IoT systems overview

CoE Training on Traffic engineering and advanced wireless network planning

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Objectives

- Present the different IoT systems and their classifications

Summary

I. Introduction

II. IoT Technologies

   A. Fixed & Short Range

   B. Long Range technologies

      1. Non 3GPP Standards (LPWAN)

      2. 3GPP Standards

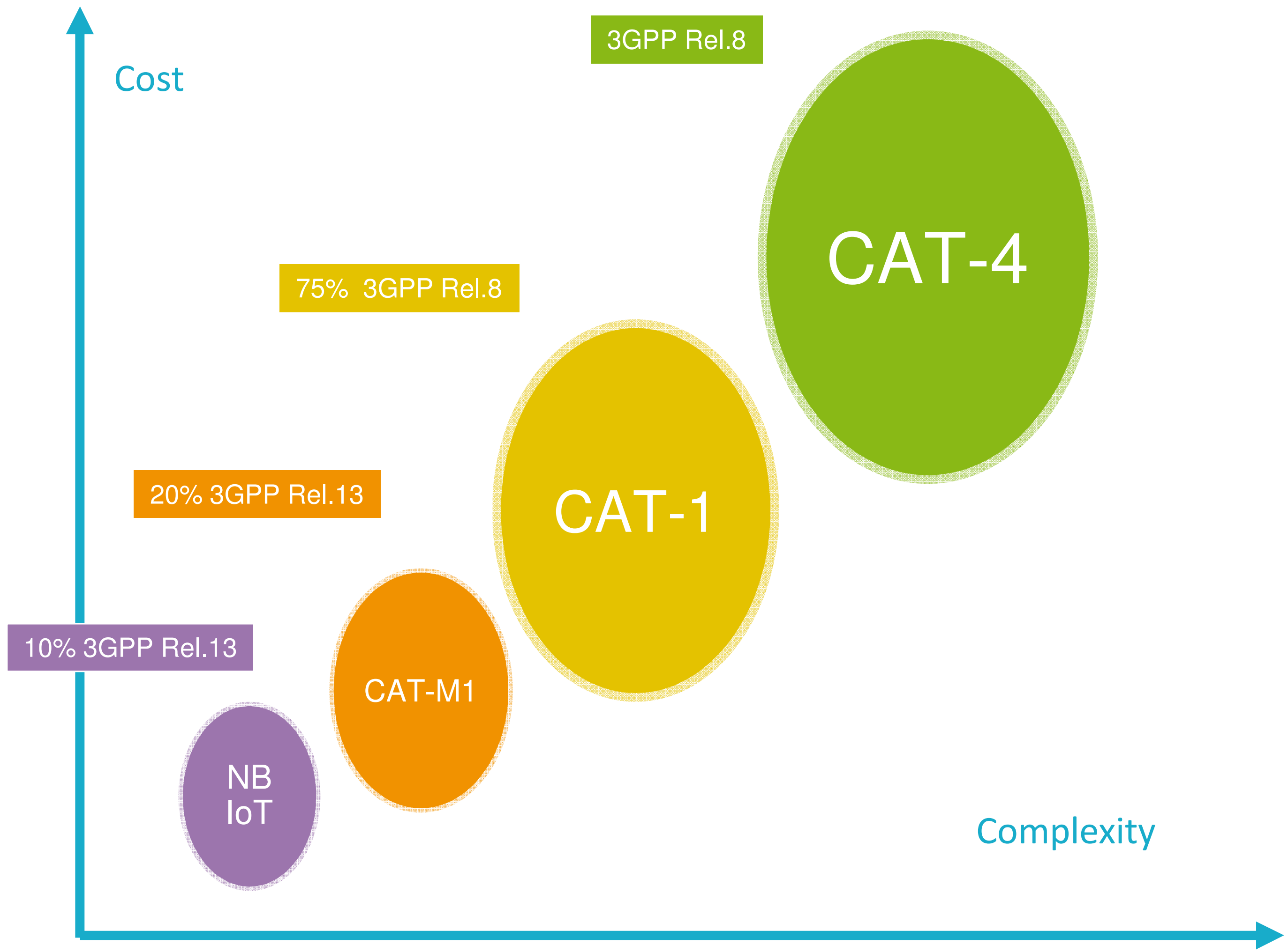
IoT communications are or should be:

- Low **cost**,
- Low **power**,
- Long **battery duration**,
- High **number of connections**,
- Low **bitrate**,
- Long **range**,
- Low **processing capacity**,
- Low **storage capacity**,
- Small **size devices**,
- Relaxed **latency**,
- Simple **network architecture** and **protocols**.

IoT Main Characteristics

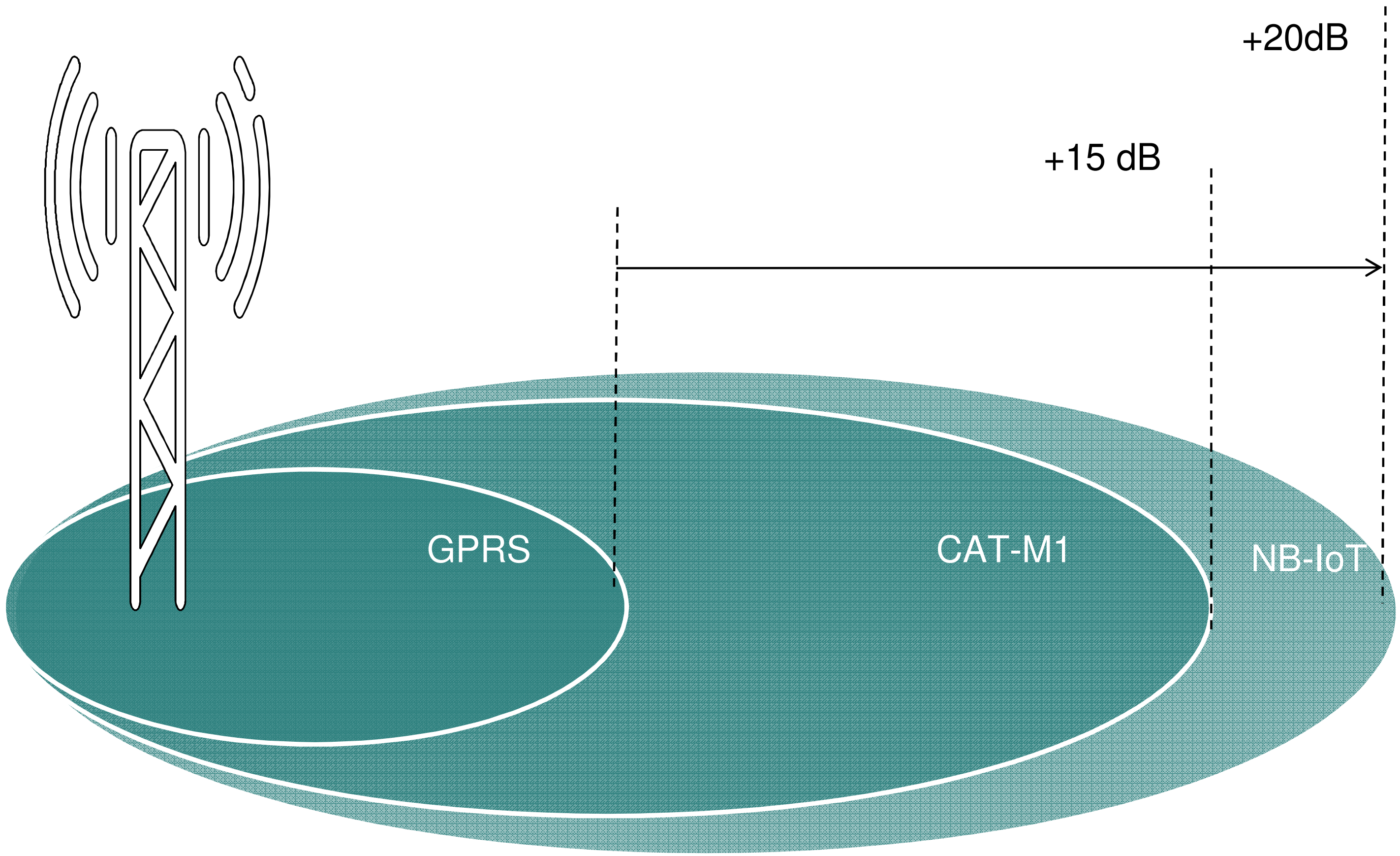
- **Low power**,
- **Low cost** (network and end devices),
- **Short** range (first type of technologies) or **Long** range (second type of technologies),
- **Low bit rate** (≠ broadband!),
- **Long battery** duration (years),
- Located in **any area** (deep indoor, desert, urban areas, moving vehicles …)

Low cost

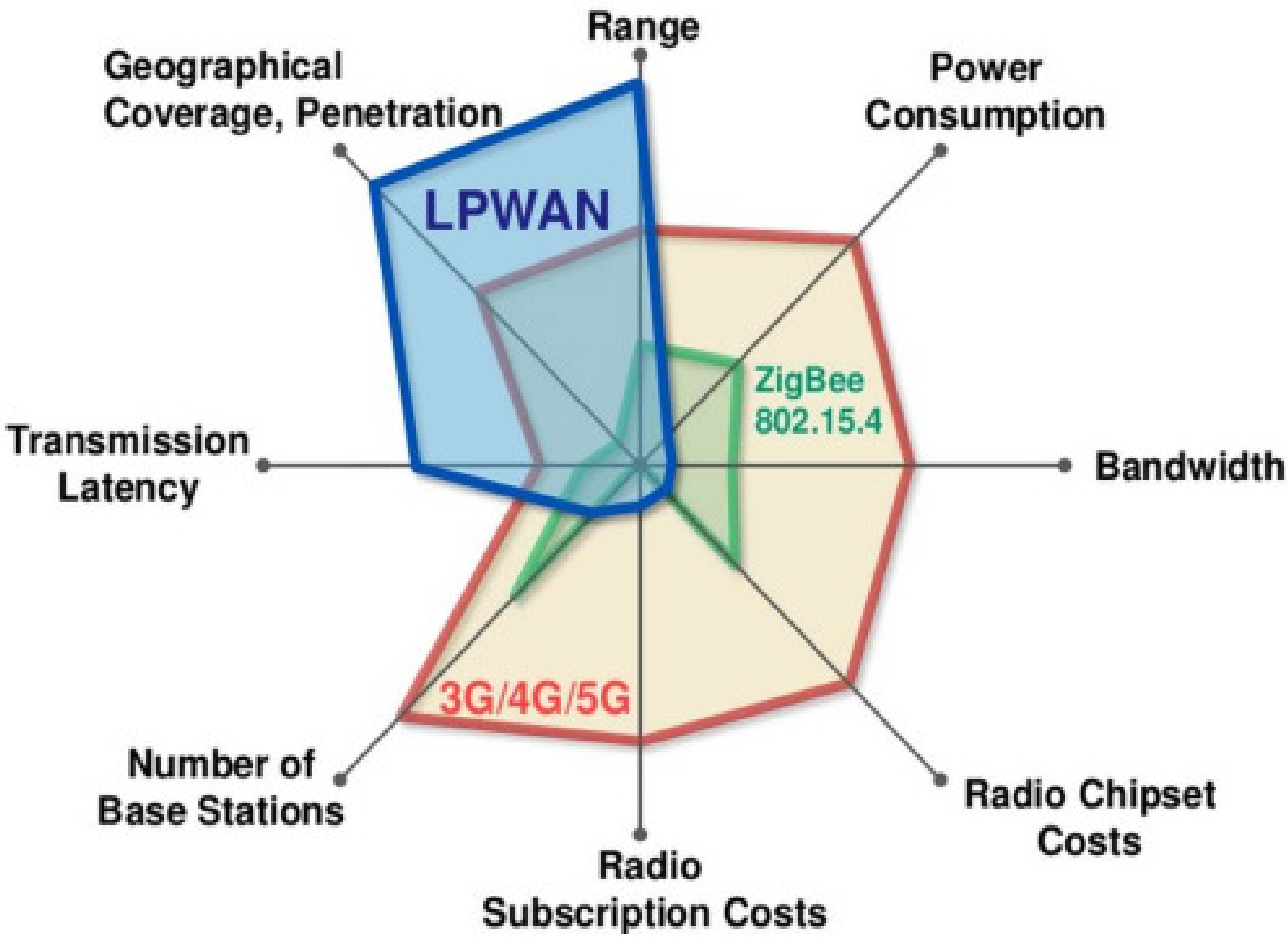


Cost
3GPP Rel.8
CAT-4
75% 3GPP Rel.8
CAT-1
20% 3GPP Rel.13
CAT-M1
10% 3GPP Rel.13
NB IoT
Complexity

Extended coverage



IoT Specificities



IoT Specificities and Impacts on Network planning and design

Characteristics	*Impact*
Low power and **Wide Range**	• High sensitivity (Gateways and end-devices with a typical sensitivity around -150 dBm/-125 dBm with Bluetooth/-95 dBm in 2G/3G/4G) • Low frequencies ➔ strong signal penetration • Narrow band carriers ➔ far greater range of reception • +14 dBm (ETSI in Europe) with the exception of the G3 band with +27 dBm, +30 dBm but for most devices +20 dBm is sufficient (USA)
Low deployment and **Operational Costs**	• Low gateways cost • Wide range ➔ Extended coverage + strong signal penetration (deep indoor, Rural) • Low numbers of gateways ➔Link budget: UL: 155 dB (or better), DL: Link budget: 153 dB (or better)
Long Battery life (10mA RX current, 100nA sleep current)	• Low Power • Idle mode most of the time. • Connected mode just for transmission (some mA) • < 100 MHz clock frequency • Embedded memory of a few Mo • Idle mode allowing an energy consumption of around 100 µW

N.B.: planning tasks only apply to long range technologies (type 2).

IoT Specificities and Impacts on Network planning

Characteristics	*Impact*
Shared Spectrum ➔ Interference Management	- Clear channel assessment - Frequency hopping - OFDM/CDMA access and NOMA technologies - Activity rate around 1% (regulation and energy constraints)
Service diversity	- Diversity of the traffic models - Diversity of the transmission modes
Low bitrates (hundreds to thousands of bits/sec. compared to 250 Kbit/s in ZigBee and 1-2 Mbit/s in Bluetooth)	- Low capacity and lower number of gateways
Small payloads (around 1000 bits): encrypted device ID and measurement or actuation command	- Low capacity and lower number of gateways
Simple topology (single-hop links)	- Simplifies the coverage of large areas - Share the existing cellular networks infrastructure

IoT Networks and Services are **Very Different** from « Classical Networks » in Many Aspects and Especially from a Planning Perspective

- Communicate with Low Cost and Low Power ⇨ Repetition
- Communicate in a Shared Bandwidth ⇨ Spread Spectrum + Low Activity Rate
- Communicate in Wide Areas ⇨ Low Sensitivity

IoT components

Identification	Sensors	Connection	Integration	Data processing	Networks
•RFID •Bar codes •AND •…	•Temperature •Hydrometer •Accelerometer •Gyro meter •Nanotechnologies	•Bluetooth •ZigBee •Z-Wave •WiFi •Sigfox •LoRa •NB-IoT •…	•Simple middleware •Decisional analysis of complex systems	•Databases •ERP •CRM •3D data warehouse •Semantic Web and ontologies	•Internet •EPC

IoT generated value

- IoT is a system to **collect**, **store**, **process**, **manage**, **analyze**, … information and data from almost any object.
- Value is **not in the network** (collection and connectivity) but **it is in the data** itself.
- IoT is an opportunity for countries and people to better have a control of their data and especially, **give value to local information and data**.

Summary

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   B. Long Range technologies

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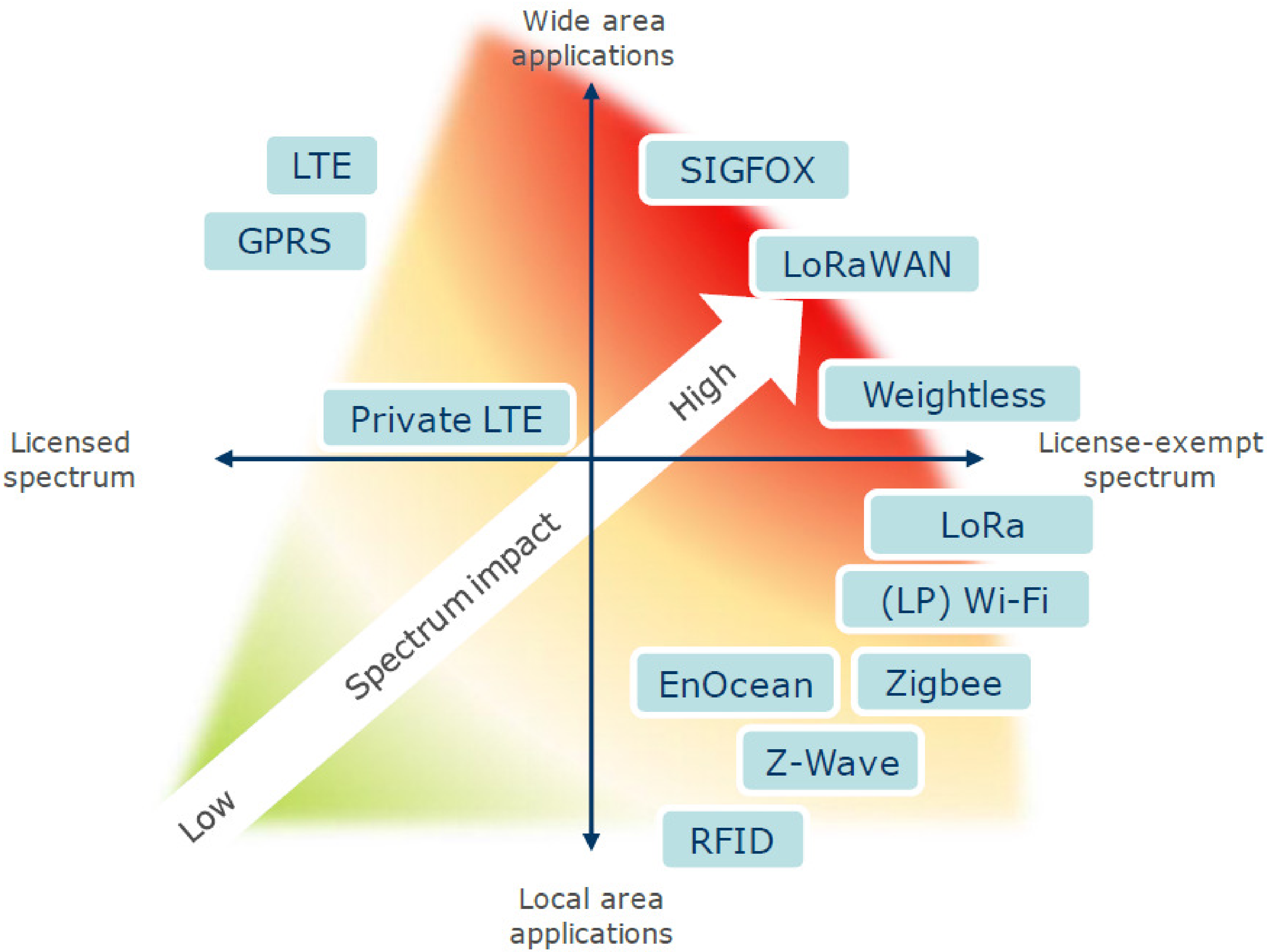
II. IoT Technologies

IoT wireless technologies overview



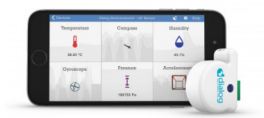
IoT 4 layers model

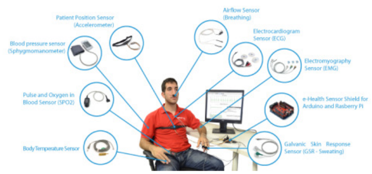
Integrated Applications

Information Processing

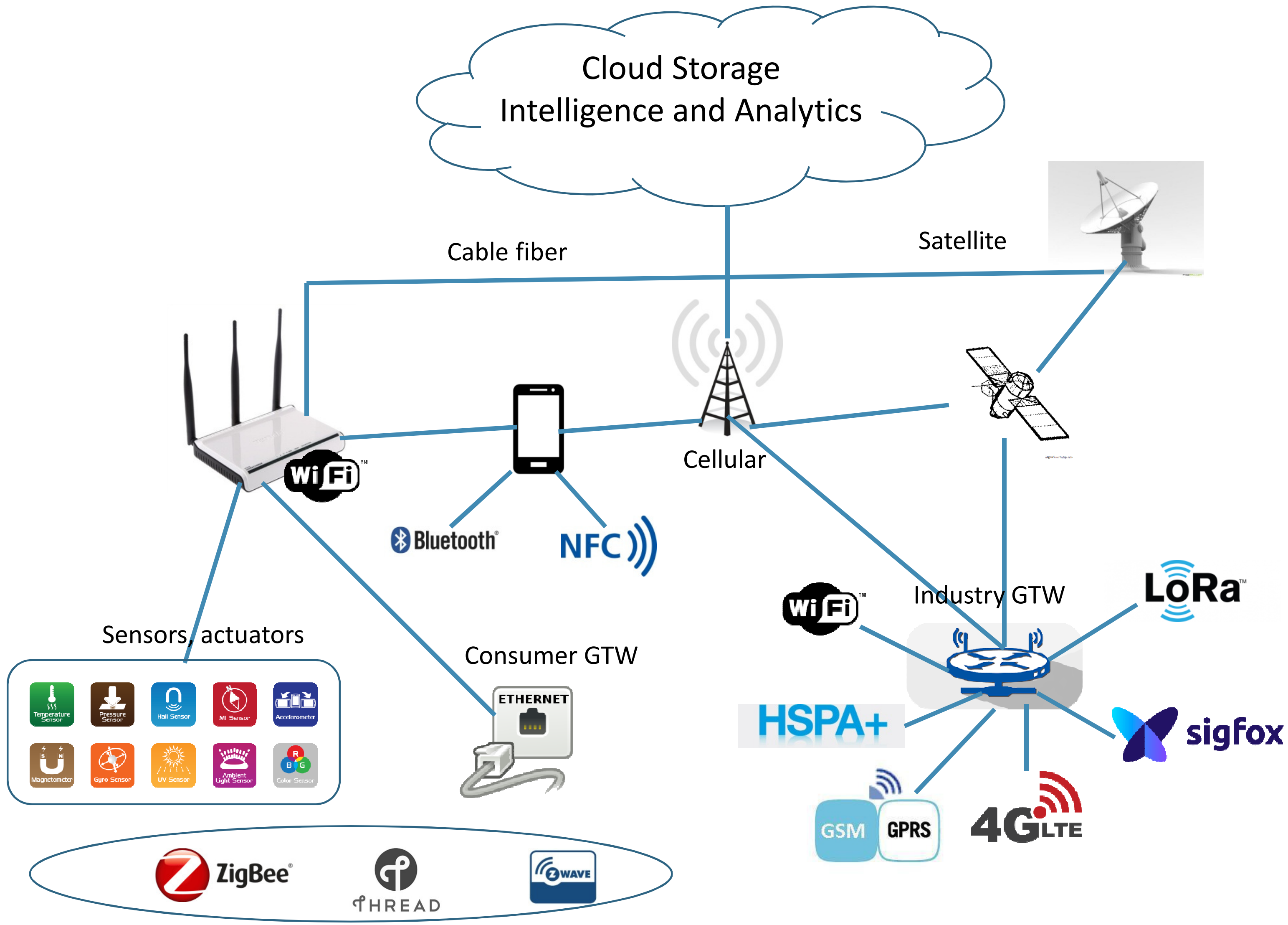
Network Infrastructure

Sensing and Identification



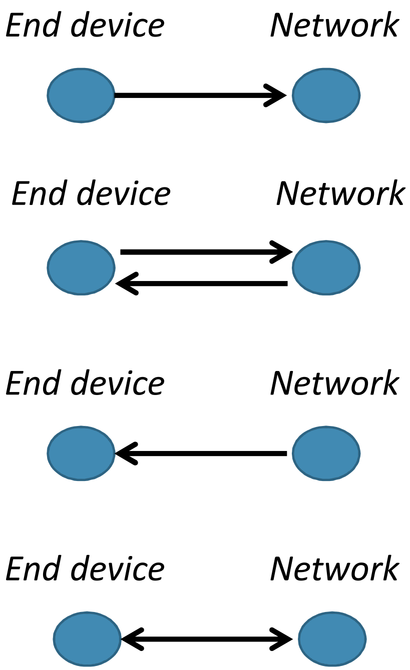


IoT network general architecture



Things classification

- Things/Objects differentiate according to:
  - ➢ The **range** (short, medium, long)
  - ➢ The **type of interaction** with the system (i.e., service type):



- ***Alarm*** (transmission initiated by the end-device only, according to the events, bursty traffic),
- ***Measurements*** (triggered either by the end-device or by the system),
- ***Control*** (transmissions initiated by the system),
- ***Combination*** of these.

Things states and operations

The device can:

- **Publish** or **Subscribe**
- Be **online** or **offline**
- Manage messages of **different formats**
- Have different ty**pes of communication channels**
- Have **one channel** or **several data streams**

Quiz 1 – IoT networks architecture

1. What are the main features of an IoT system?
2. What are the 4 layers of an IoT network?
3. What are the main components of an IoT network?
4. What are the different types of objects in IoT?
5. What are the operations an object (i.e., end-device) can achieve?
6. What kinds of IoT networks can be distinguished?

Summary

A. Fixed & Short Range

B. Long Range technologies

1. Non 3GPP Standards (LPWAN)
2. 3GPP Standards

A. Fixed & Short Range

i. RFID

ii. Bluetooth

iii. Zigbee

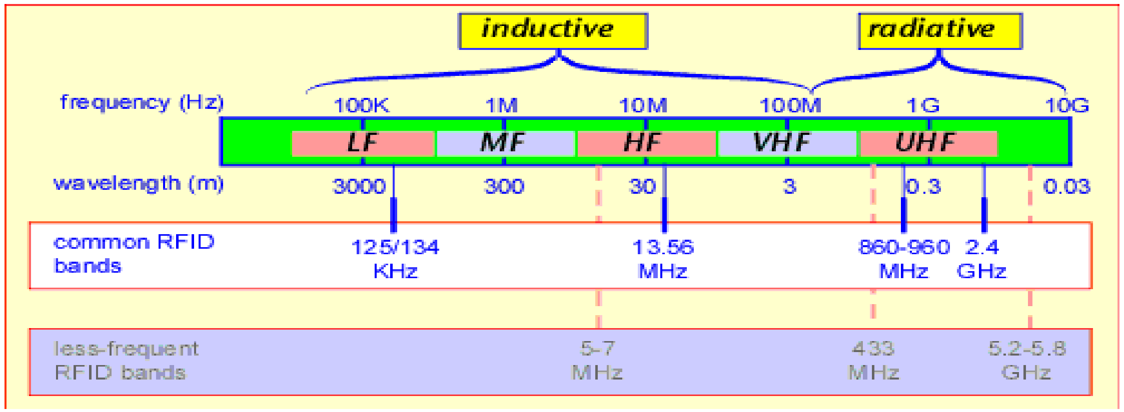
iv. WiFi

i. RFID

RFID (Radio Frequency Identification)

- Appeared first in 1945
- *Features*: Identify objects, record metadata or control individual target
- More complex devices (e.g., readers, interrogators, beacons) usually connected to a host computer or network
- Radio frequencies from 100 kHz to 10 GHz
- *Operating*: reading device called a reader, and one or more tags

RFID Frequencies



RFID

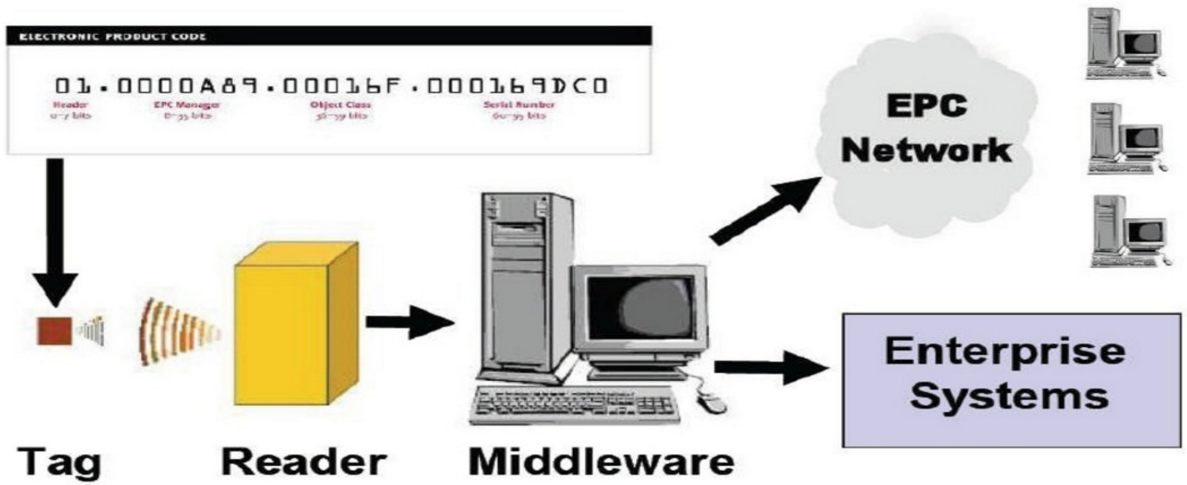
How does it work?

Tag

- Microchip connected to an antenna
- Can be attached to an object as his identifier

Reader

- RFID reader communicating with the **RFID tag** through radio waves



Different Types of TAGs

	Passive Tags	Active Tags
Power	Powering through RF **from Reader**	**Internal** to the Tag
Battery	**No**	**Yes**
Availability	Only in the field of Radar	Continuous
Required Signal Strength to Tag	Very High	Very Low
Range	Up to **3-5m**	Up to **100m**
Multi Tag Reading	Few Hundred within 3 meters from the reader	1000's of tags recognized
Data Storage	128 bytes	128 bytes with search and access

Short or very short range technology, most applications are based on manual involvement and limited to presence detection.

ii. Bluetooth

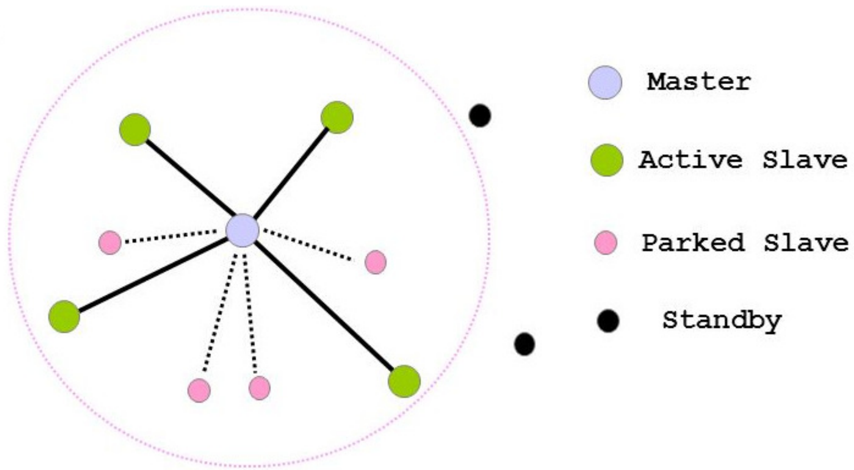
Bluetooth characteristics

- **Low Power** wireless technology
- **Short range** radio frequency at **2.4 GHz** ISM Band
- Wireless *alternative* to wires
- Creating **PANs** (*Personal area networks*)
- Support Data Rate of 1 Mb/s (data traffic, video traffic)
- Uses frequency-hopping spread spectrum

Class	Maximum Power	Range
1	100 mW (20 dBm)	~100 m
2	2,5 mW (4 dBm)	~10 m
3	1 mW (0 dBm)	~1 m

Bluetooth Piconet

- Created instantly and automatically between Bluetooth devices within the same area
- A ***master*** device and others ***slaves***
- Slaves cannot directly send data to each others
- All traffic must go through the ***master***
- Up to 7 active slaves



Bluetooth Scatternets

- Two or more piconets
- Devices that participate in two piconet act as **gateways**

Bluetooth Low Energy

- Enables IoT features
- Lowest cost and Easy to implement
- Improvements for ease of discovery & connection
- Low latency, fast transaction (3 ms from start to finish)
- Data Rate 1 Mb/s: sending just small data packets
- **Bluetooth 5**: 4x range, 2x speed and 8x broadcasting message capacity.

Range	~ 150 m
Output Power	~ 10mW(10 dBm)
Max current	15 mA
Modulation	GFSK at 2.4 GHz
Sleep current	~ 1 µA

Low cost, available, ready to go.

iii. ZigBee

ZigBee

Control and **wireless sensor** network

Based on the **IEEE 802.15.4** Standard

Created by the **Zigbee alliance**

Low data rates and low power consumption

Small packet networks

Operates on unlicensed bands:

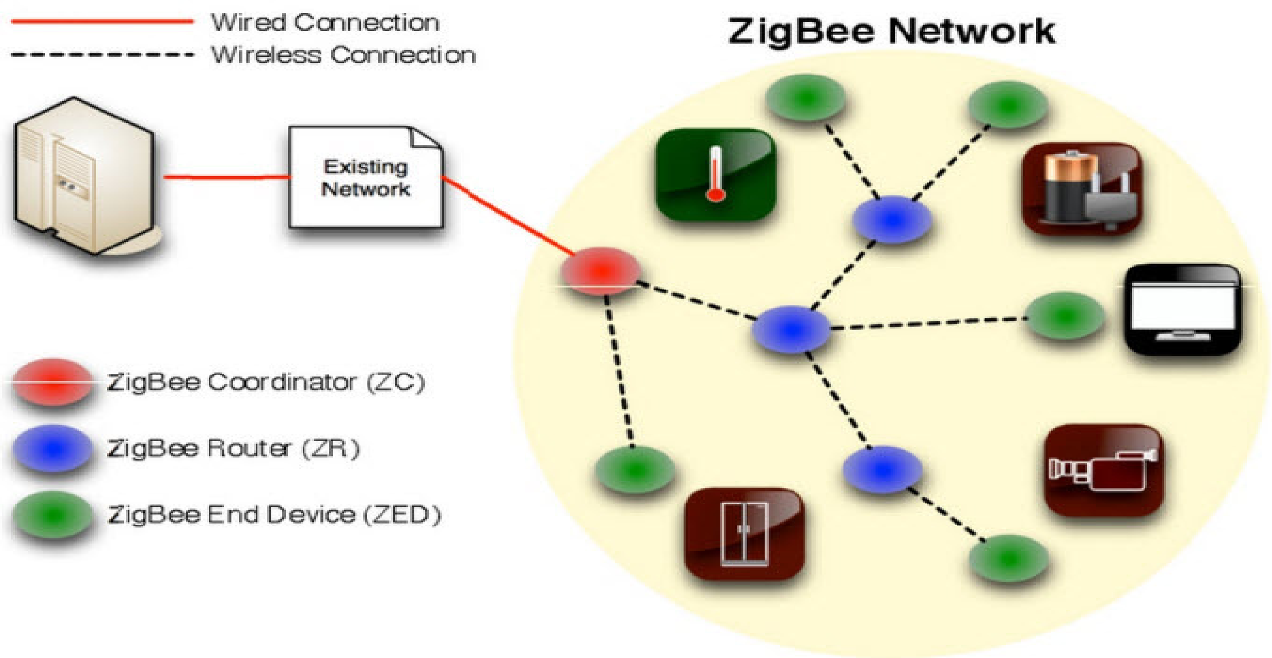
- ISM 2.4 GHz at 250 Kbps
- 868 MHz at 20 Kbps
- 915 MHz at 40 Kbps

Topology:

Star, Cluster Tree, Mesh

Up to 65 000 nodes on a network

ZigBee



- **Coordinator**: acts as a root and bridge of the network
- **Router**: intermediary device that permit data to pass to and through them to other devices
- **End Device**: limited functionality to communicate with the parent nodes

Low cost, available, ready to go.

iv. WiFi

WiFi

- Wireless technology
- Alternative to Wired Technologies
- IEEE 802.11 standard for WLANs

Standard	Frequency bands	Throughput	Range
WiFi a (802.11a)	5 GHz	54 Mbit/s	10 m
WiFi B (802.11b)	2.4 GHz	11 Mbit/s	140 m
WiFi G (802.11g)	2.4 GHz	54 Mbit/s	140 m
WiFi N (802.11n)	2.4 GHz / 5 GHz	450 Mbit/s	250 m
IEEE 802.11ah	900 MHz	8 Mbit/s	1000 m

Wi-Fi HaLow

- A new low-power, long-range version of **Wi-Fi** that bolsters **IoT** connections, it will be available in 2018

- Wi-Fi HaLow is based on the IEEE 802.11ah specification
- Data rates > 100 kbit/s

- Wi-Fi HaLow will operate in the unlicensed wireless spectrum in the 900MHz band
- MAC is designed to support thousands of connected devices

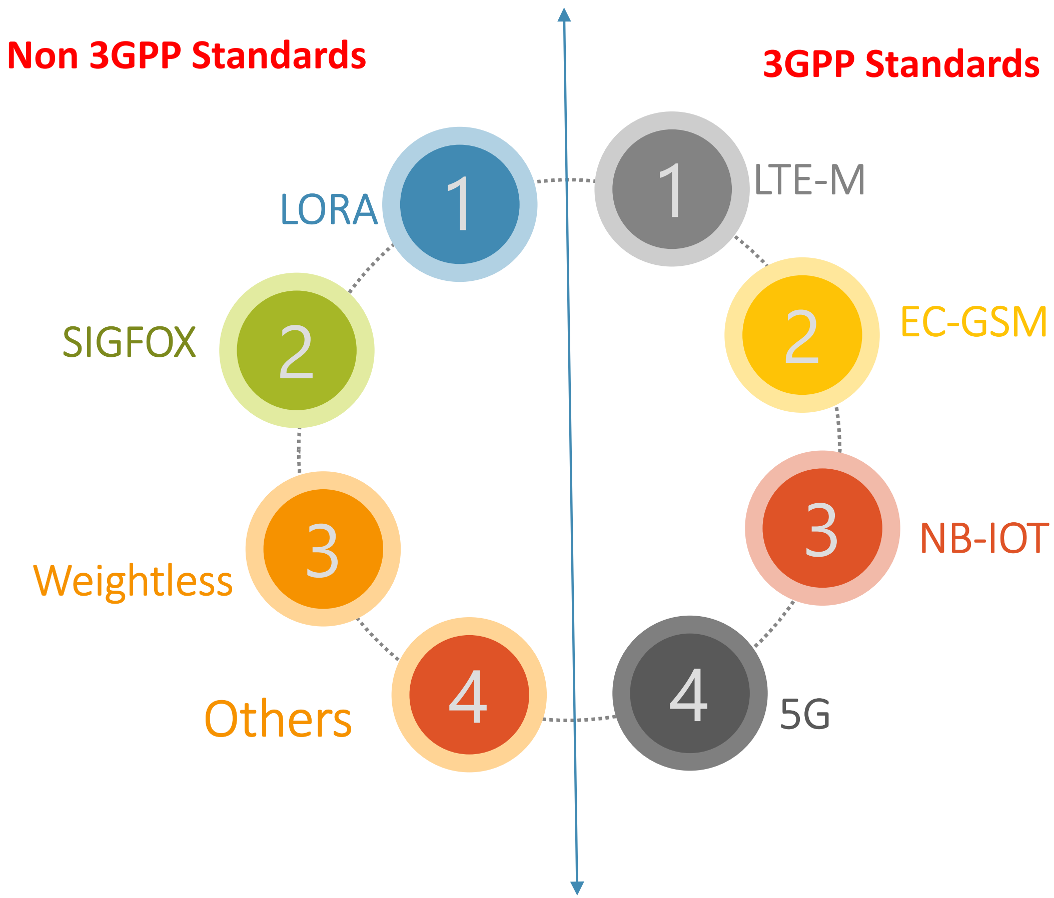
- It will easily penetrate walls and barriers thanks to the propagation capabilities of low-frequency radio waves.

- Its range will be nearly double today's available Wi-Fi (1 kilometer)
- Power Saving mode allows objects to remain inactive during max idle period after which, the STA is disassociated > 5 years sleeping!

- WiFi is longer range than Bluetooth and ZigBee
- More flexible
- Closer to networks

WiFi-based IoT Devices

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

Quiz 2 – Short range IoT systems

1. What are the main 2 technologies used for IoT short range?
2. What are the main changes introduced in existing short range system to allow IoT communications?
3. What are the main advantage of using existing systems?
4. What are the offered bitrates with these systems?
5. What are the maximum ranges these systems can offer?

Summary

A. Fixed & Short Range

B. Long Range technologies

1. Non 3GPP Standards (LPWAN)
2. 3GPP Standards

B. Non 3GPP Standards (LPWAN)

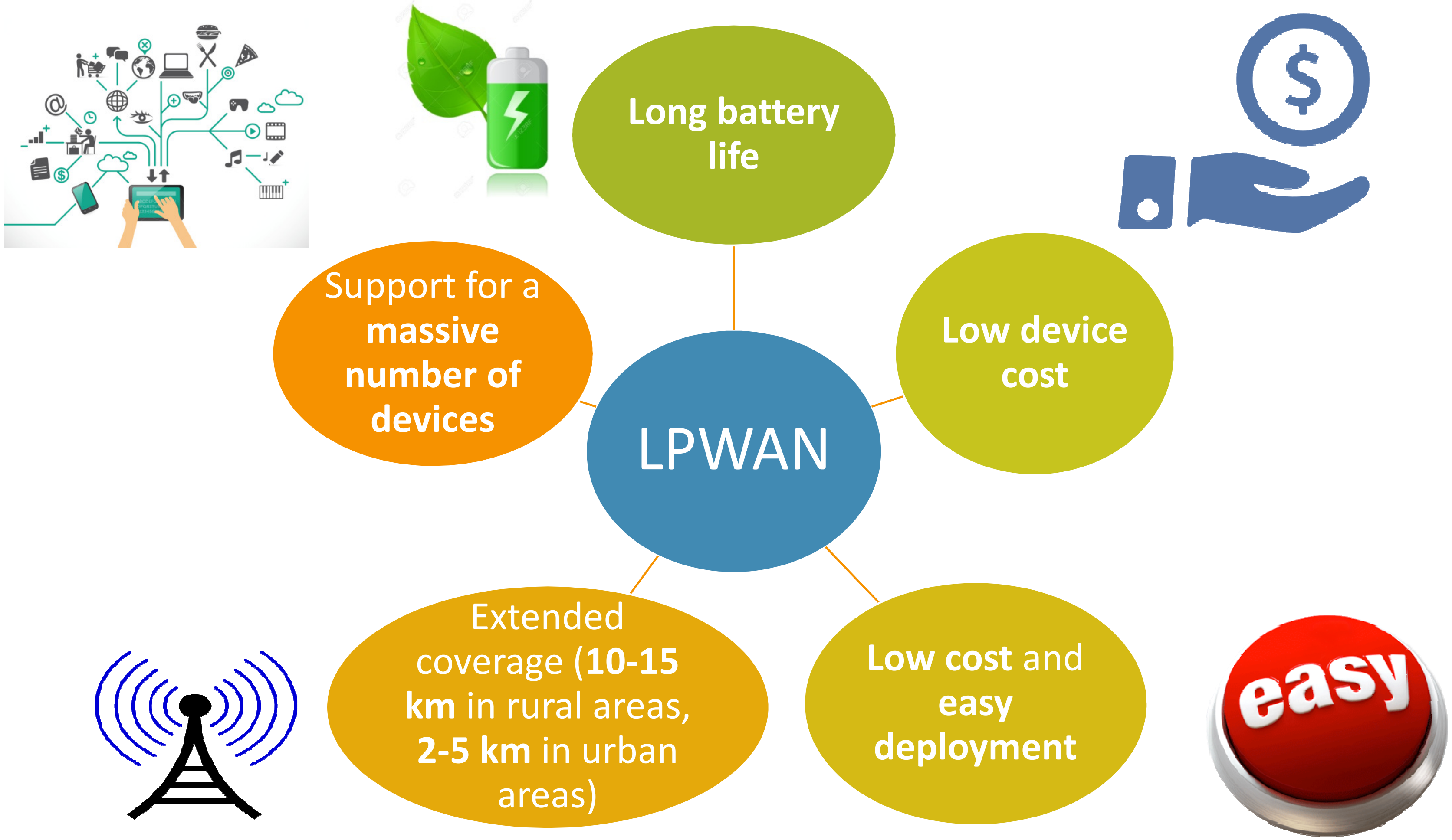
i. LoRaWAN

ii. Sigfox

iii. RPMA

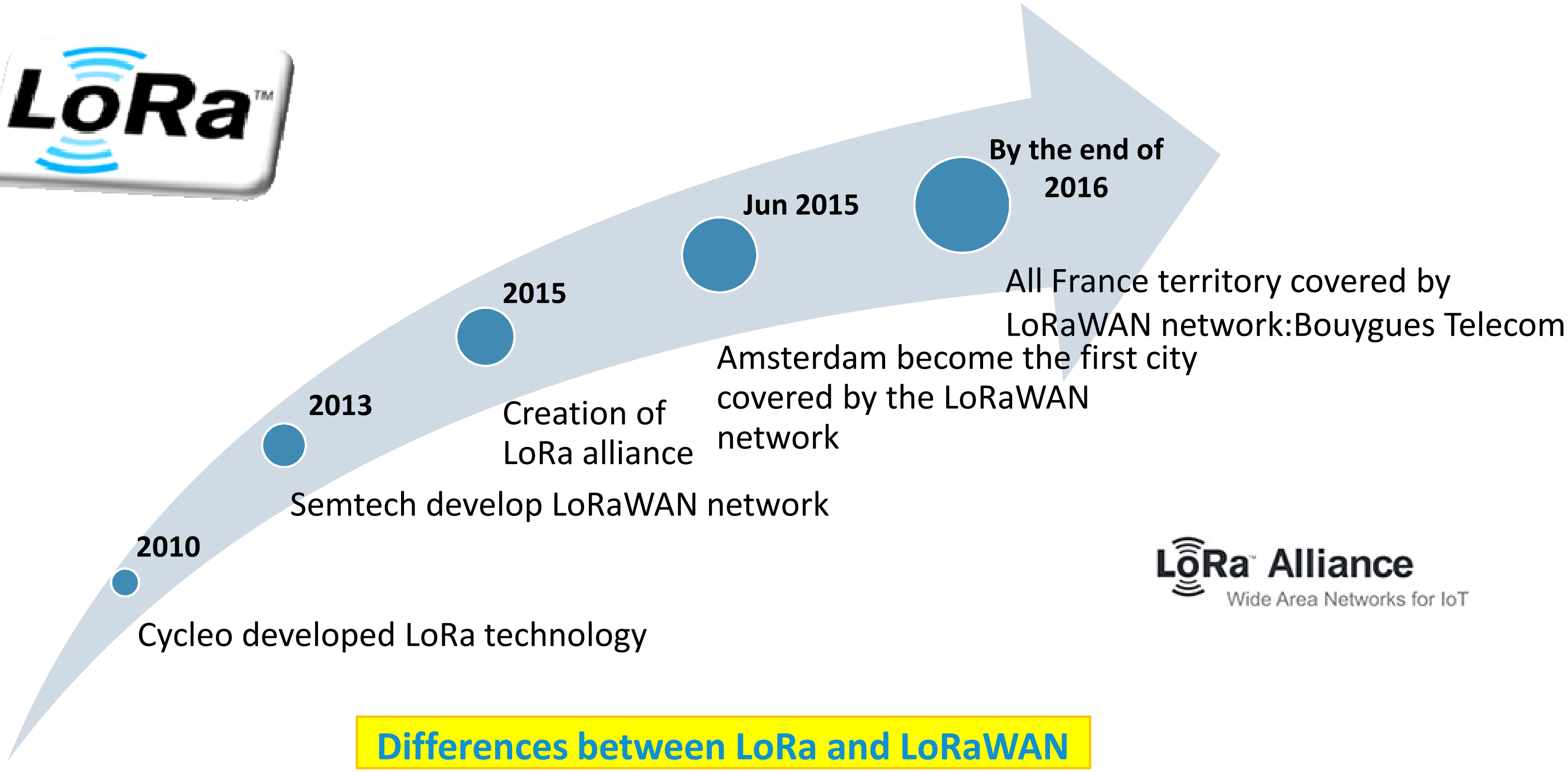
iv. Others

LPWAN Requirements



i. LoRaWAN

Roadmap



Differences between LoRa and LoRaWAN

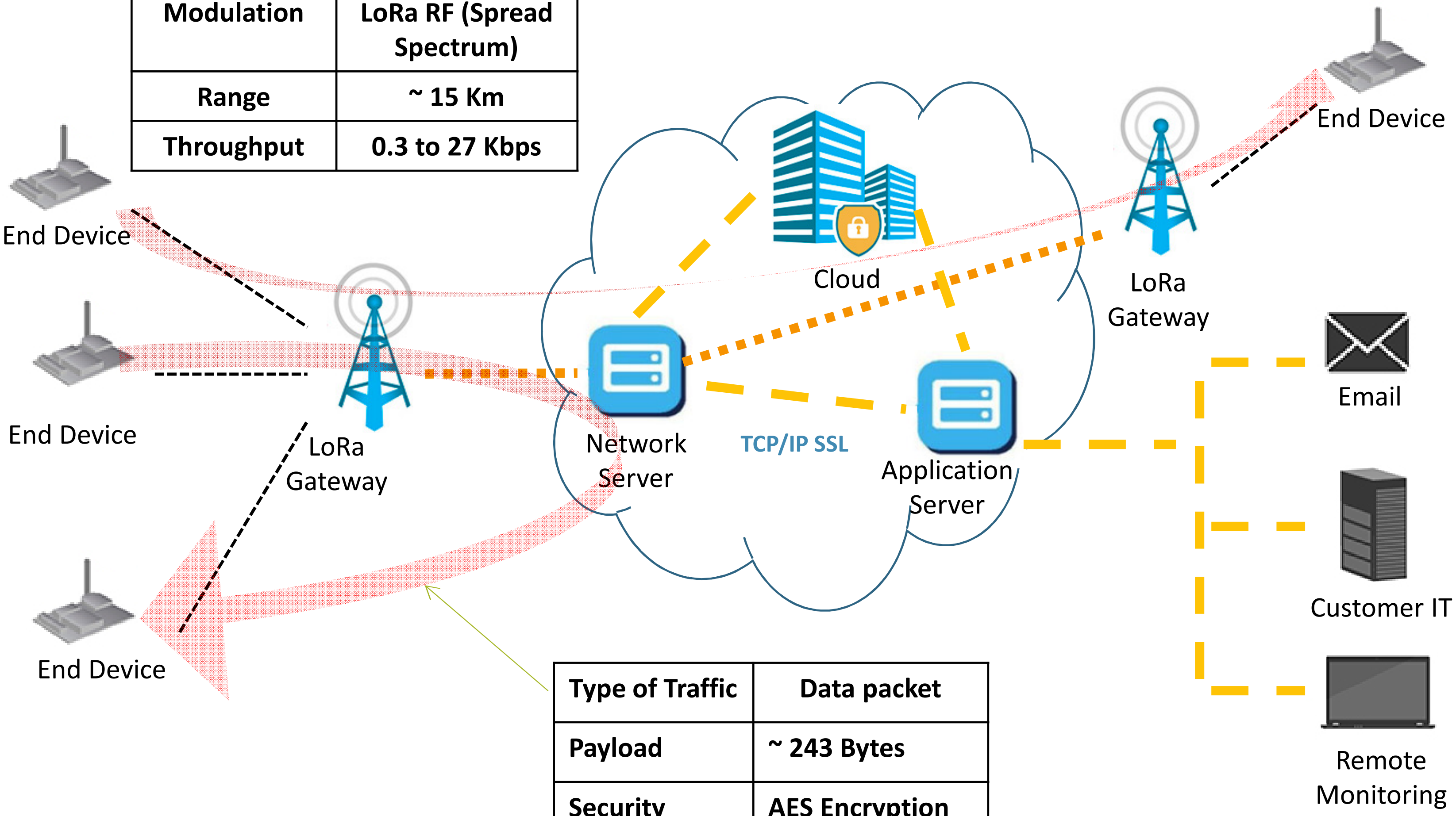
- **LoRa** contains only the link layer protocol. LoRa modules are a little cheaper that the LoRaWAN ones.
- **LoRaWAN** includes the network layer too so it is possible to send the information to any Base Station already connected to a Cloud platform. LoRaWAN modules may work in different frequencies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

LoRa Alliance

International Operators	International development of the solution	Bouygues Telecom, belgacom, SingTel, SK telecom, swisscom, kpn, FastNet, orange, Three.co.uk, Telstra
Integrators and industrialists	Appropriate technology and maintain it over time	IBM, Sagemcom, Cisco, actility, kerlink
Manufacturers of End-points	Broadcast end devices	Adeunis RF, MultiTech Systems, éolane
Manufacturers of Semiconductors	Integrate LoRa technology	Semtech, Microchip

- 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.

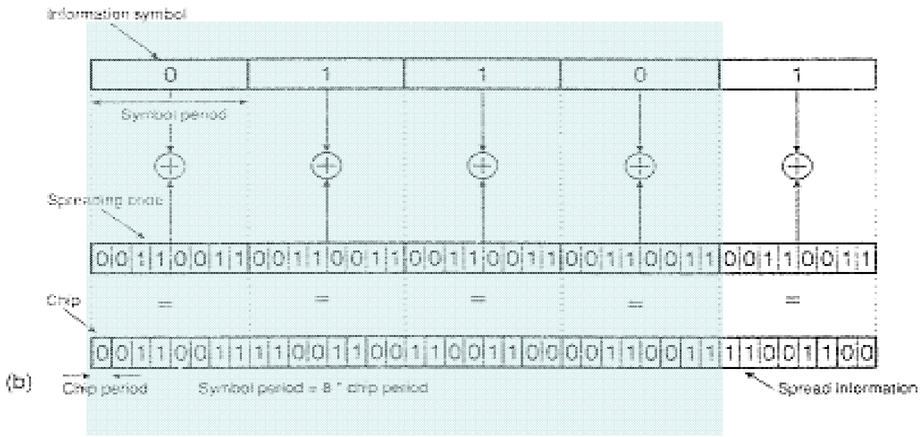
Architecture

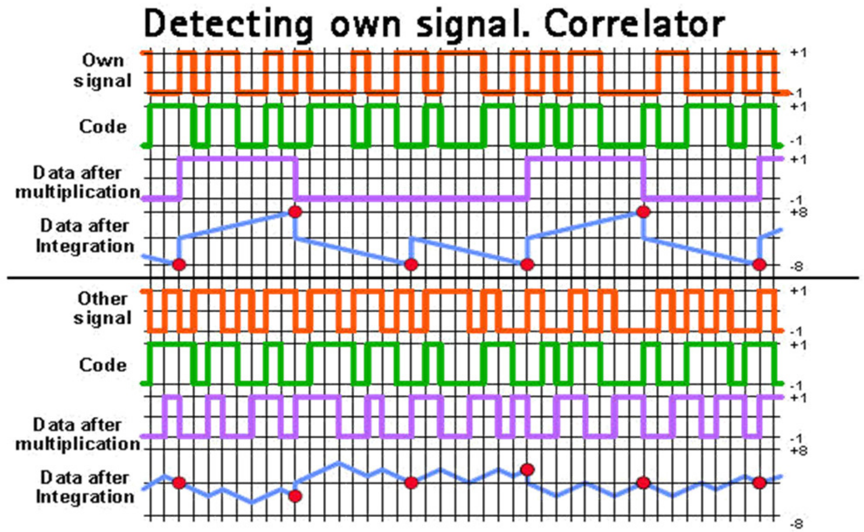


Modulation	LoRa RF (Spread Spectrum)
Range	~ 15 Km
Throughput	0.3 to 27 Kbps

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

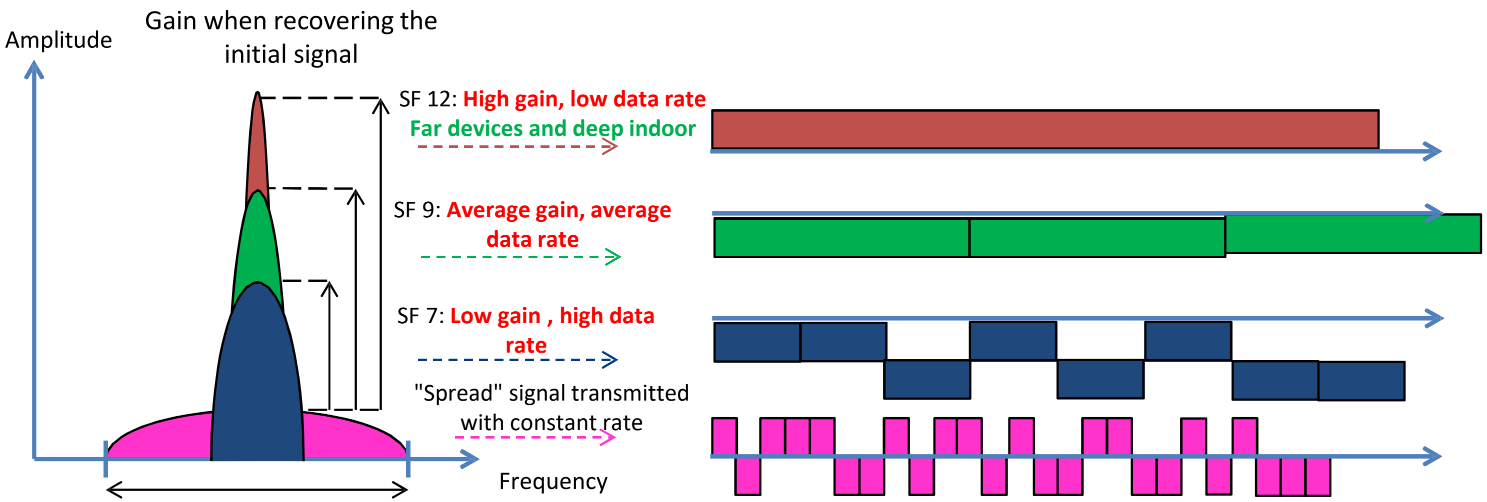
Spread spectrum basics





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

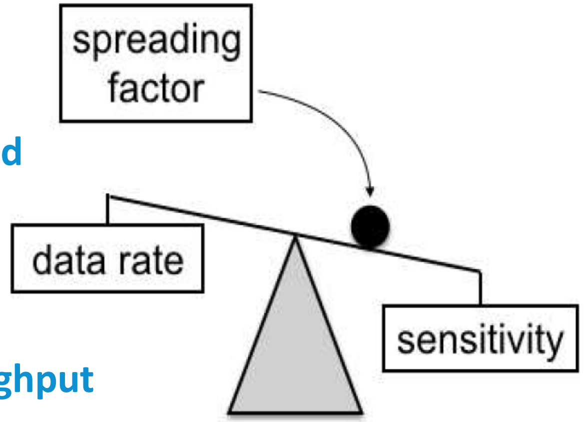
➔ The network **increases** the SF (*Spreading Factor*) ➔

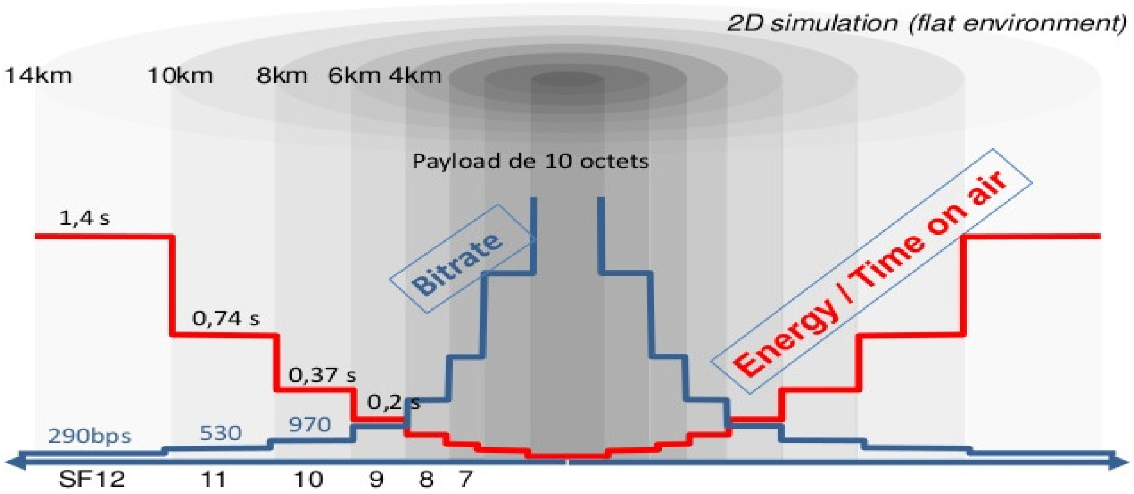
Throughput decreases but **the connection is maintained**

Close:

➔ **Low sensitivity** sufficient

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



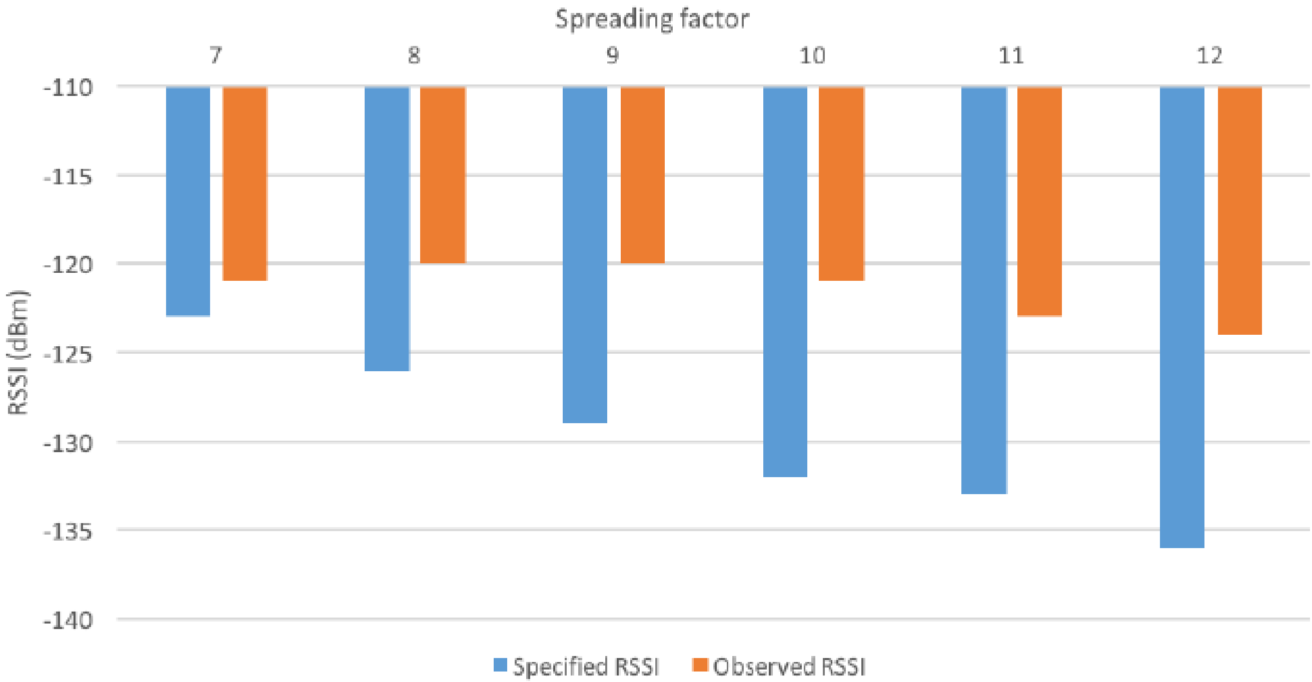


Adaptive throughput

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)

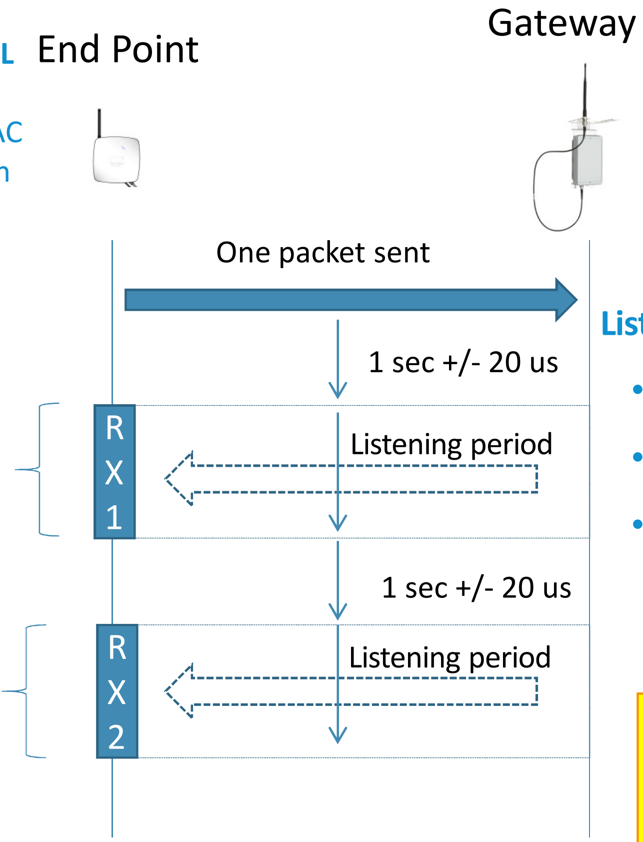
LoRaWAN: device classes

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 (« **b**eacon »)	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 (« **c**ontinuous »)	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**



Listening period: varies according to the spreading factor SF

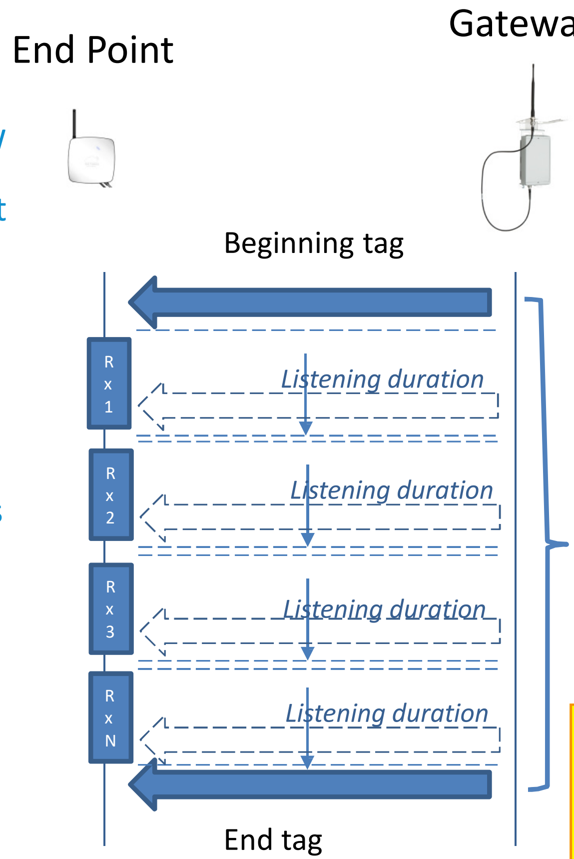
- 5.1 ms at SF7 (outdoor and close devices)
- 10.2 ms at *SF8 …*
- 164 ms at SF12 (deep-indoor or far devices)

- 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

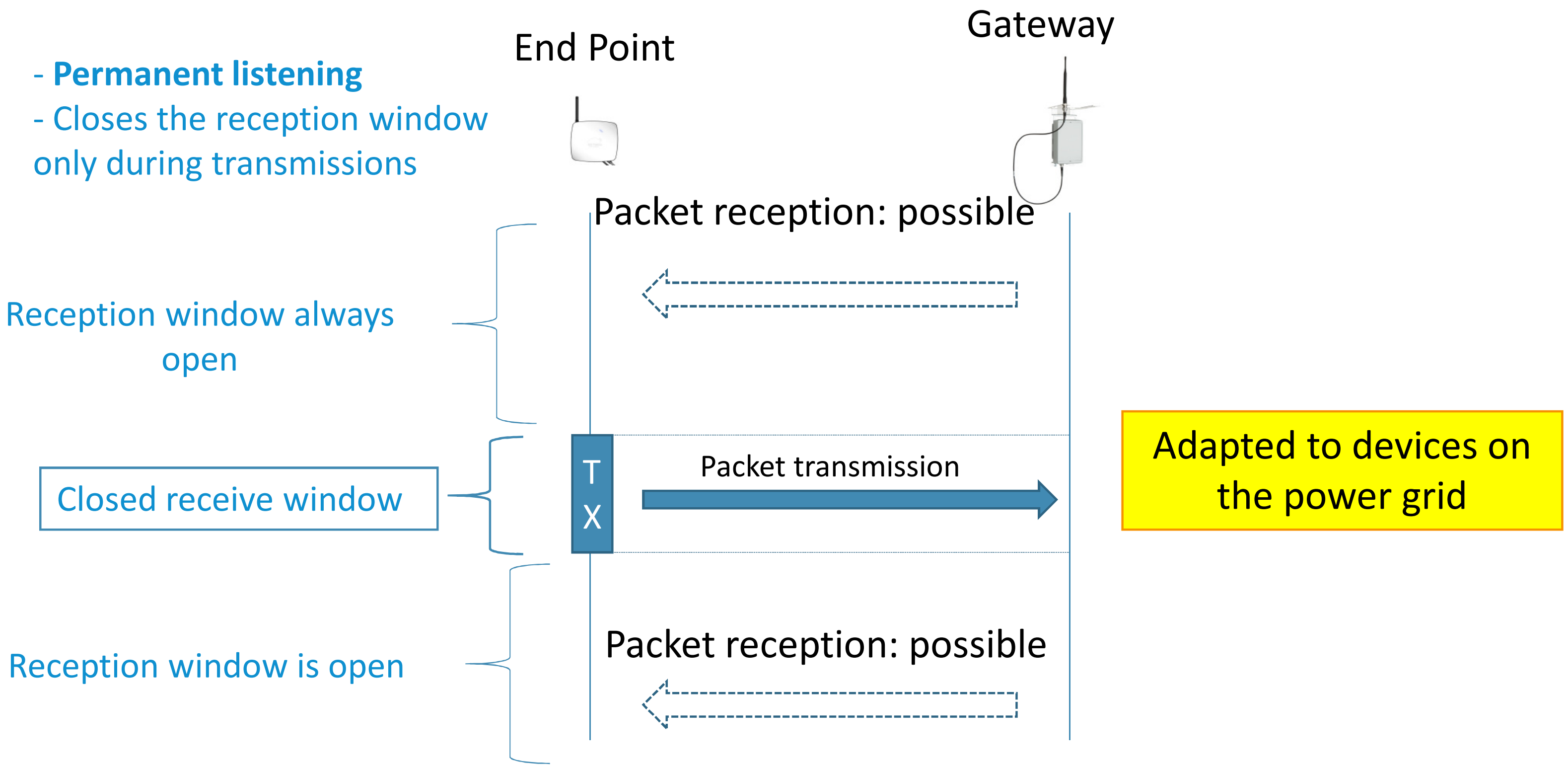


Listening duration: varies according to the SF

- 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*):**

Network identifier	network address of the end-device
7 bits	**25 bits**

- **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

83

Network Operators

57

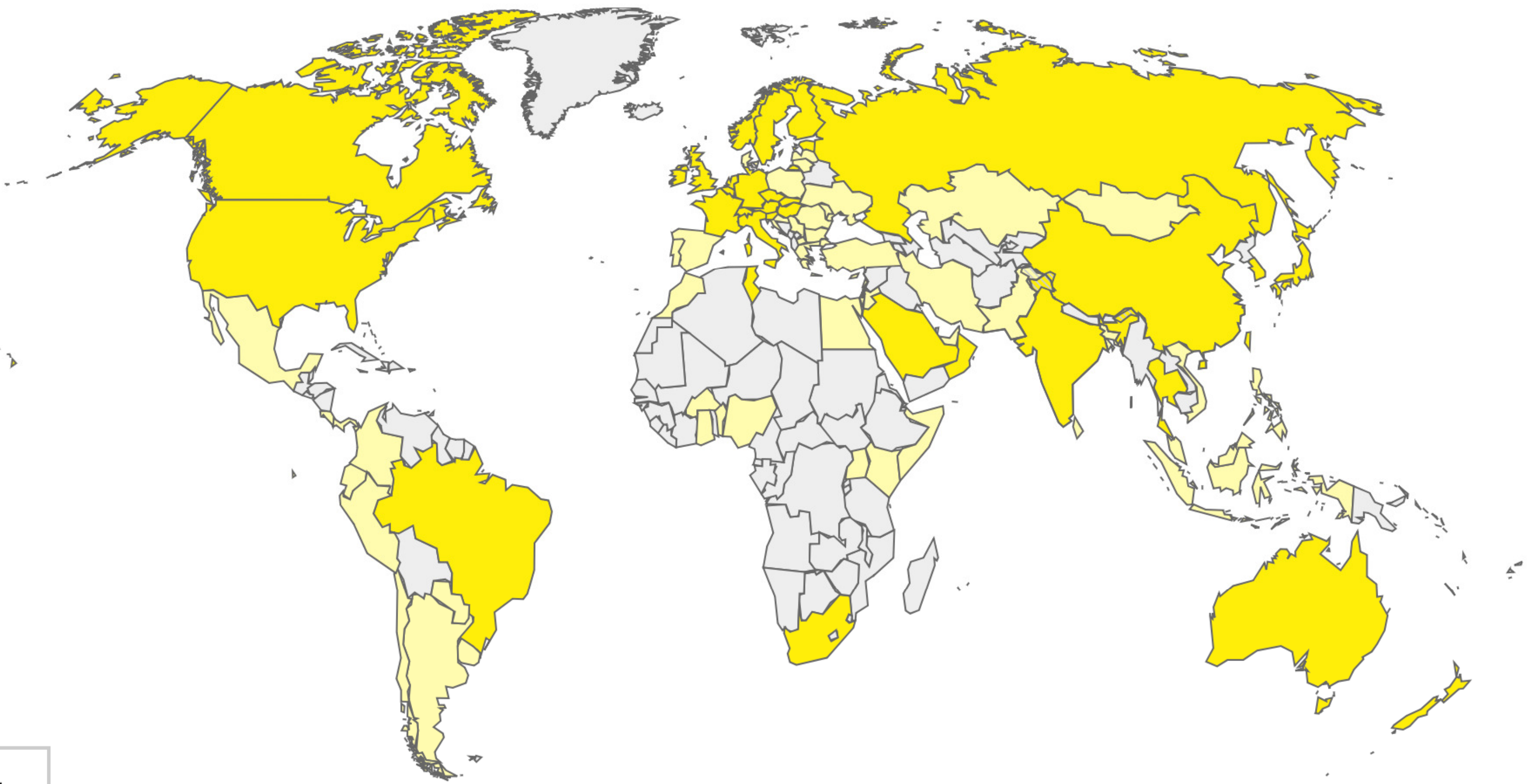
Alliance Member Operators

49

Countries operating in

95

Countries with LoRaWAN Deployments

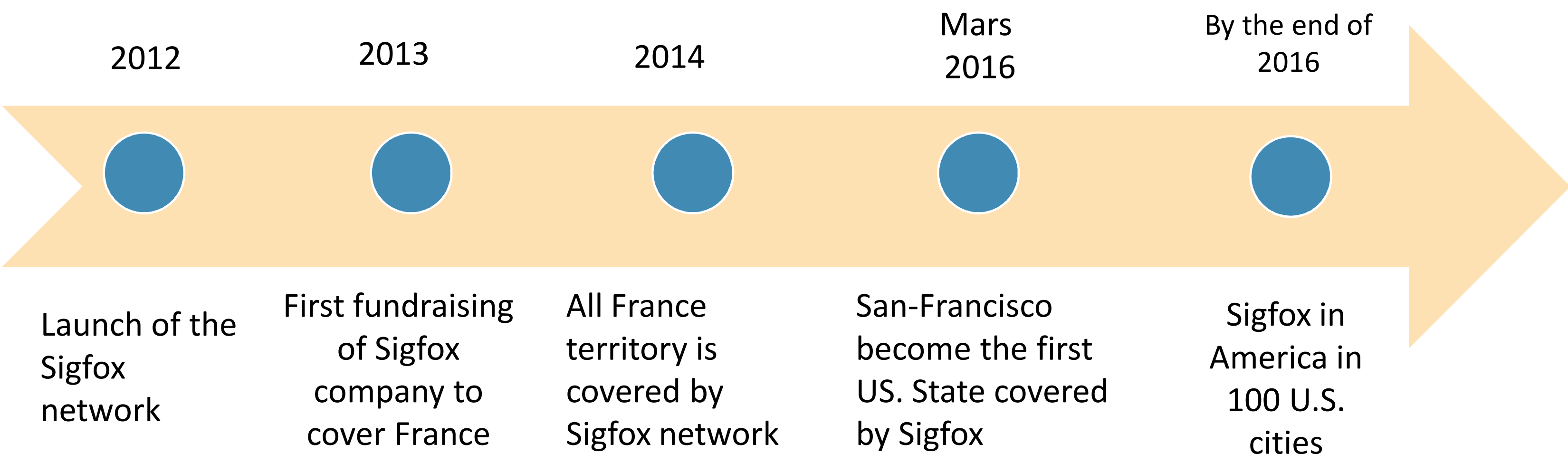


Alliance Member Public Networks

Other LoRaWAN Deployment

ii. Sigfox

Roadmap

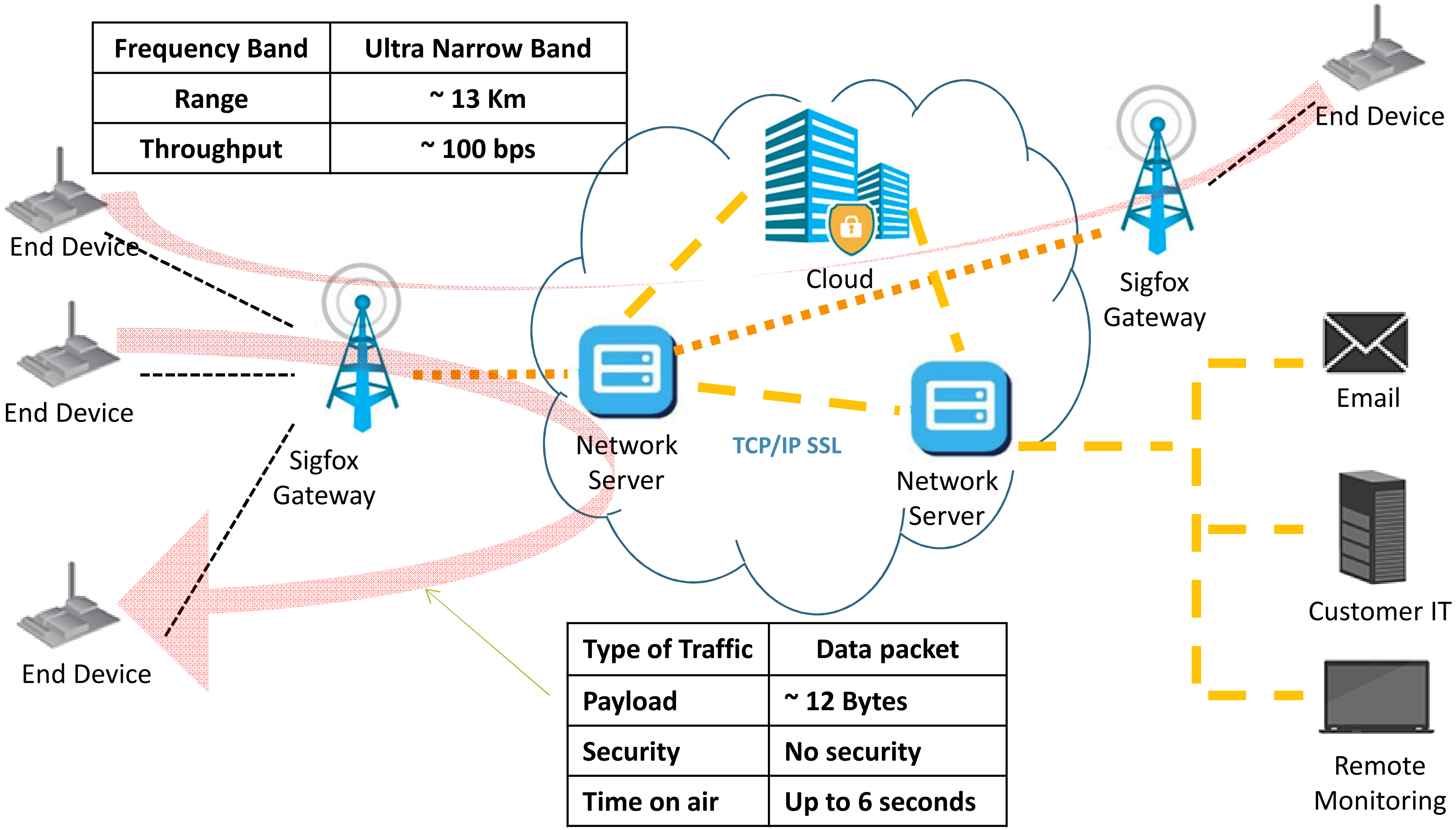

2012
Launch of the Sigfox network
2013
First fundraising of Sigfox company to cover France
2014
All France territory is covered by Sigfox network
Mars 2016
San-Francisco become the first US. State covered by Sigfox
By the end of 2016
Sigfox in America in 100 U.S. cities

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

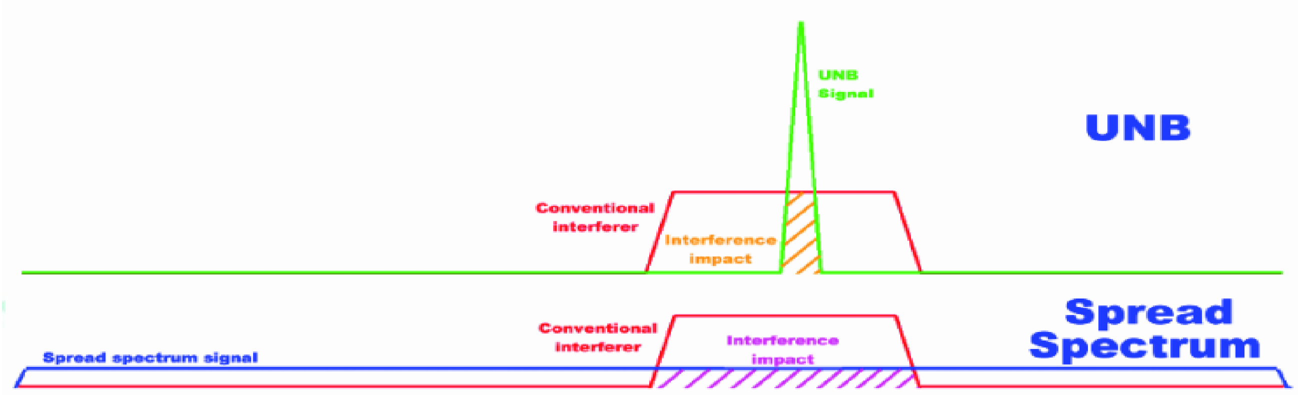


Type of Traffic	Data packet
Payload	~ 12 Bytes
Security	No security
Time on air	Up to 6 seconds

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

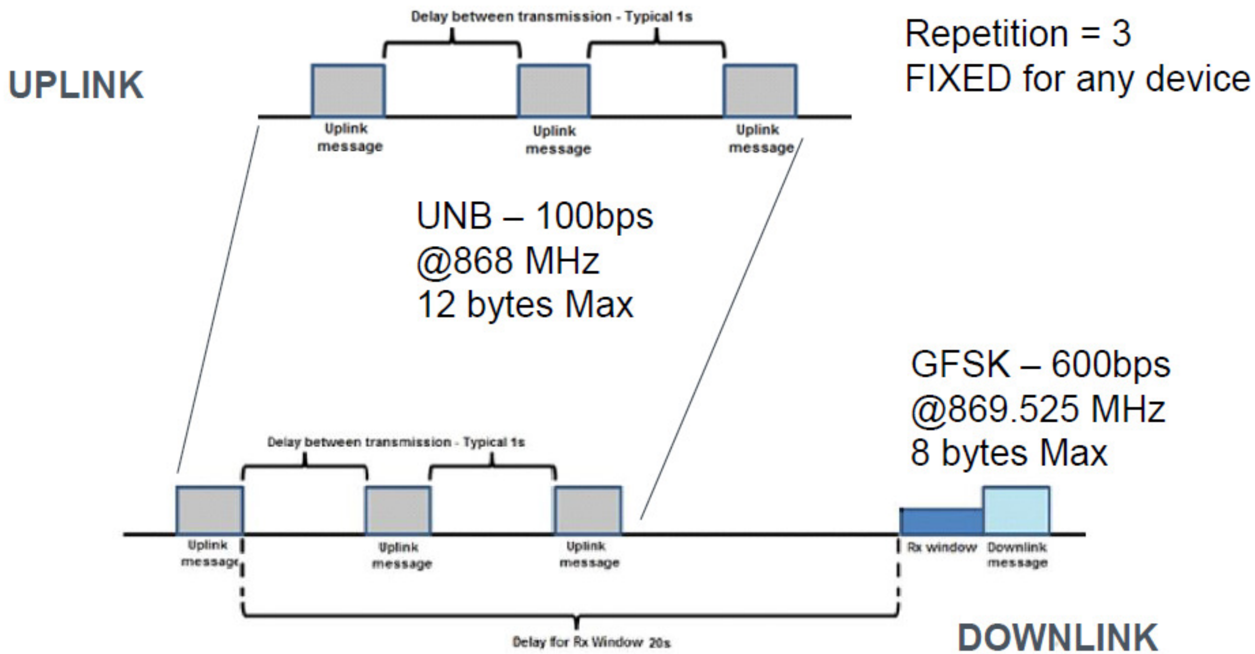


Frequency spectrum:

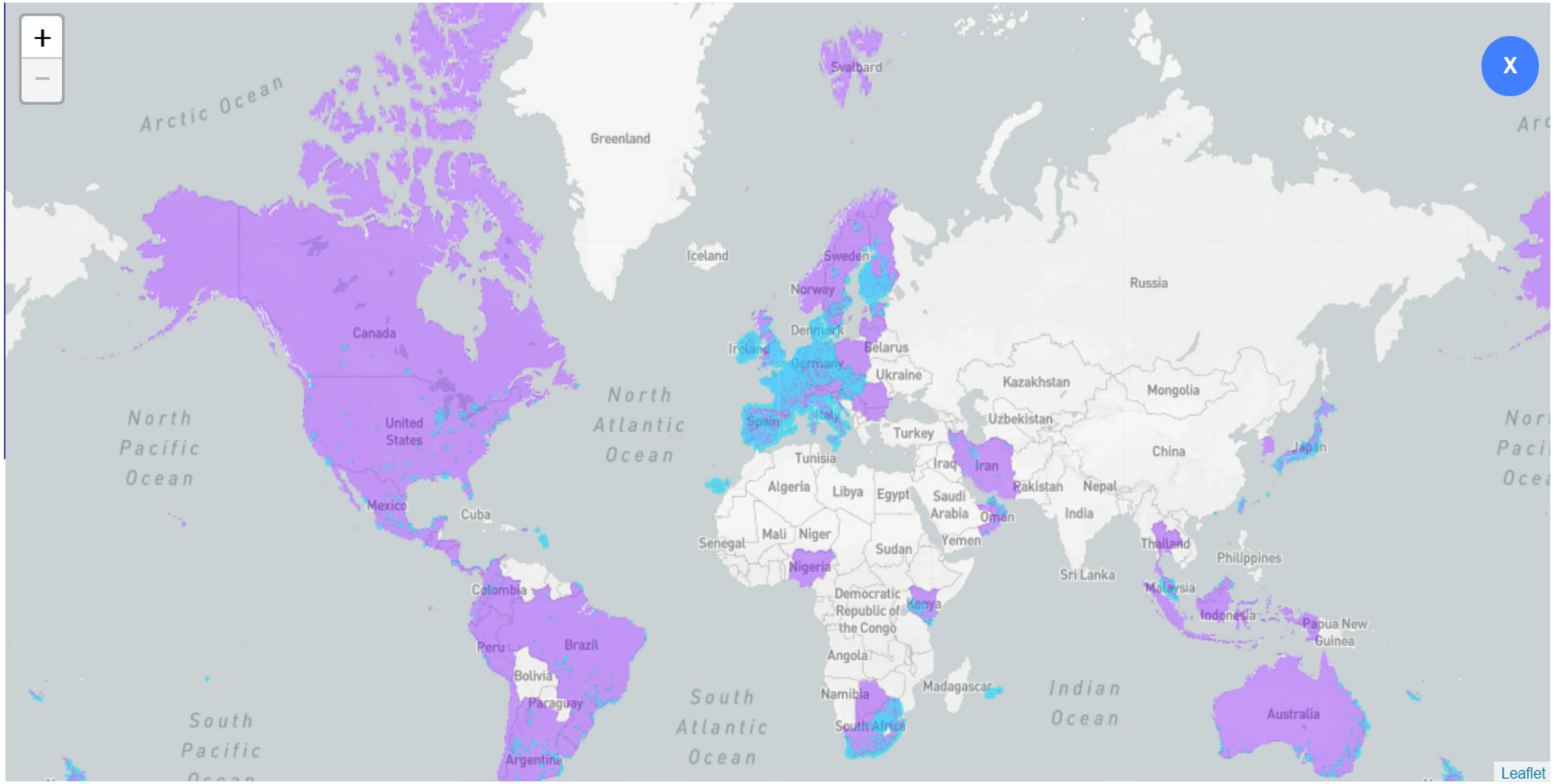
- 868 MHz in Europe
- 915 MHz in USA

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



iii. RPMA

Roadmap

2008

RPMA was developed by On-Ramp Wireless to provide connectivity to oil and gas actors

September 2015

it was renamed Ingenu, and targets to extend its technology to the IoT and M2M market

2016

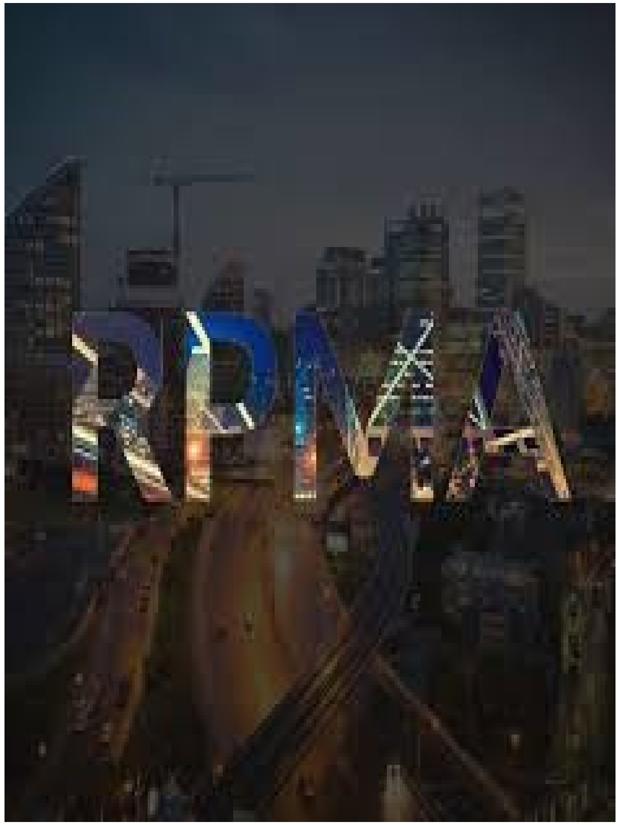
RPMA was implemented in many places Austin, Dallas/Ft. worth, Hostton,TX,Phenix,AZ, ….

2017

RPMA will be invaded in many others countries: Los Angeles, San Franscisco-West Bay,CA,Washington,DC, Baltimore,MD, Kanasas City

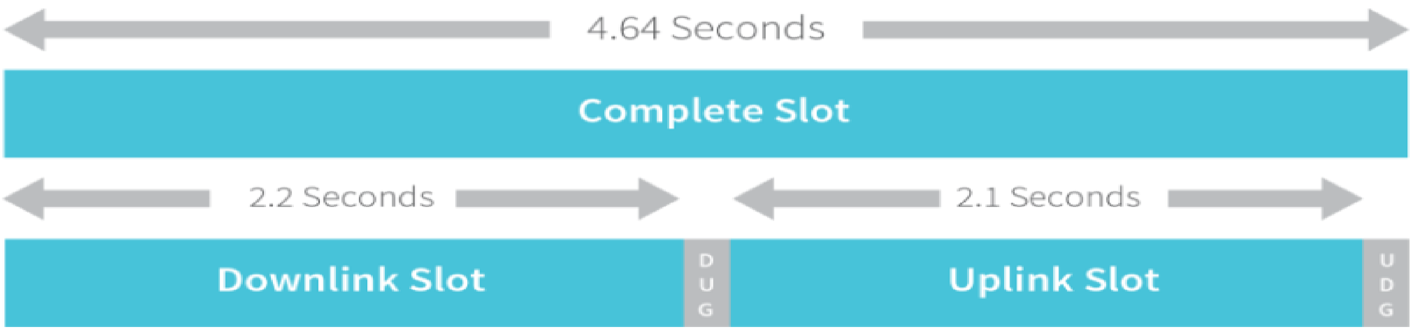
INGENU RPMA overview

- *Random Phase Multiple Access* (RPMA) technology is a low-power, wide-area channel access method used exclusively for machine-to-machine (M2M) communication
- RPMA uses the 2.4 GHz band
- Offer extreme coverage
- High capacity
- Allow handover (channel change)
- Excellent link capacity



INGENU RPMA Overview

- RPMA is a Direct Sequence Spread Spectrum (DSSS) using:
  - Convolutional channel coding, gold codes for spreading
  - 1 MHz bandwidth
  - Using **TDD frame** with power control:
    - **Closed Loop Power Control:** the access point/base station measures the uplink received power and periodically sends a one bit indication for the endpoint to turn up transmit power (1) or turn down power (0).
    - **Open Loop Power Control:** the endpoint measures the downlink received power and uses that to determine the uplink transmit power without any explicit signaling from the access point/base station.



TDD frame

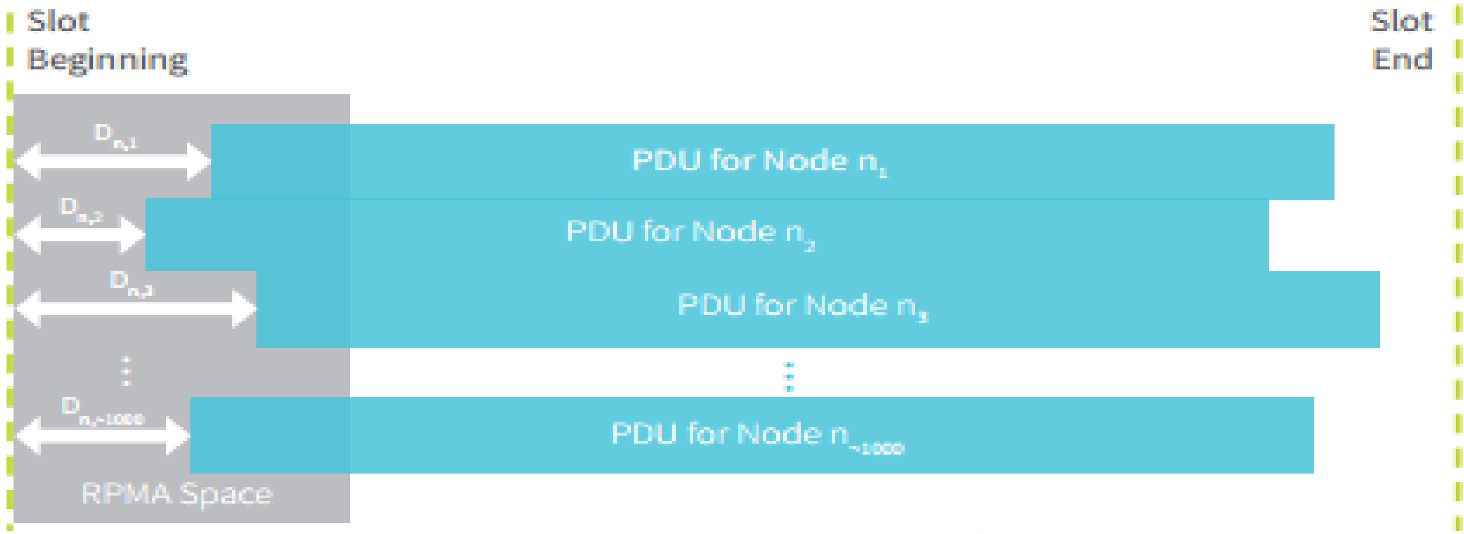
Specifications of RPMA Solution

- ❑ **Time/Frequency Synchronization**
- ❑ **Uplink Power Control**
  - ✓ Creating a very tightly power controlled system in free-spectrum and presence of interference which **reduces** the amount of **required endpoint transmit power** by a factor of >50,000 and mitigates the **near-far effect**.
  - ✓ Frame structure to allow continuous channel tracking.
  - ✓ Adaptive spreading factor on uplink to optimize battery consumption.
- ❑ **Handover**
  - ✓ Configurable gold codes per access point to eliminate ambiguity of link communication.
  - ✓ Frequency reuse of 3 to eliminate any inter-cell interference degradation.
  - ✓ Background scan with handover to allow continuous selection of the best access point

❑ Downlink Data Rate Optimization

- ✓ Very high downlink capacity by use of adaptive downlink spreading factors.
- ✓ Open loop forward error correction for extremely reliable firmware download.
- ✓ Open loop forward error correction to optimize ARQ signaling. Signaling only needs to indicate completion, not which particular PDUs are lost.

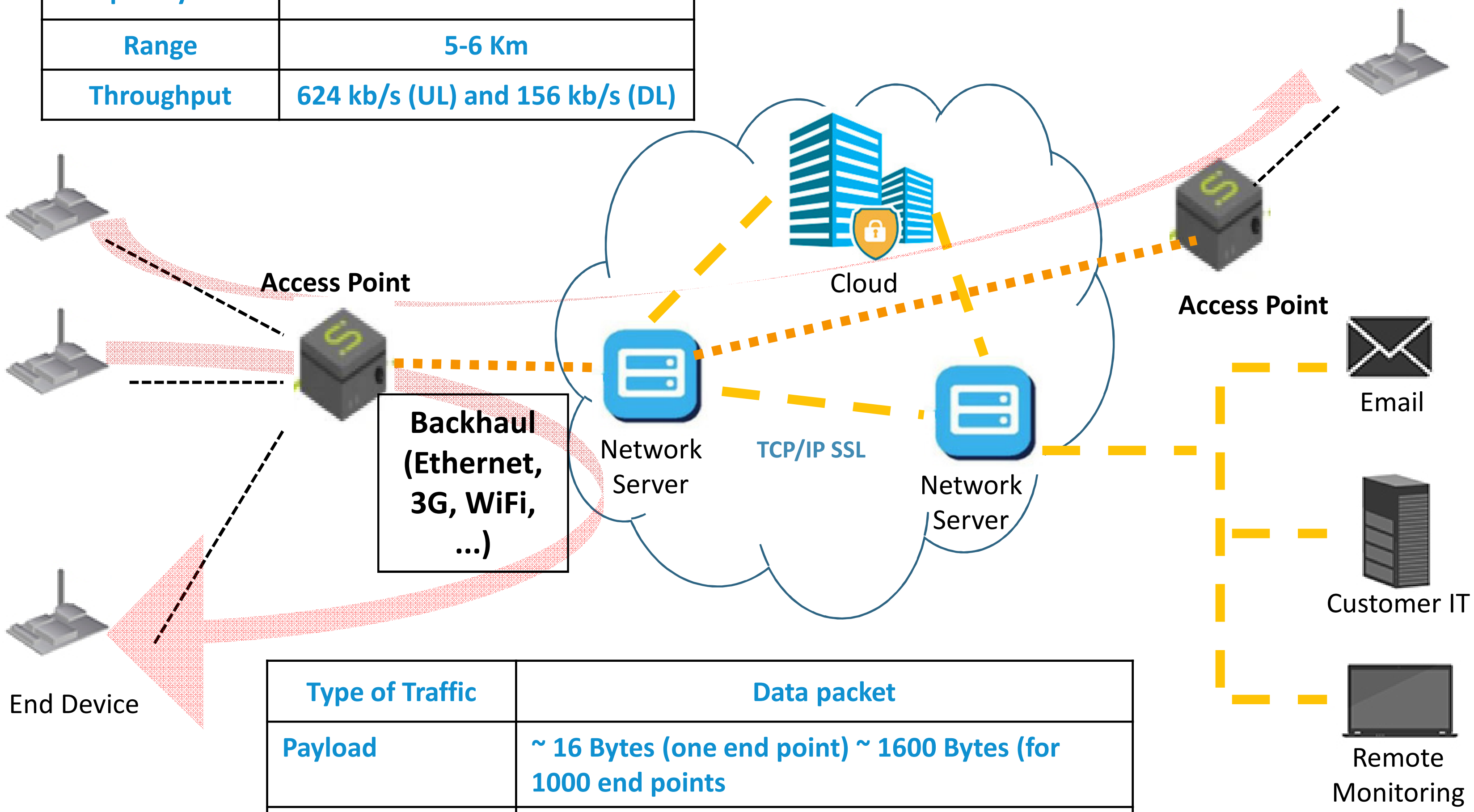
RPMA a Random multiple access Network



- Random multiple access is performed by delaying the signal to transmit at each end-device
- Support up to **1000 end devices** simultaneously
- For the uplink, or the downlink broadcast transmission, a unique Gold code is used.
- For unicast downlink transmission, the **Gold code** is built with the **end-device ID**, such that **no other end-device is able to decode the data**.

INGENU RPMA architecture

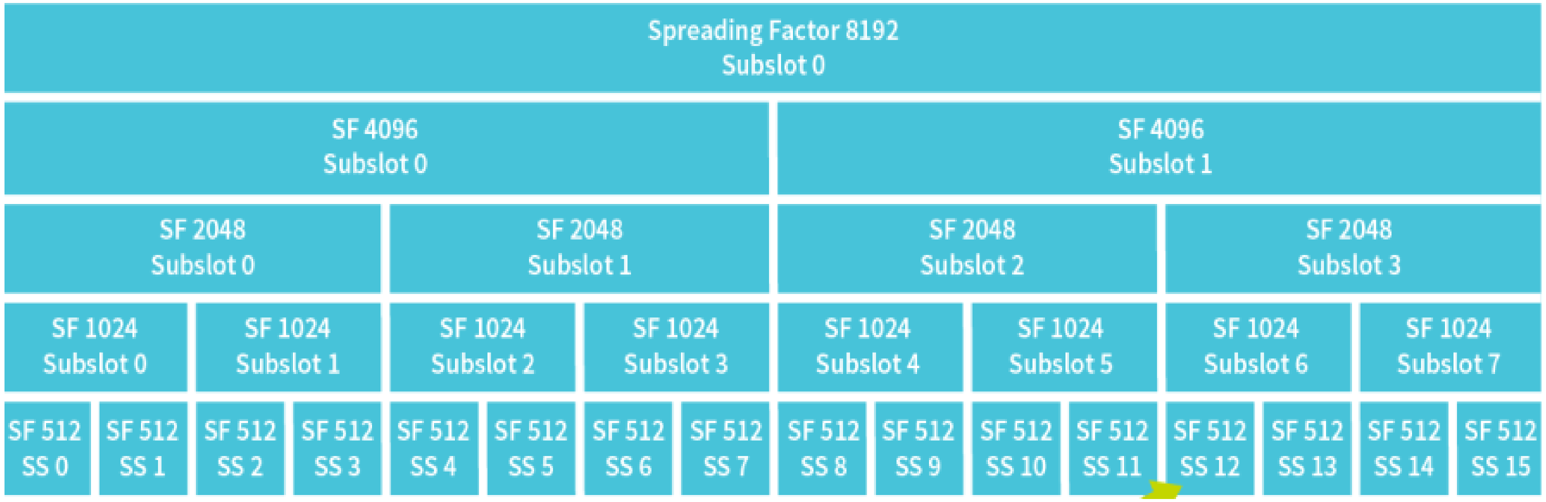
Frequency Band	2.4 GHZ
Range	5-6 Km
Throughput	624 kb/s (UL) and 156 kb/s (DL)



Type of Traffic	Data packet
Payload	~ 16 Bytes (one end point) ~ 1600 Bytes (for 1000 end points
Security	AES Encryption

Uplink Subslot Structure

❖Uplink Subslot Structure Supporting Flexible Data Rate

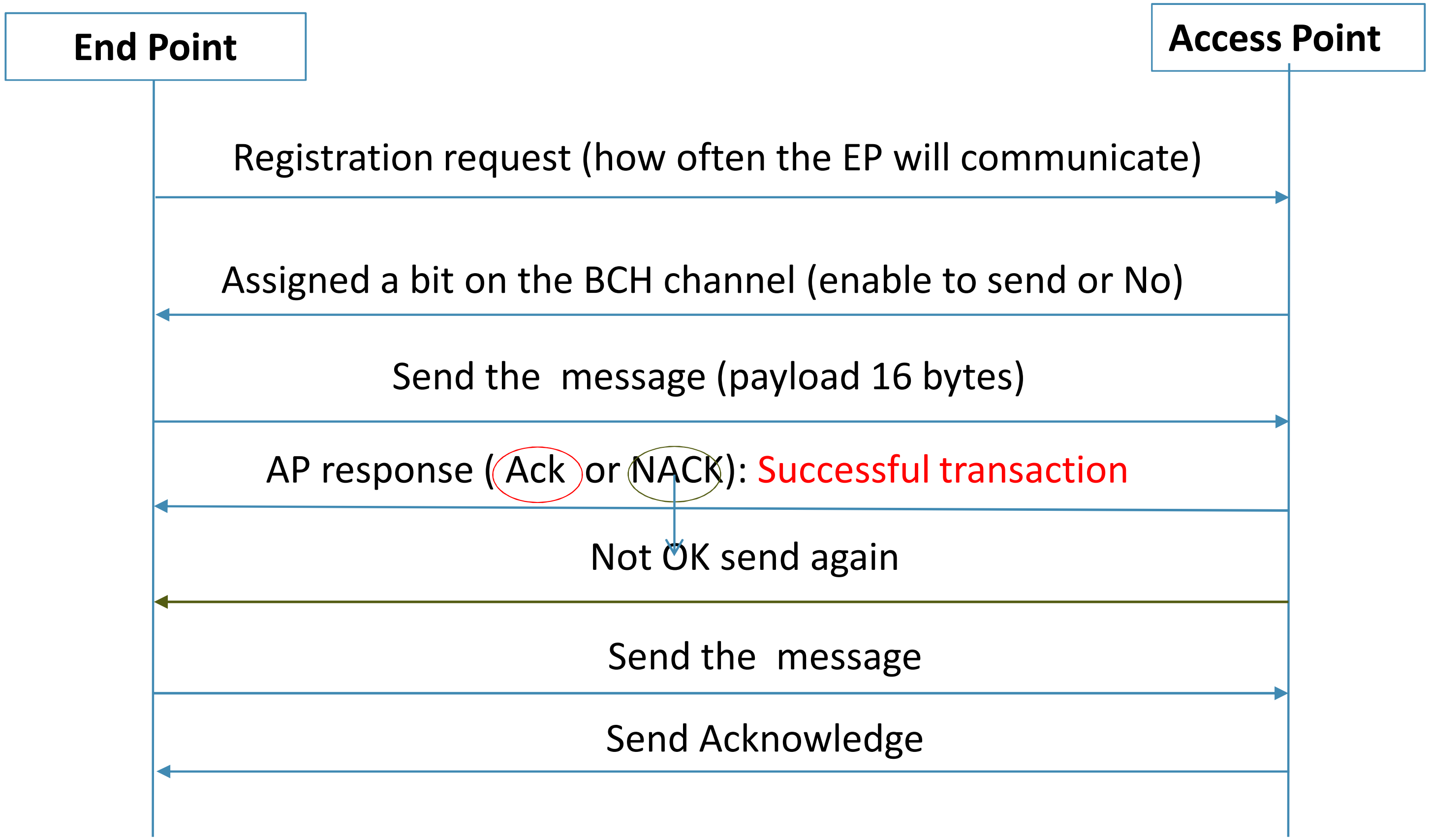


Step 1: Choose Spreading factor from 512 to 8192

Step 2: randomly select subslot

Step 3: Randomly select delay to add to subslot start from 0 to 2048 chips

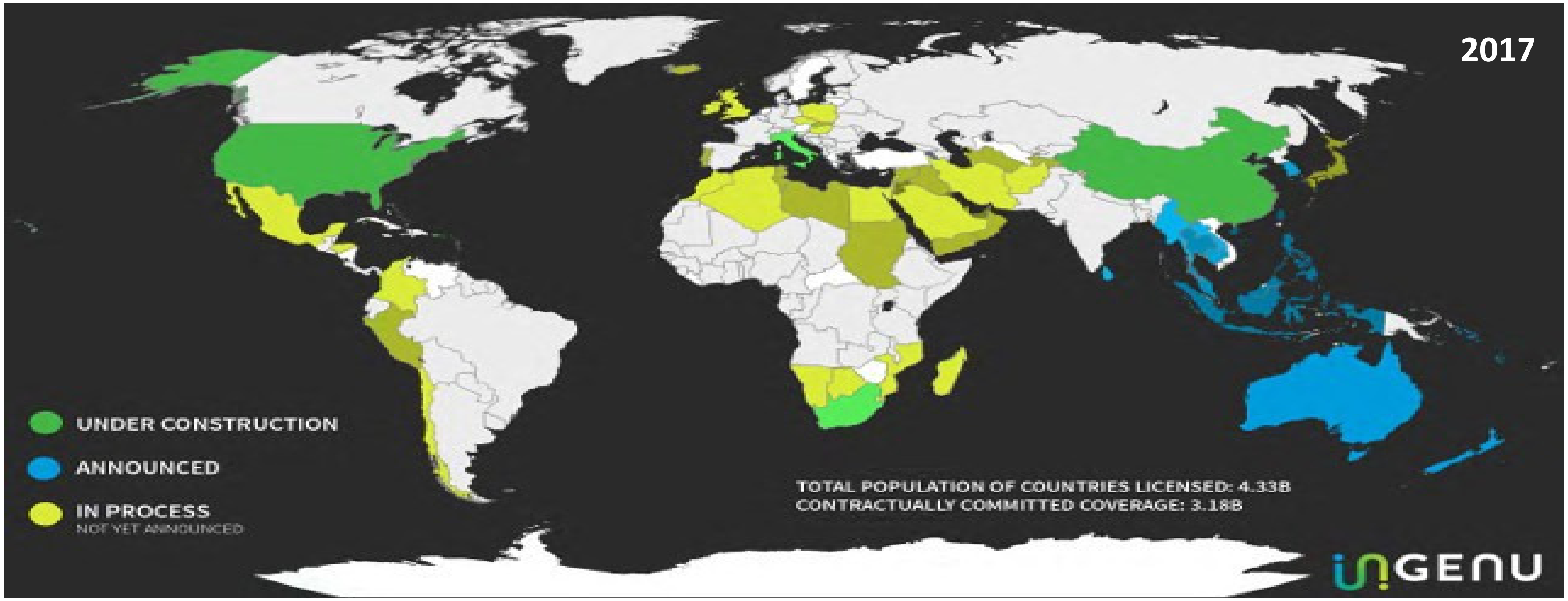
How end point can transfer a data?



RPMA security

- Message confidentiality: use of powerful encryption
- Message integrity1 Replay protection
- Mutual Authentication
- Device Anonymity
- Authentic firmware Upgrades
- Secure Multicasts

RPMA’s current and future presence



- ❑ Presence in Texas, with networks in Dallas, Austin, San Antonio, Houston, and large white space areas.
- ❑ Ingenu offer the connectivity to more **50% of the Texas state population**.
- ❑ Three densely populated Texas markets are served by only **27 RPMA access points**
- ❑ RPMA currently provides **more than 100,000 square miles** of wireless coverage for a host of IoT applications.

RPMA's current and future presence

Currently live	Coverage Rollout Q3	Coverage ROLLOUT Q4 2016	Coverage planned 2017
• Austin,TX • Dallas/Ft.worth, TX • Hostton,TX • Phenix,AZ • Riverside,CA • San Antonio,TX • San Diego,CA	• Columbus, OH • Indianapolis,IN	• Atlanta,GA • Jacksonville,FL • Miami,FL • Oriando,FL • New Orleans,LA • Charlotte,NC • Albuquerque • Memphis,TN • Nashville,TN EL paso,TX • Salt Lake City,UT • Richmound, • Virginia beach,VA	• Los Angeles,CA • San Franscisco-West Bay,CA • Washington,DC • Baltimore,MD • Kanasas City • Greeensboro,NC • Las Vegas,NV • Oklahorma City, OK • And many more cities

v. Others

EnOcean

- Based on **miniaturized power converters**
- **Ultra low power** radio technology
- Frequencies: 868 MHz for Europe and 315 MHz for the USA
- Power from pressure on a switch or by photovoltaic cell
- These power sources are sufficient to power each module to transmit wireless and battery-free information.
- EnOcean Alliance in 2014 = more than 300 members (Texas, Leviton, Osram, Sauter, Somfy, Wago, Yamaha ...)

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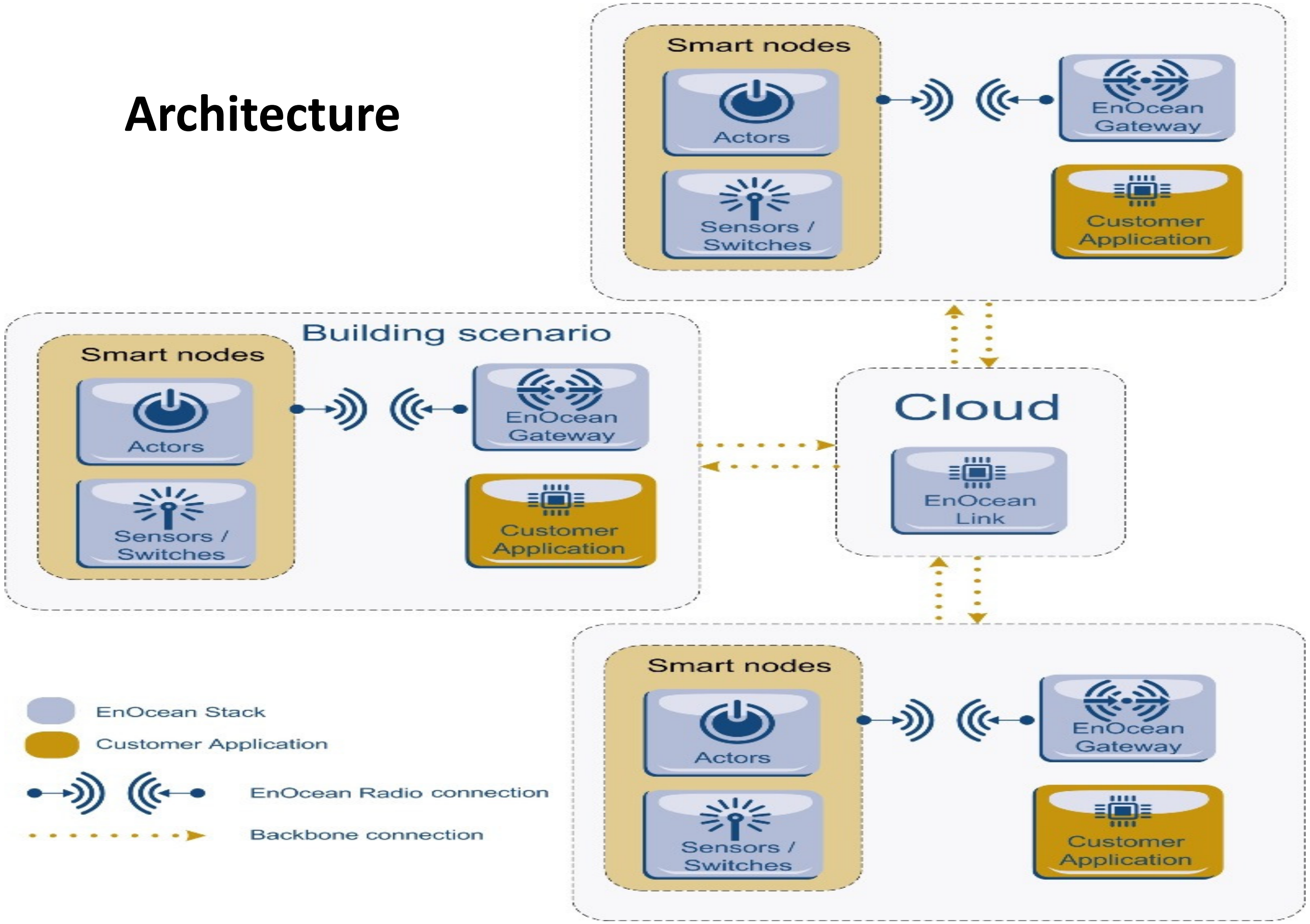
Architecture



ZWave

- Low power radio protocol
- Home automation (lighting, heating, ...) applications
- Low-throughput: 9 and 40 kbps
- Battery-operated or electrically powered
- Frequency range: 868 MHz in Europe, 908 MHz in the US
- Range: about 50 m (more **outdoor**, less indoor)
- Mesh architecture possible to increase the coverage
- Access method type CSMA / CA
- Z-Wave Alliance: more than 100 manufacturers in

ZWave

Services

Quiz 3 – LPWAN

1. What are the main 2 IoT non-3GPP networks?
2. What are the main characteristics of LPWAN?
3. What are the 3 classes defined in LoRaWAN?
4. What is the particular SigFox model proposed for the users?
5. How many times a SigFox message is transmitted?
6. What multiple access technique is used in LoRa and SigFox?
7. What is the advantage of this multiple access technique in LPWAN communications?

Thank you!