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The Internet Of Things
C5 : LPWAN Sigfox & LoRa

2 French technologies

3

sigfox

- Created in TOULOUSE (FRANCE) in 2009
- FRANCE fully covered since 2013
- Found rising
  - 15M€ in 2014
  - 100M€ in 2015
  - 150M€ in 2016
- Hardware device solution from most of the silicon vendors
- 72 countries deployed and seen as a single global network (as of Nov. 2020)
- Acquire by Unabiz in 2022.

LoRaWAN™

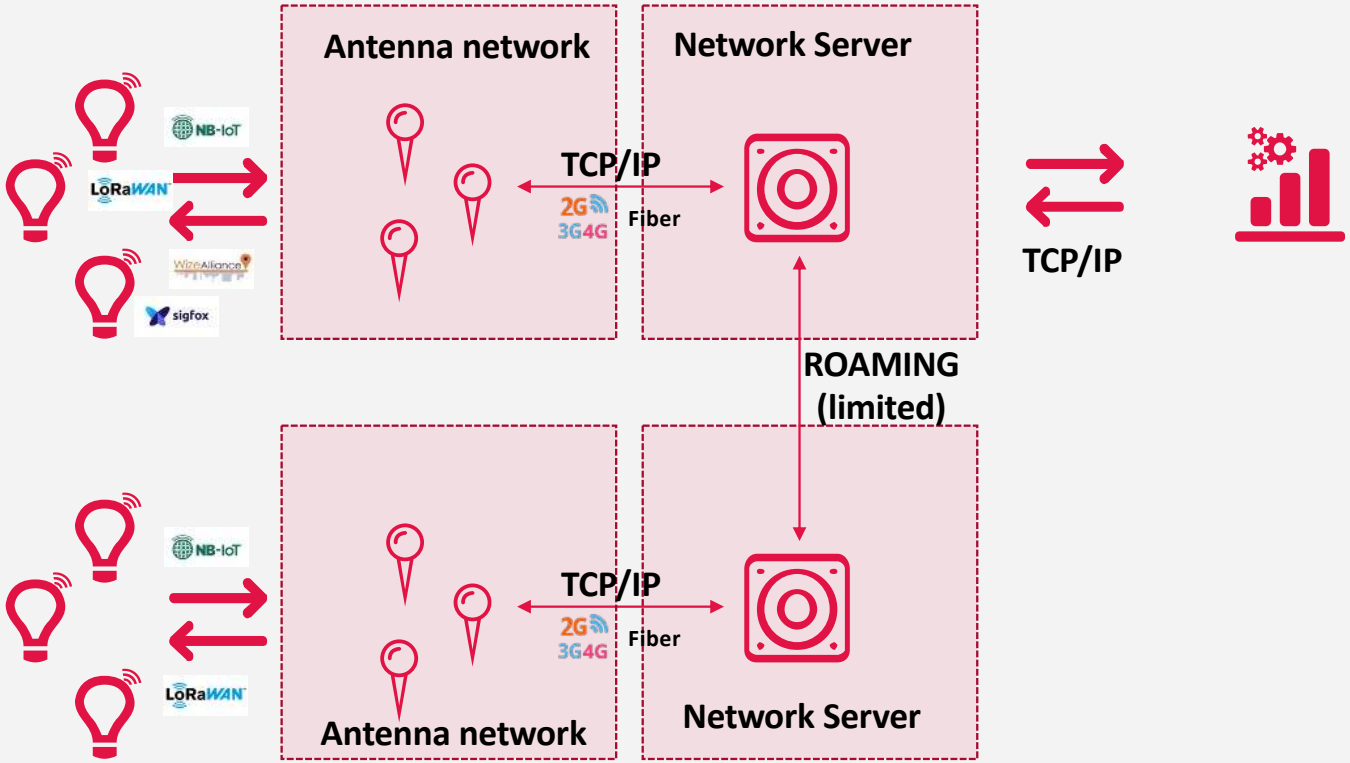
- Created in GENOBLE (FRANCE) in 2009
- Acquired by SEMTECH in 2012 for a price range between 5M$ and 25M$
- SEMTECH is a Silicon vendor with an exclusivity. 1 licence acquired by St Microelectronics.
- LoRaWan 1.0 released in 2015
- Deployed by about only 5 telecom company nation wide.
- Thousands of private networks
  - TTN – crowdsourced global network
  - HELIUM – crowdsourced global network as a blockchain

LPWAN have a common architecture

The devices messages are captured by multiple antennas around.

The antennas forward the messages to a network server owned by the network operator (private or public)

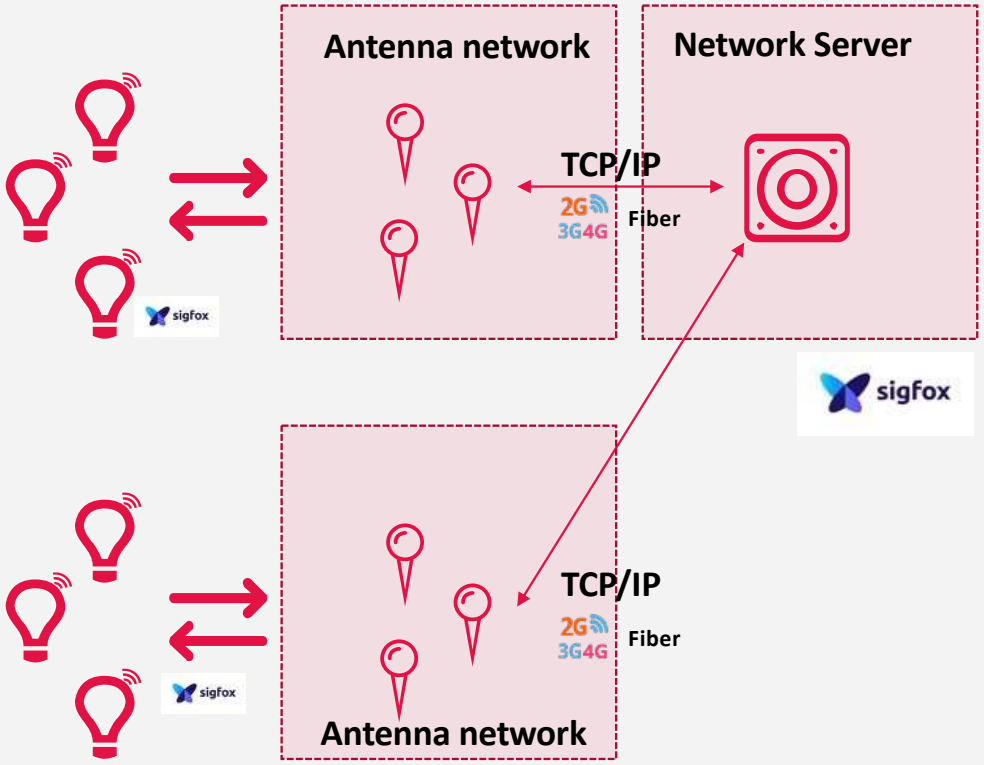
Then the network server transfers the payload to the custom backend, eventually, roam it to another network server.



LPWAN have a common architecture

Sigfox is a particular case with a World-Wide network and a single Network Server

72 countries
1.1B people



4

Save power: don’t be connected

Compared to classical communication network, LPWAN are using non connecter mode. It means a device can deep sleep for month, wake up, fire a message and back to sleep.

This means a lot of power saving and a strong resilience against jamming.

Network do not have edge access control, but centralized control managed by network server.

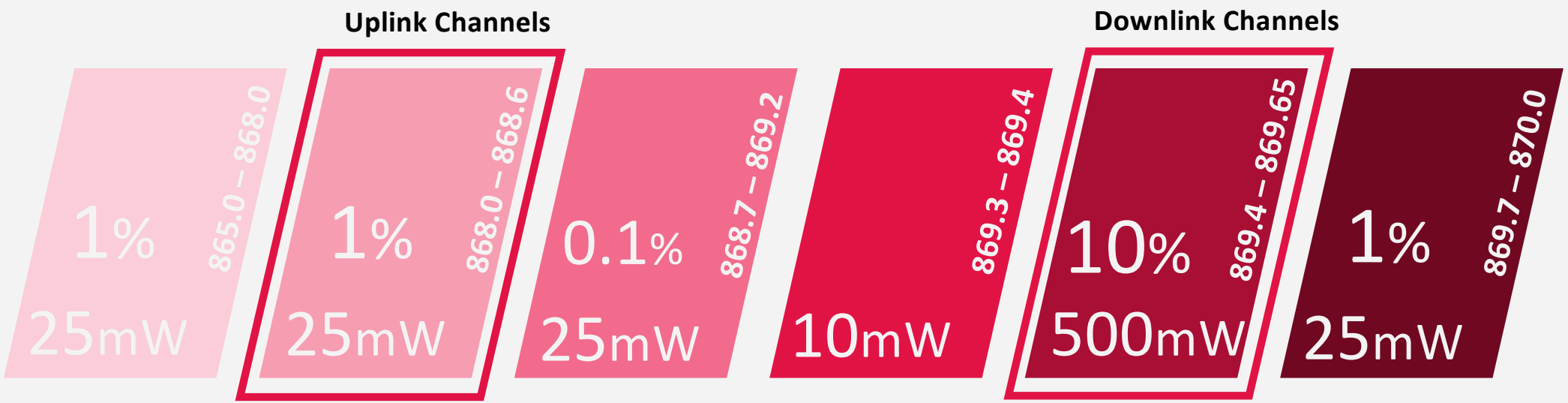
Shared radio band

SIGFOX & LoRaWan are using ISM bands, they are free for use in condition you respect rules defined by the regulation. This regulation differ in the different zones. The purpose is the same, share the radio band in a balanced way between the user.
In Europe, the rule is to limit communication to 1% of the time per device. In North America it's to not transmit on the same channel for more than a given time.

9

European regulation on 868MHZ ISM band

865Mhz-870 Hz



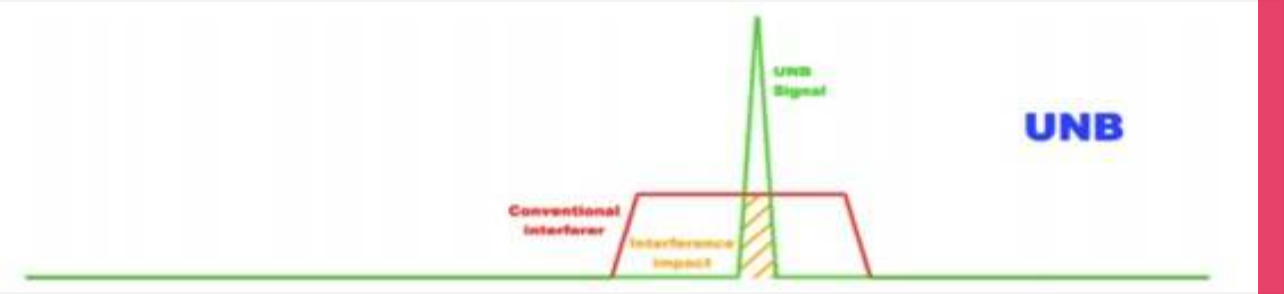
European regulation is defined by different laws like ERC-REC-70-03E for EUROPE and the application in FRANCE is based on ARCEP 2012-0612 and 2014-1263 published on JORF 30/01/2015.

It limits the transmission time for any equipment to a certain percentage of the time during a sliding hour. This proportion of time depends on the frequency band. This is what we named DUTY-CYCLE. This is the percentage value in the above description. It also limit the transmission power.

https://www.disk91.com/2017/technology/internet-of-things-technology/all-what-you-need-to-know-about-regulation-on-rf-868mhz-for-lpwan/

Etre entendu sur de très longues distances malgré le bruit ambiant

2 approches différentes pour 1 même objectif



SigFox – Ultra Narow Band

Emettre un signal sur une bande de fréquence la plus fine possible pour ainsi maximiser la puissance en un point et passer au dessus du bruit.

LoRa – Etalement de spectre

Emettre un même signal sur plusieurs fréquences pour « contourner » les bruits

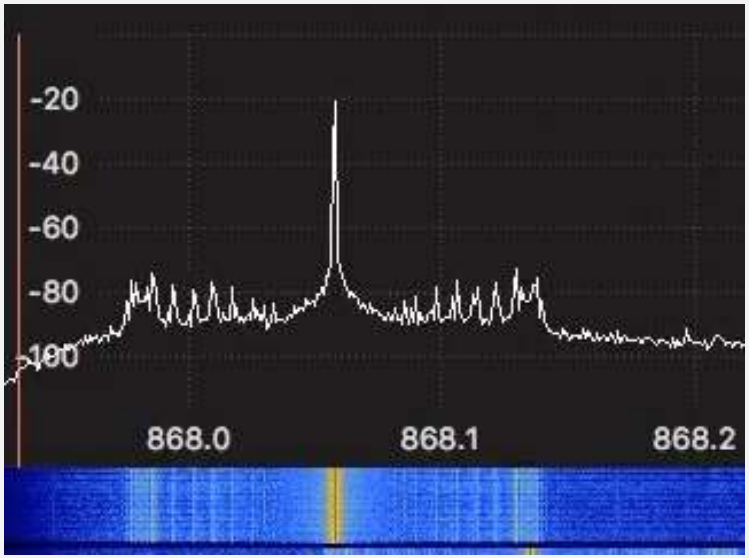
sigfox

Is an asymmetric technology

The technology use for transmitting data is simple when the technology required to receives Sigfox messages is highly complex and based on Software Defined Radio.

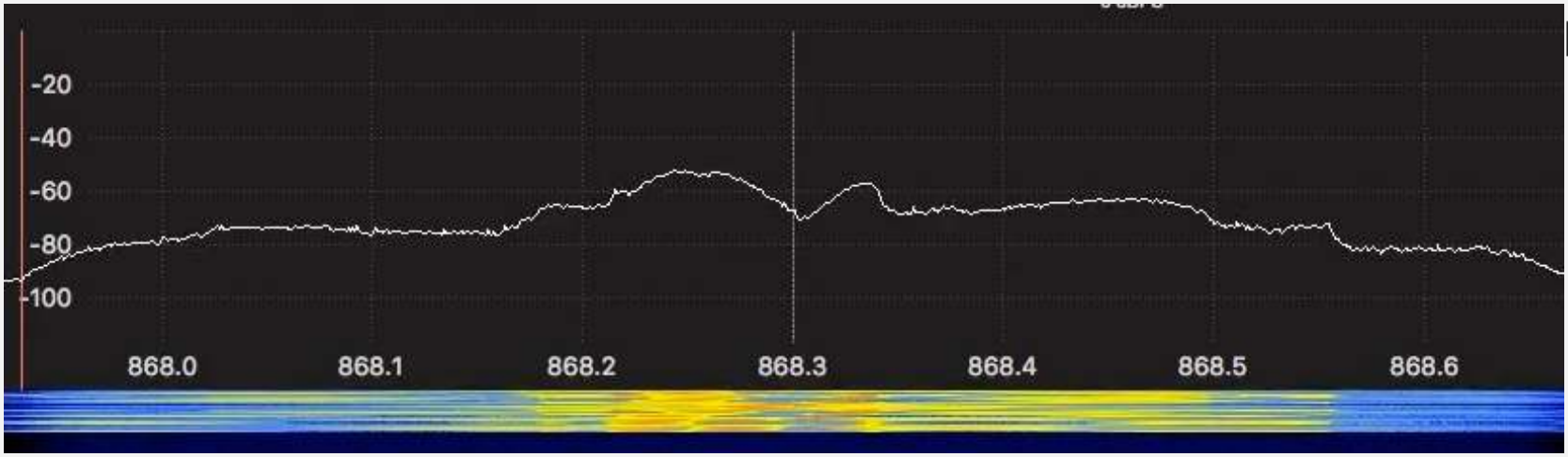
Is a symmetric technology

Transmission and reception are based on the same technology and complexity level.



sigfox

The radio technology is totally different for reaching the same goal



LoRa

7

https://www.disk91.com/2017/technology/internet-of-things-technology/learn-about-sigfox-and-lora-radio-technologies/

Let’s make a short break

LEARNING AT THIS STEP

1

LPWAN SIGFOX & LoRaWAN ARE 15 YEARS OLD NOW

Both has been created in FRANCE and now deployed all over the World

2

THEY RELY ON ISM BAND TO BE DEPLOYED AT LOW COST

This means respecting regulation rules in place to share the ISM band between all the different technologies using it.

3

THE TECHNOLOGIES BEHIND ARE DIFFERENT

But they are reaching the same goal: allowing to communicate over long distance with a minimum of energy

Sigfox, one IoT network to cover the entire World

sigfox

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An asymmetric network

The technology use for transmitting data is simple when the technology required to receives Sigfox messages is highly complex.

A Software Defined Radio Network

Simplicity and efficiency

ISM BAND (free of access)

Use of 868MHz band in Europe, Africa. 902MHz -920 MHz in North, South America and Asia. In each of them the exact frequencies differ.

LOW POWER / WIDE AREA

With only 14dBm in Europe, the coverage is 60km. Distance record was 1023km from Spain to Eire in 2016. Only 1000 antennas allows to cover most of a country like FRANCE. Compared to 4000 for LoRaWan and 50.000 for 4G

LOW THROUGHPUT

Transmission is limited to 100 **bits** / seconds in Europe and up to 600 **bits** / seconds in North America. This is related to the different regulations.

FIXED PACKET LENGTH

User payload limited to 12 byte per frame. Only available options are 0, 4, 8, 12 bytes.

BI-DIRECTIONAL

Devices can receive message from the network (DOWNLINK) up to 4 times a day, right after an uplink communication. A device can request more than 4 downlink per day. Other are best-effort only.

REGULATION APPLICATION

The application of the regulation is under the device maker responsibility. You can transfer up to 6 consecutive frames in Europe if you want.

Sigfox over the technology

Sigfox is at first a global, world-wide telecom operator. Here is a big part of the innovation.

A single device can communicate all over the world without roaming consideration.

Sigfox is deployed in many countries and growing fast

- 72 countries in November 2020
- 5,7M KM2 covered
- 1.3B people covered
- 16M devices connected in 2019

X2 on every 18 Months since 7 years

Reduced “Time to get the first fired frame”

As everything is already defined in the protocol, in a developer perspective, the time to getting started with the Sigfox technology is short. Device design is also simplified and regulation difference have a limited impact in most of the use-cases.

Security and reliability

MESSAGE SIGNATURE

All the messages are signed with an EAS processed and indexed. It proves the emitter identity and allow to reject usurped or replayed messages in a 4096 messages cycle.

ENCRYTION

Clear payload is the default setting. AES-CTR can be activated when the devices has been designed for. It is part of the standard Sigfox lib. Sigfox is complex to receive for real: open-source receivers are only working under 2 meters.

JAMMING PROTECTION

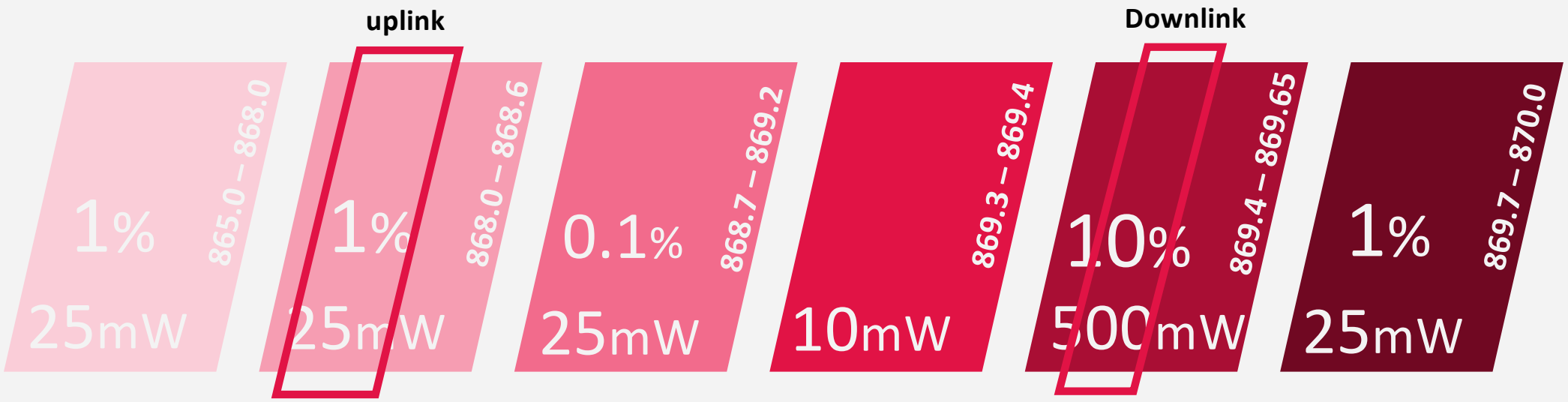
As Sigfox doesn’t require any reception for firing a message it’s really complicated to JAM it. This is one of the reason it has been chosen in Securitas solutions. To jam Sigfox you basically need to jam the different base-station around… forget it.

COMMUNICATION RELIABILITY

Every frame is replicated to get 3 transmissions of the same message on different frequencies. It allows a 99.99xx deliverabilty is the covered zones.

European regulation on 868MHZ ISM band

USE OF 865Mhz-870 Hz

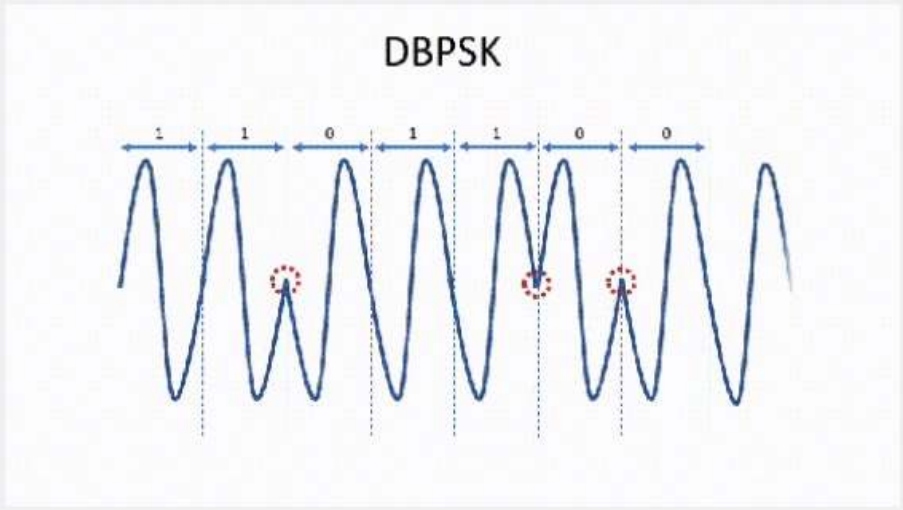


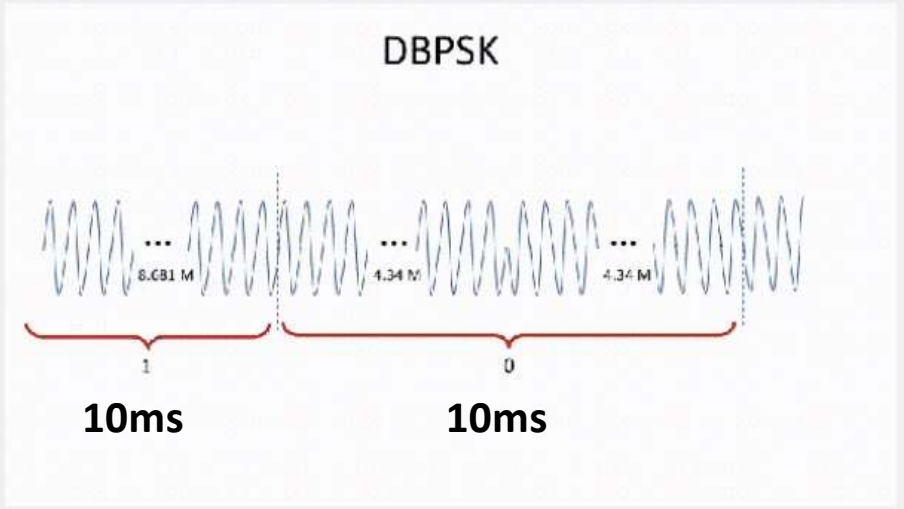
Sigfox only 200KHZ. In Europe it is centered on 868.130MHz. In these 200KHz there are 2000 channel, each of them have a size on only 100Hz

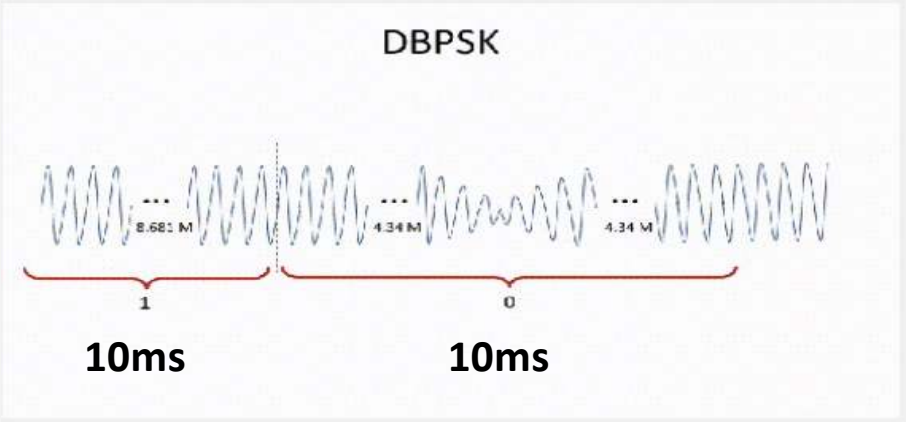
DOWLINK are using a 10% duty cycle band for two reasons:
- A base-station responds to many different devices
- The radio situation for a base-station is better than for a device. You need more power to be received by a device.

SigFox – Transmission radio sur DBPSK

Differential Binary Phase Shift Keying





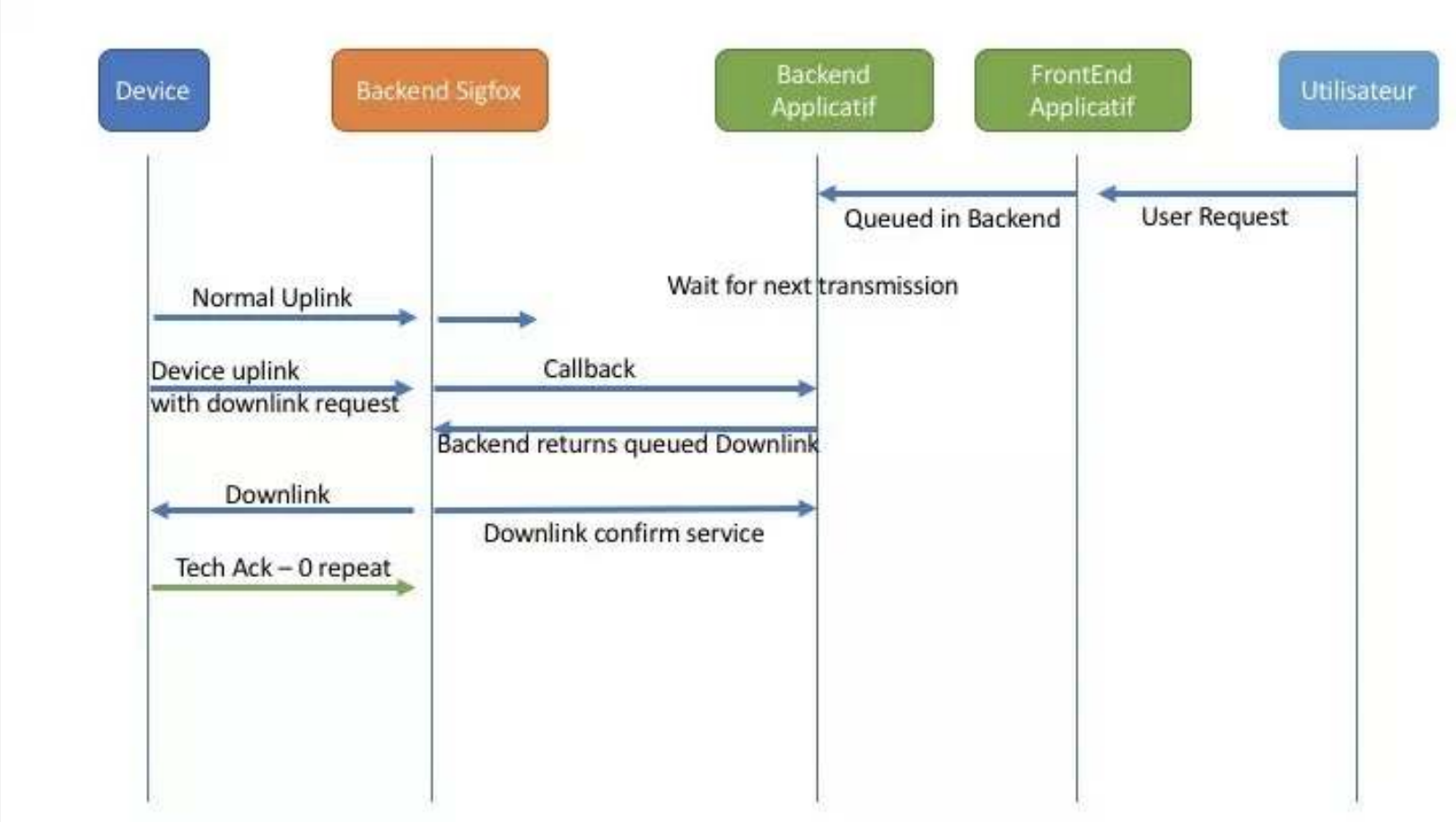


Temps d'une trame:

- 12B : 2,08s
- 8B : 1,76s
- 4B : 1,44s
- 1B : 1,2s

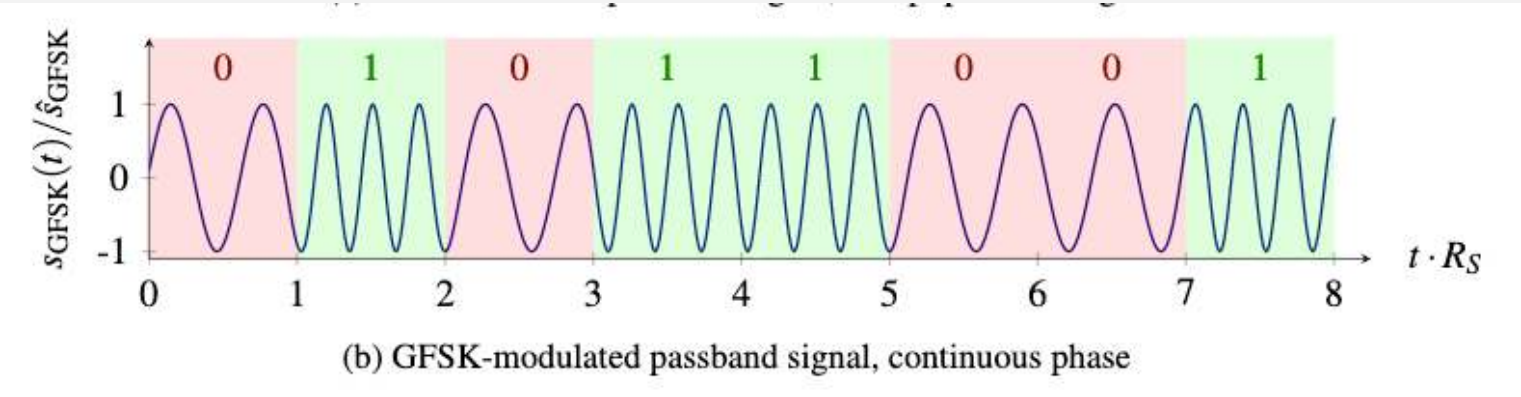
8

Sigfox – Downlink communications



SigFox – Downlink transmission is GFSK

Gaussian Frequency-Shift keying (because a device can't receive DBPSK)



(b) GFSK-modulated passband signal, continuous phase

Symbol rate

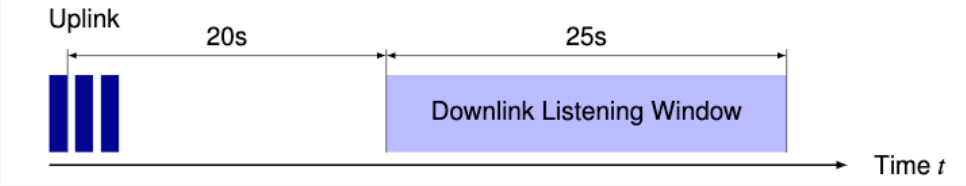
- 600 Bit/s

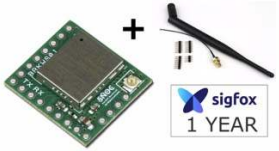
Frequency

- Determined from the uplink message frequency

It works long-range because

- Frequency is 869.4MHz to 869.65MHz
- So the transmission power is 500mW





10

11

Sigfox get benefit of a large ecosystem with hundreds of available devices and tons of device-kit.
Standard radio chip + MCU price starts about $1.5 / Ultra low-cost solution starts at 0,20€ for radio + MCU solution.

https:// partners.sigfox.com
https:// makers.sigfox.com

Devkit includes 1 year of communication

Sigfox has been used to closely work with the startup eco-system even if in the last year they are most focusing on big company & at scale projects

SIGFOX NETWORK SERVER

Also call Sigfox backend. It receives messages and help IoT solution administrator to manage the subscription and device fleet.

Network server is where you link your device with your final application.

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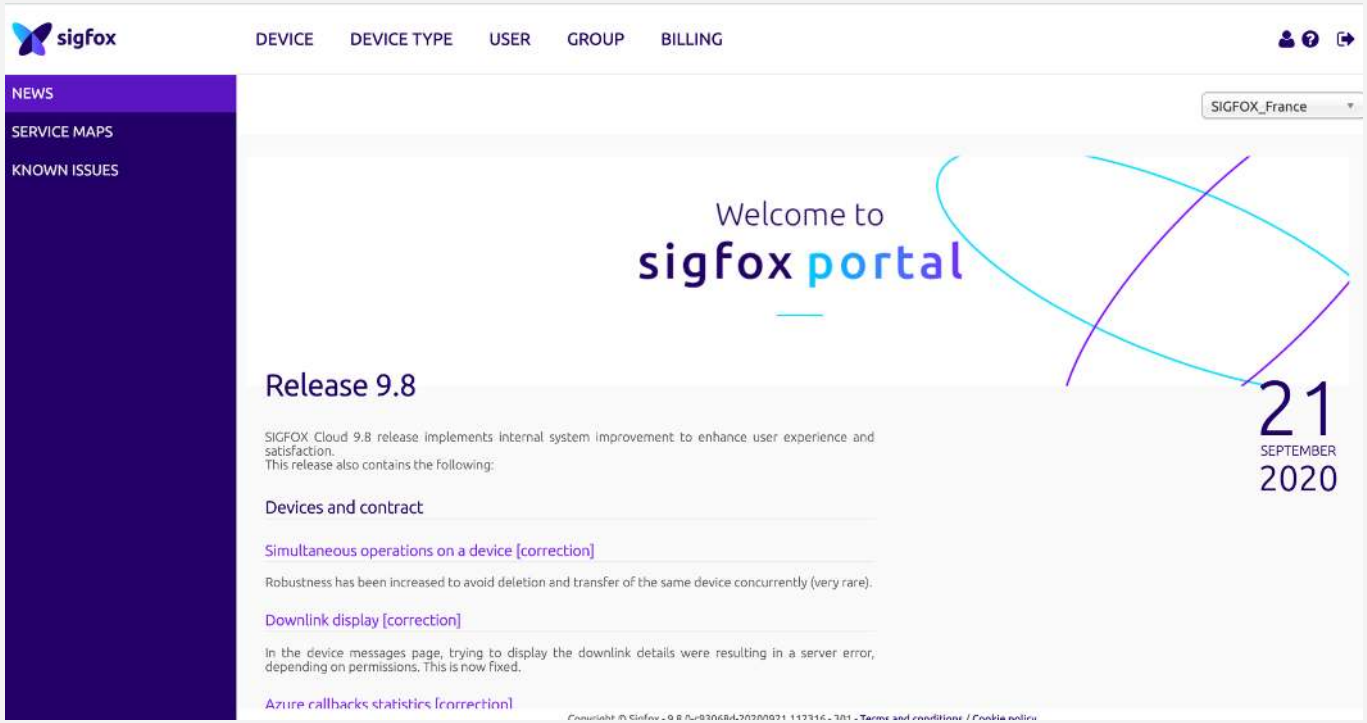


TRACKING USE-CASES

The main Sigfox use-cases in volume are in two domains:

- Security
- Assets tracking

In the domain, Sigfox propose a solution to get a device localization from a single frame based on received radio signal or WiFi signals around. This avoid using a GNSS chip for getting a location.

Precision and compliance vary:

- 1km to 20km for received radio signal
- 30m for WiFi signals when exists

This option is ATLAS.

THE THINGS NETWORK

LoRaWan, many IoT networks deployed on your own

LoRaWAN™

LoRa

A POINT-TO-POINT RADIO COMUNICATION TECHNOLOGY

LoRaWAN®

A NETWORK RUNNING OVER LoRa.

LoRa Numbers (as of Nov 2020)

180.000.000

LoRa compatible transceivers already distributed by Semtech

1.000.000

LoRa based gateway chips sold

This could cover 1,5x the total earth surface and 5x the surface where human live. But the real coverage is … 1-2% ?

POINT-TO-POINT RADIO TECHNOLOGY

ISM BAND (free of access)

Use of 868MHz band in Europe, Africa. 902MHz -920 MHz in North, South America and Asia. In each of them the exact frequencies differ. Each channel is 125KHz large.

LOW POWER / WIDE AREA

With only 14dBm in Europe, the coverage is 15km. Distance record was 832km from a balloon (cheating). Only 4000 antennas allows to cover most of a country like FRANCE.

LOW THROUGHPUT

Transmission is limited to 250 **bits** to 5400 **bits** / s depending on Spread Factor choice, for 125kHz bandwidth. Can be 11kbps for 250KHz.

VARIABLE PAYLOAD LENGTH

User payload can be 59 to 250 bytes depending on Spread Factor and regulation. FCC have a maximum authorized time in the air.

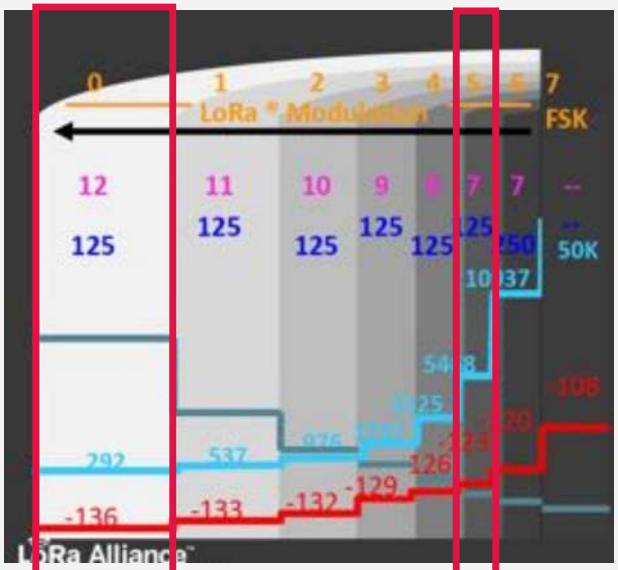
BI-DIRECTIONAL

Devices can receive message from the network (DOWNLINK) right after an uplink communication. Downlink messages are used to ack transmission and to transfer data to the device. Firmware update capability, in certain conditions, has been proven.

REGULATION APPLICATION

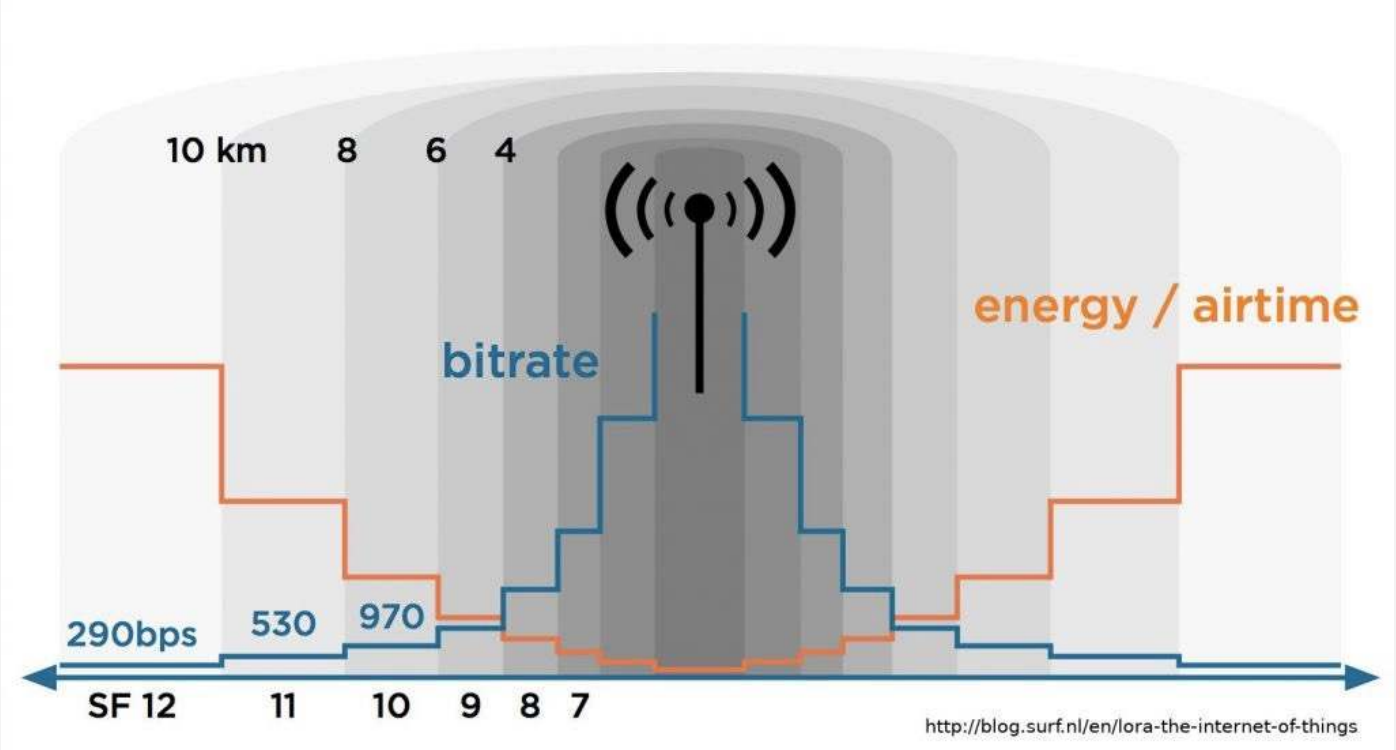
Usually, the regulation rules are managed in the LoRa and LoRaWan stacks. Therefore, what you can do depends on the implementation and the zone you are.

SPREAD FACTOR – SPEED AND COVERAGE

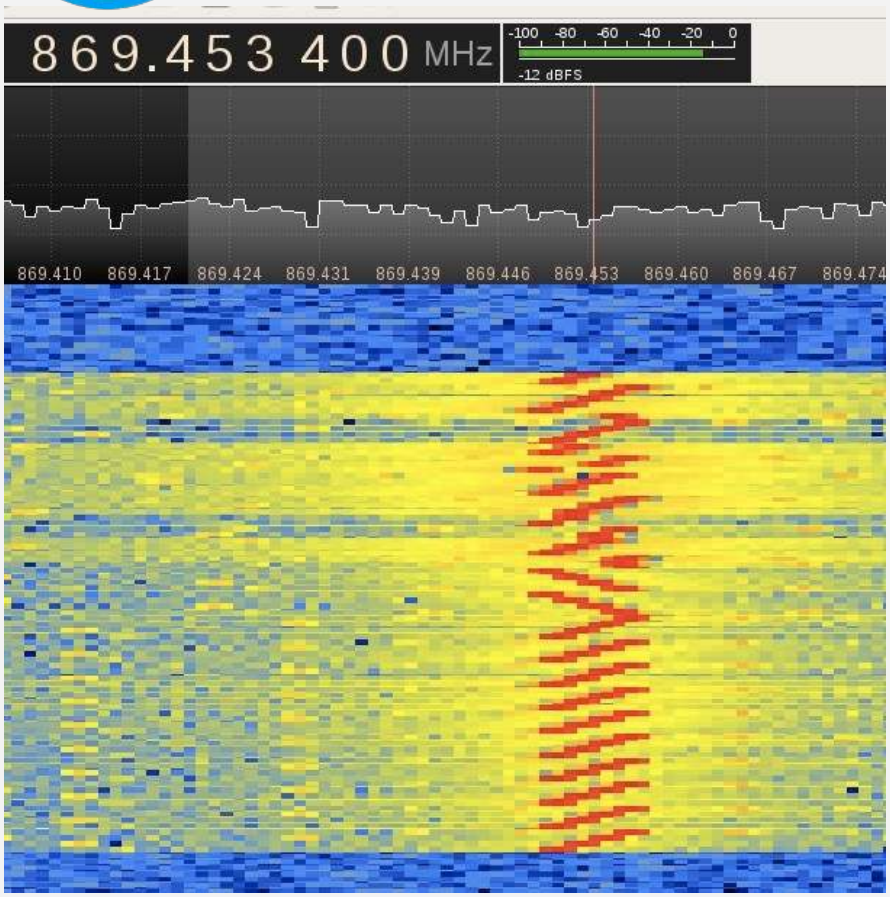


SF12
250bps
-136dBm
sensitivity

SF7
5400bps
-133dBm
sensitivity

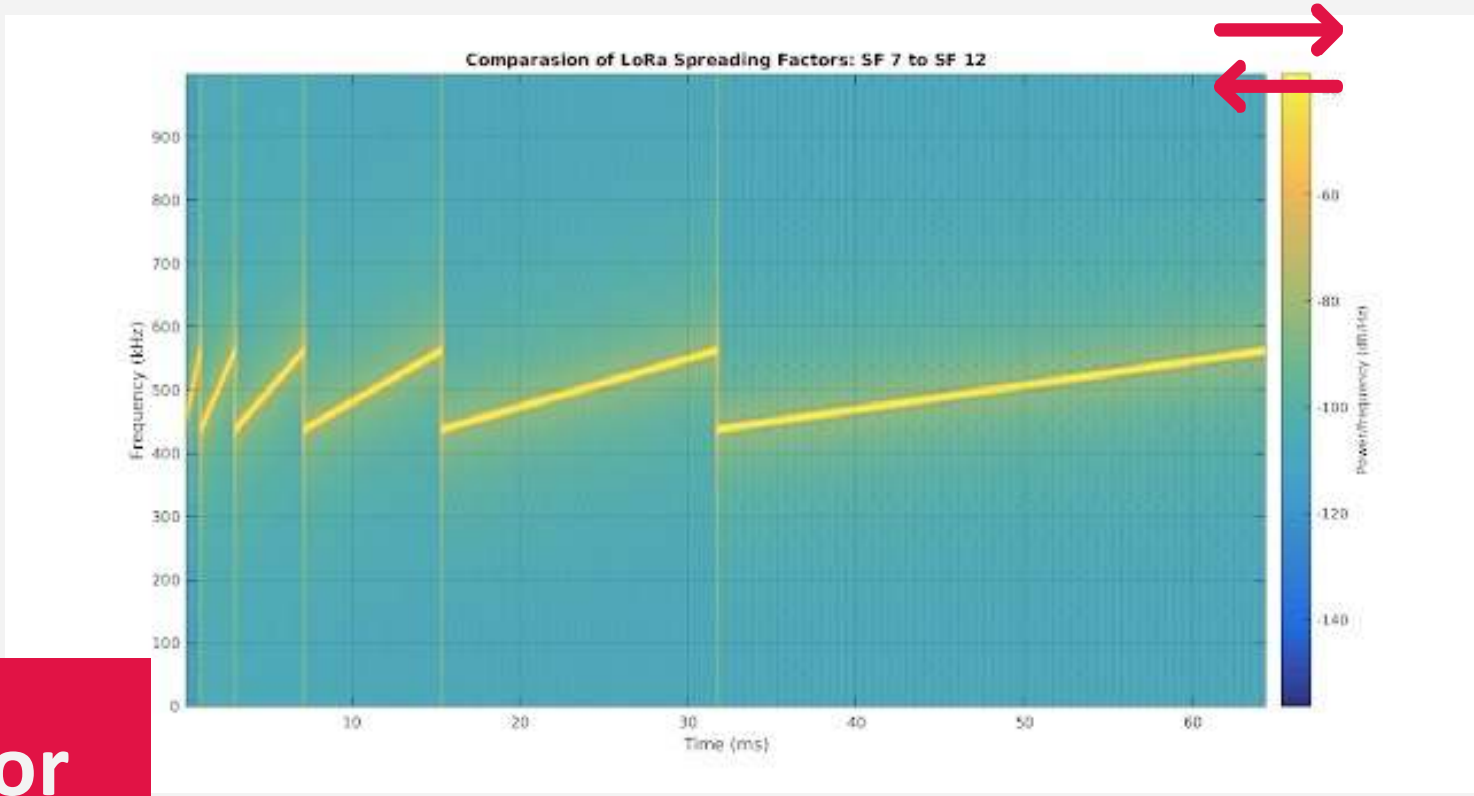


RADIO MODULATION PRINCIPLES



Data are transmitted by shifting the radio signal frequency. This movement creates a pattern encoding the data.

Any other noisy signal in the middle of this movement will be ignored.



LoRa Spread Factor principle

Getting more time to execute the frequency movement pattern allows a better decoding over noise. Better distance achieve, less loss, but lower throughput

LoRaWan is one of the existing network implementation for LoRa.

Amazon SideWalk is another implementation of LoRa to build a network.

LoRa is also widely used in point-to-point application.

Network layer

LoRaWAN is a specification defined by LoRa-Alliance (telecom operators and industrial companies, 500+ actors) since 2015.

It defines one of the way to create a network over LoRa with the ability to support multiple public operator in each area

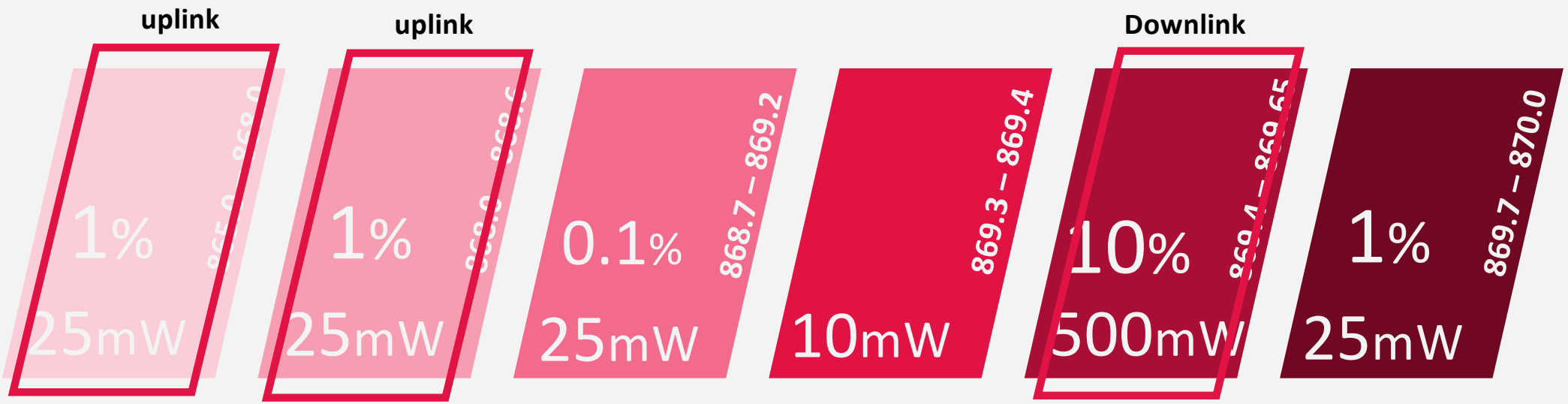
Defines the frequencies to be used (part of them), the frame format, encryption, ADR commands and the way to join a network

2 join procedures has been defined: OTAA (regular one, with session keys negotiation) and ABP (where the sessions keys are static). Over The Air Activation vs Activation By Personalization.

Defines the encryption procedures

Encryption is mandatory in a system where multiple networks co-exist. The encryption protects each operators against the competition as it protects the customer payload to be captured. The algorithm and the key generation are defined by the LoRaWAN specifications.

USE OF 865Mhz-870 Hz



LoRaWAN defines, for Europe, 3 standard channels any device will use for the JOIN process. Each of them are 125kHz (375KHz are used). Center frequency are 868.1 868.3 and 868.5 in Europe. They are occupying all the 868.0 -> 868.6 band. LoRaWAN networks in Europe supports 8 channels, other 5 channels are defined by the network operator, usually, in the other 1% bands.

In FCC zone, the constraint is to use a minimum of 64 different channel with channel hopping. This requires 64 LoRaWan gateways (rare and expensive) most of the implementations currently implement only 8 channels gateways. The devices will have to communicate over 64 channels to respect the regulation. Consequently, 75% of communications are lost.

LoRaWAN architecture

All the DEVICES are communicating to GATEWAYS, a gateway receives all the LoRaWAN messages, this includes messages already received by another gateway of the network. It also includes GATEWAY from other networks. All the packets are transferred to the NETWORK SERVER (LoRaWAN cloud here)

The NETWORK SERVER is decrypting the communication (only the NETWORK SERVER you belongs to have the keys for it), it also manage the JOIN procedure and ADR (Adaptative Data Rate) parameters with the DEVICES. It also forward the PAYLOAD to the CUSTOMER IT usually using HTTP POST or MQTT integration protocol.

LoRaWAN DOWNLINKS

DOWNLINK are immediately following an UPLINK communication

The first one is on the same frequency as the UPLINK 1 second after it

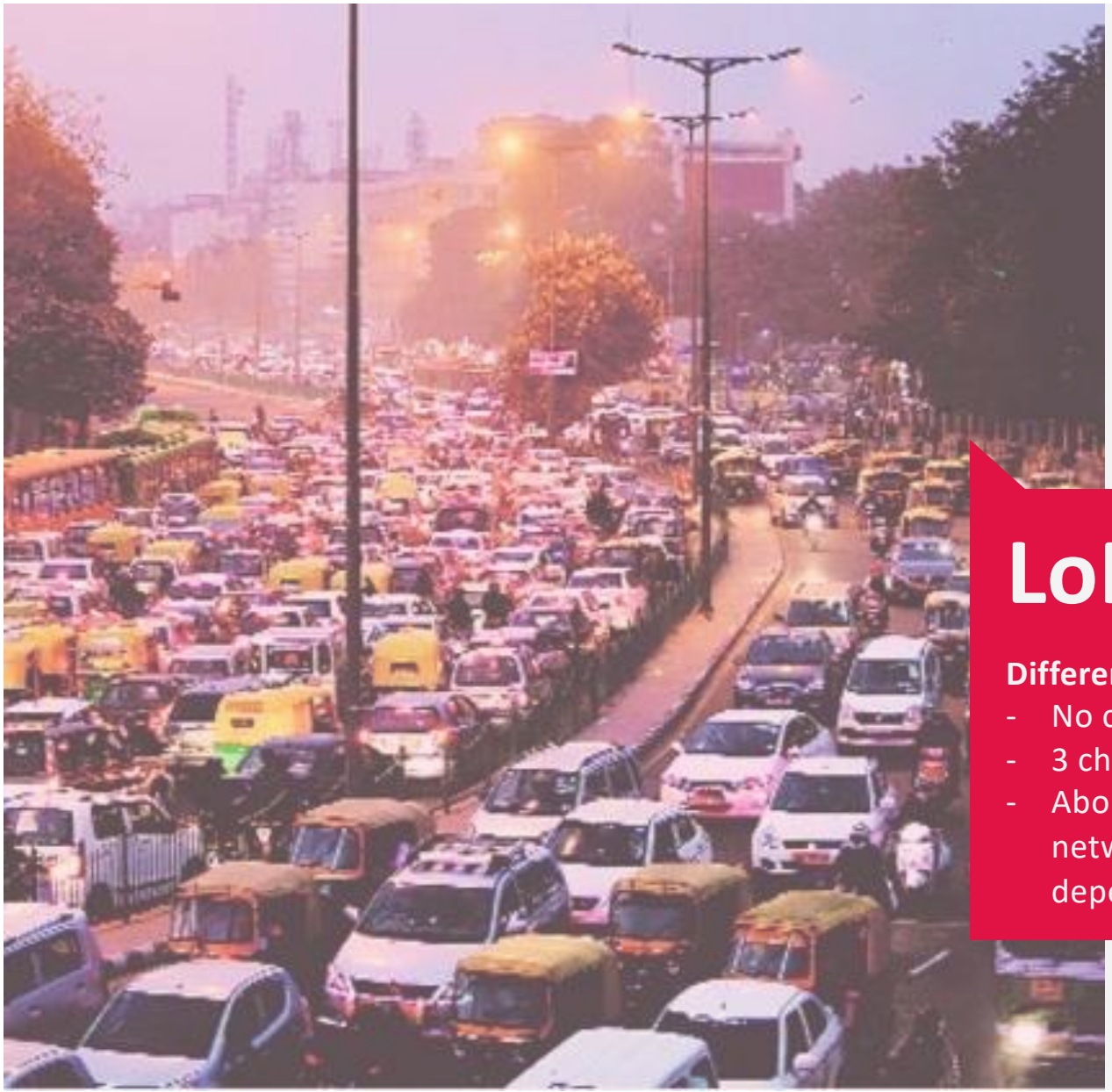
Speed can be different. The channel rules are applied (power, duty-cycle…)
This time is short for a Gateway – Network Server communication.

The second one is on 869.525Mhz allowing a 27dBm transmission

It happen 2 seconds after Uplink. Gateway gets more time to receive the Payload from the Network server

A downlink is acked by the device, multiple downlinks can be chained.

The downlink payload have to be queued in the network server: there is not enough time to loop the request with the customer IT.



LoRaWAN scalability

Different factors are limiting the scalability

- No congestion management
- 3 channels are common for all the networks
- About 1000 device in a same area (even in different networks) will saturate the 8 available channels. (it depends on SF and duty cycle…)

LoRaWAN STRENGHT AND WEAKNESS

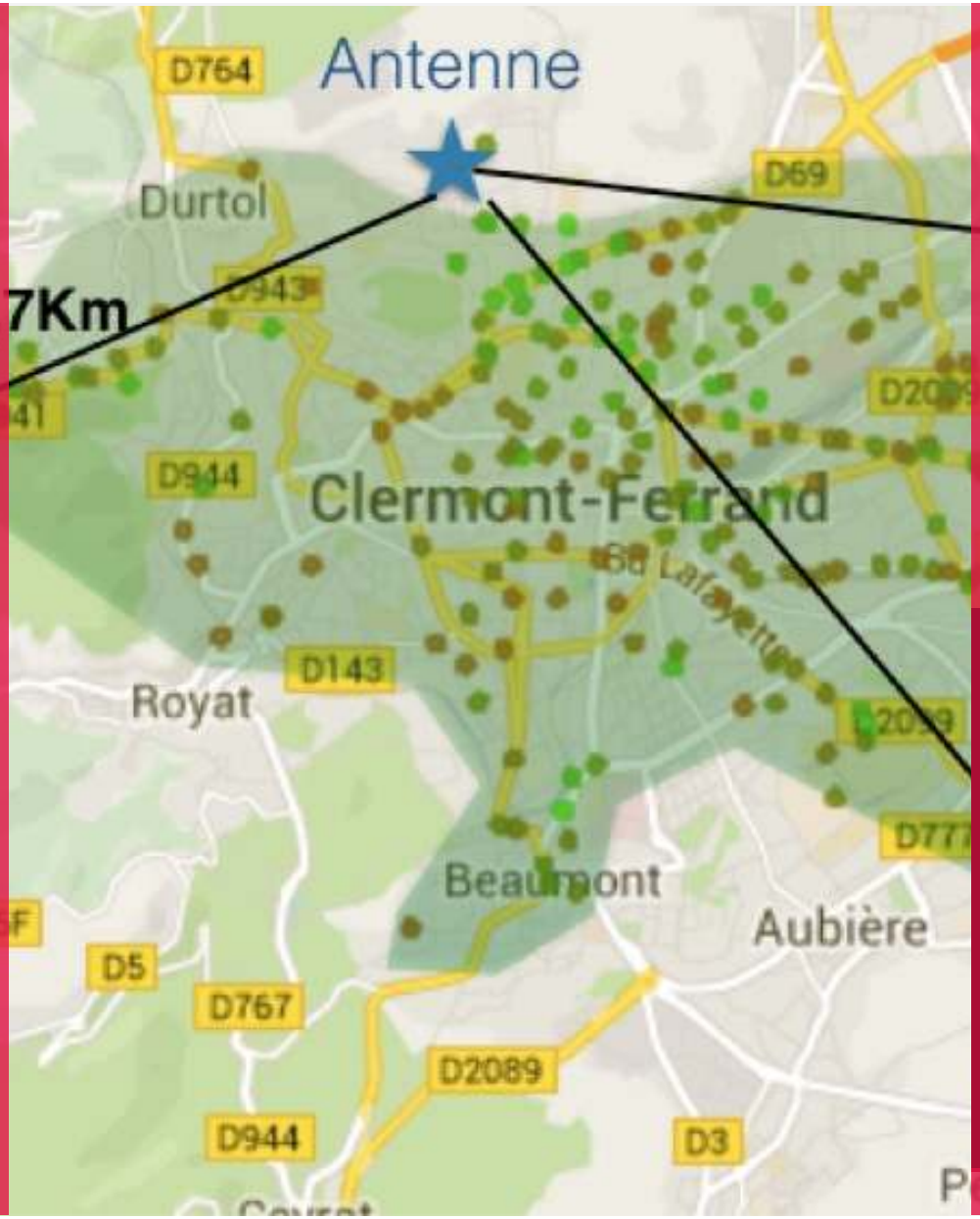
Strength

- Ability to offer TDOA location computing (Time Difference Over the Air) for non-GPS tracking (hundreds of meter precision)
- Ability to deploy private networks at low cost.
- Ability to support mobility with a reasonable loss rate.
- Throughput enabling multiple use-cases.

Weakness

- Complex channel management in roaming and complex roaming. Channel map for a network operator have to be global.
- A really limited number of public offer and complex roaming capability makes it limited to private usage or country usage when covered.
- Software complexity making it a bit more expensive than competitors on the device side. Even if the price is decreasing. Today it is starting at 5€ / device.

Private deployments



Public Application

The map displayed here has been made with a single LoRaWan antenna network deployed in a high position. All the city around is covered. The investment is about 500€ in 2020 for a such result.

Smart city application

Sensors deployed all around the city

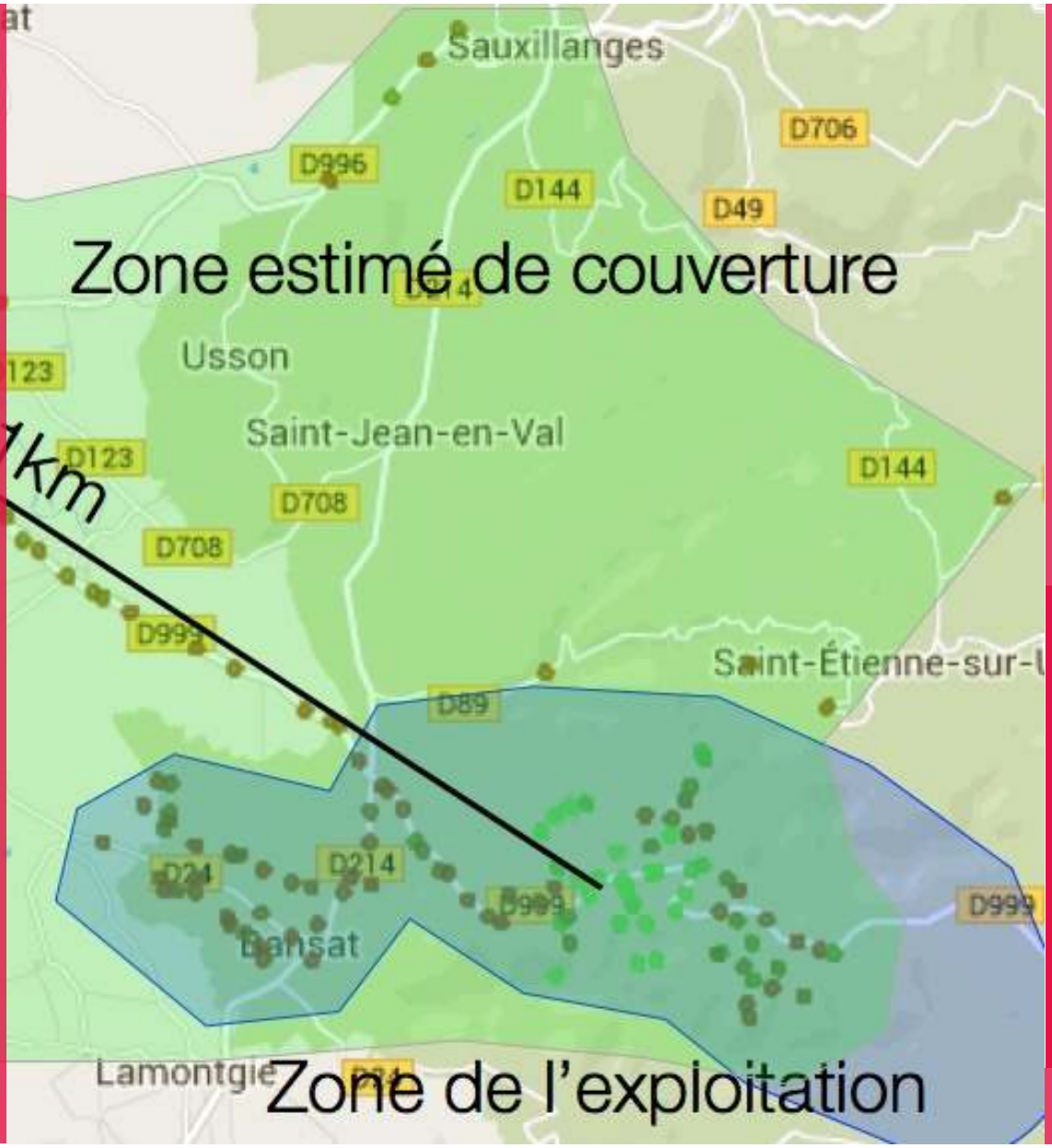
Local mobility

Collect information about public transport or parking availability …

Public network

Offering an IoT network access to all the citizens for private purpose.

Private deployments



Industrial Applications

Many industrial sector can get benefit of low-cost wide area networks.

This map has been made with a gateway on top of an Agricultural building. It basically cover all the area where the farmers are working and much more.

Agricultural domain

Get sensors data from field, animals, machines in real time.

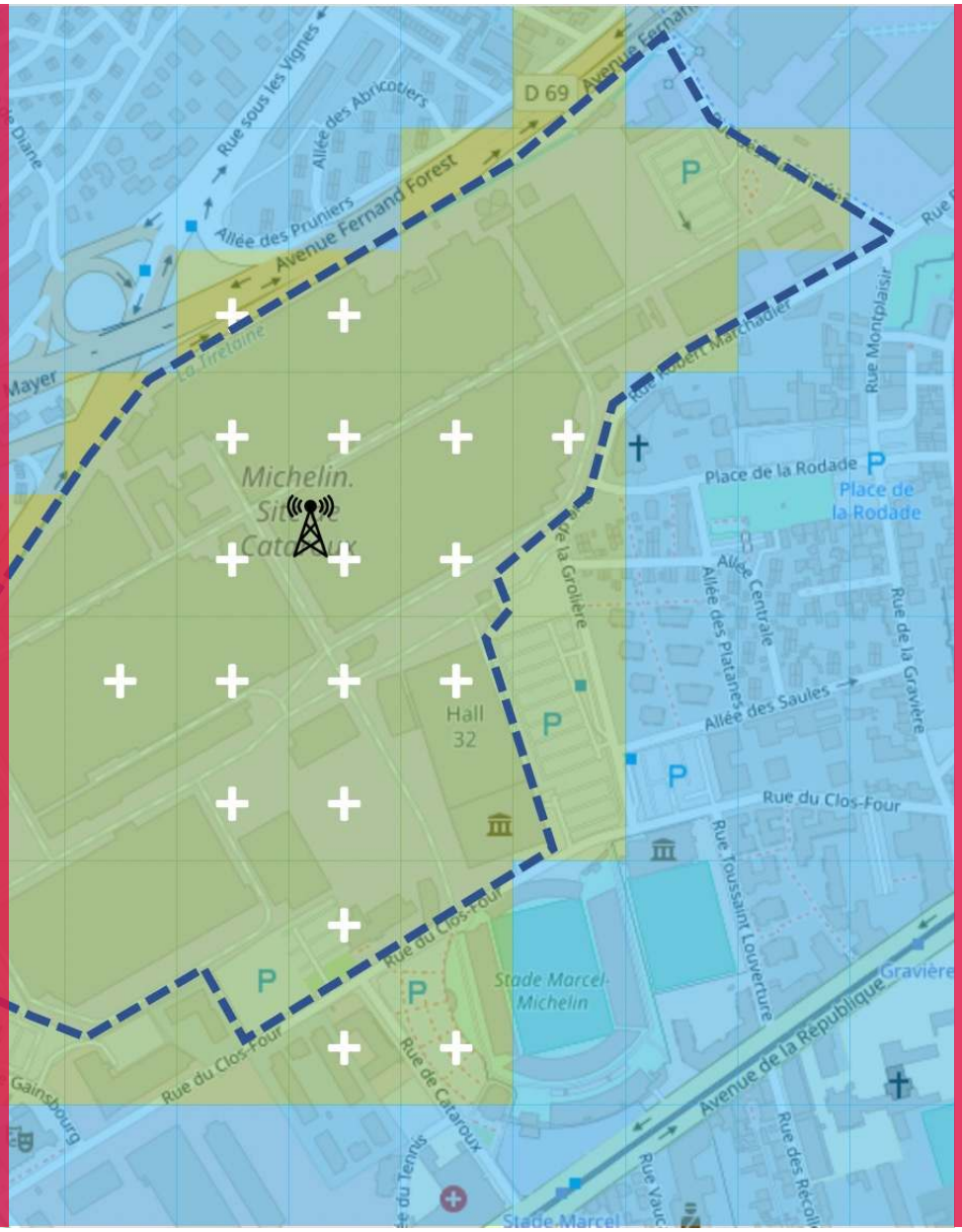
Mining

Usage, performance, maintenance, vehicule tracking, people safety … Many application in area where classical network access is limited.

Industry

Provide a global coverage on an industrial site, process reporting, safety, inventory management…

Private deployments



What we get with a simple indoor gateway

An investment around 300€ allows to get a coverage in an industrial site, even Indoor and without interacting with existing network

Indoor vs Outdoor coverage

10 km coverage is what you can get with a good outdoor spot.
Indoor antenna performance are usually around 300m around.

On the left: an example of two gateways coverage (outdoor has a larger coverage than what your see here, outdoor did not). Scale is the same

Crowdsourced

The Things Network

Is a crowdsourced network, deployed World-wide and free for use. Deployed by passioned people it proposes a good quality network In the main big cities.

Open-source mindset. This network is use in many business application: the network server is use for simplifying private deployment.

A professional version is available with Network Server SLA. TheThingsIndustry is the most innovative organization in the LoRaWan area since 2015. They are also pushing the market by making low-cost hardware and opensource solution.

Basically it is Uber for Telecom industry

Crowdsourced

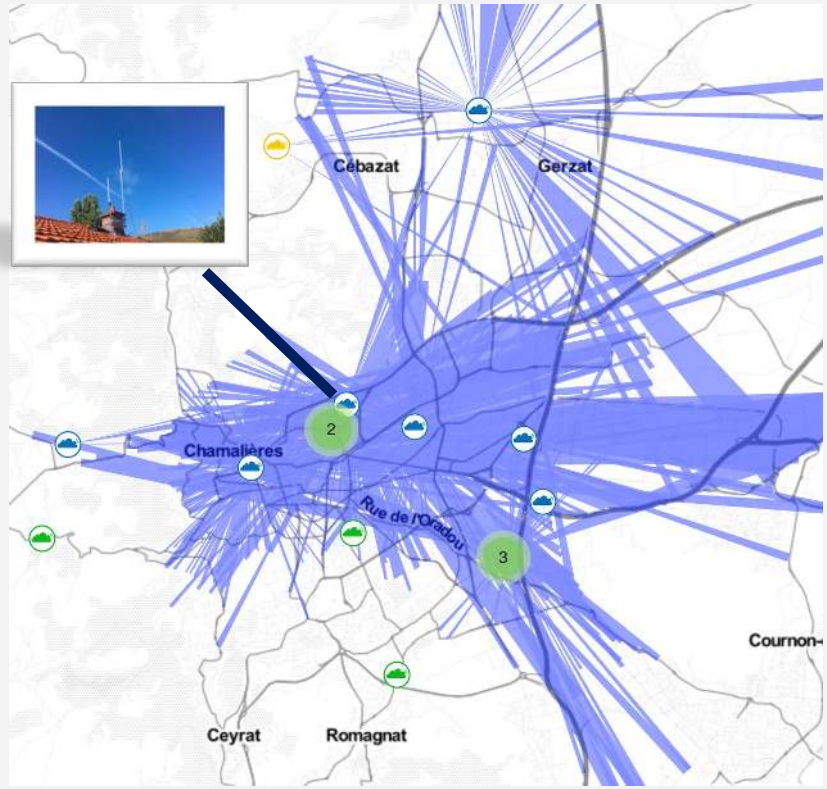
Created in 2015

15900 Gateway running
In 150 countries
500.000 devices using it

Most of the gateways have been deployed in Europe.

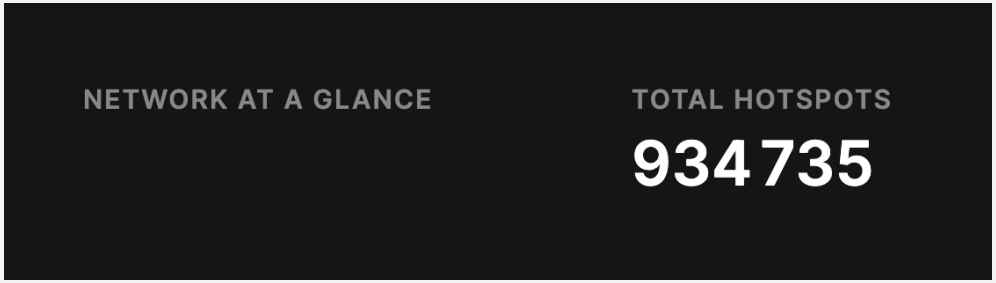
Crowdsourced

THE THINGS NETWORK



Coverage example made by a short number of people in a medium size city.

Crowdsourced



HELIUM

Is also crowdsourced IoT network, but it targets a different category of people to deploy the network. Instead of tech passionate, it target crypto investors.

Helium is an IoT network managed with a blockchain. Helium contributor are mining HNT tokens against coverage.
Communication are billable with a flat and low price.

Basically it is UBER + BITCOIN for Telecom industry

Crowdsourced

934735 Hotspot deployed in 3 years.

Limited coverage due to indoor installation in most of the cases.

A GLOBAL INITIATIVE

3GPP - Traditional telecom technologies applied on IoT

Multiple technologies

LTE-M is a power saving version of LTE (aka 4G)
NB-IoT is the LPWAN solution from 3GPP
Both have been added in best effort mode to 4G

Both will natively be provided and improved with 5G equipment's.

Telecom operator technologies

LTE-M

- LTE-M => LTE-MTC - Machine Type Communication
- eMTC => enhanced Machine Type Communication
- LTE CAT-M1/2

- IP Based – directly accessible

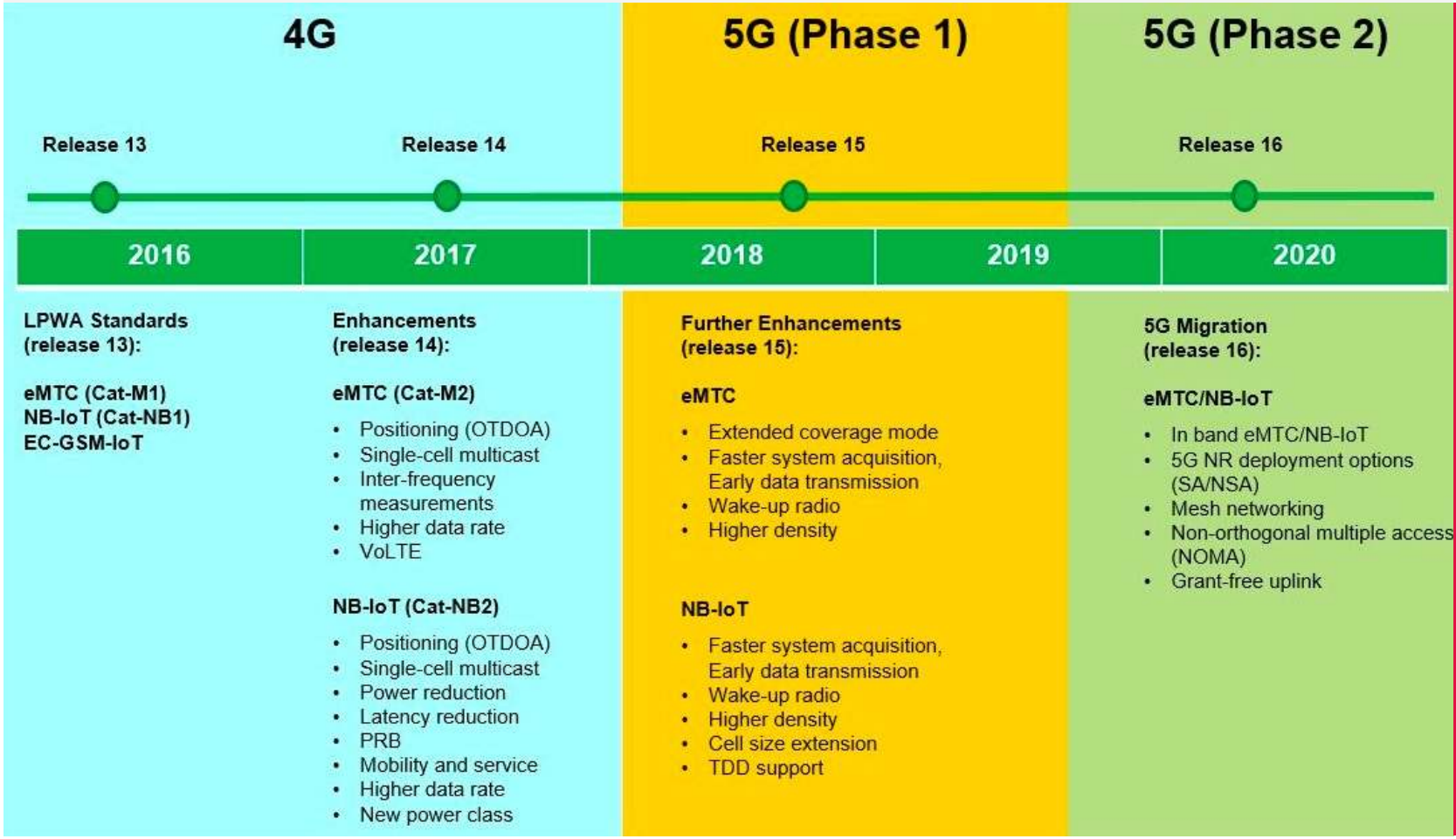
NB-IoT

- LTE CAT-NB1/2 => Narrow Band
- Accessible through an operator network kernel

Both are using licensed spectrum with no duty-cycle restrictions

Both are deployed by telecom operator and subject to subscription

3GPP Roadmaps



LTE-M is
- Cat-M1/Cat-M2
- eMTC

Nb-Iot is
- Cat-NB1/Cat-NB2

Release 13 has been deployed in France in 2019 for LTE-M (Orange)

Release 13 has been announced in France in 2019 for Nb-IoT (SFR)

Deployment time-line is impacted by chip time-to-market

Radio chips are available 18 month after spec

The chip industry need a reasonable time to implement the new 3GPP specification in silicon. It's about 18 months process before getting a released version. Then the design of object hardware can start for a second 18 months process. Therefore we have a 3 years shift between technology announcement and market availability.

On the operator side update can be software when the within the same generation. Hardware deployment (with large investment) is needed to change from a generation to the next one.

3GPP Solutions

LTE-Cat M / LTE-Cat NB are solutions based on 4G (LTE)

V·T·E [7][8]	LTE Cat 1	LTE-M				NB-IoT		EC-GSM-IoT
		LC-LTE/MTCe	eMTC					
		LTE Cat 0	LTE Cat M1	LTE Cat M2	non-BL	LTE Cat NB1	LTE Cat NB2	
3GPP Release	Release 8	Release 12	Release 13	Release 14	Release 14	Release 13	Release 14	Release 13
Downlink Peak Rate	10 Mbit/s	1 Mbit/s	1 Mbit/s	4 Mbit/s		27 kbit/s	80 kbit/s	474 kbit/s (EDGE) 2 Mbit/s (EGPRS2B)
Uplink Peak Rate	5 Mbit/s	1 Mbit/s	1 Mbit/s	7 Mbit/s		62 kbit/s (multi-tone) 20 kbit/s (single-tone)	105 kbit/s	474 kbit/s (EDGE) 2 Mbit/s (EGPRS2B)
Latency	50–100ms	not deployed	10ms–15ms			1.6s–10s		700ms–2s
Number of Antennas	2	1	1			1		1–2
Duplex Mode	Full Duplex	Full or Half Duplex	Full or Half Duplex			Half Duplex		Half Duplex
Device Receive Bandwidth	1.4 – 20 MHz	1.4 – 20 MHz	1.4 MHz	4x1.4 MHz		180 kHz	180 kHz	200 kHz
Receiver Chains	2 (MIMO)	1 (SISO)	1 (SISO)			1 (SISO)		1–2
Device Transmit Power	23 dBm	23 dBm	20 / 23 dBm			20 / 23 dBm		23 / 33 dBm

At least a software update is needed on all operator equipments over 4G.

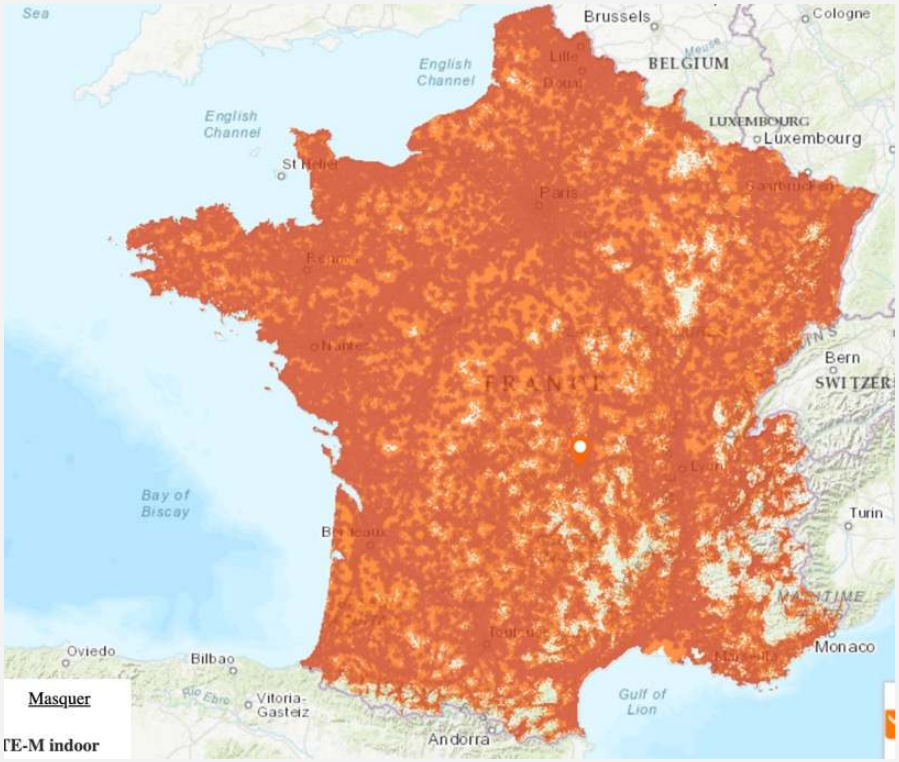
3GPP Solutions in the 5G

	Next Generation
	5G
Range (Outdoor)	< 15 km
MCL	164 dB
Spectrum	Licensed (7-900 MHz)
Bandwidth	shared
Data Rate	<1 Mbps
Battery Life	>10 years
Availability	2025

5G release 15 is still not really documented on Internet about LTE-M & NB-IoT improvement.

Operators need to change all the telecom equipment to support 5G.

LTE-M outdoor coverage



Orange network coverage in France. Dark orange is indoor coverage. Light orange = outdoor only.

Basically 4G network coverage