Low Power Wide Area Networks for IoT

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Introduction

- Low Power Long Range Wireless Technologies for IoT
  - Low power ➔ Long battery life
  - Low device cost
  - Extended coverage (0-15 km in rural areas)
    (2 -5 km in urban areas)
  - Supporting massive number of devices to be connected.
  - Less complexity and easy to deploy

Introduction

- 3GPP Standards (Licensed cellular)
  - EC-GSM
  - NB-IoT
  - LTE-M
  - 5G
- Non 3GPP Standards (Unlicensed)
  - LoRa
  - Sigfox
  - Weightless
  - Others

LPWAN - LoRa, SigFox, LTE-M and NB-IoT

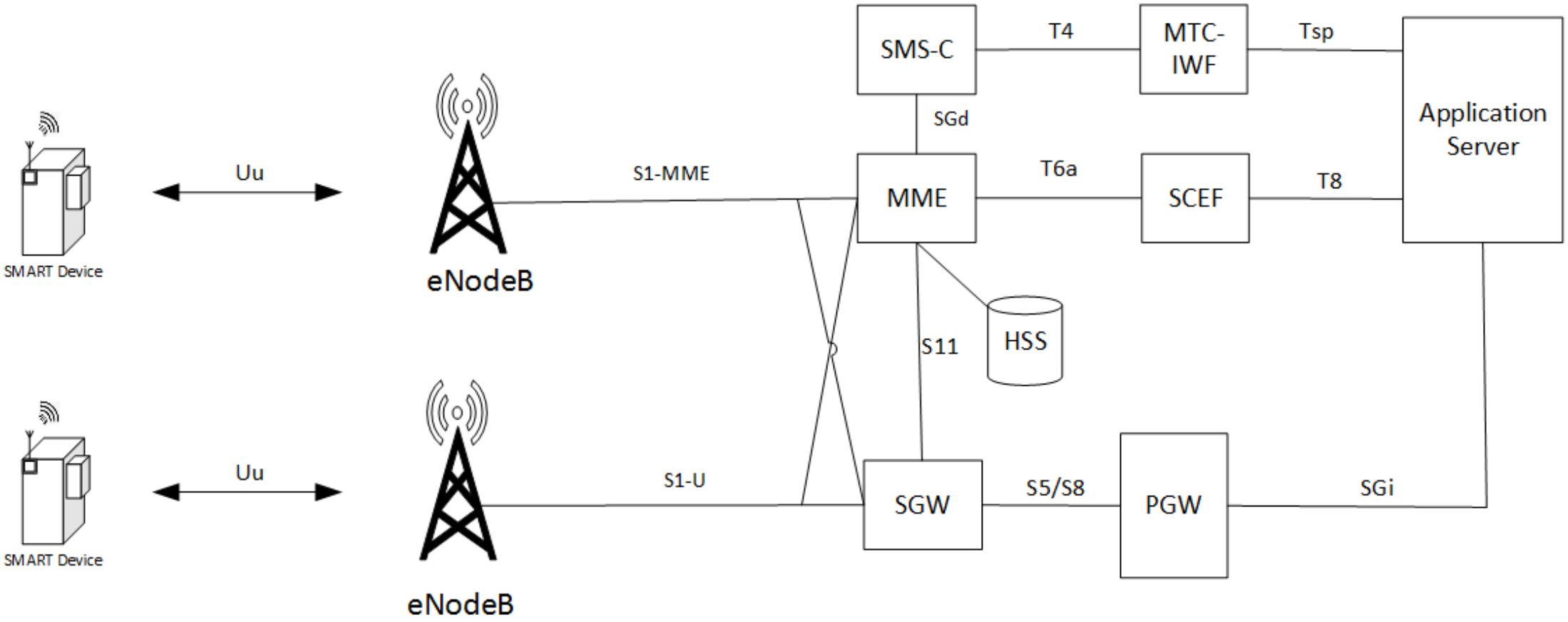
- Wireless communication technologies specifically for IoT
- LPWAN (Low-Power Wide-Area Network)
- Long Range, Low Power, Low Bit Rate

LPWAN technologies in the market				
	LoRa	SigFox	LTE-M	NB-IoT
Frequency Band	Unlicensed	Unlicensed	Licensed (LTE)	License (LTE)
Data Rate	10 kbps	~ 100 bps	1 Mbps (UL/DL)	200 kbps (UL/DL)
Bandwidth	125 kHz	100 Hz	1.4 MHz	180 kHz
Standardization	De-Facto Standard	De-Facto Standard	3GPP Rel. 13	3GPP Rel. 13
Coverage	~ 10 km	~ 12 km	~ 11 km	~ 15 km

What is NB-IoT?

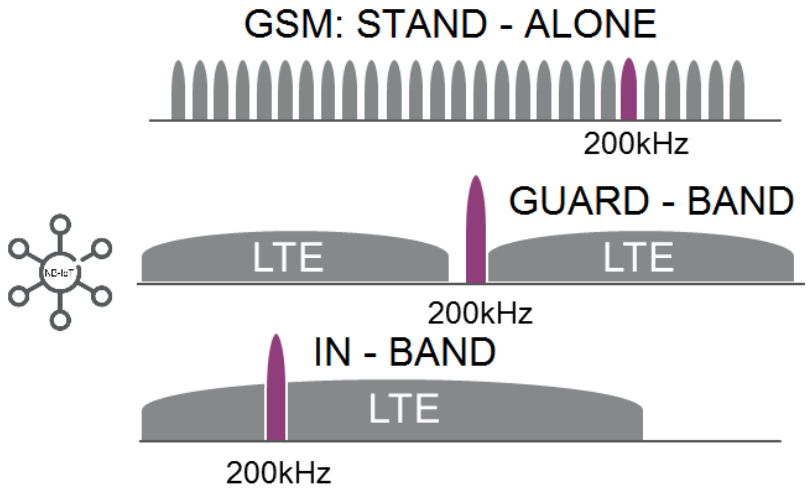
- Wireless data communication technology that uses a cellular network topology especially dedicated to connect things that will be seen in the IoT era
- Carrier wave in an unused guard band between LTE channels independent technology which is currently part of the LTE
- Developed by Huawei and Ericsson
- Power consumption is low
- Network connectivity used licensed band to provide QoS
- Also able to provide proven security and features like mobility and roaming
- 200 kbits/sec 200 kHz bandwidth
- Design for massive IoT use cases, 1000 of devices per base station

NB-IoT Network Architecture



NB-IoT Devices and Features

- New Radio interface in E-UTRAN from 3GPP Rel-13
- Simple devices with little amount of data
- Relaxed requirements on radio
- Ultra-low device cost
- Low power consumption
- Integrated with LTE cells or stand-alone
- Deployment in-band, standalone, or guard-band
- Maximum Coupling Loss (MCL): 164 dB
- Two UE categories, NB1, NB2 (Rel-14)



Limitations of NB-IoT

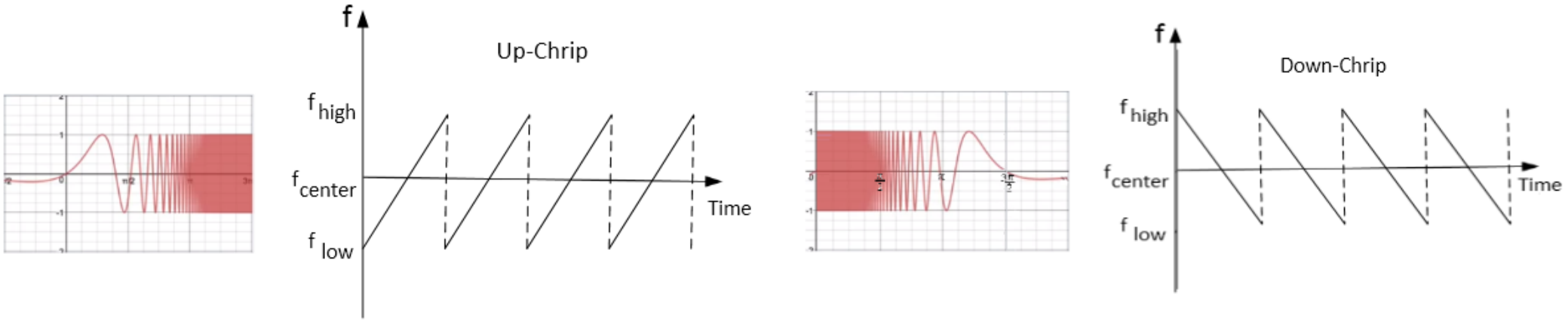
- SIM Card required
- Option: EUICC (“embedded SIM”,“eSIM”, “Soft SIM”)
- Over-The-Air updates via mobile network with the currently active profile HTTP used for transport
- Need to provide number for each device, increase in device volume will require to upgrade the telephone numbering system.

What is LoRa?

- Wireless data communication technology that used radio modulation technique that can be generated by Semtech LoRa transceiver chips
- Physical layer for long range communications
- Low bandwidth
- Low battery usage
- High immunity to interference
- Operations in the license-free ISM bands all around the world
  - 433, 868, 915 MHz
  - Regulated (power, duty-cycle, bandwidth)
  - EU: 0.1% or 1% per sub-band duty-cycle limitation (per hour)
- Link budget (EU): 156 dB

LoRa Physical Protocol

- LoRa is a spread spectrum modulation technique derived from chirp spread spectrum (CSS) technology.
- Uses wideband linear frequency modulated chirp pulses to encode information
- The signal is deliberately spread in the frequency domain



LoRa Protocol

- Uses ALOHA or slotted ALOHA for MAC Layer protocol.
- Unslotted Aloha:
  - Simpler and no synchronization
  - When frame first arrives transmit immediately
  - Collision probability increases
- Slotted ALOHA:
  - All frames same size
  - Time is divided into equal size called slots
  - Nodes start to transmit frames only at beginning of slots
  - Nodes are synchronized
  - If 2 or more nodes transmit in slot, all nodes detect collision

LoRa Parameters

Parameter	Value Range	Explanation
frequency	433 MHz,863 -870 MHz/ 902 – 928 MHz	The frequency use to transmit data
Tx power	23 dBm,/ 2 -14 dBm / 5- 20 dBm	Power used to transmit
bandwidth	125/250/500 kHz	Data bandwidth
Spreading factor	7-12	Frequency spreading factor
Coding rate	4/5,4/6,4/7,4/8	Error correction data are (how many error correction bits)

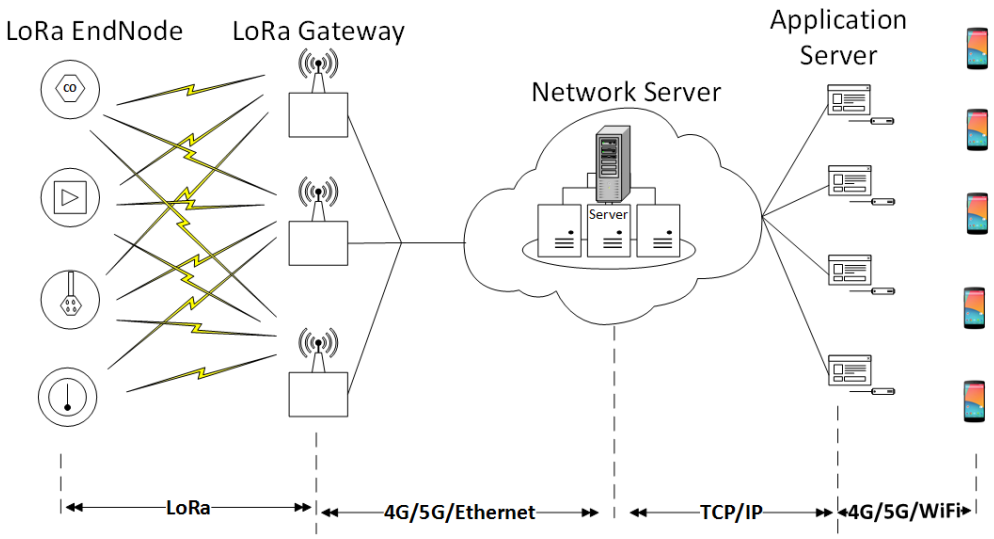
LoRa Applications

LoRa is perfect for the sensor node running on the coin cell/solar power to transmit small amount of data using them in

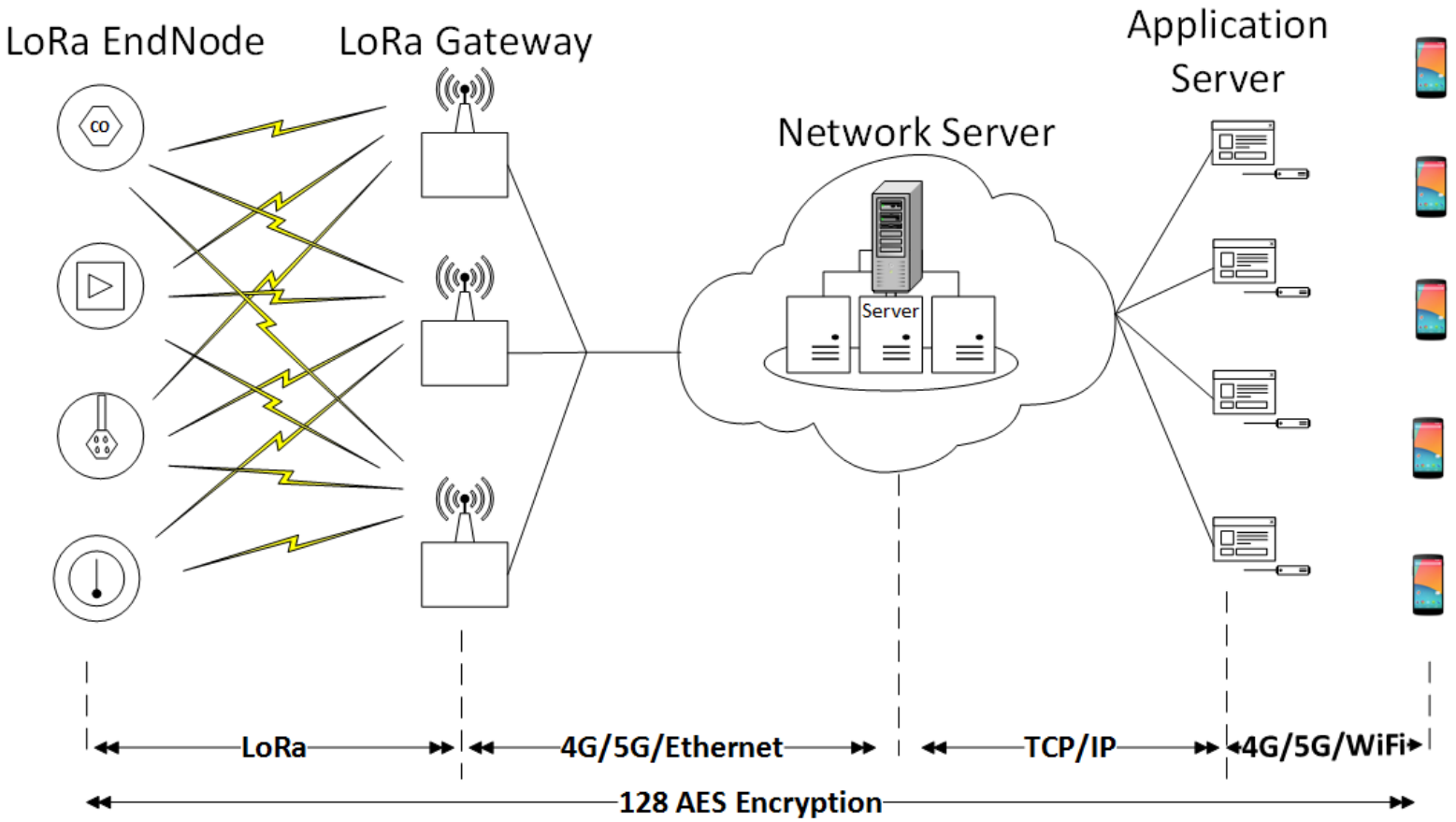
- Internet of Things,
- SMART home,
- machine to machine communication and
- much more….
- Able to use LoRa in point to point communication or built a LoRa network called LoRaWAN

What is LoRaWAN?

- Communication protocol and architecture that utilizes the LoRa physical layer
- Data rates are defined that range from 300 bps to 5.5 kbps
- Supports
  - Secure bi-directional communication
  - Mobility
  - localization



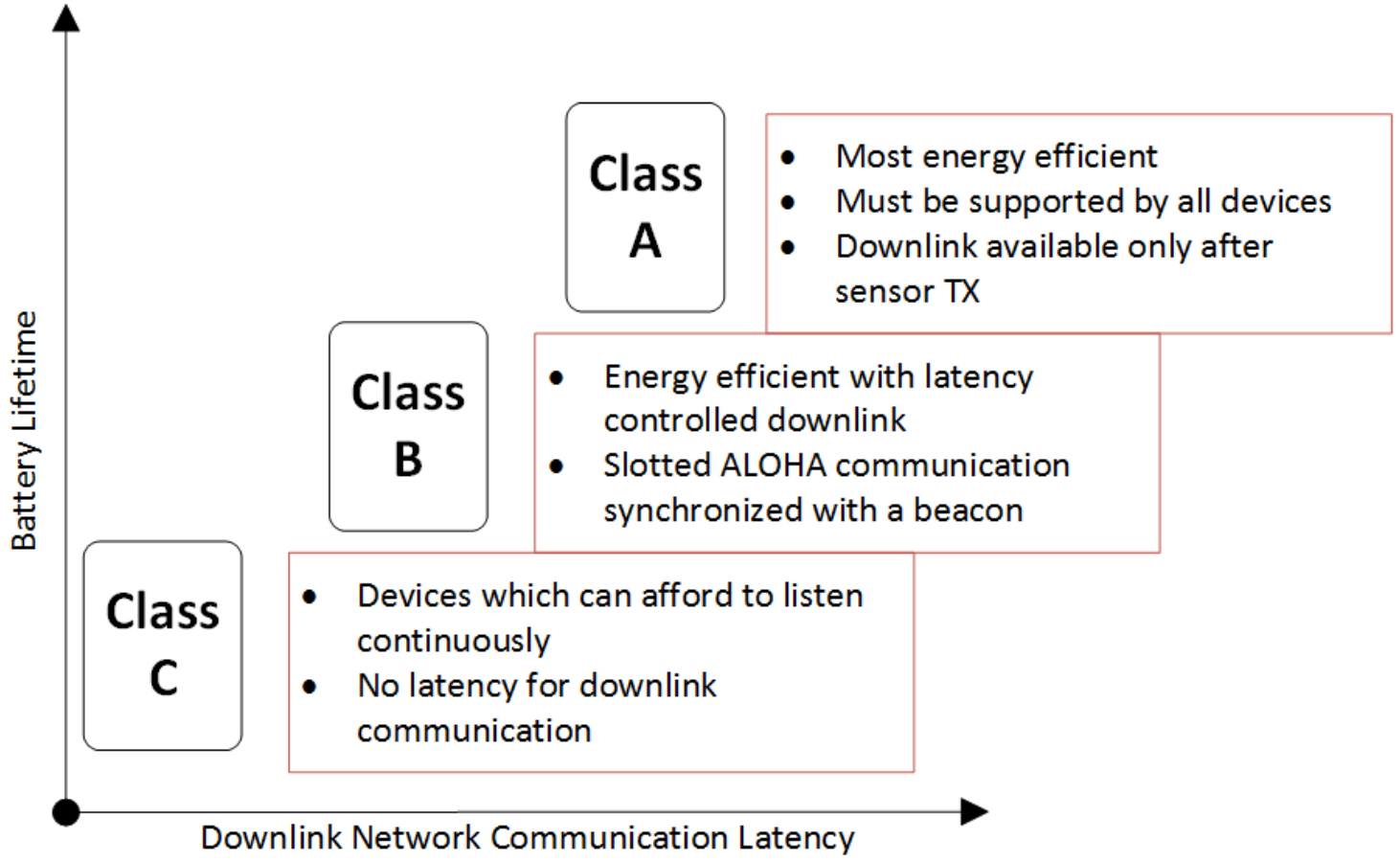
Network topology



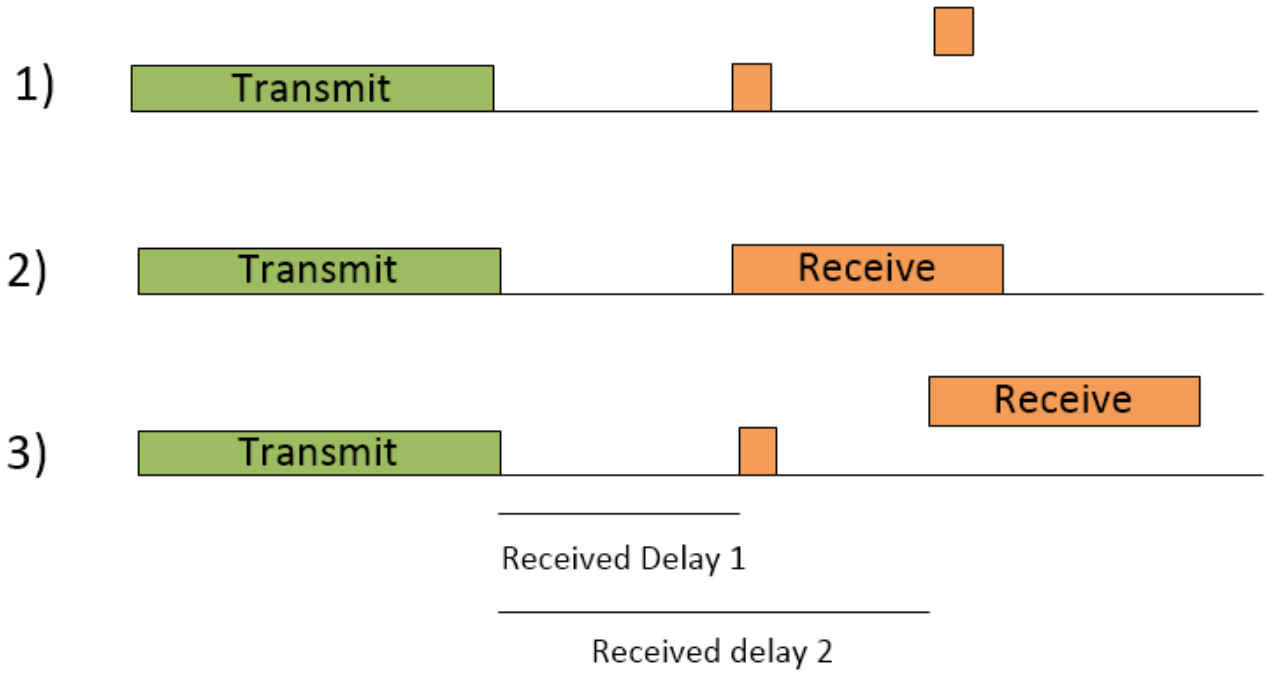
LoRa Scalability

- Gateways listen on 8 frequencies
- All SF per frequency
  - Can receive concurrently two different SF on the same frequency
- In case of collision, packet with strongest signal gets decoded (generally)
- Two dedicated high-speed channels (10 kbps and 50 kbps)
- Adaptive Data Rate (ADR), see next slide
- In case of congestion, scale by adding gateways
  - Nodes get closer to the gateway
  - Due to ADR, spreading factors will be reduced
  - More capacity (multiplicative)

LoRa WAN Classes



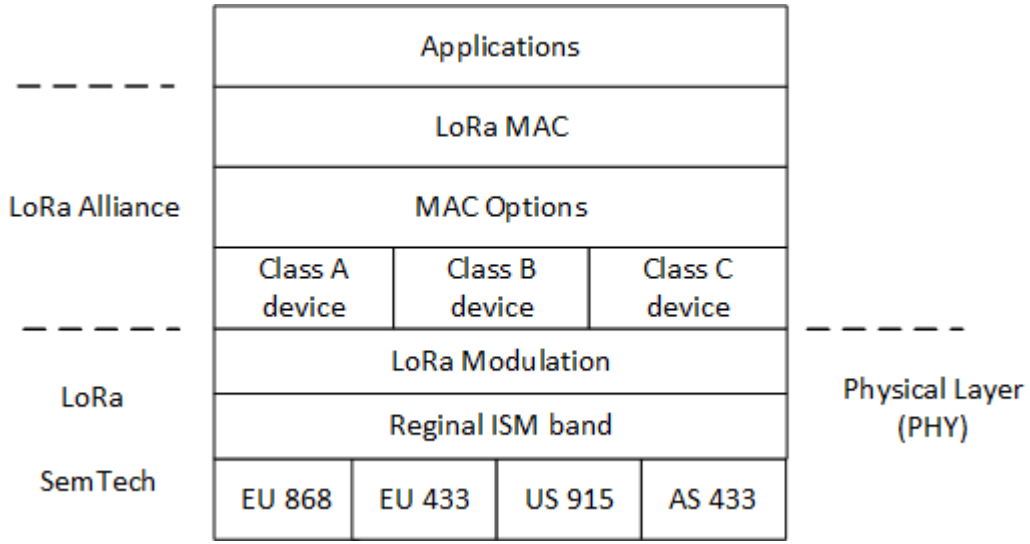
Class A Device



Receive window for Class A devices

LoRaWAN

- LoRa Protocol Stack



Parameters

- DevEUI
  - Unique identifier (64 bits) for a device (similar to MAC address)
- DevAddress
  - Dynamic address (32 bits) received by device after activation (not unique)
- AppEUI
  - Unique identifier for each app (64 bits)
- GatewayEUI
  - Unique identifier (64 bits) for each gateway

Activation a LoRa device

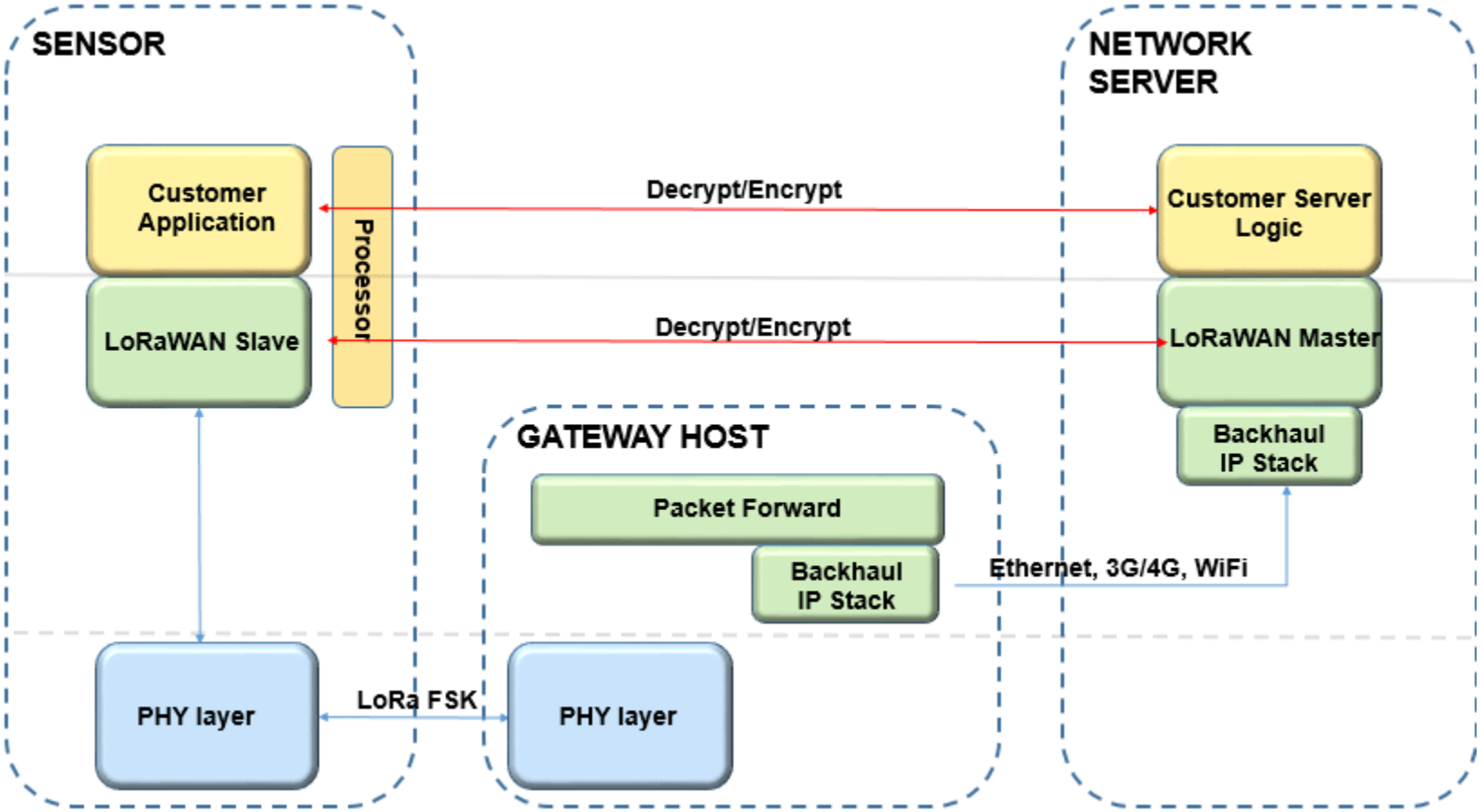
- Over the air activating (OTTA)

- Parameters
  - DevAddr, (Non-unique Device Address)
  - DevEUI (Unique 64 bit Device UID)
  - AppEUI (Unique 64 bit App UID)
  - AppKey (128 bit security key)
    - only known by the device and by the application
  - NwkSKey (128-AES, Network session key)
    - to validate the integrity of each message by Message Integrity Code, MIC
  - AppSKey (128, App session key)
    - for encryption and decryption of the payload
  - These keys are re-generated on every activation

- Activation by personalization (ABP)

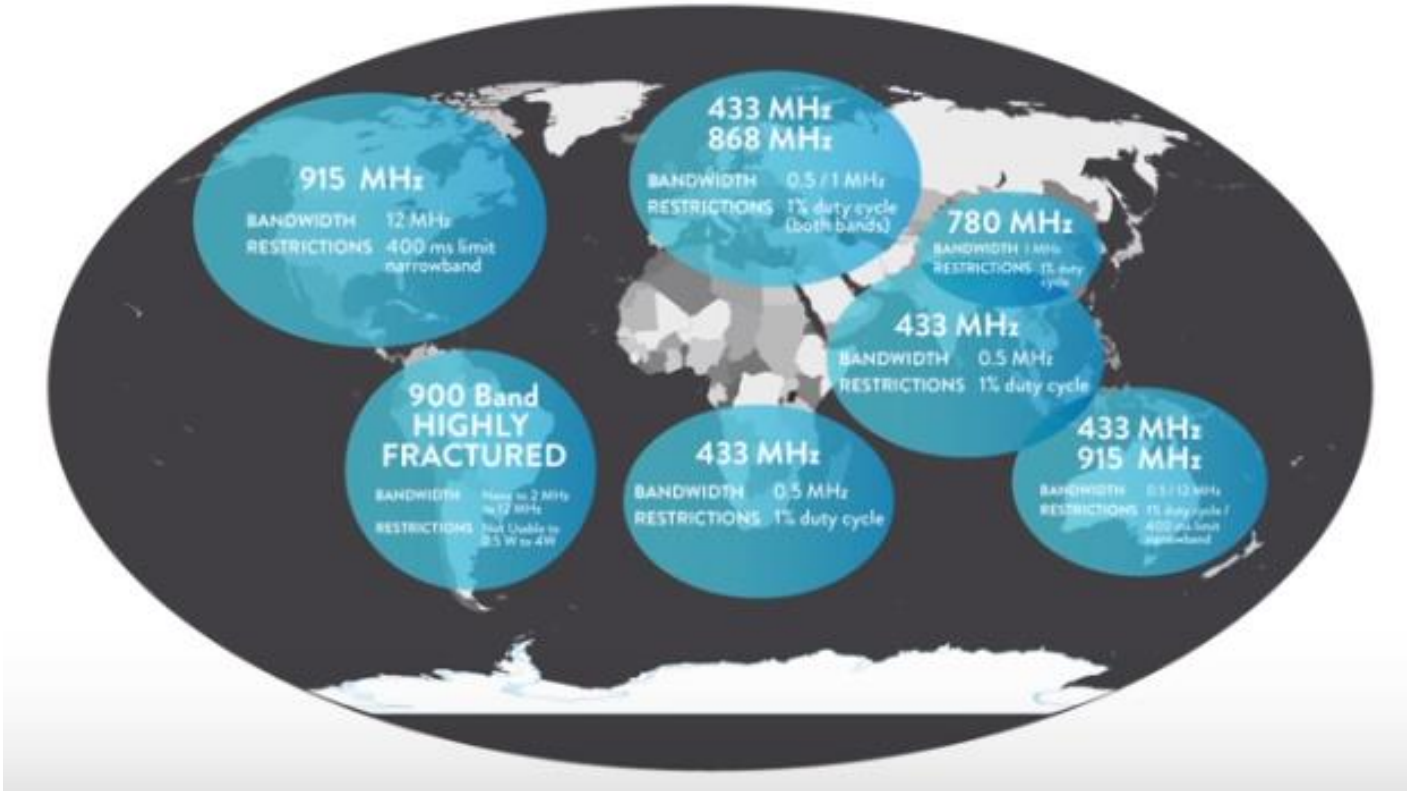
- Parameters
  - DevAddr, (Non-unique Device Address)
  - DevEUI, (Unique 64 bit Device UID)
  - AppEUI (Unique 64 bit App UID)
  - NwkSKey (128-AES, Network session key)
  - AppSKey (128, App session key)
  - These keys stay the same until the user change them
  - Less secure

LoRaWAN Network



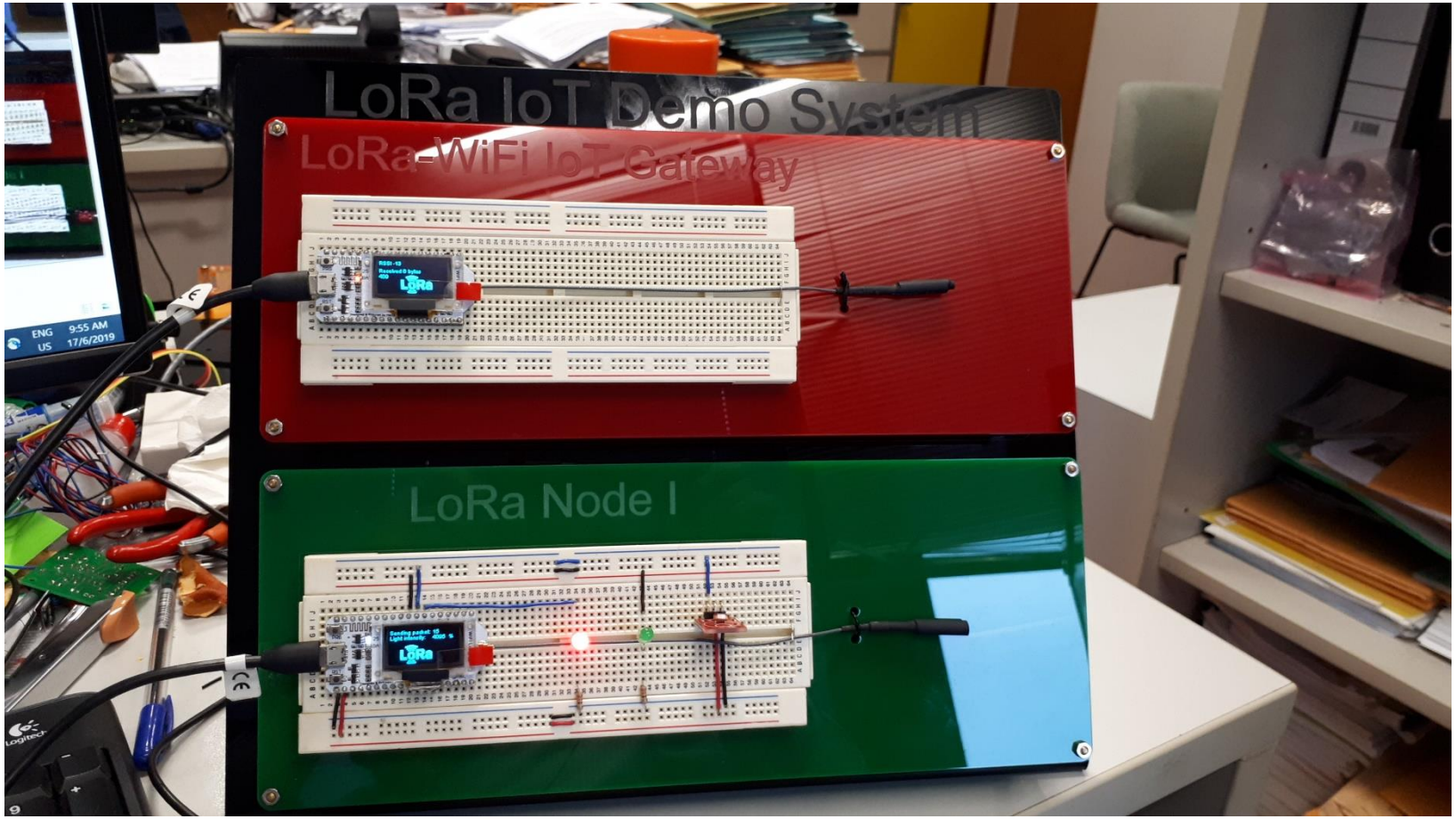
Source: https://www.researchgate.net

LoRa ISM Worldwide



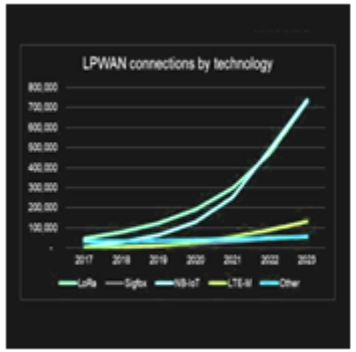
Source: https://www.engineering.com

Demo on LoRa IoT System



Parameters

- LoRa and cellular’s Narrowband-IoT (NB-IoT) are far ahead of a pack of low-power wide-area networks (LPWANs)



IoT Nets in Two-Horse LPWAN Race

LoRa and the Narrowband-IoT will grab most of the long-range IoT network action through 2023, according to a new report.

Read More

Parameters

- LoRa and NB-IoT could command 86% of all LPWA deployments by 2023.

LPWAN connections by technology - Worldwide, 2017-2023
(thousands of connections)

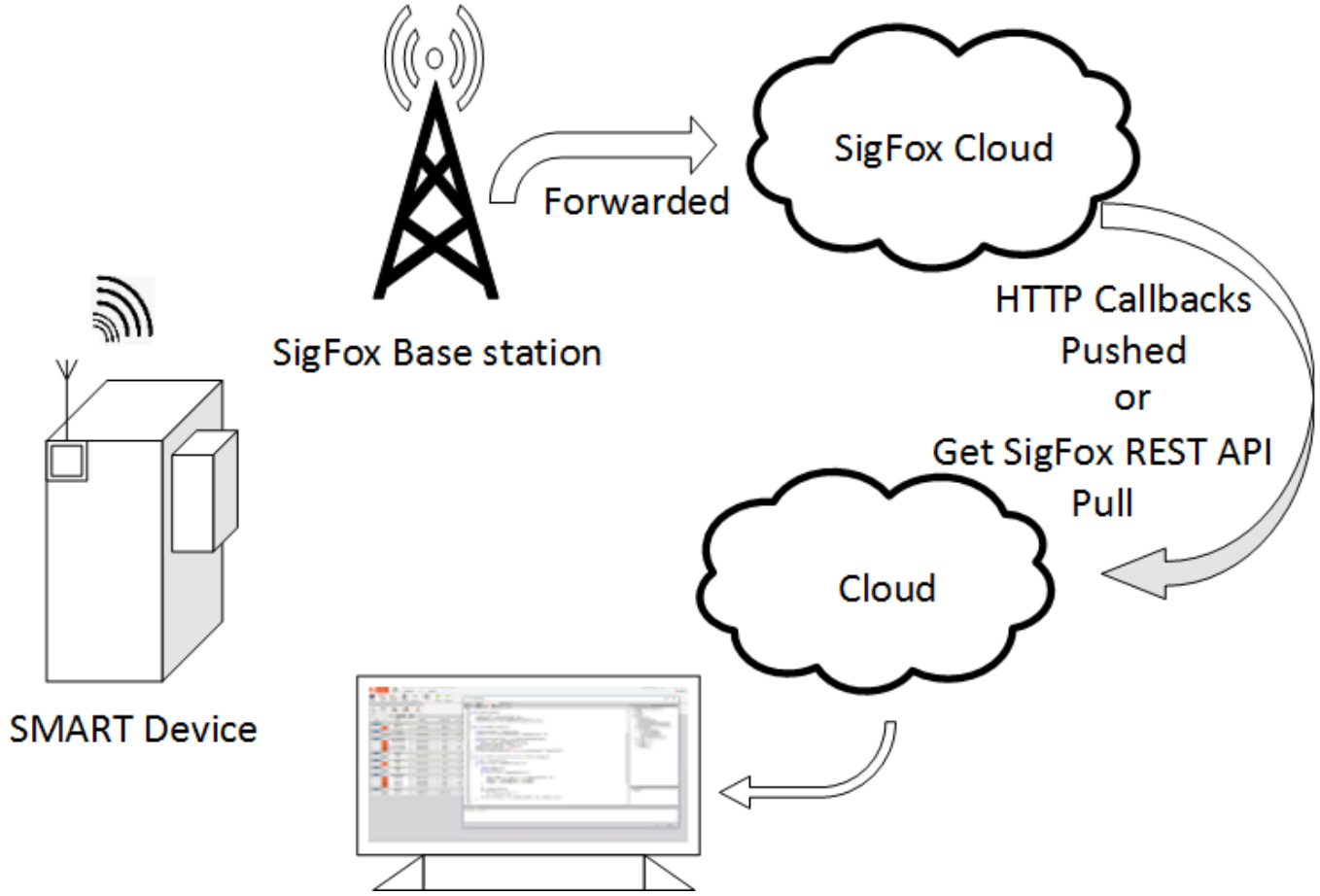
	2017	2018	2019	2020	2021	2022	2023
LoRa	46,388	78,339	123,329	190,755	299,061	470,690	730,686
Sigfox	2,458	6,155	11,928	19,943	30,124	42,925	58,046
NB-IoT	5,428	27,421	64,940	129,581	252,077	491,192	739,802
LTE-M	861	3,858	10,508	25,933	56,041	89,826	132,746
Other	32,402	34,123	36,585	39,897	43,936	49,219	55,704
Grand total	**87,537**	**149,896**	**247,289**	**406,109**	**681,239**	**1,143,852**	**1,716,985**

Source: IHS Markit

What is sigfox?

- Wireless data communication technology that **uses a cellular network topology** especially dedicated to connect things that will be seen in the IoT era
- Offers strong connectivity and direct access to the internet.
- Allows very tiny data packets to be sent.
- Power consumption is low
- Ultra Low Bandwidth and low bit rate: 100 to 600 bits/sec
- Sigfox is significantly cheaper than other solutions then 3G and 4G.
- Sigfox is a Franch global network operator found in 2009 with 80 employees.

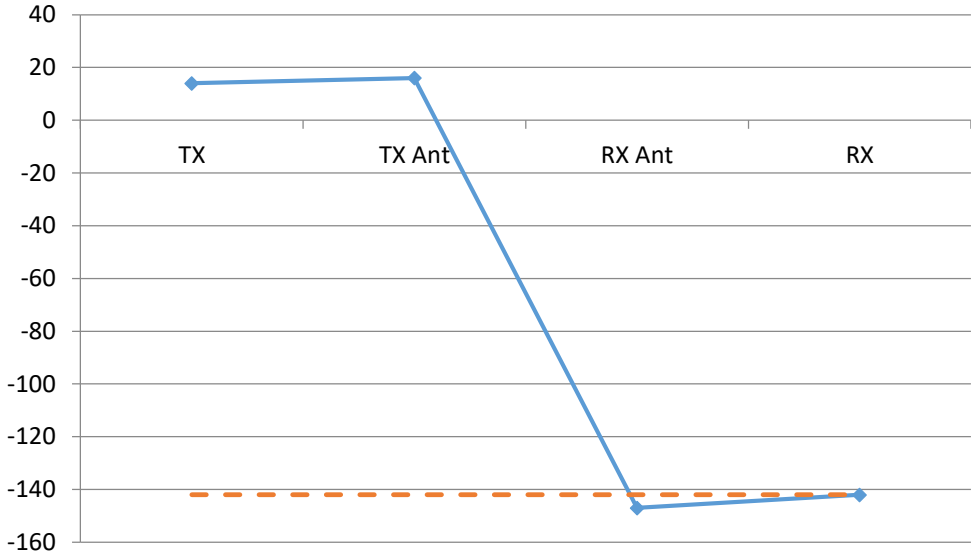
How sigfox works!



Sigfox Messages

- SigFox messages : 12 bytes of data for Uplink (D-BPSK modulation)
- : 8 bytes of data for Downlink
- Timestamp and a unique device ID is automatically sent separately
- 6 messages/ hour or 140 messages/day for one device
- 1% duty cycle for Devices
- 10% duty cycle for Base Stations
- Uses three type of diversity to provide high resistance to interference
  - Time diversity
  - Frequency diversity
  - Space diversity

Sigfox Radio Link Budget



Device transmit power = 14 dBm

Tx Antenna Gain = 2 dBi

Tx EIRP = 14 + 2 = 16 dBm

Base Station Antenna Gain = 5 dBi

Receiver Sensitivity for 100 bits/sec = -142 dBm

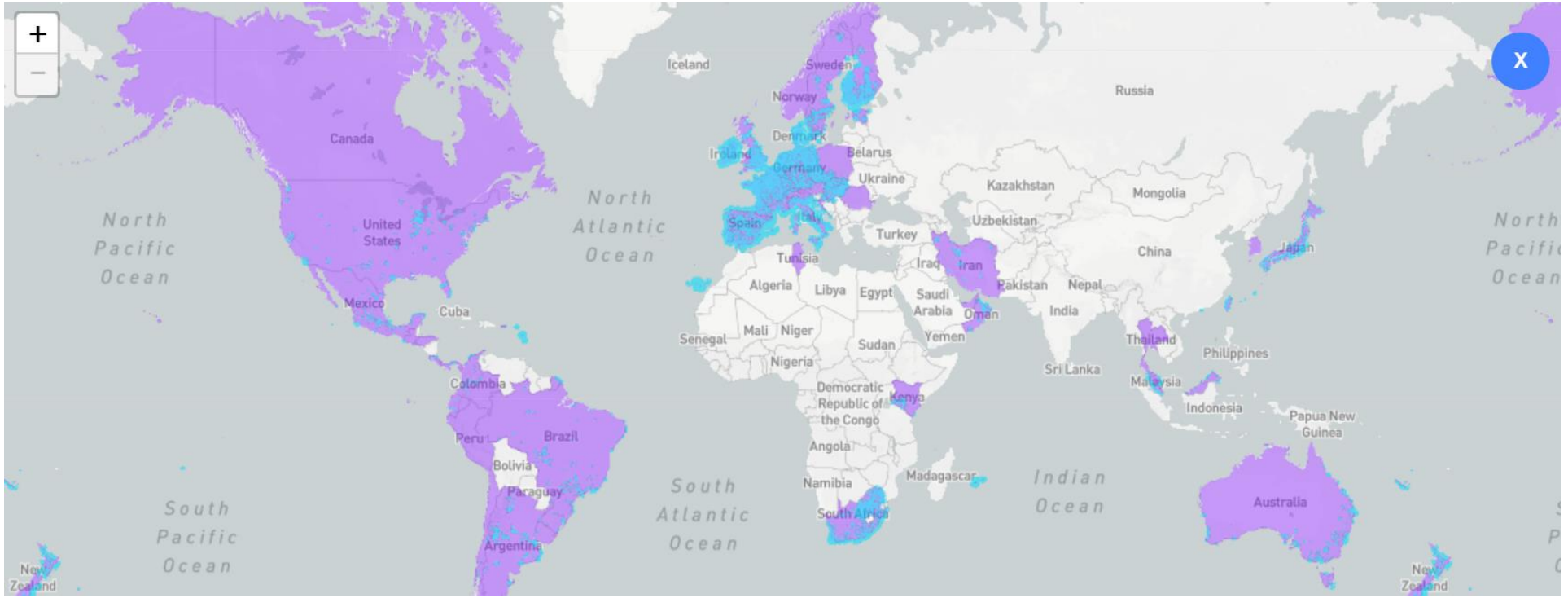
The theoretical link budget = 14 +2 +5 +142 = 163 dB

Sigfox Radio Configuration Zone

Sigfox uses unlicensed bands

- RCZ1: Europe
  - 868 MHz, +14 dBm
- RCZ2: North America
  - 902 MHz, 22 dBm
- RCZ3: Japan, Korea
  - 920 MHz, +14 dBm
- RCZ4: South America
  - 920 MHz, +22 dBm

Sigfox Coverage



https://www.sigfox.com/en/coverage