Design and development of embedded systems for the Internet of Things (IoT)

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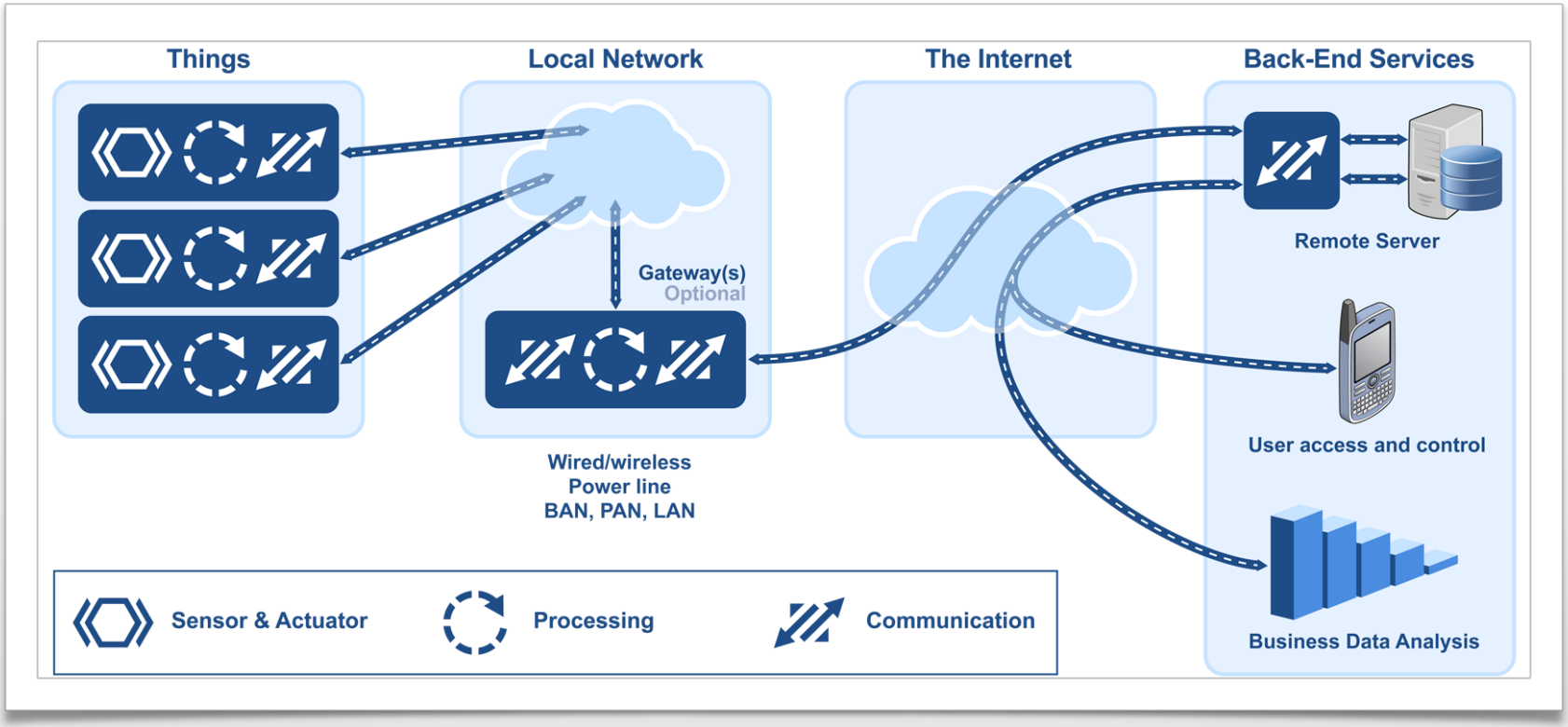
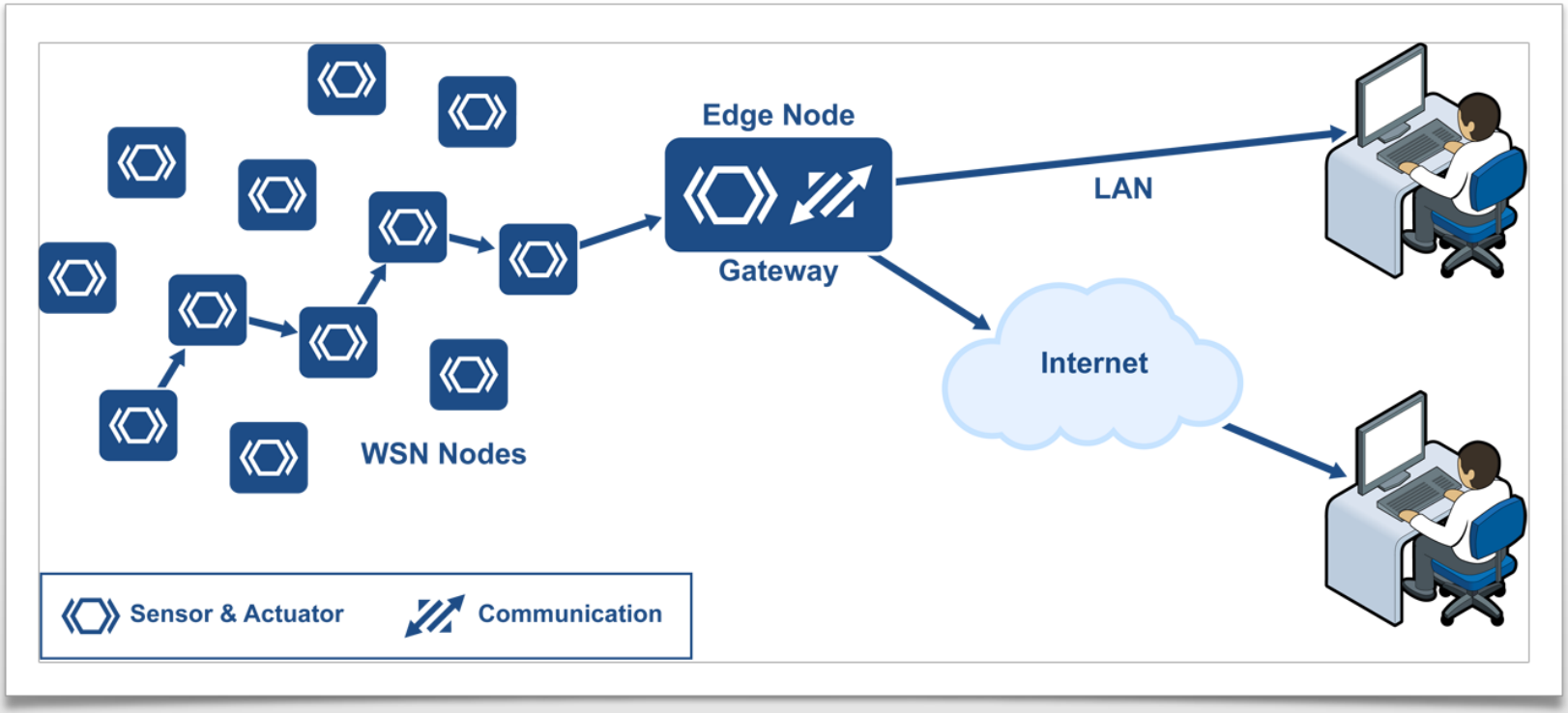
W • SENSE
INTEGRATED CABLELESS SOLUTIONS

Network communication



Everything should be connected

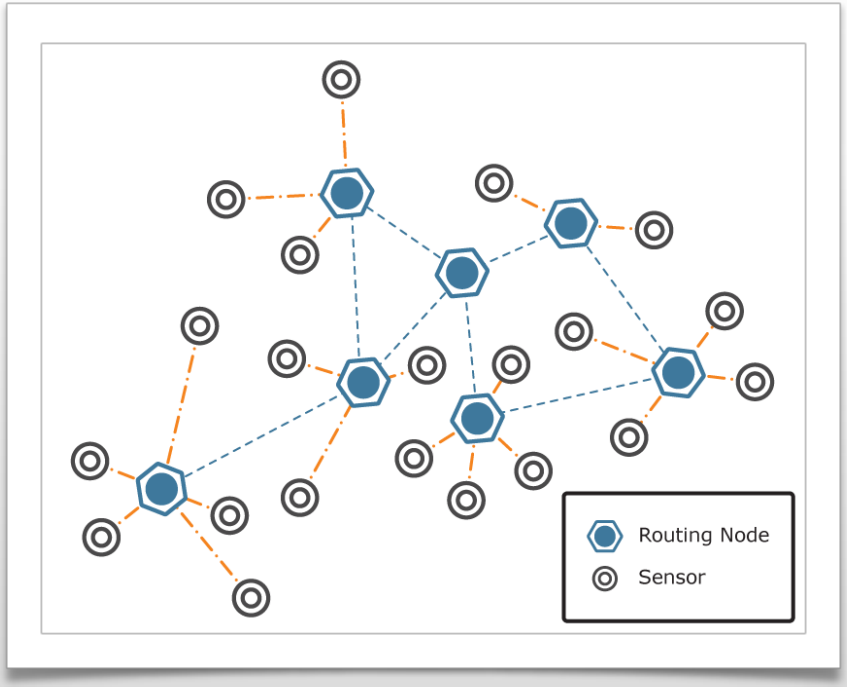
Network communication (2)



The IoT is the evolution of a Wireless Sensor Network

Wireless Sensor Network (WSN)

"A WSN is a wireless network consisting of spatially distributed autonomous devices using sensors to **monitor** physical or environmental conditions"



LIMITED COMPUTATIONAL RESOURCES

LIMITED ENERGY RESOURCES

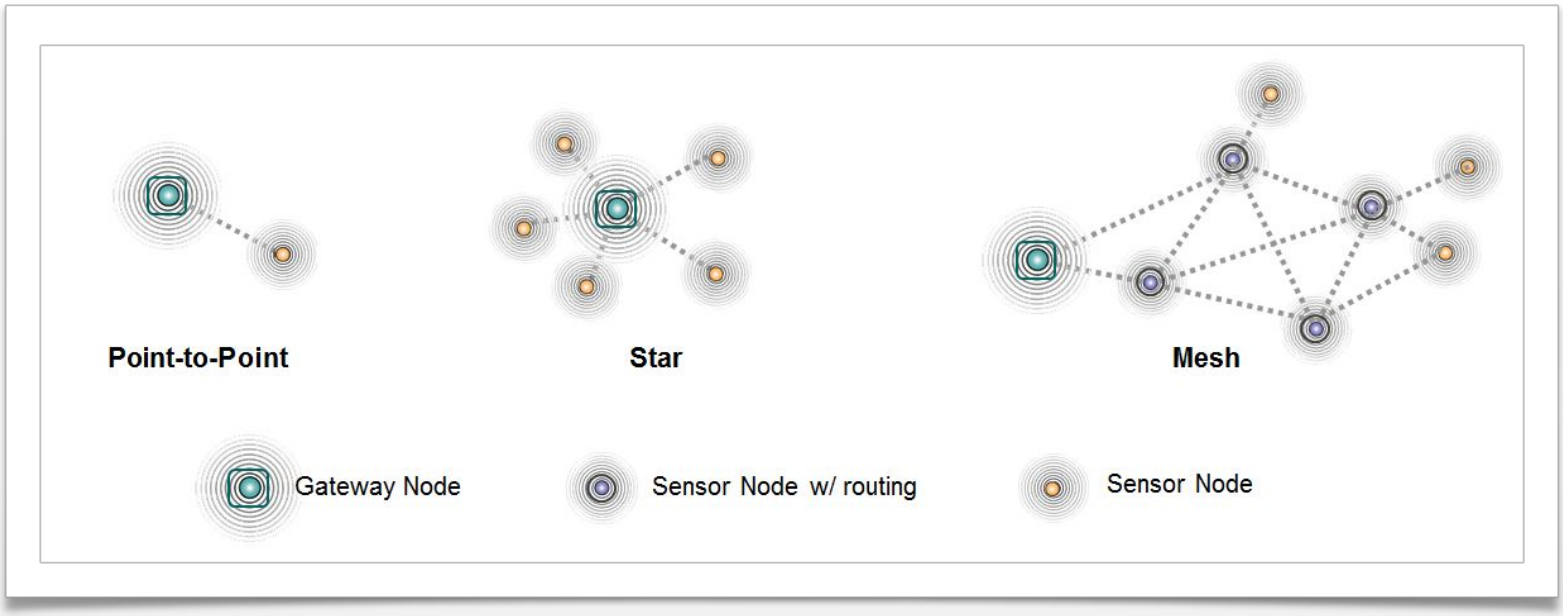
AUTONOMOUS NETWORK

SENSING

SCALABILITY

MOBILITY

Network topologies



Point-to-Point

Star

Mesh

Point-to-Point topology

It isn't a real network topology but sometimes can be useful for some specific applications *(traffic data systems, broadcast systems)*.

Can be used between a **Gateway** and a **Node** or between just two nodes.

The only advantage is
the simplicity of the communication.

Star topology

A star networks has a middle router/gateway that connects all nodes.

The advantage of star topology is that all the complexity in the network is driven to a central node.

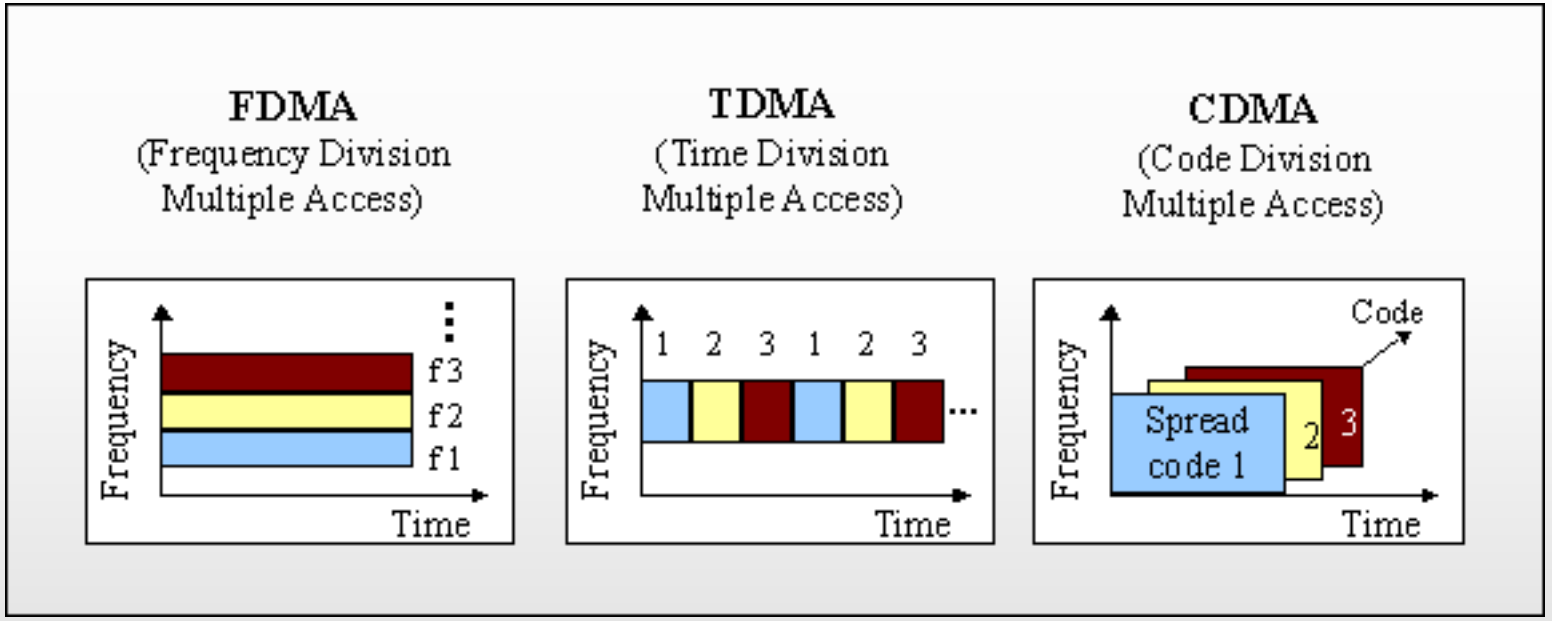
A MAC algorithm such as **FDMA**, **TDMA** or **CDMA** should be used to handle collisions.

The primary disadvantage is the radio links between the gateway and the end node that means**:**

- **more energy it has to spend to communicate**
- **single point of failure.**

Star topology (2)

Medium Access Control Algorithms



Mesh topology

In a mesh network all nodes cooperate to distribute data in a network.

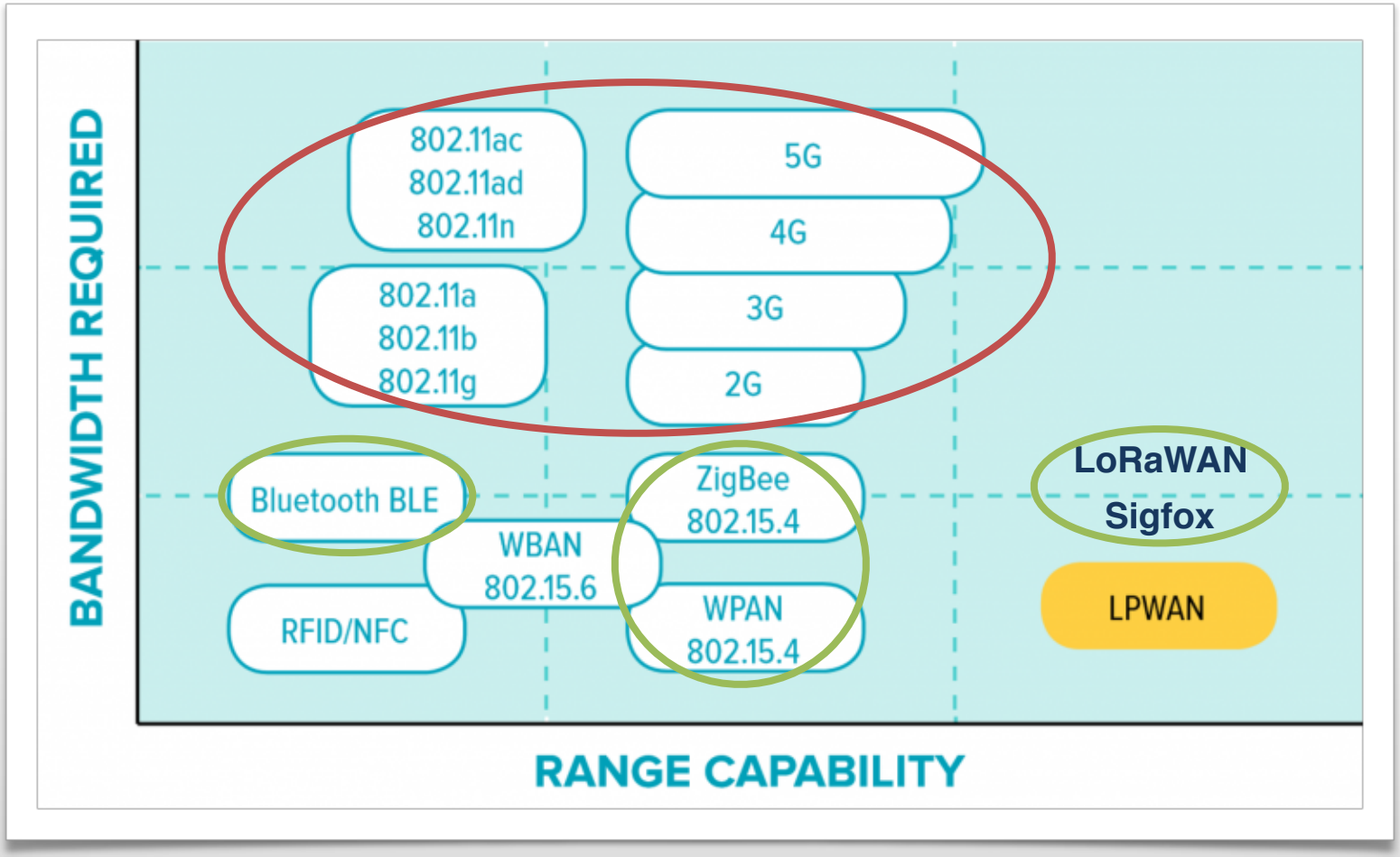
The primary advantage of mesh topology that a node needs **low power transmit** that means**:**

- **long batteries duration**
- **high throughput in the network**

The primary disadvantage of mesh topology is **the limited range (30-100 m)** of the nodes installed that means**:**

- **high number of nodes to install**
- **network complexity**

Communication technologies



802.15.4 and ZigBee

The standard **802.15.4** is a standard defined by **IEEE** that specify the **PHYSICAL** and **MAC** layer.

ZigBee is a commercial standard based on top of 802.15.4.

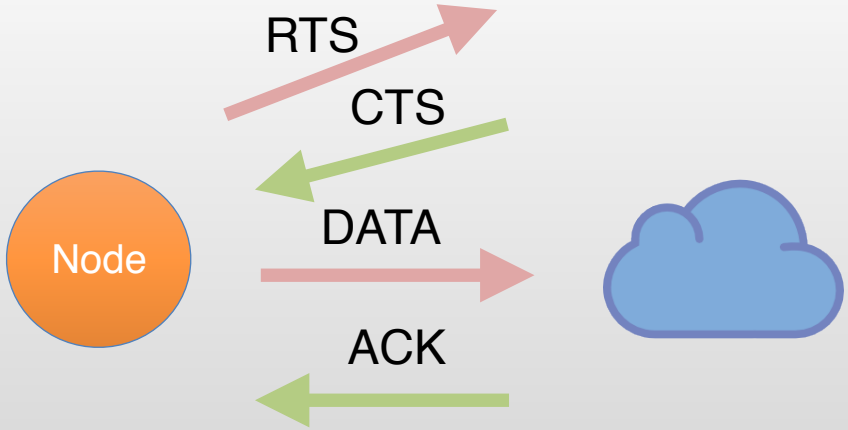
The technology is designed for:

- Low-cost hardware
- Low-speed but high energy saving
- No infrastructure

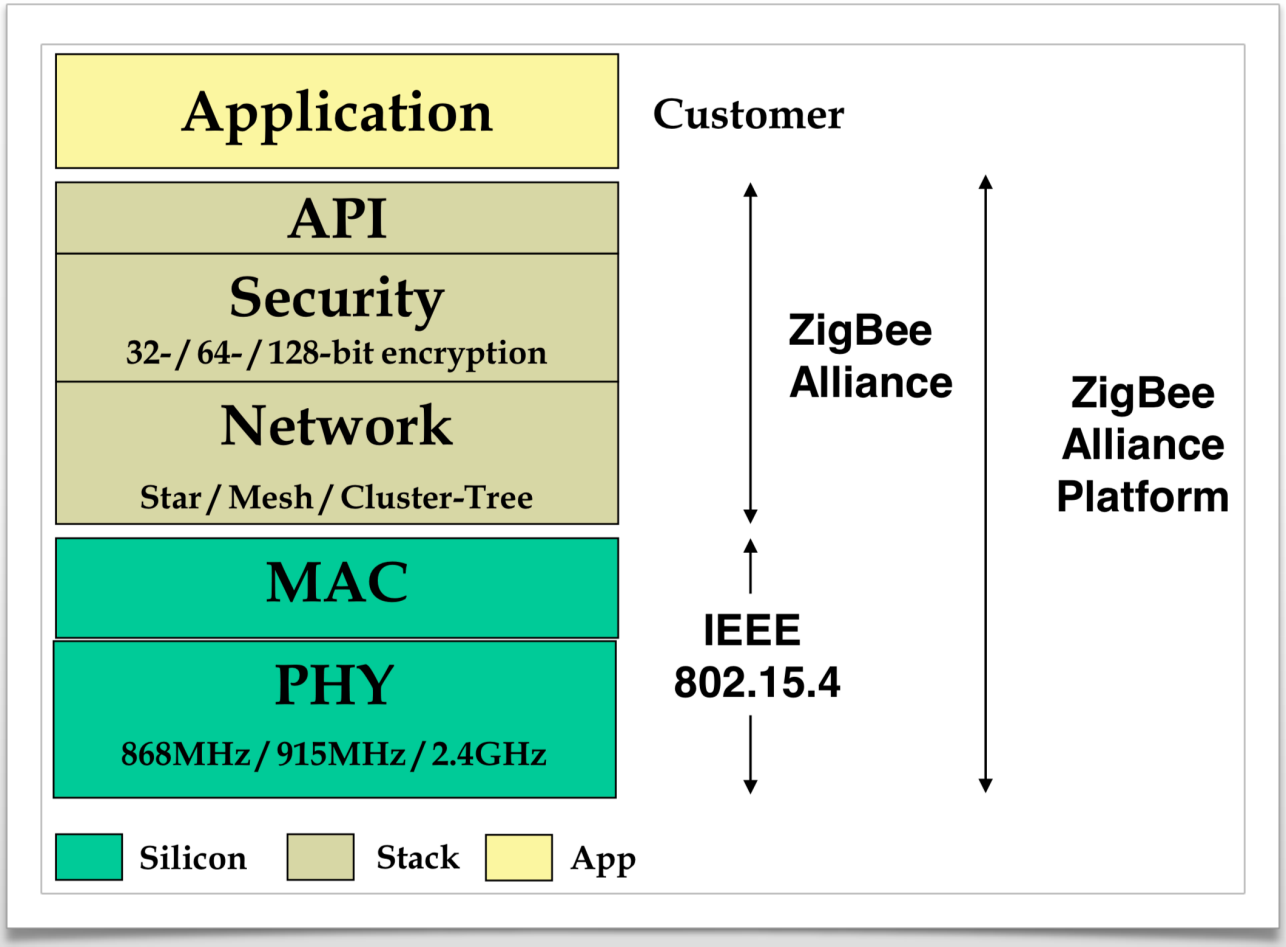
802.15.4

The standard works on **2.4 GHz** (the same of WiFi with **24 channels not overlapped**) but the **868 MHz** band is also supported (basically no one uses this option).

The access to the channel is guaranteed by the **CSMA/CA** mac protocol.



ZigBee


Application
API
Security
32- / 64- / 128-bit encryption
Network
Star / Mesh / Cluster-Tree
MAC
PHY
868MHz / 915MHz / 2.4GHz
Customer
ZigBee Alliance
IEEE 802.15.4
ZigBee Alliance Platform
Silicon
Stack
App

Bluetooth

BT is a technology that use the same frequency band of ZigBee and WiFI (**2.4 GHz**).

Famous for the connections with laptops and mobile phones it is used because has a **better energy approach** then WiFi or 3G/4G solutions.

Different are the topology defined:

- **Point-to-point**
- **Broadcast**
- **Mesh**

BT - Point-to-Point

This kind of topology is the most famous in the bluetooth world.

It is used for establishing a connection with a single device.

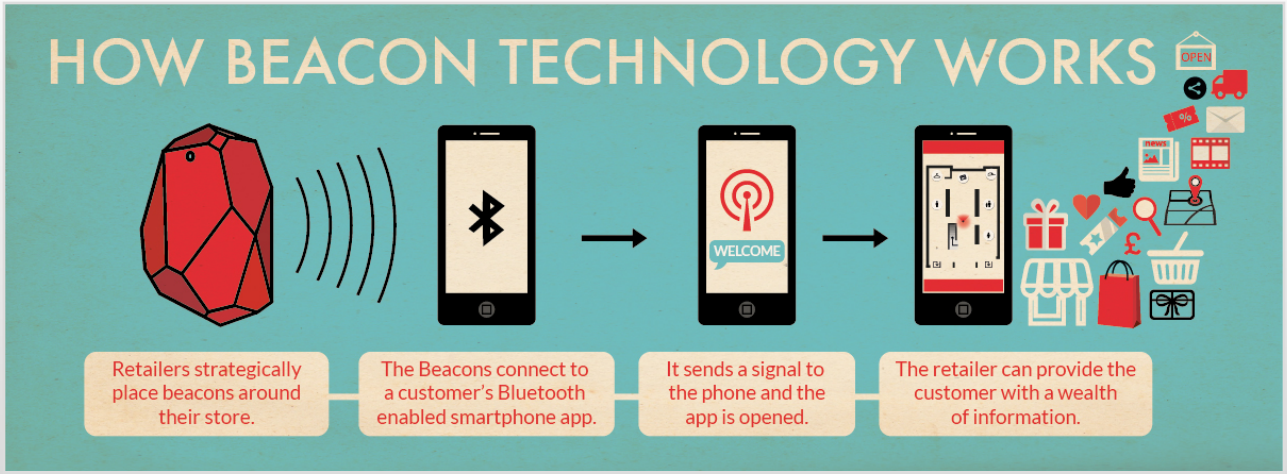
Optimized for **audio streaming** *(speakers, headsets, cars)* and **data transfer** *(fitness tracker, health monitor and pc transfer)*.

BT - Broadcast

It is used for establishing a connection one to many.

This is technology of the **Beacon Systems**.

Suited for sharing common informations *(retailers, point of interests)* and tracking systems such as **Indoor Localization** and **Way-Finding solutions** and **asset-tracking**.



BT - Mesh

It is used for establishing a connection many to many.

Not well known and used respect to the other topologies. Can be a good solution for the future.

Possible problems:

- Not work very well on **outdoor** scenario with **possible congestions** on the same band
- The **range is not so long** (ideally 50 m) that means more sensors to build a big mesh solution
- Usually **not robust for dynamic applications**
- Consume more than ZigBee and 802.15.4 standard

Bluetooth versions

Specifications	1.1	2.0 + EDR	2.1 + EDR	3.0 + HS	4.0 + LE
Adopted	2002	2004	2007	2009	2010
Trasmission Rate	723.1 Kbps	2.1 Mbps	3 Mbps	24 Mbps	25 Mbps
Standard Range	10 m	10 m	10 m	10 m	50 m
NFC Support		Yes	Yes	Yes	Yes

	Bluetooth V2.1	Bluetooth Low Energy
Standardization Body	Bluetooth SIG	Bluetooth SIG
Range	~30 m (class 2)	~50 m
Frequency	2.4–2.5 GHz	2.4–2.5 GHz
Bit Rate	1–3 Mbit/s	~200 kbit/s
Set-Up Time	<6 s	<0.003 s
Voice Capable?	Yes	No
Max Output Power	+20 dBm	+10 dBm
Modulation Scheme	GFSK	GFSK
Modulation Index	0.35	0.5
Number of Channels	79	40
Channel Bandwidth	1 MHz	2 MHz

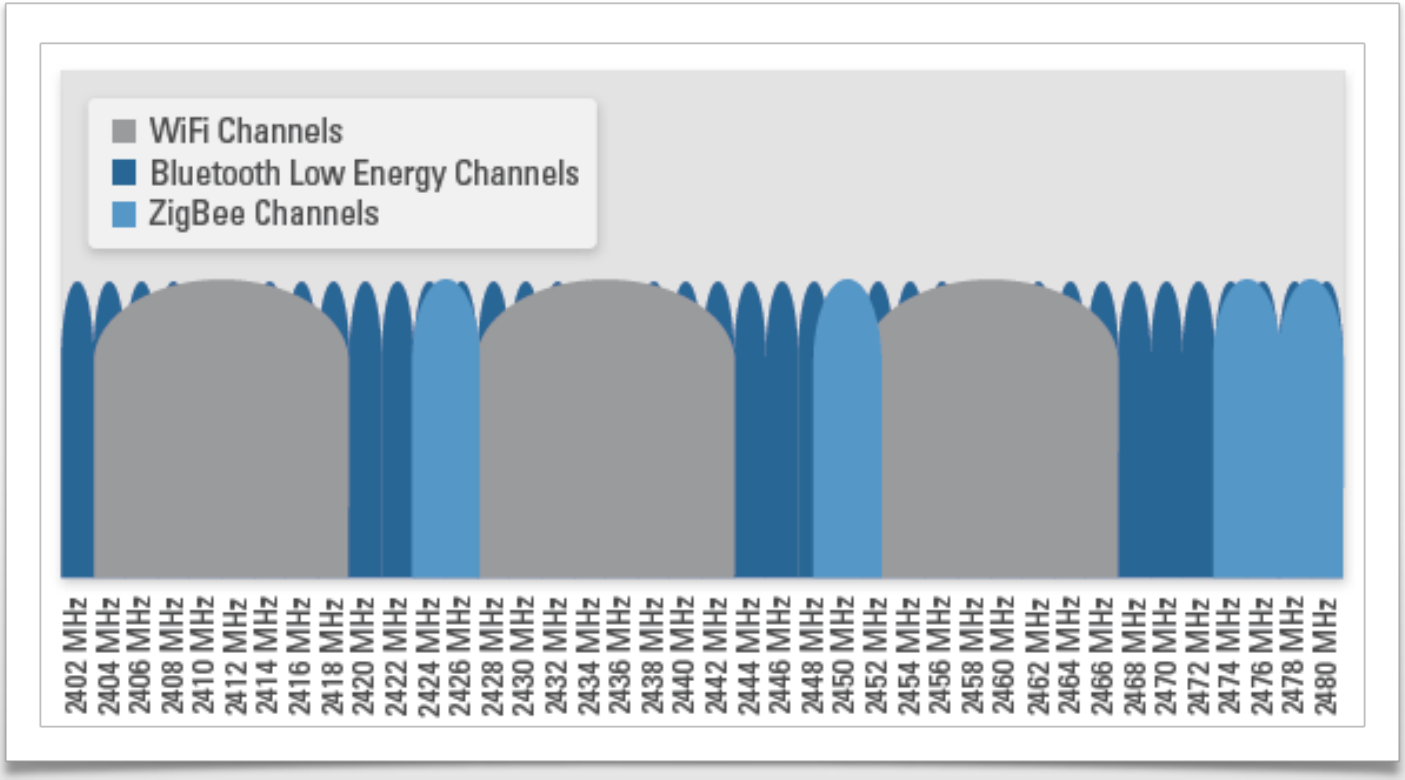
EDR: Enhance Data Rate

HS: High Speed Data Rate

LE: Low Energy

Bluetooth 5.0

2.4 GHz channel



Too many guys in the same room

2.4 GHz channel (2)

For this reason other technologies with
other frequency bands and
other medium channels are growing up:

Sub-GHz Wireless (<1GHZ)
Visible Light Communication
Acoustic Communication

LPWAN

A **Low-Power Wide-Area-Network** is a wireless communications class of technologies designed to allow **long range communications** with specific constraints in mind.

- **Low bit rate** (0.3 kbit/s to 50 kbit/s per channel) with small packet size
- **High energy efficiency**
- Optional **third-party infrastructure**
- Designed for **IoT** and **M2M** systems

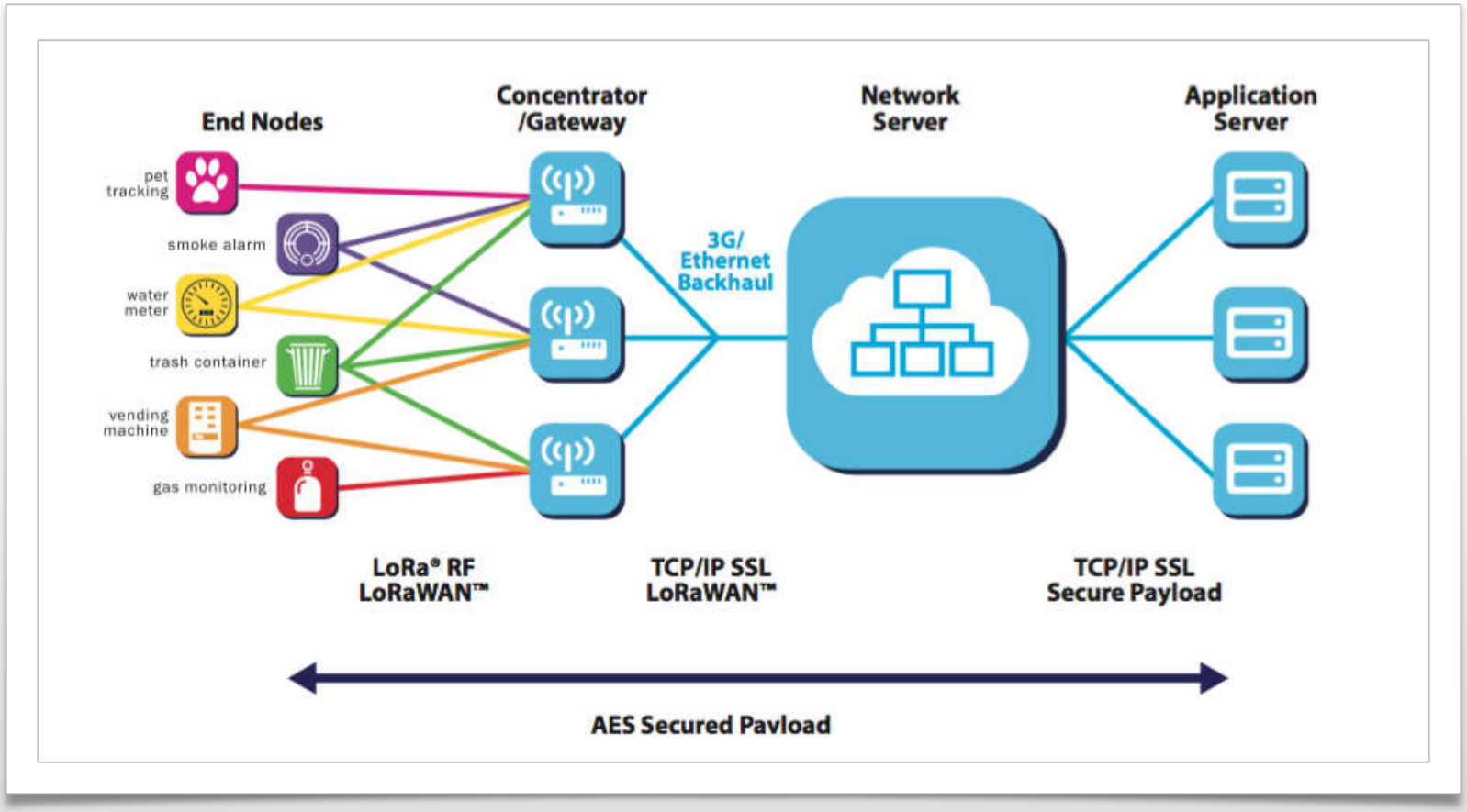
LPWAN (2)

Typically this kind of communication systems are tailored to work on **low frequency** *(800-900 MHz)* used in the past by the **old GSM technology or standard radio**.

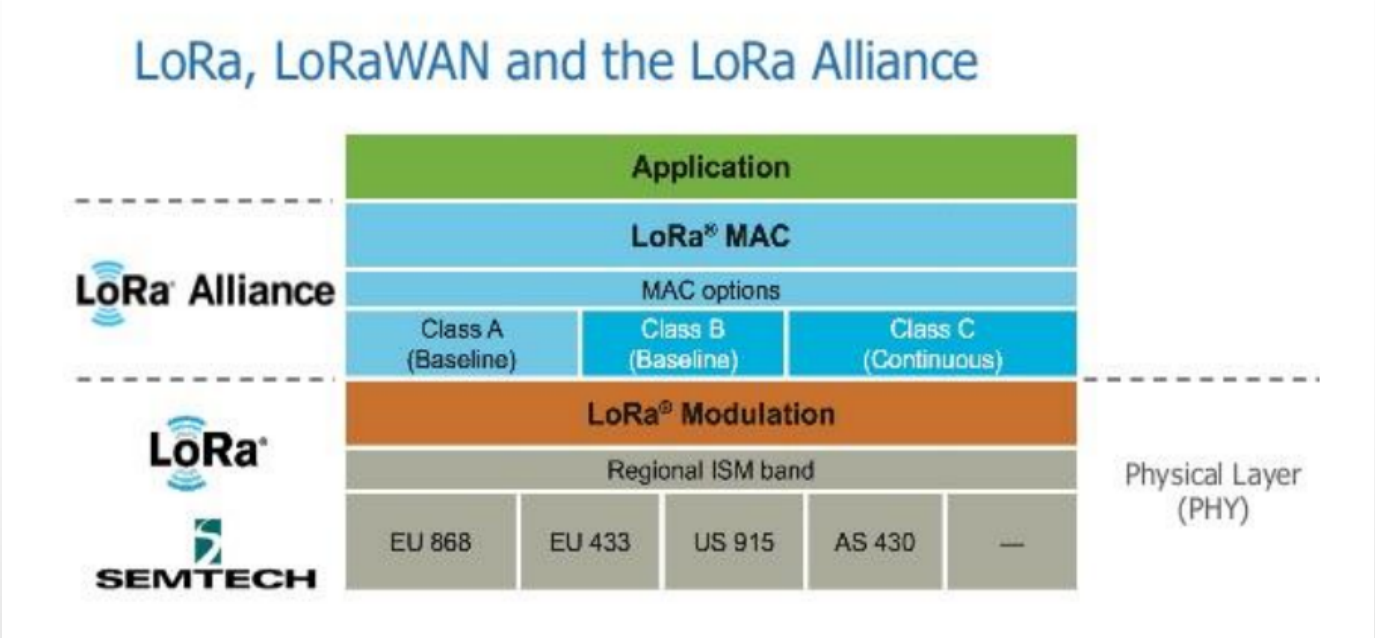
The most famous LPWAN examples are:

- **Sigfox**
- **LoRaWAN**

LoRaWAN


End Nodes
Concentrator /Gateway
Network Server
Application Server
pet tracking
smoke alarm
water meter
trash container
vending machine
gas monitoring
3G/ Ethernet Backhaul
LoRa® RF LoRaWAN™
TCP/IP SSL LoRaWAN™
TCP/IP SSL Secure Payload
AES Secured Payload

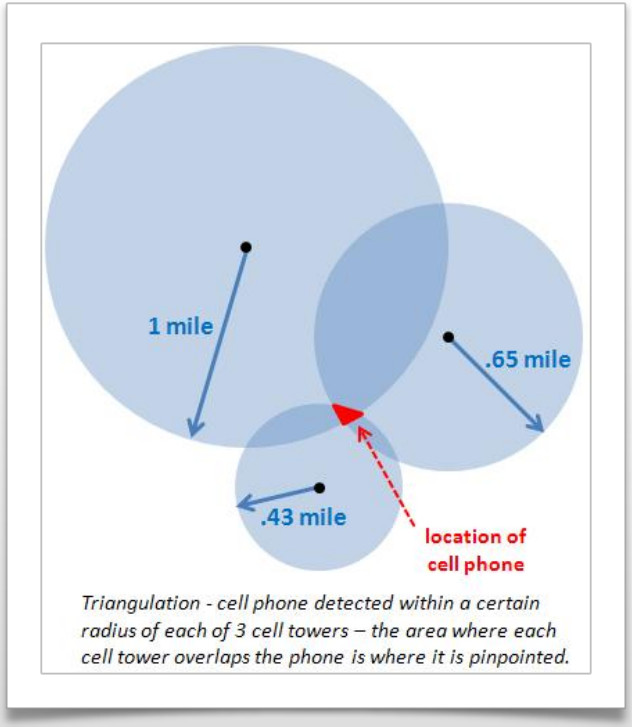
LoRa vs LoRaWAN



LoRa is different from LoRaWAN

LoRaWAN as GeoLocation Service

LoraWAN thank to the triangulation of the antennas is able to geolocate a connected node.



1. **Localization**

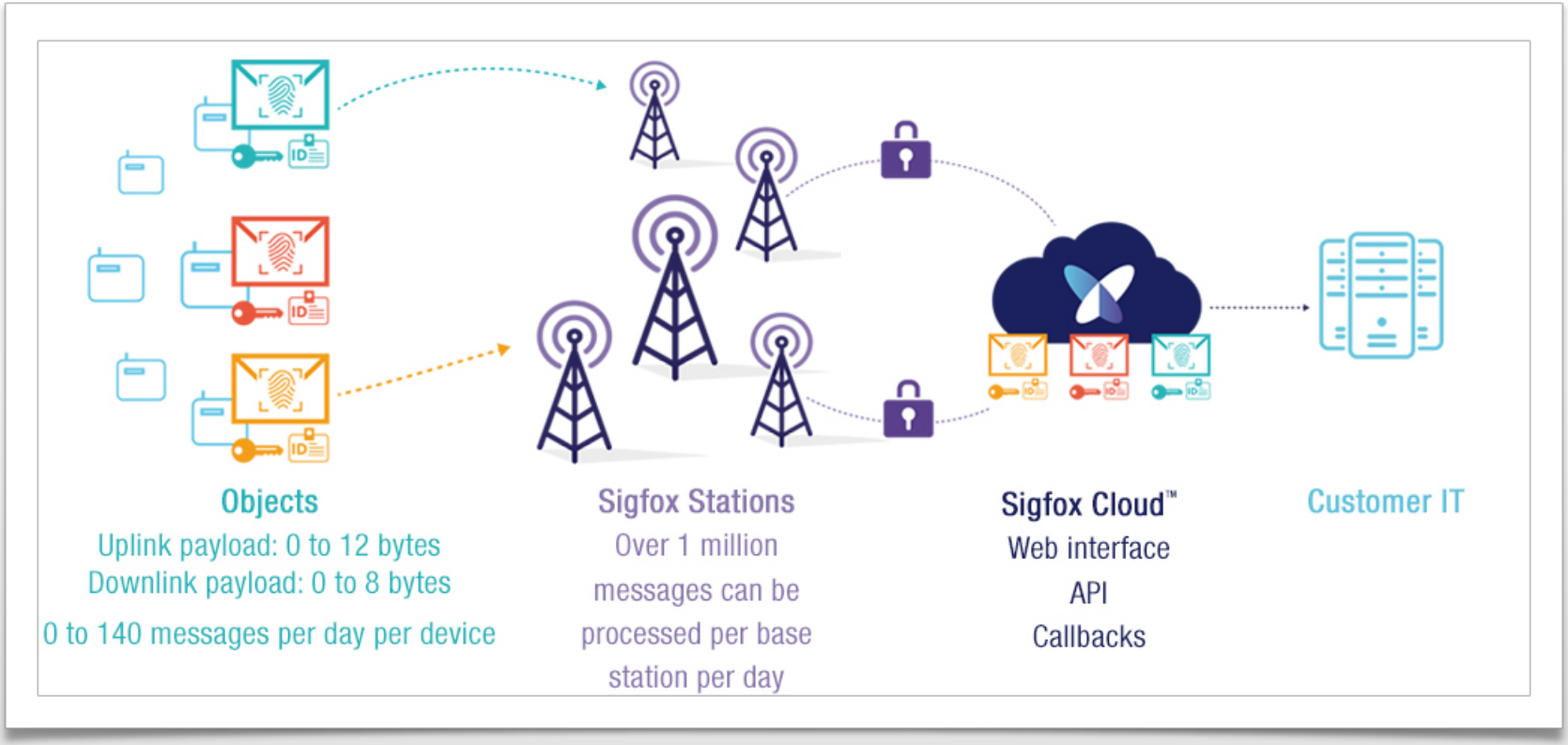
GPS and WiFI free

2. **High energy efficiency**

3. **Low-level precision**

(ideally 50 m usually 100 m)

Sigfox


Objects
Uplink payload: 0 to 12 bytes
Downlink payload: 0 to 8 bytes
0 to 140 messages per day per device
Sigfox Stations
Over 1 million
messages can be
processed per base
station per day
Sigfox Cloud™
Web interface
API
Callbacks
Customer IT

LoRaWAN vs Sigfox

LoRaWAN uses **Chip Spread Spectrum** technology to modulate the signal instead **Sigfox** uses **Ultra narrowband**.

This means that **Sigfox has a better higher spectral efficiency and noise mitigation**.

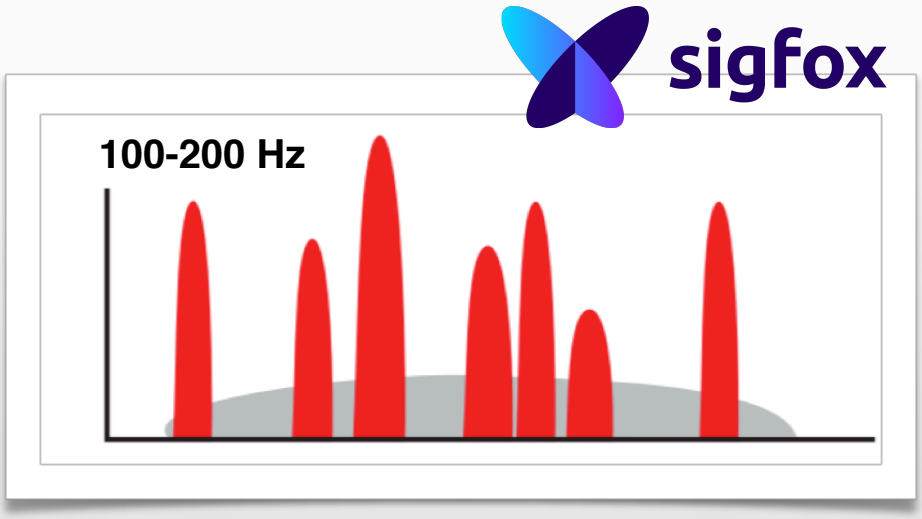
The hardware specification is open for Sigfox and implemented from different hardware vendors (ex. STM) instead **with LoraWAN you have to use the hardware sell by SemTech (now LoRa Alliance is able to certified external hardware)**.

You have to pay to use Sigfox and it is able to receive only 4 messages per day and send 140 messages.

LoraWAN allow the bidirectional communication.

LoRaWAN vs Sigfox (2)

Ultra Narrow Band (UNB) and D-BPSK modulation



LOW-COST COMPONENTS

LOW BITRATE

HIGH ENERGY EFFICIENCY

HIGH SENSITIVITY

Basically no collisions

LoRaWAN vs Sigfox (3)

	SIGFOX	LORA
Frequency band	868/902 MHz (ISM)	433/868/780/915 MHz (ISM)
Urban range	3-10km	2-5km
Rural range	30-50km	15-20km
Packet size	12 bytes	Defined by user
Devices per access point	1M	100k
Status	In deployment	Spec released June 2015
Topology	Star	Star

Possible network configurations

Next lesson

In the next lesson we will talk about the protocols to manage the network such as:

- **Data propagation** and **time synchronization**
- **6LowPan** and **Coap**
- Application level protocols (**MQTT**, **REST**)

and we will start to work with **Python** on MQTT and REST.

Hardware available

1x Discovery Kit (**STM32F303** with 3D **Gyroscope**, 3D **Accelerometer**, 3D **Magnetometer**)

4x Bluetooth Low Energy (**X-NUCLEO-IDB05A1**, Arduino UNO R3 Connector)

1x MEMS Inertial and Environmental (**X-NUCLEO-IKS01A1** with 3D **Accelerometer**, 3D **Gyroscope**, 3D **Magnetometer**, **pressure, humidity** and **temperature** sensors, Arduino UNO R3 Connector)

2x UART to Bluetooth Classic

2x UART to Serial

For the next lesson

You have to install:

- Python 3
- Eclipse Paho MQTT
- Requests