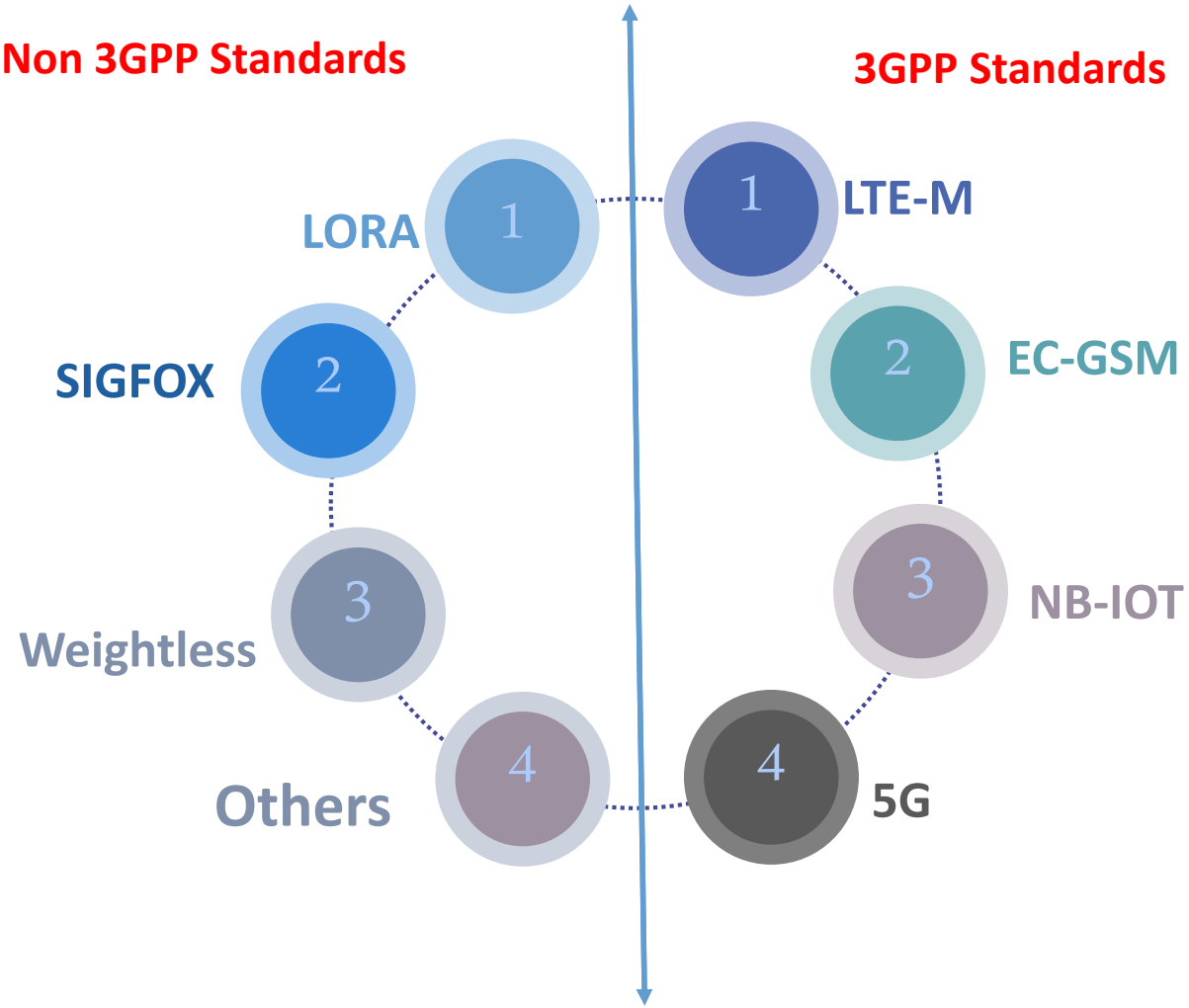
IoT Long Range Technologies: Standards

LONG RANGE TECHNOLOGIES



Wide-area M2M technologies and IoT

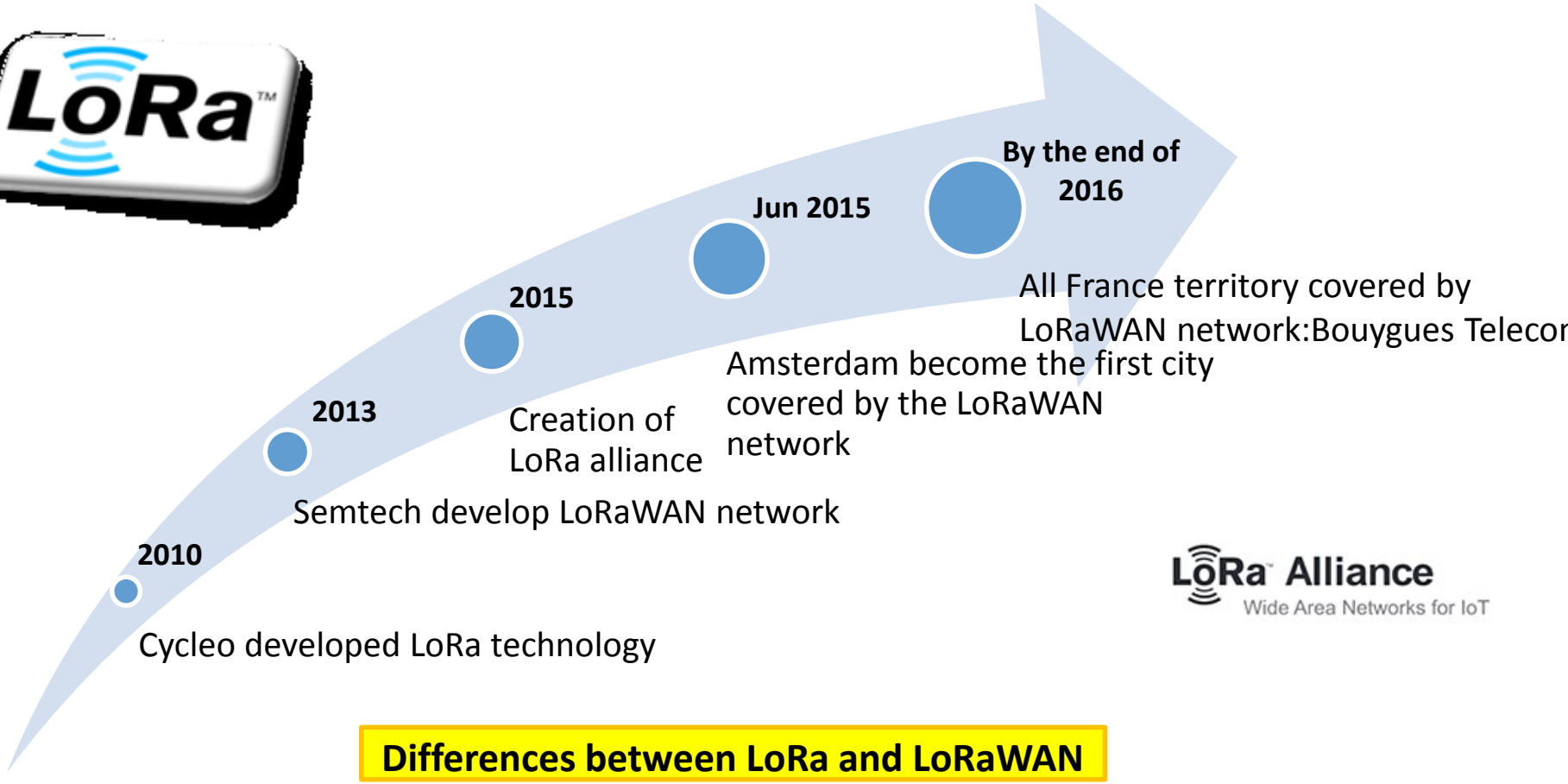
Carrier frequency		Technology	Channel bandwidth	Representative data rate	Link budget target or max. range
Licensed cellular		LTE Cat. 0	20 MHz	DL: 1 Mb/s UL: 1 Mb/s	140 dB
		LTE Cat. M	1.4 MHz	DL: 1 Mb/s UL: 1 Mb/s	155 dB
		NB-IoT	200 kHz	DL: 128 kb/s UL: 64 kb/s	164 dB
		EC-GSM	200 kHz	DL: 74 kb/s UL: 74 kb/s	164 dB
Unlicensed	2.4 GHz	Ingenu RPMA	1 MHz	UL: 624 kb/s DL: 156 kb/s	500 km line of sight
	Sub-1 GHz	LoRa chirp spread spectrum	125 kHz	UL: 100 kb/s DL: 100 kb/s	15 km rural 5 km urban
	Sub-1 GHz	Weightless-N	200 Hz	UL: 100 b/s	3 km urban
	Sub-1 GHz	Sigfox	160 Hz	UL: 100 b/s	50 km rural 10 km urban

H. S. Dhillon et al., "*Wide-Area Wireless Communication Challenges for the Internet of Things*," IEEE Communications Magazine, February 2017

LPWAN REQUIREMENTS

i. LoRaWAN

Roadmap



Differences between LoRa and LoRaWAN

- **LoRa** contains only the link layer protocol. LoRa modules are a little cheaper that the LoRaWAN ones.
- **LoRaWAN** includes the network layer too so it is possible to send the information to any Base Station already connected to a Cloud platform. LoRaWAN modules may work in different frequencies by just connecting the right antenna to its socket.

LoRa Alliance

International Operators — International development of the solution

Integrators and industrialists — Appropriate technology and maintain it over time

Manufacturers of End-points — Broadcast end devices

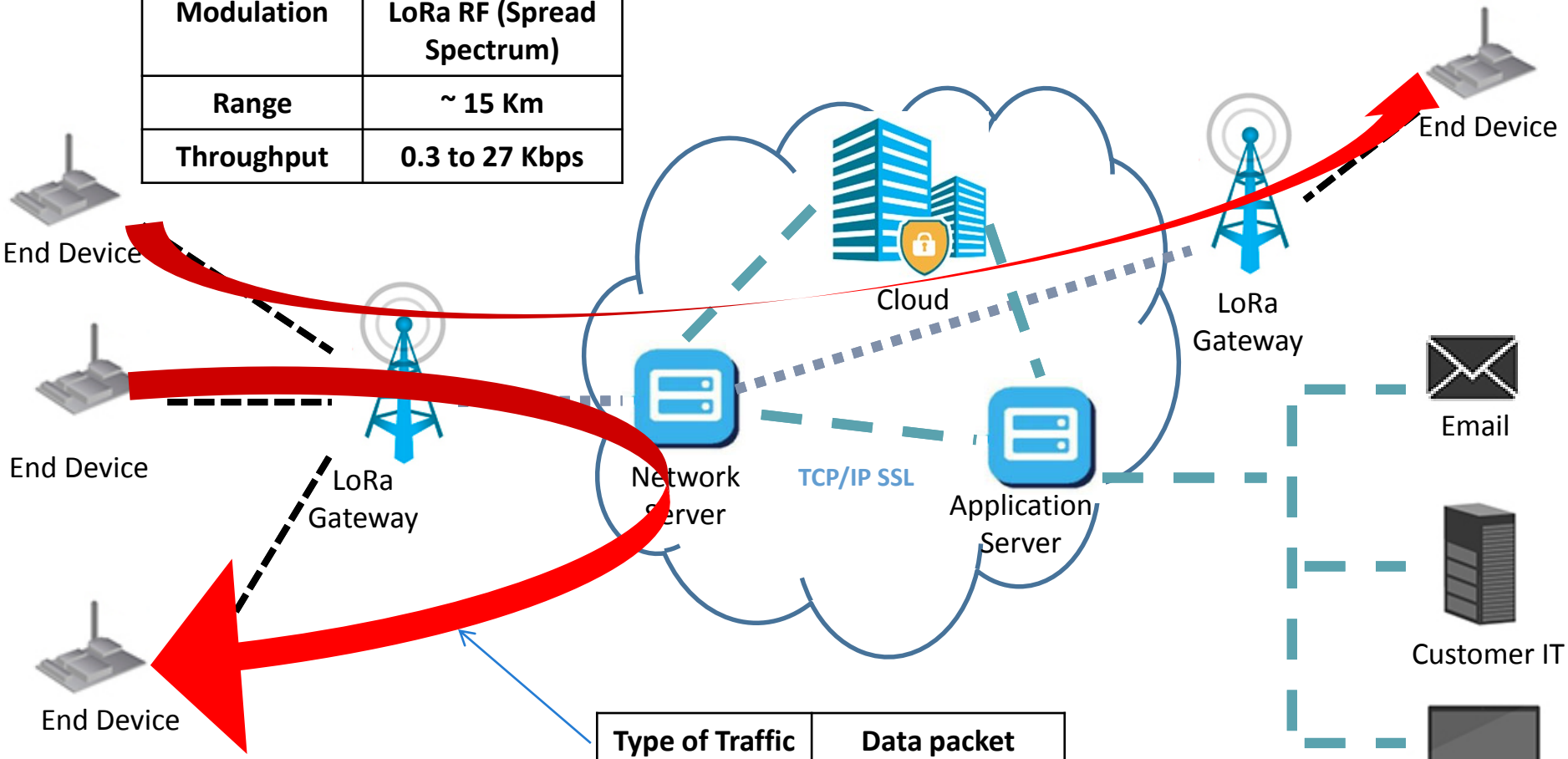
Manufacturers of Semiconductors — Integrate LoRa technology

LoRa technology Overview

- LoRaWAN is a *Low Power Wide Area Network*
- LoRa modulation: a version of Chirp **Spread Spectrum** (CSS) with a typical channel **bandwidth of 125KHz**
- High **Sensitivity** (End Nodes: Up to **-137 dBm**, Gateways: up to **-142 dBm**)
- Long range communication (up to **15 Km**)
- Strong indoor penetration: With High Spreading Factor, Up to **20dB** penetration (**deep indoor**)
- Occupies the entire bandwidth of the channel to broadcast a signal, making it **robust** to channel noise.
- **Resistant** to Doppler effect, multi-path and signal weakening.

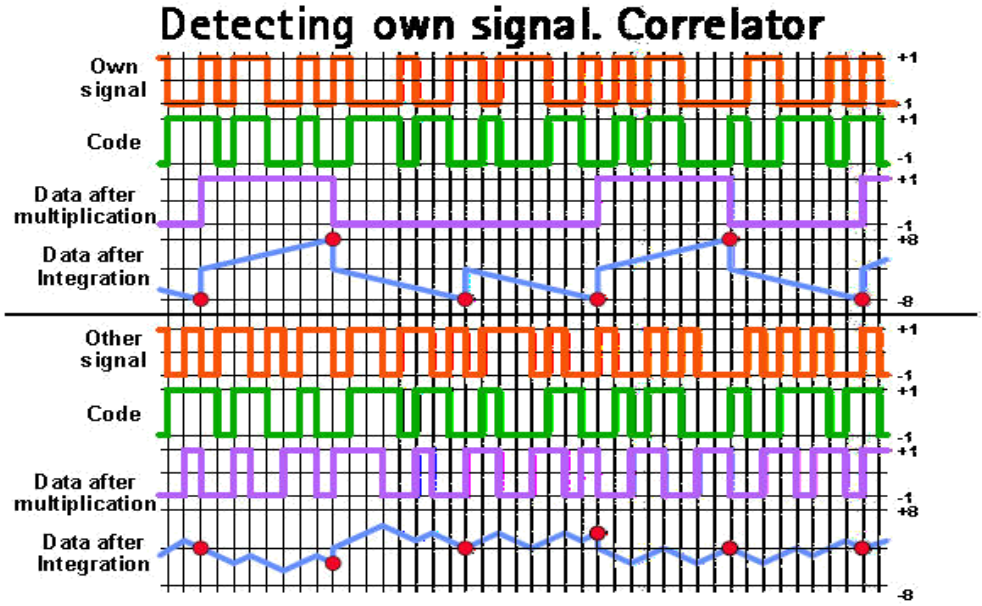
Architecture

Modulation	LoRa RF (Spread Spectrum)
Range	~ 15 Km
Throughput	0.3 to 27 Kbps



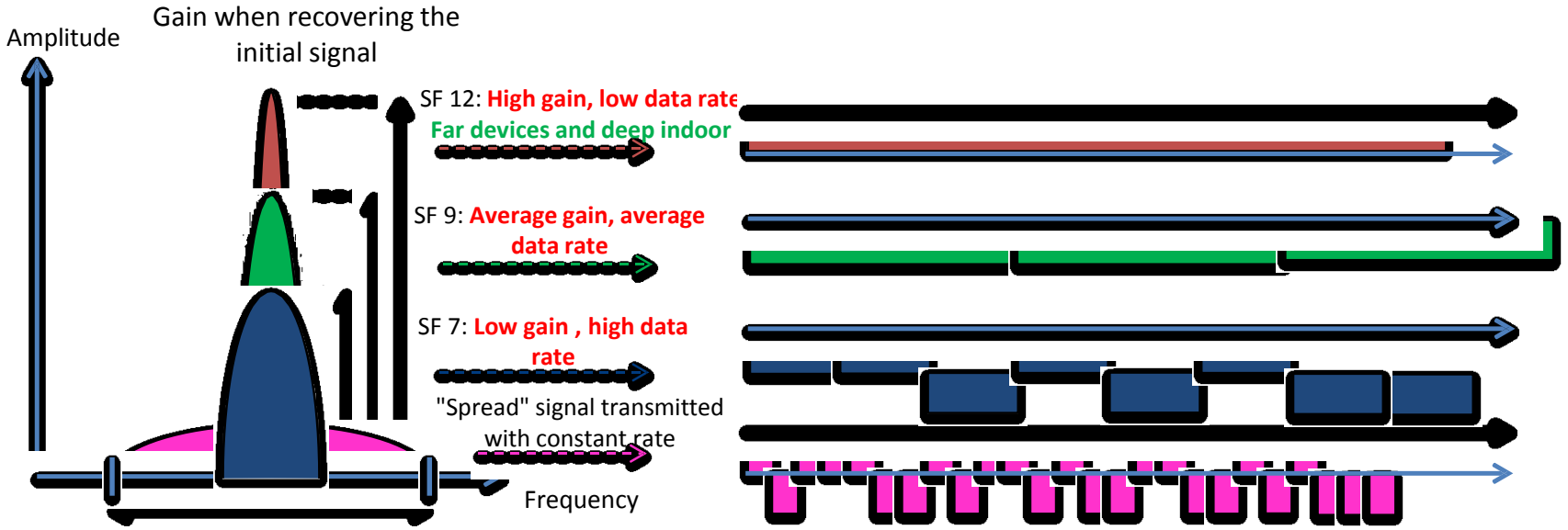
Type of Traffic	Data packet
Payload	~ 243 Bytes
Security	AES Encryption

Spread spectrum basics



Spectrum

- Orthogonal sequences: 2 messages, transmitted by 2 different objects, arriving simultaneously on a GW without interference between them (*Code Division Multiple Access* technique: CDMA , used also in 3G).
- **Spread Spectrum**: Make the signal more robust , the more the signal is spread the more robust. Less sensitive to *interference* and *selective frequency fadings* .



Spectrum: unlicensed, i.e. the 915 MHz ISM band in the US, 868 MHz in Europe

Spectrum (Influence of the Spreading Factor)

Far with obstacles:

➔ **High sensitivity** required

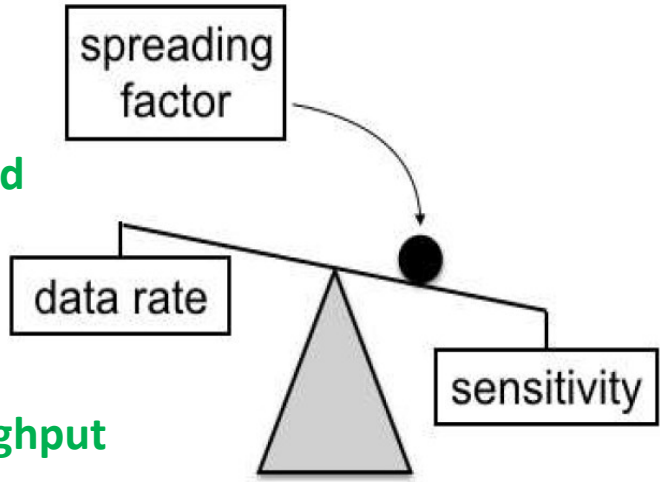
➔ The network **increases** the SF (*Spreading Factor*) ➔

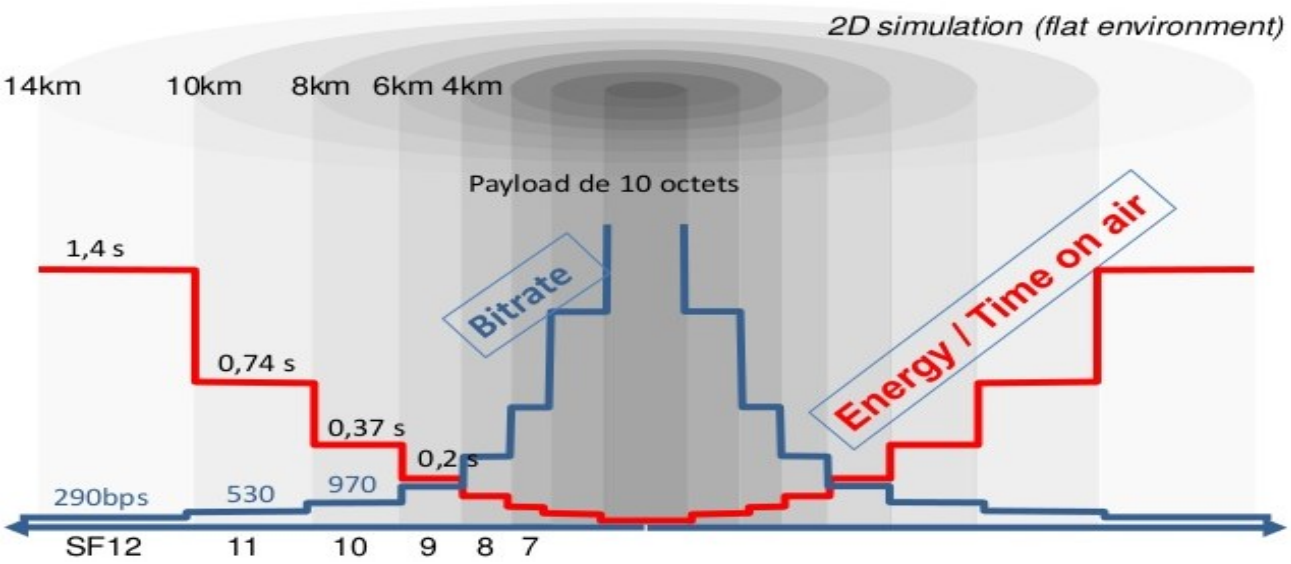
Throughput decreases but **the connection is maintained**

Close:

➔ **Low sensitivity** sufficient

➔ **Decrease** of SF (SPREADING FACTOR), **increase of throughput**



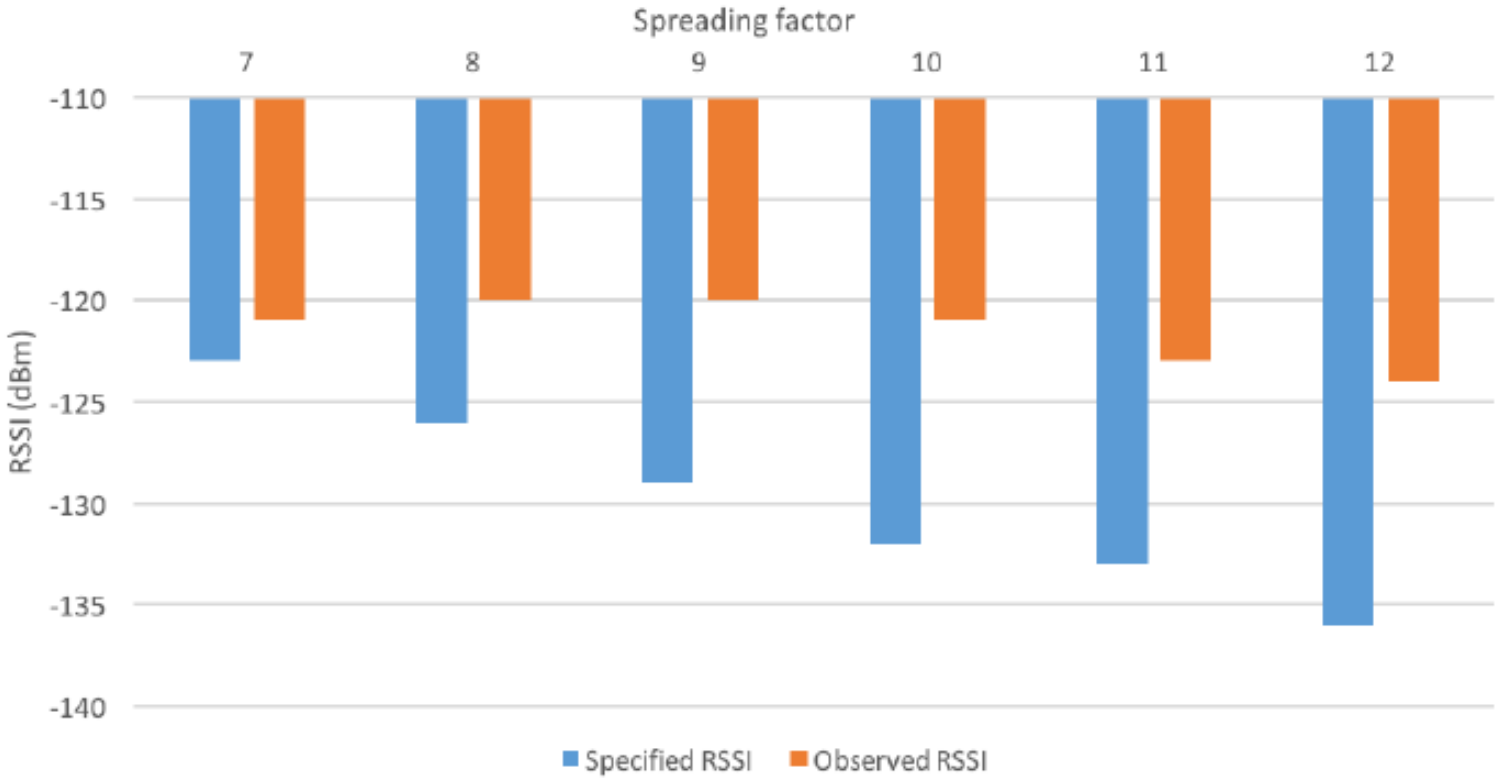


Adaptive throughput

ADR: *Adaptive Data Rate*

RSSI and SF versus BW

BW \ SF	7	8	9	10	11	12
125 kHz	−123	−126	−129	−132	−133	−136
250 kHz	−120	−123	−125	−128	−130	−133
500 kHz	−116	−119	−122	−125	−128	−130



SF, bitrate, sensitivity and SNR for a 125 kHz channel

Spreading factor	Bitrate (bit/sec)	Sensitivity (dBm)	LoRa demodulator SNR
7 (128)	5 469	-124 dBm	-7.5 dB
8 (256)	3 125	-127 dBm	-10 dB
9 (512)	1 758	-130 dBm	-12.5 dB
10 (1024)	977	-133 dBm	-15 dB
11 (2048)	537	-135 dBm	-17.5 dB
12 (4096)	293	-137 dBm	-20 dB

SF and repetition can be either **manual** (i.e., determined by the end-device) or **automatic** (i.e., managed by the network)

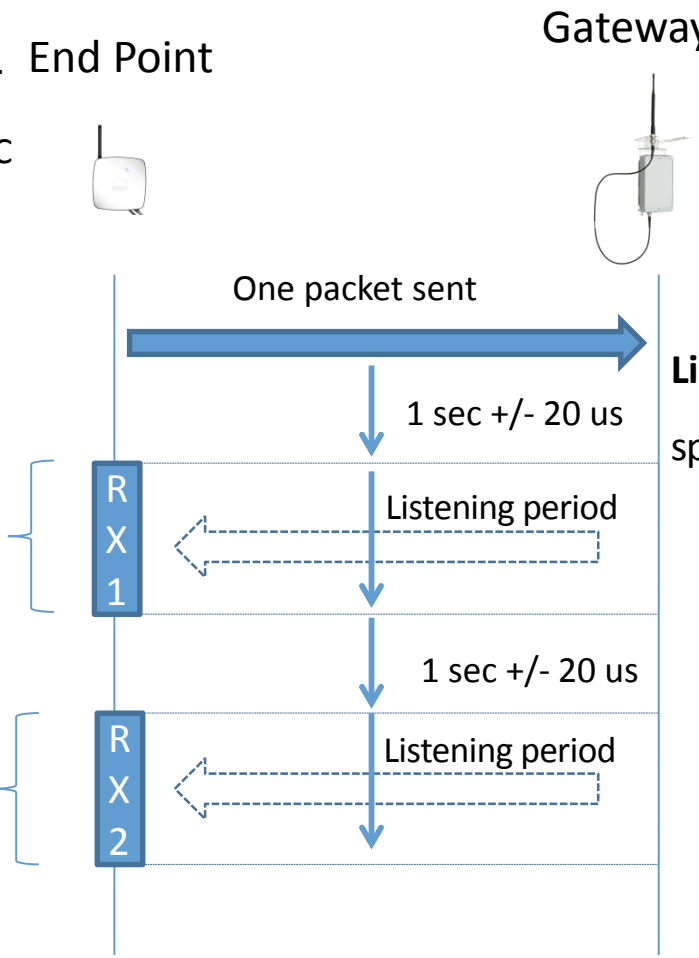
LoRaWAN: device classes

Classes	Description	Intended Use	Consumption	Examples of Services
A (« all »)	**Listens only after end device transmission**	Modules with **no latency constraint**	The **most economic** communication Class energetically.. **Supported by all modules**. **Adapted to battery powered modules**	• **Fire Detection** • **Earthquake Early Detection**
B (« beacon »)	The module listens at a **regularly adjustable frequency**	Modules with **latency constraints** for the **reception of messages of a few seconds**	**Consumption optimized**. **Adapted to battery powered modules**	• **Smart metering** • **Temperature rise**
C (« continuous »)	Module **always listening**	Modules with a ***strong reception latency constraint*** (less than one second)	Adapted to **modules on the grid** or with **no power constraints**	• **Fleet management** • **Real Time Traffic Management**

➔ **Any LoRa object can transmit and receive data**

Class A

Open **2 windows for DL reception** (acknowledgments, MAC commands, application commands...) **after sending a packet**



1st receive window

2nd receive window

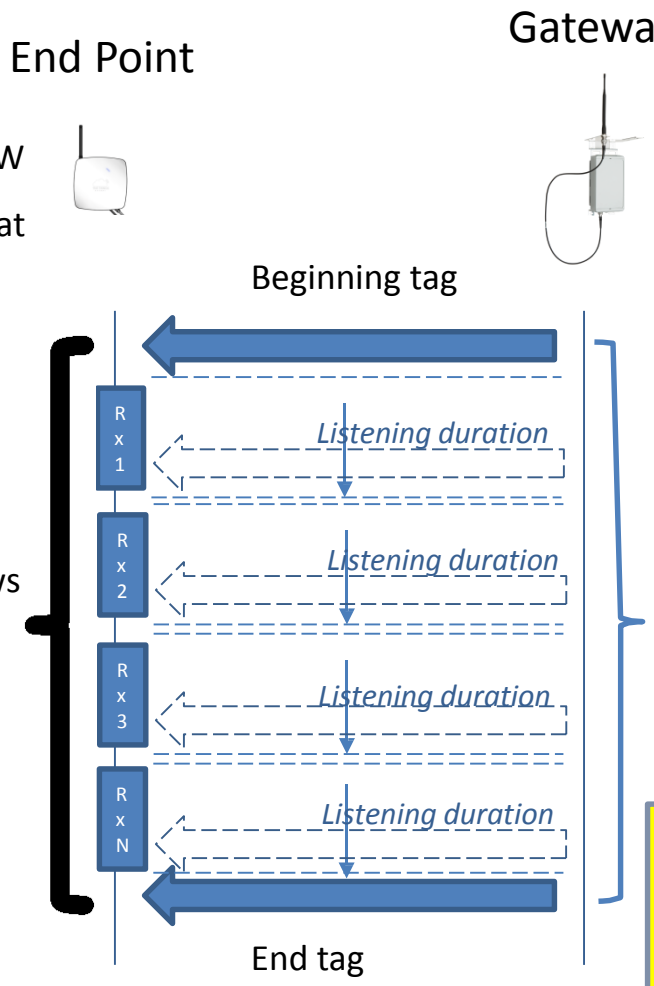
Listening period: varies according to the spreading factor SF

- 5.1 ms at SF7 (outdoor and close devices)
- 10.2 ms at *SF8* …
- 164 ms at SF12 (deep-indoor or far devices)

- Very economic energetically
- Communication triggered by the end device

Class B (Synchronized mode)

- **Synchronized** with the GTW
- **Opens listening windows** at regular intervals.



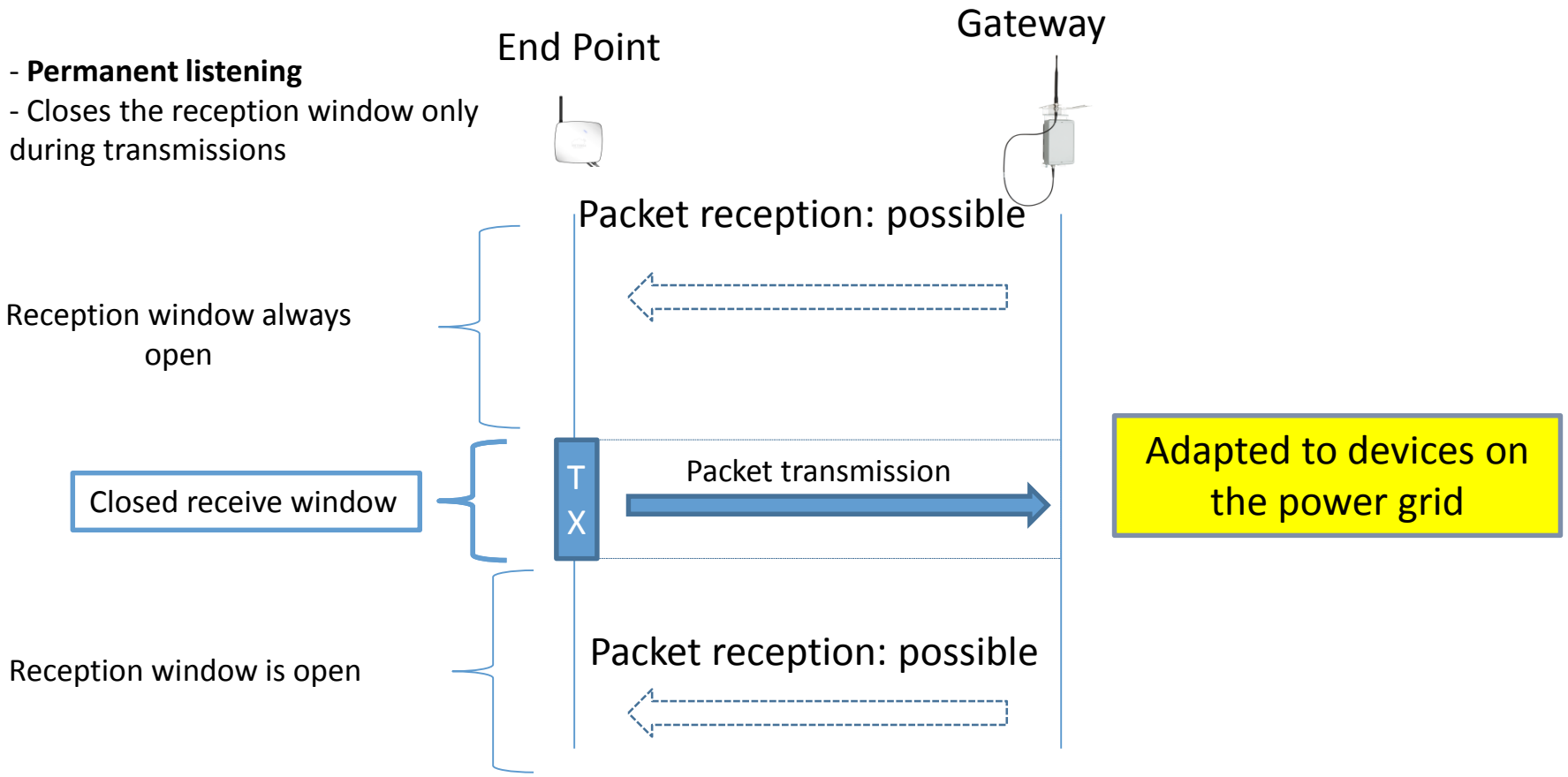
Opens N reception windows between the two tags

Listening duration: varies according to the SF

- Optimized energy consumption
- Communication initiated by the GTW

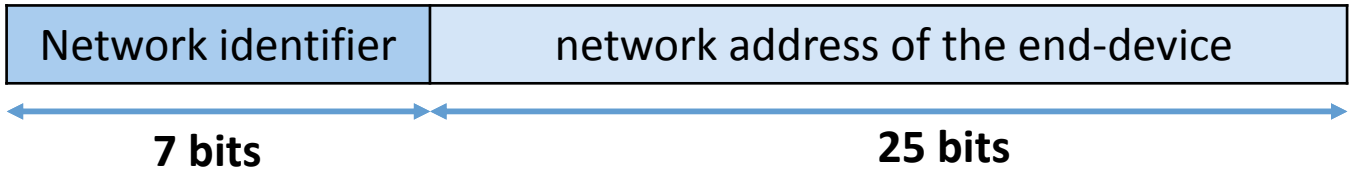
Class C

- **Permanent listening**
- Closes the reception window only during transmissions



Identification of an end device in LORA

- **End-device address (*DevAddr*):**



- **Application identifier (*AppEUI*):** A global application ID in the IEEE EUI64 address space that uniquely **identifies the owner of the end-device**.
- **Network session key (*NwkSKey*):** A key used by the network server and the end-device to calculate and verify the message integrity code of all data messages to ensure data integrity.
- **Application session key (*AppSKey*):** A key used by the network server and end-device to encrypt and decrypt the payload field of data messages.

Current state

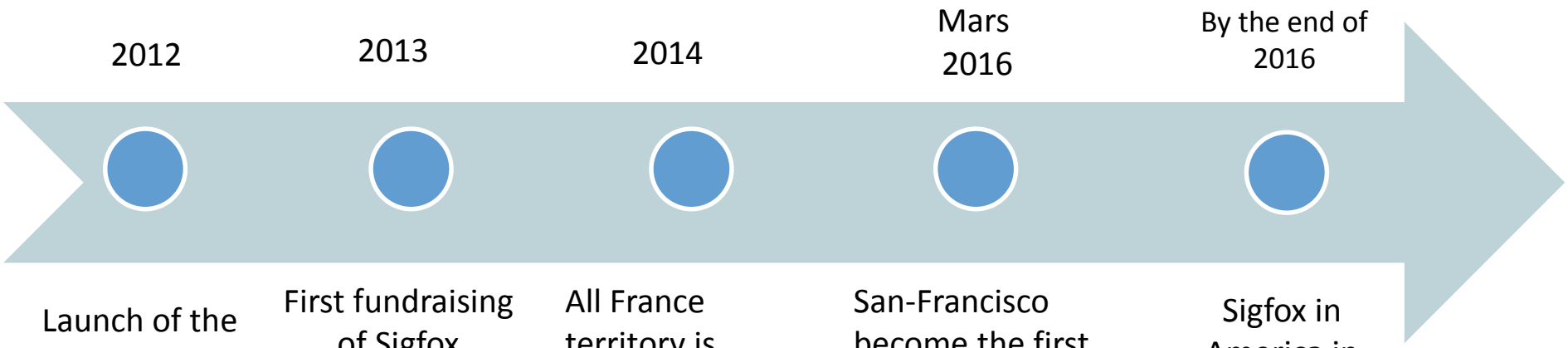
Amsterdam: was the first city covered by LoRaWAN with only 10 Gateways for the whole city at $ 1200 per unit. Since then, several cities have followed the trend:

By the end of 2016 , France will all be covered by LoRa

ii. Sigfox

Roadmap


sigfox
Make Things Come Alive

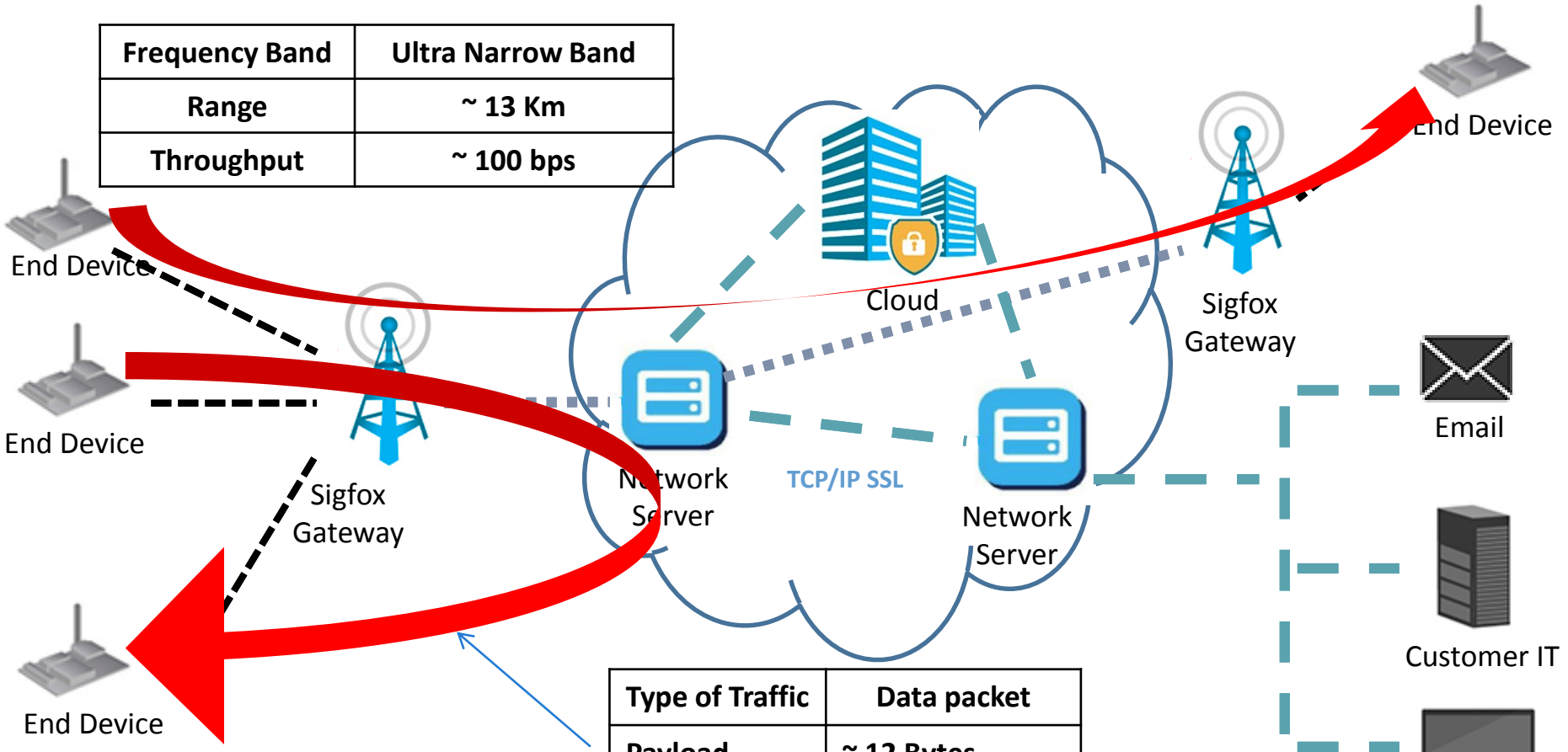

2012
2013
2014
Mars 2016
By the end of 2016
Launch of the Sigfox network
First fundraising of Sigfox company to cover France
All France territory is covered by Sigfox network
San-Francisco become the first US. State covered by Sigfox
Sigfox in America in 100 U.S. cities

Sigfox Overview

- **First LPWAN** Technology
- The physical layer based on an **Ultra-Narrow band wireless** modulation
- **Proprietary** system
- Low throughput (**~100 bps**)
- Low power
- Extended range (**up to 50 km**)
- **140 messages/day/device**
- Subscription-based model
- **Cloud platform** with Sigfox –defined API for server access
- **Roaming capability**

Architecture

Frequency Band	Ultra Narrow Band
Range	~ 13 Km
Throughput	~ 100 bps

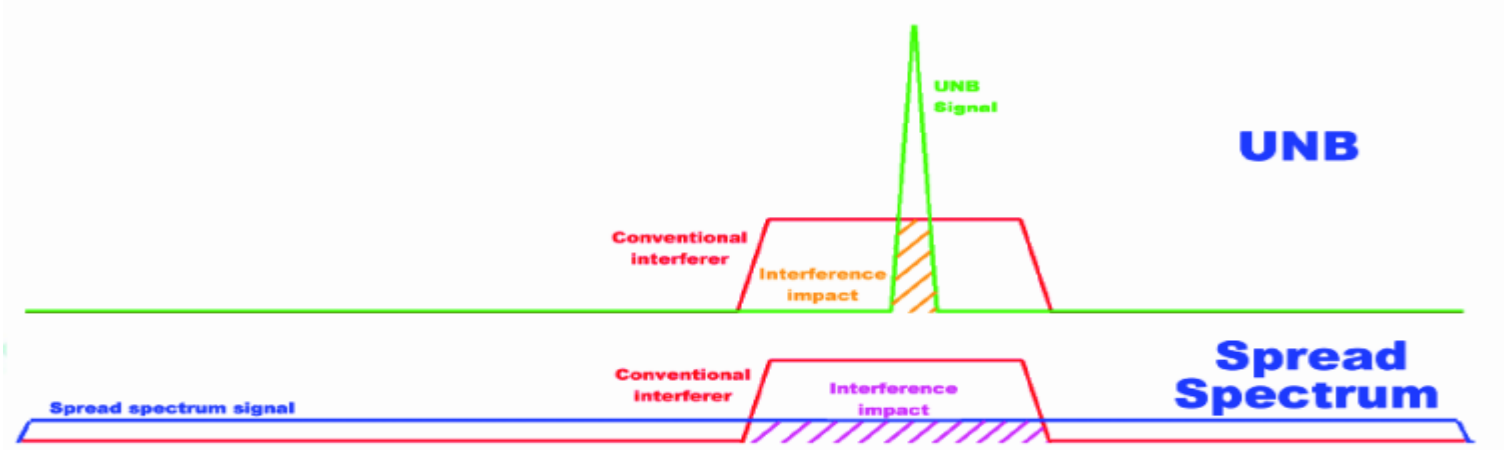


Type of Traffic	Data packet
Payload	~ 12 Bytes
Security	No security
Time on air	Up to 6 seconds

By default, data is conveyed over the air interface without any encryption. Sigfox gives customers the option to either implement their own end-to-end encryption solutions.

Spectrum and access

- **Narrowband** technology
- Standard radio transmission method: binary phase-shift keying (**BPSK**)
- Takes very narrow parts of spectrum and changes the phase of the carrier radio wave to encode the data

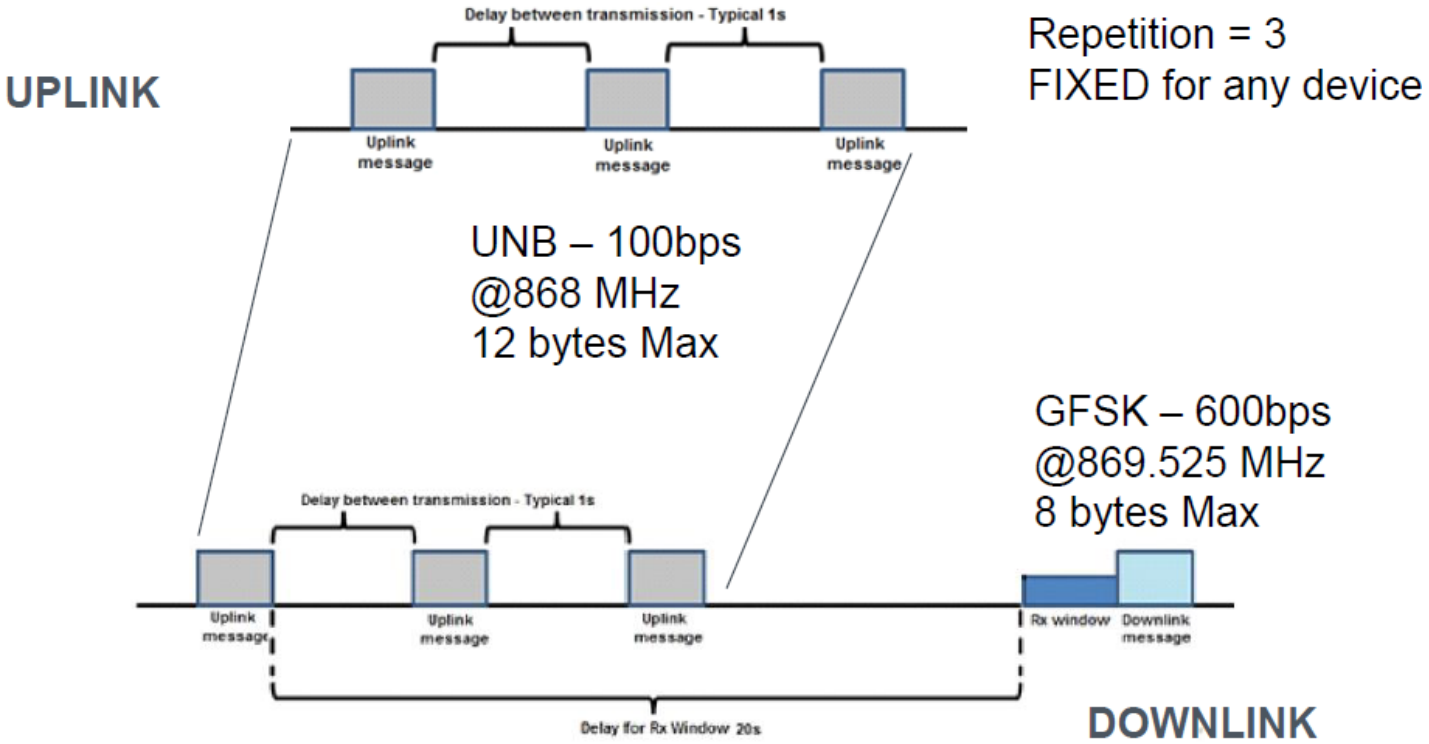


Frequency spectrum:

- 868 MHz in Europe
- 915 MHz in USA

Sigfox transmission

- Starts by an **UL transmission**
- Each message is transmitted 3 times
- A **DL message** can be sent (option)
- Maximum payload of **UL messages** = 12 data bytes
- Maximum payload of **DL messages** = 8 bytes



Current state

Covered countries **Covered areas** **End devices**

- SIGFOX LPWAN deployed in France, Spain, Portugal, Netherlands, Luxembourg, and Ireland , Germany, UK, Belgium, Denmark, Czech Republic, Italy, Mauritius Island, Australia, New Zealand, Oman, Brazil, Finland, Malta, Mexico, Singapore and U.S.

Sigfox company objectives:

- ✓ Cover **China** in 2017
- ✓ 60 countries covered by the end of 2018

SIGFOX
One network A billion dreams