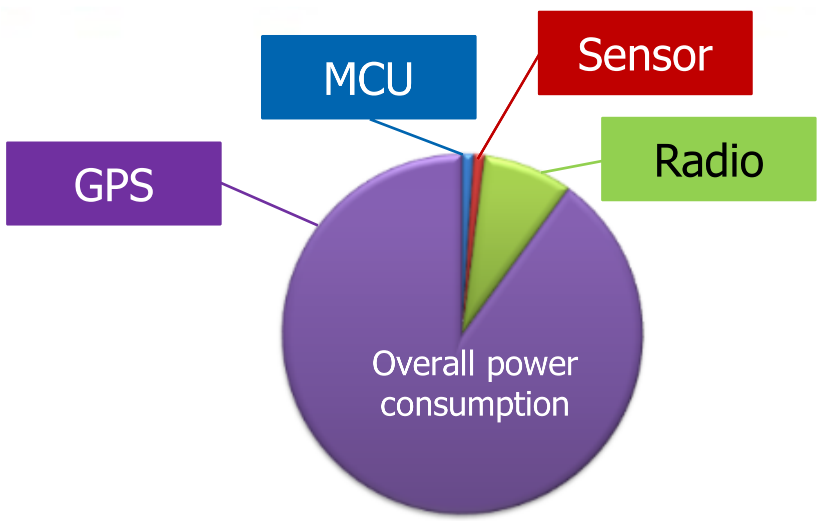
LoRa Vision


Coverage
Over
20 miles
Low cost
module
ISM band
Low Power
20 years
battery life
Geolocate
w/o GPS
Secure
AES-128
Eco-system
adoption
500+ member
LoRa
Alliance™
High
Capacity
Millions of
messages
per gateway
LoRa®

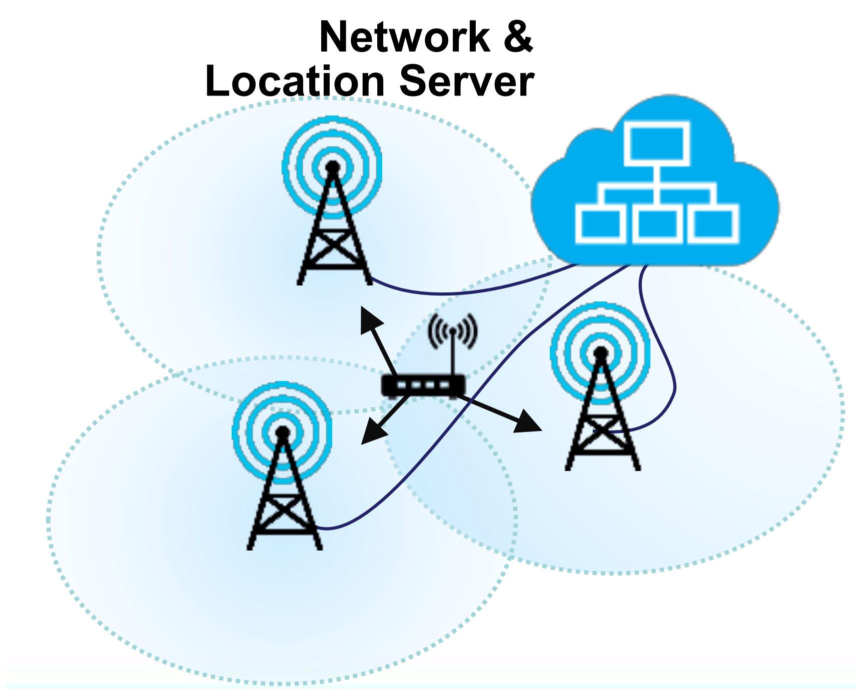
LoRa Brief History

- 2012: Semtech acquires Cycléo (Grenoble)
- 2013: Launch of first LoRa radio by Semtech
- 2014: First mobile network operator trials
- 2015:
  - Launch of LoRa Alliance
  - Multiple sensors, gateways, modules available
  - Public, private, hybrid network deployments
- Today:
  - Over 500 LoRa Alliance members
  - Low power geolocation

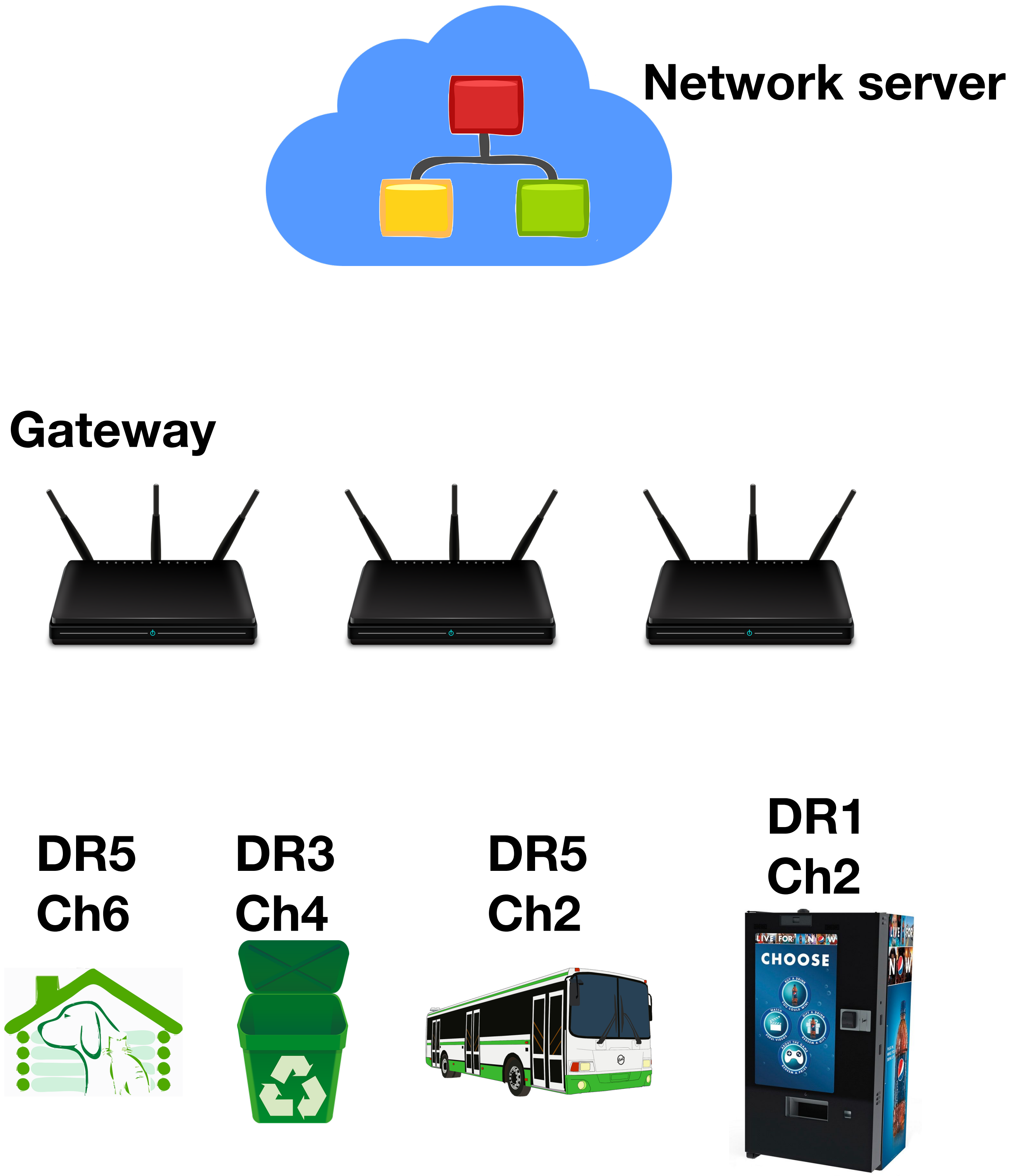
LoRa geolocation feature



Low Power | **GPS-free location** | **Optimize operations**



LoRaWAN Network



Multi-channel gateways

- Simultaneous reception of messages
- Scalable capacity
- Indoor or outdoor
- Adaptive data rate
- Supports geo-location

LoRaWAN sensors

- Smart building
- Smart city
- Agriculture
- Supply chaine
- Smart energy
- Insurance
- Smart health

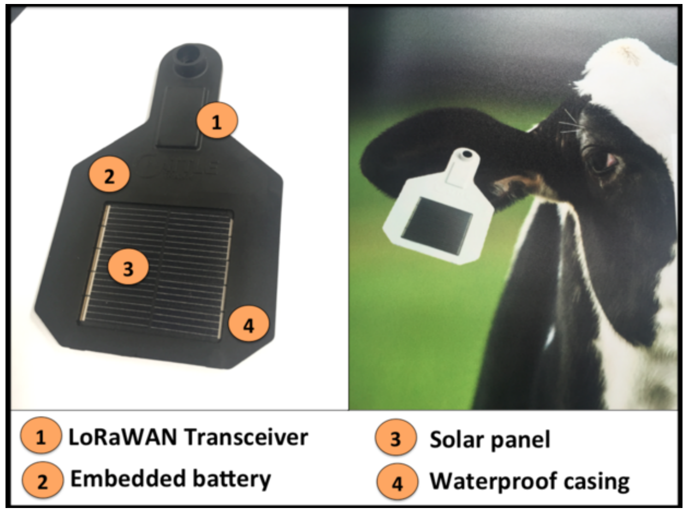
LoRaWAN examples

Parking sensor

Asset Tracker

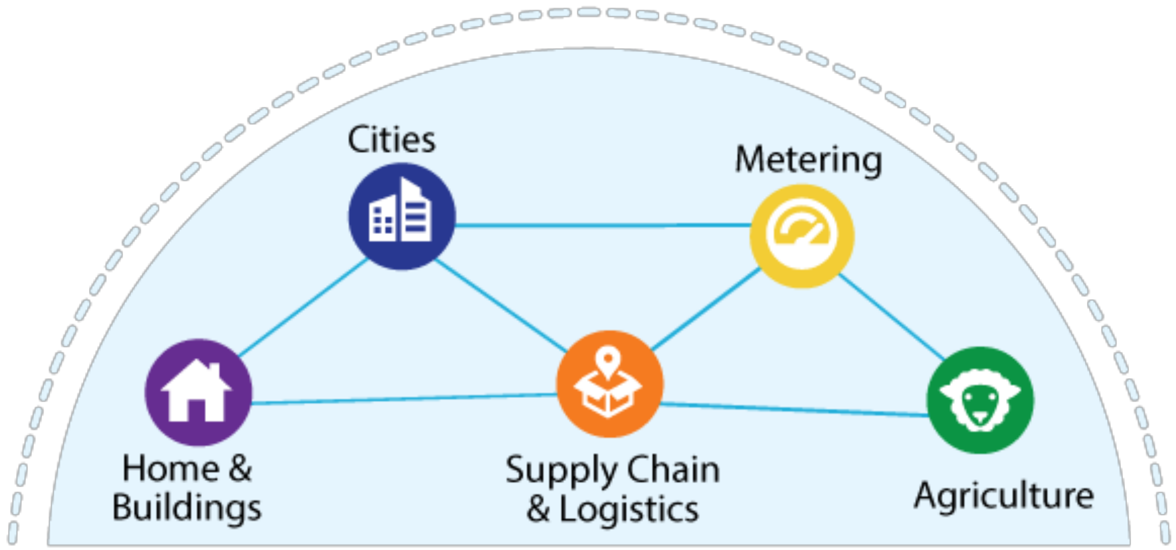
Smart meter

https://www.youtube.com/watch?v=2m9nAAv7GM4



Cattle monitor

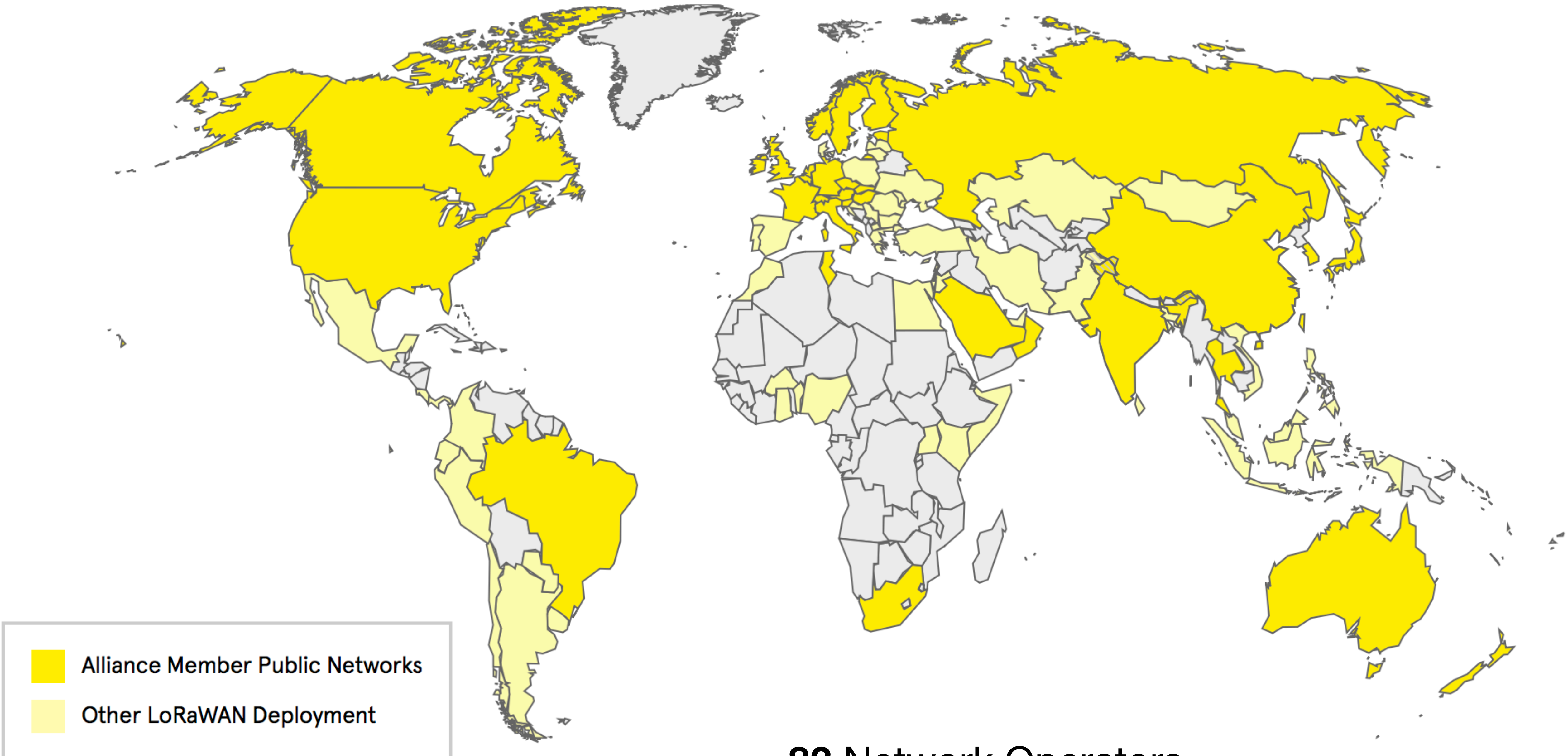
Leak detection



LoRaWAN for sensor nodes

- LoRaWAN specification defined by the LoRa Alliance
- Open source stack for ARM Cortex-M MCUs
- Portable to other MCU or CPU architectures
- Option 1: GitHub
  - https://github.com/Lora-net/LoRaMac-node (Master & develop branches)
  - http://stackforce.github.io/LoRaMac-doc/ (Documentation)
- Option 2: ARM mbed
  - https://developer.mbed.org/teams/Semtech/code/
  - Many sample applications on mbed™ platform

LoRaWAN Coverage

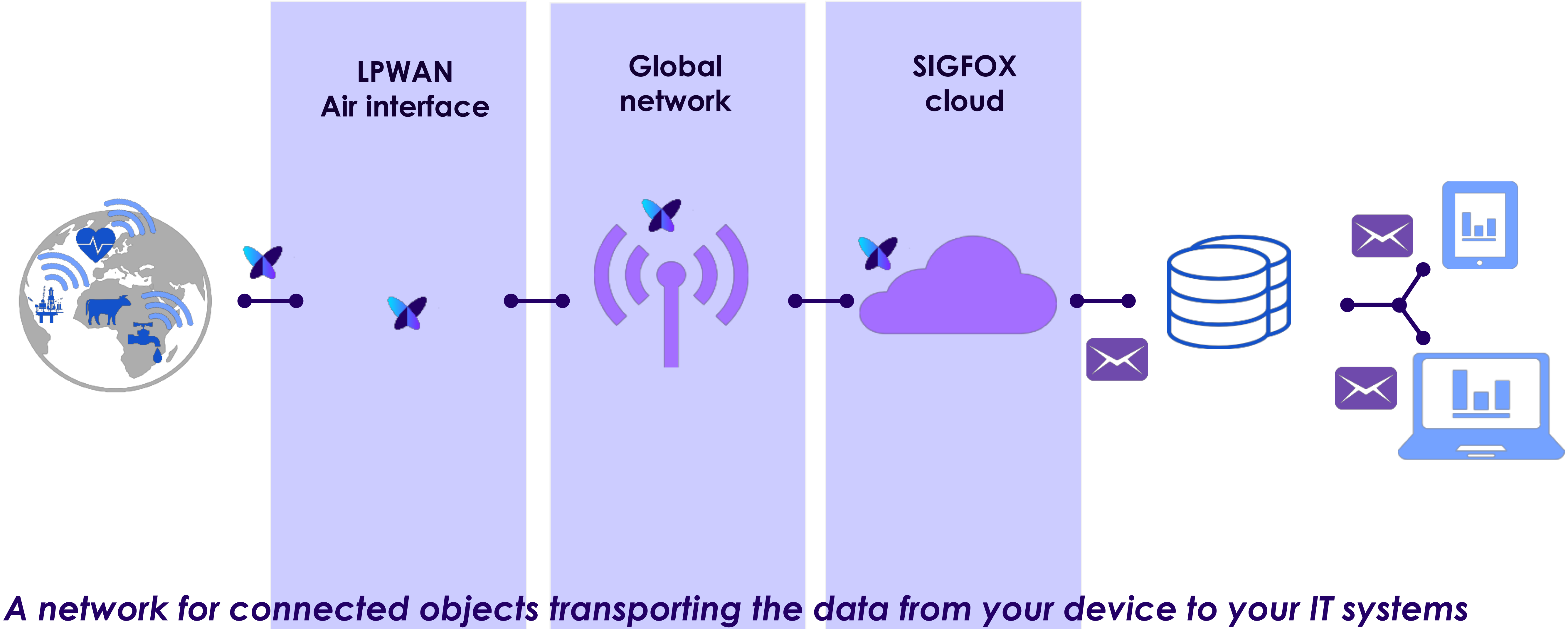


83 Network Operators
57 Alliance Member Operators
49 Countries operating in
95 Countries with LoRaWAN Deployments

SigFox

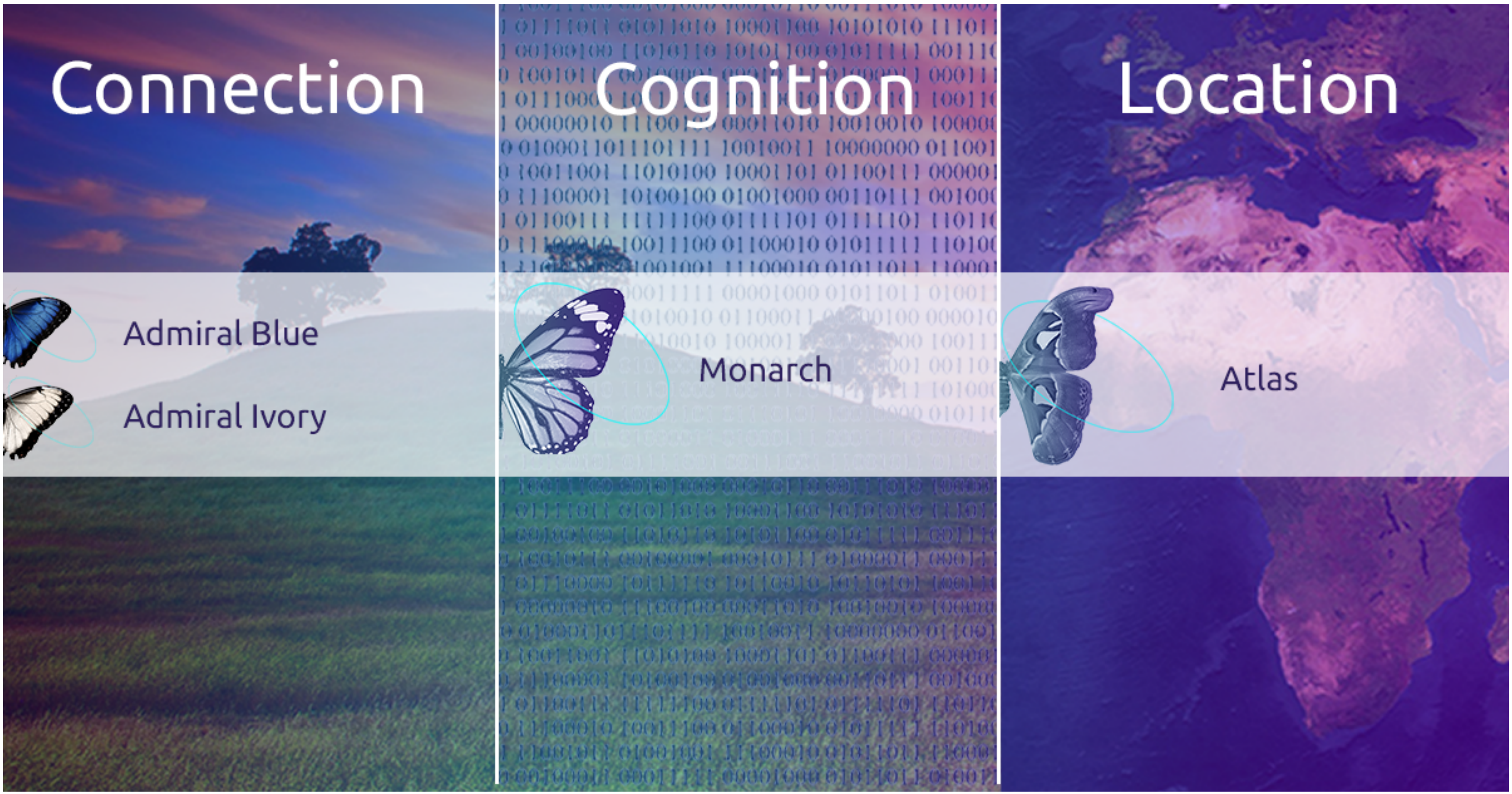
Make Things Come Alive

What it provides ?



A network for connected objects transporting the data from your device to your IT systems

SigFox services

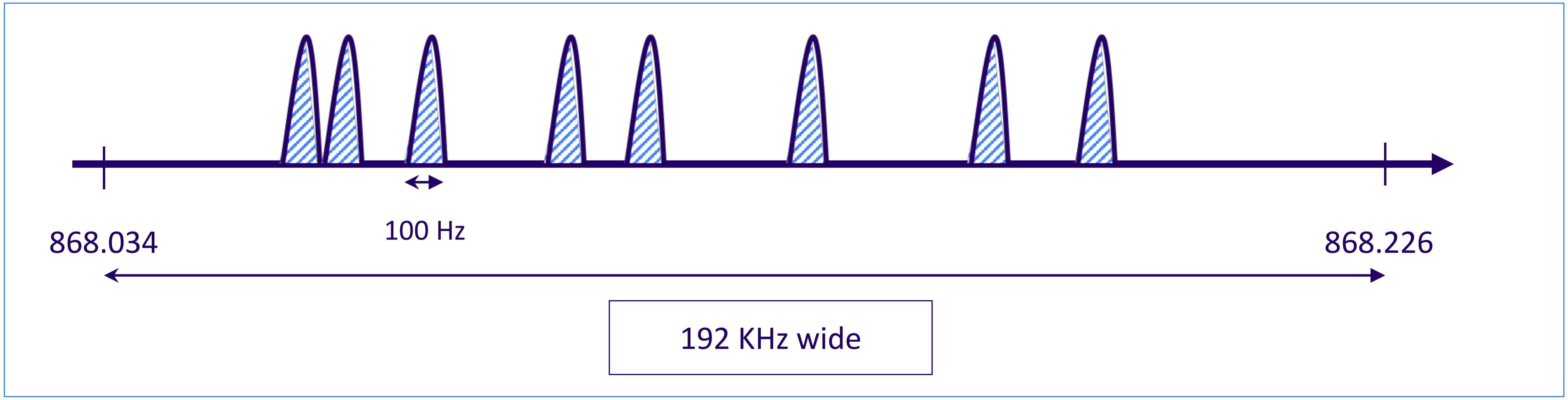


SigFox Technical Details

- Ultra Narrow Band
- Random Access
- Cooperative Reception
- Small messages
- Security

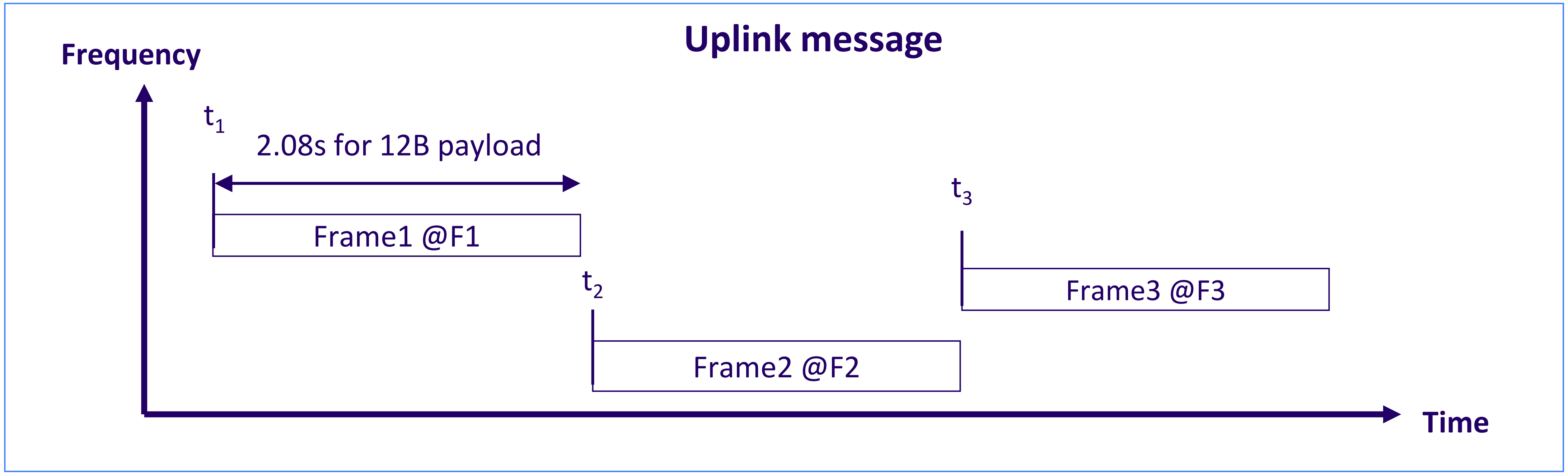
Ultra Narrow Band

- Currently spreads on a 200KHz part of the spectrum
- High spectrum efficiency 1bit/s = 1Hz of bandwidth
- Each message is ~100Hz wide



Random Access

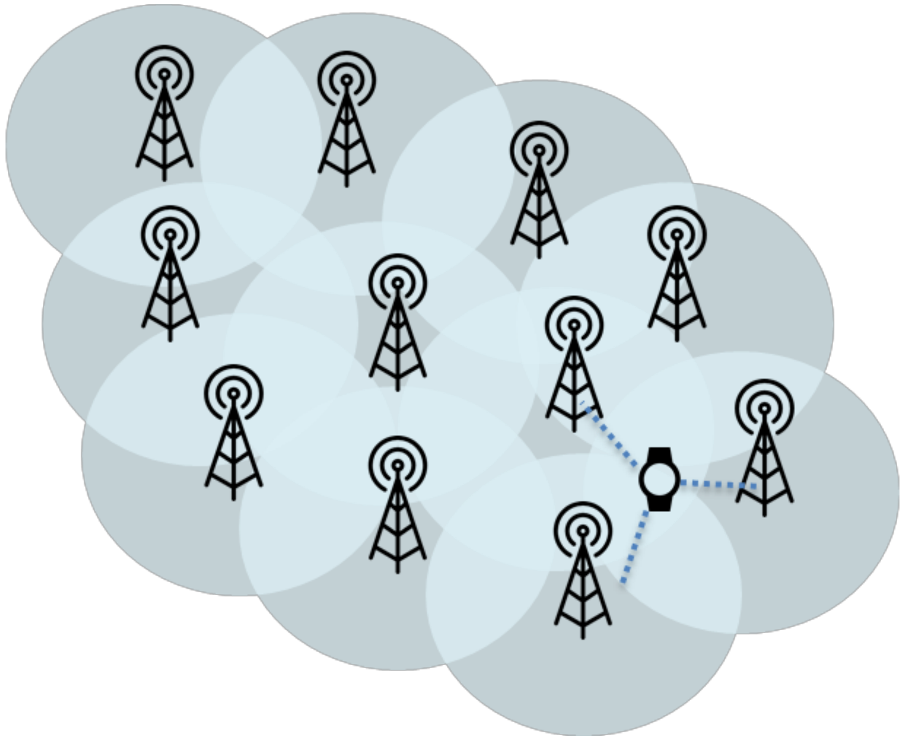
- Unsynchronized transmission between the network and the device
- The device transfers a small amount of energy on a random frequency with no protocol overhead (frequency hopping)
- SIGFOX Base stations permanently listen to the spectrum and interpret received UNB signals
- The same frame is sent 3 times enabling time and frequency diversity



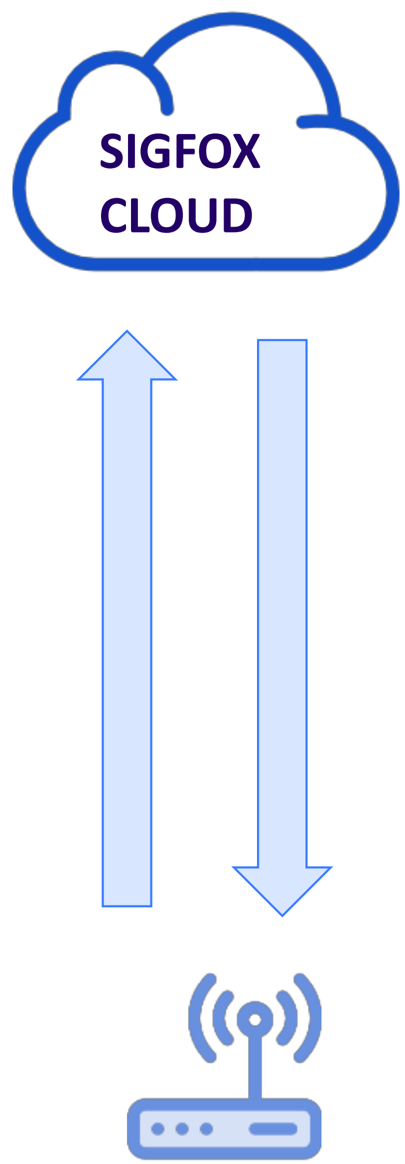
Cooperative Reception

- The radio planning is done in a way that in average a message is received by 3 different Base stations

- The spatial diversity increases the chances of receiving the message without errors on one of the nearby base stations



Small Messages



UPLINK
12-Byte payload

- Sensor data
- Event status
- GPS fix
- Application data

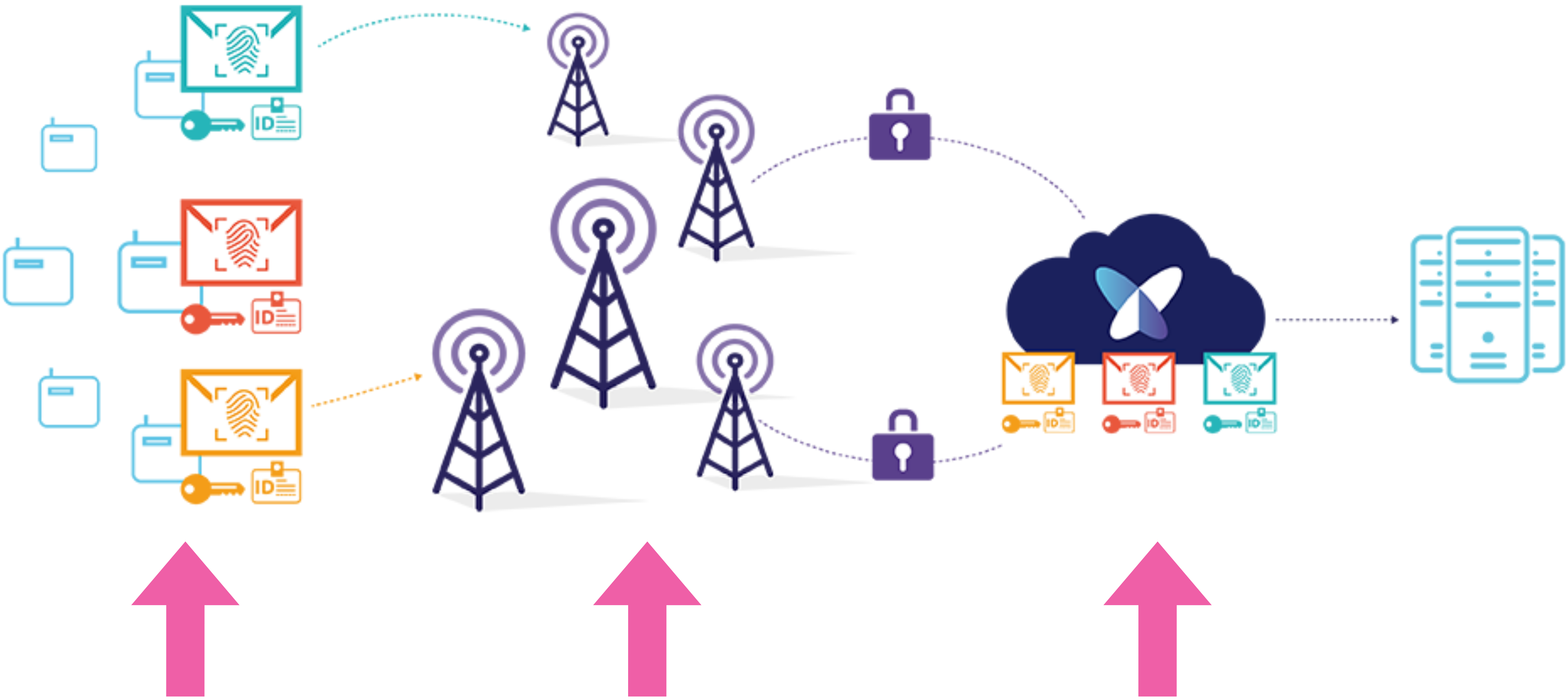
DOWNLINK
8-Byte payload

- Action / actuator trigger
- Device management
- Application parameter setting

1 % duty cycle for Objects
Up to 6 messages/hour

10 % duty cycle for Base Stations
4 guaranteed downlink msg/day

Security



- Sigfox ReadyTM device not connected thru IP
- payload cyphering and secure element as an option

- Random frequencies.
- anti-jamming

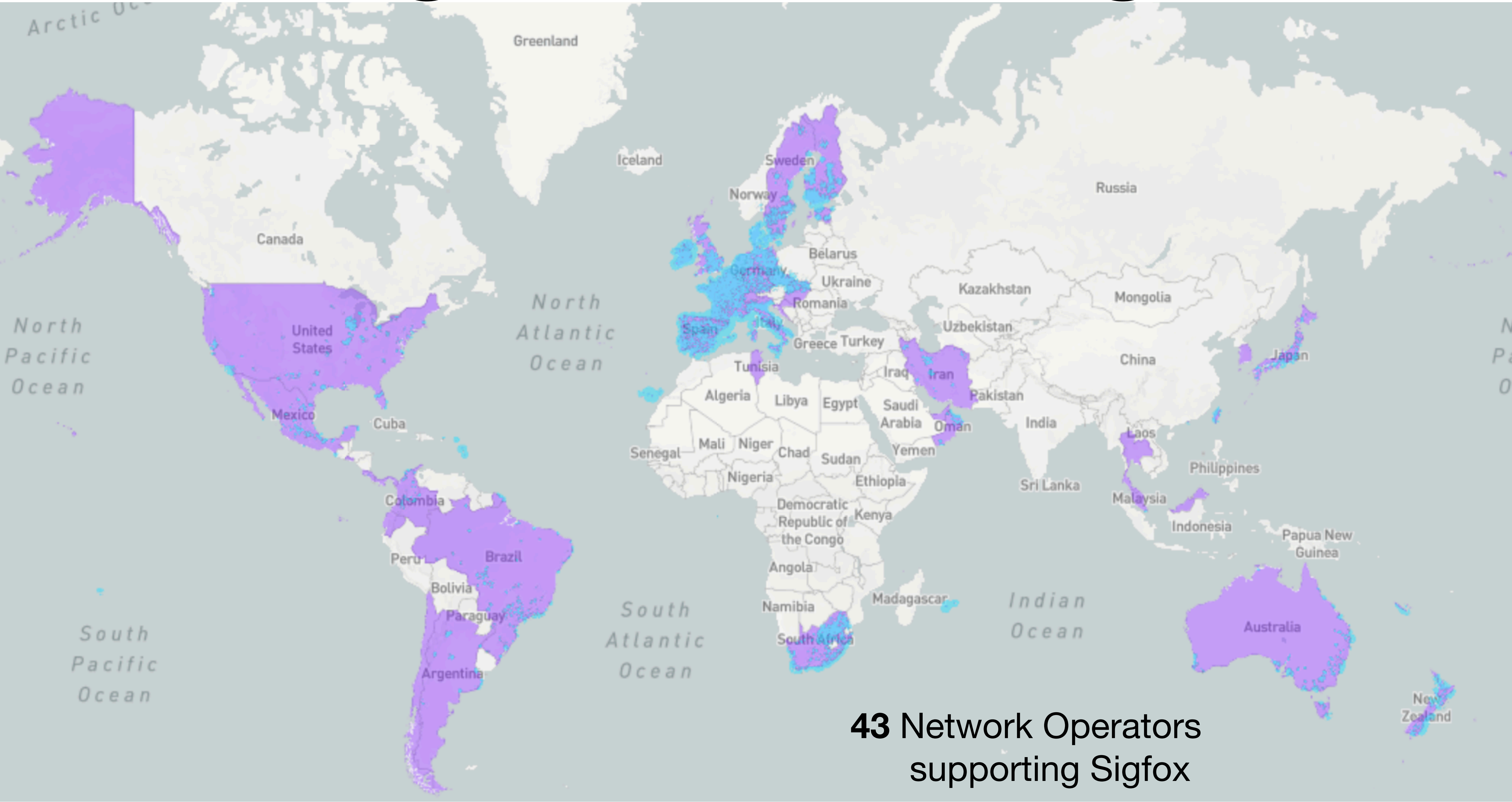
- Secure transmission
- Authentication and Integrity
- Anti replay

Use cases

Assets Management and Tracking Freight Monitoring	Air Liquide, AIRBUS, evian
Smart Building Management Office management Smart metering	COFELY Services GDF SUEZ, water-link, CSM Connected Space Management, HXPERIENCE Like Never Before
Infrastructure monitoring Preventive maintenance	Air Liquide, SNCF, GRTgaz
Customer satisfaction	VINCI Airports
Security as a backup Stolen vehicle recovery	TRAQUEUR, Securitas Direct

https://www.youtube.com/watch?v=WUIrsOfzLqk

SigFox Coverage



43 Network Operators supporting Sigfox

Useful links

- sigfox.com for general and coverage information
- partners.sigfox.com for existing solutions ranging from RF modules to application platforms
- resources.sigfox.com to access useful documentation and ask questions
- build.sigfox.com a guide for building a device from design to industrialization

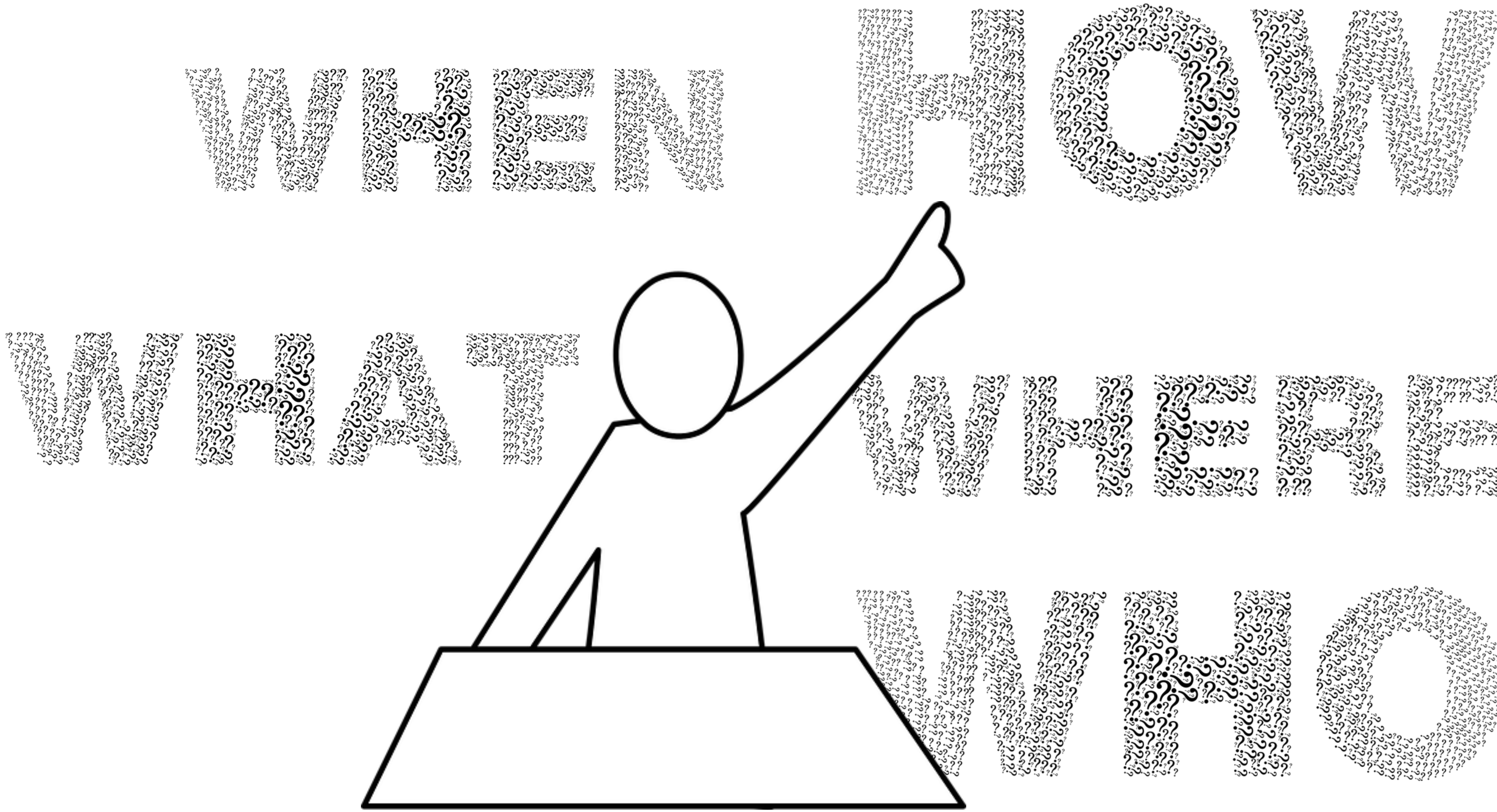
TP 3
HANDS ON INTERFACE RF SUB 1GHZ

04

Communication entre micro-contrôleurs

- 2 binômes par groupe
- Test de code sur dépôt git
- Implémentation de protocole simple
- Implémentation sécurité

Questions ?



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