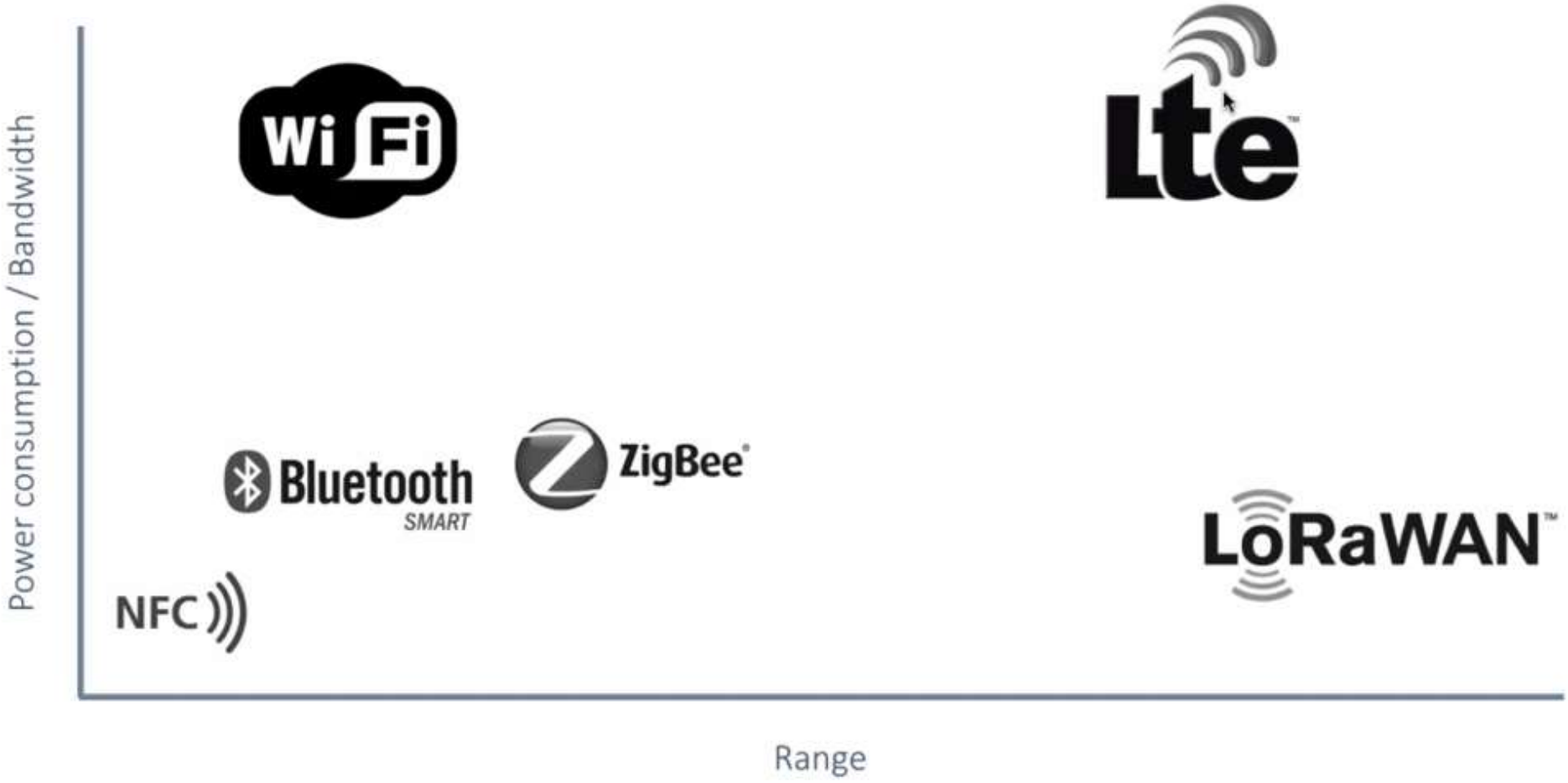
LoRaWAN

- **Low speed, but long range and low power** communication protocol
- Open specification so anyone is free to implement the protocol

- Typical range: long, 5-10 km
- Max output power: low, 0.025 W
- Bandwidth: very low, between 290 bps and 50 kbps
- Security: protocol to exchange to set unique set of AES keys
- Cost: cheap client equipment, needs access point or service provider

- Good for: isolated or private network on a farm or in a city, **ideal for sensors that only seldomly send a value**, like a soil moisture sensor sending its measurements every 10 minutes or a water trough alarming that it is empty

LoRaWAN- Where its placed



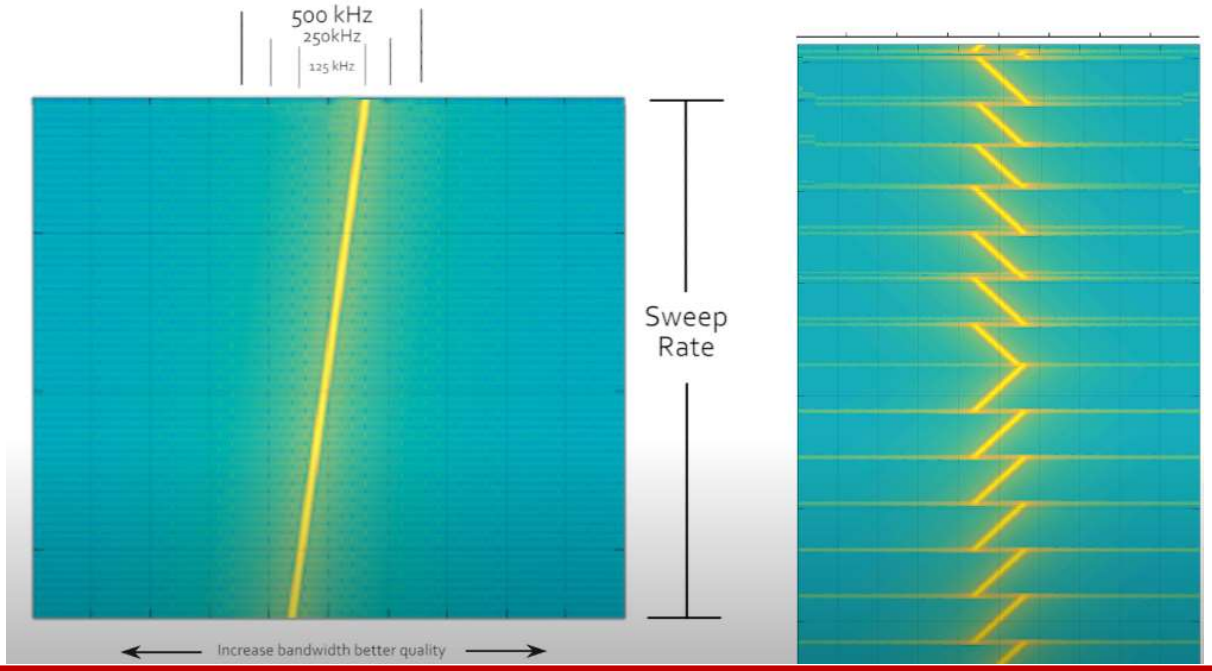
LoRaWAN

- **LoRa** is a **physical layer** for a long-range and low-power IoT protocol while **LoRaWAN** represents the **MAC layer**.
- These proprietary LPWAN technologies and carriers have the advantage of using the **unlicensed spectrum** and that, simply, is reducing data plan cost.
- LoRaWAN will be **5x to 10x lower in their data rates** compared to traditional 3G or LTE connections for large volume deployments (>100,000 units).
- A single LoRaWAN gateway has the **potential to cover a significant amount of area**. Example *Belgium, with a land area of 30,500 km2, is completely covered by seven LoRaWAN gateways.*

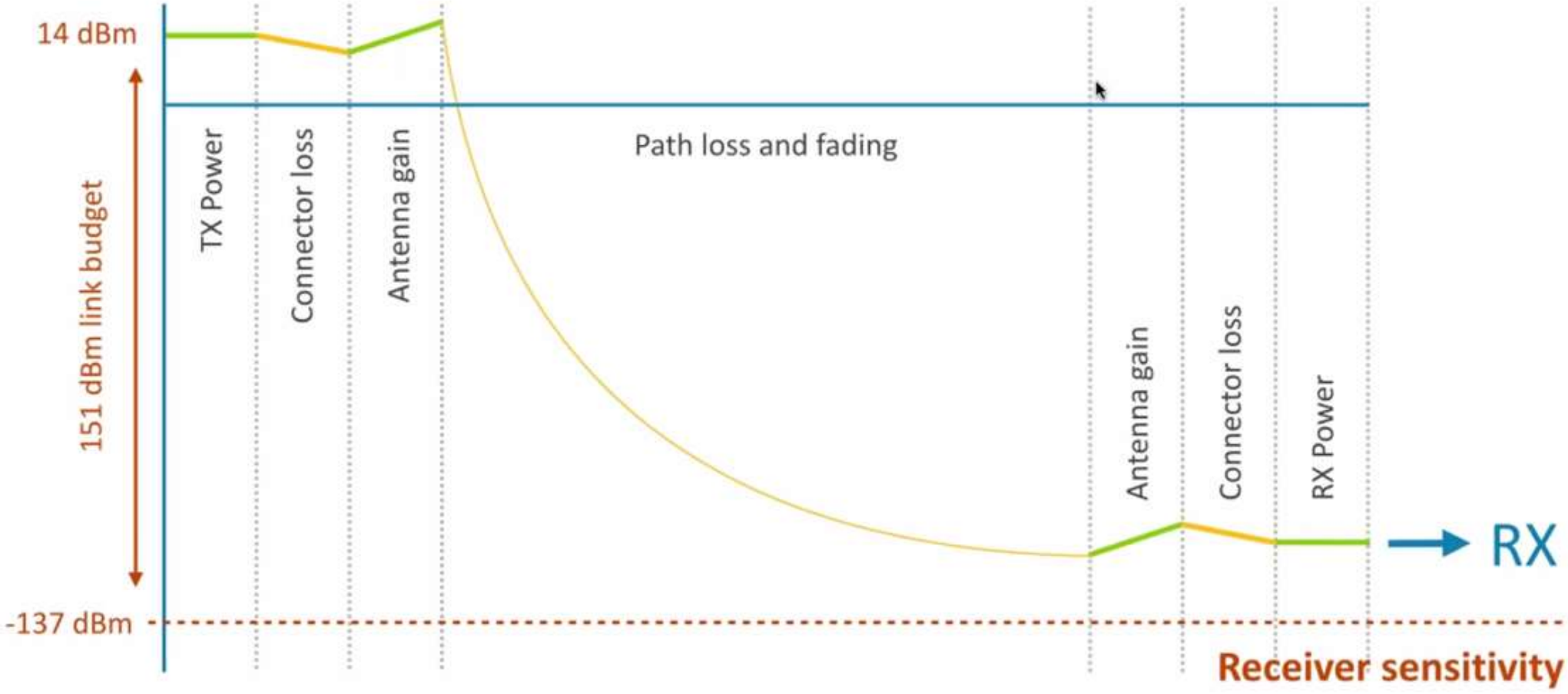
LoRa Physical Layer

- LoRa represents the physical layer of a LoRaWAN network. It manages the modulation, power, receiver and transmission radios, and signal conditioning.
- The architecture is based on the following bands in ISM license-free space:
  - **915 MHz:** In the USA with power limits but no duty cycle limit.
  - **868 MHz:** In Europe with a 1% and 10% duty cycle.
  - **433 MHz:** In Asia.

A derivative of **Chirp Spread Spectrum (CSS)** is the modulation technique used in LoRa. CSS balances data rate with sensitivity in a fixed channel bandwidth.



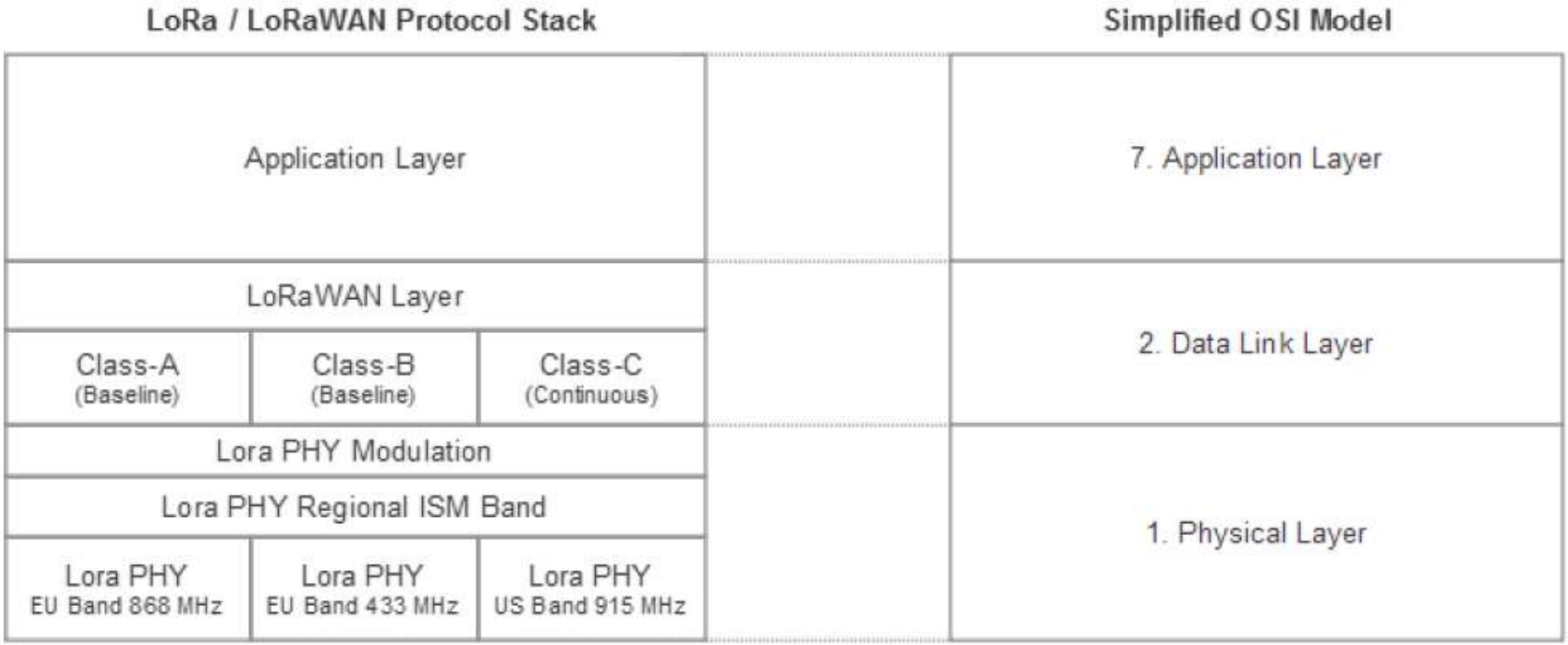
LoRa High Link Budget



LoRaWAN MAC Layer

LoRaWAN represents the MAC that resides on top of a LoRa PHY.
The LoRaWAN MAC is an open protocol while the PHY is closed.
There are three MAC protocols that are part of the data link layer. These three-balance latency with energy usage.

- **Class-A** is the best for energy mitigation while having the highest latency.
- **Class-B** is between Class-A and Class-C.
- **Class-C** has minimum latency but the highest energy usage.



Device Classes

Flexibility in power conservation versus fast network initiated transmission

Class A 😴

Device initiated communication

Devices are typically in deep sleep and send messages on intervals and/or events

Only after uplink transmission, there is a receive window for downlink messages

Best for most sensor applications and battery conservation

Class B ⏰

Time synchronized communication

The network broadcasts beacons for devices to sync time

In so-called ping slots, devices wake up and the network may send downlink messages

Best for most downlink intensive applications

Class C ⚡

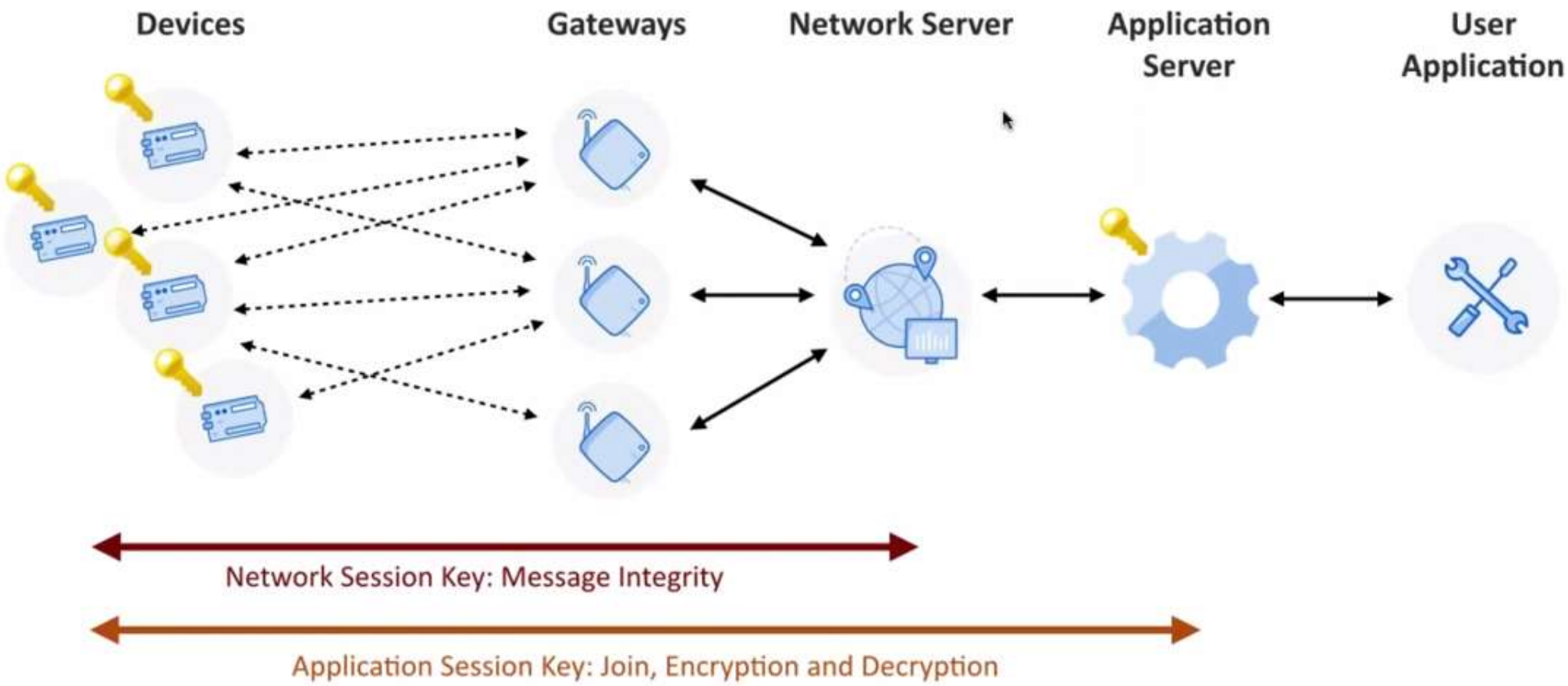
Network initiated communication

The devices are continuously listening, often temporarily or on power supply

The network can send downlink message at any given time

Best for downlink intensive applications that require low latencies

LoRaWAN Topology



SigFox

- **Low speed and low power, but also long range**
- Meant for remote meter reading, also used for any remote data uplink
- Proprietary network and protocol

- Typical range: long, 24 km, global (partial) coverage https://www.sigfox.com/en/coverage
- Max output power: low, 0.025 W
- Bandwidth: very low, up to 140 messages per object per day, 12 bytes payload, 100 bps
- Security: no encryption
- Cost: cheap client equipment, for transmission about 1/12€ per device per year

- Good for: remote electricity or water meter reading, mostly useful if you do not need to send data to the device

NB-IoT Introduction

- **Low Power Wide area network**
- Narrow Band IoT also known as Cat-M2
- Based on 4G/LTE
- Features Deep Indoor Penetration
- Long Battery Life
- Connections of Thousands of Devices in a Cell
- Cost Efficient Implementation
- Good Network Coverage in difficult environment e.g. basement or remote regions
- Optimal security though end-to-end encryption
- Applications
  - Focused on very low data rates, ideal for simple sensor application
  - Smart Meter
  - Agriculture
  - Home Automation
  - Street lighting

NB-IoT Features

- NB-IoT, also known as Cat-NB
- Cat-NB operates in the licensed spectrum.
- The goal is to reduce power (10-year battery life), extend coverage (+20 dB), and reduce cost ($5 per module).
- Cat-NB is based on the Evolved Packet System (EPS) and optimizations to the Cellular Internet of Things (CIoT).
- Channels are much narrower than even the 1.4 MHz Cat-M1, cost and power can be reduced even further.

Significant differences between Cat-NB and Cat-M1 include:

1. **Very narrow channel bandwidth**: As with Cat-M1, which reduced the channel width to 1.4 MHz, Cat-NB reduces it further to 180 kHz for the same reasons (reducing cost and power).
2. **No VoLTE**: As the channel width is so low, it does not have the capacity for voice or video traffic.
3. **No mobility**: Cat-NB will not support handover and must remain associated with a single cell or remain stationary. This is fine for the majority of secured and fastened IoT sensor instruments.

NB-IoT Deployment Options

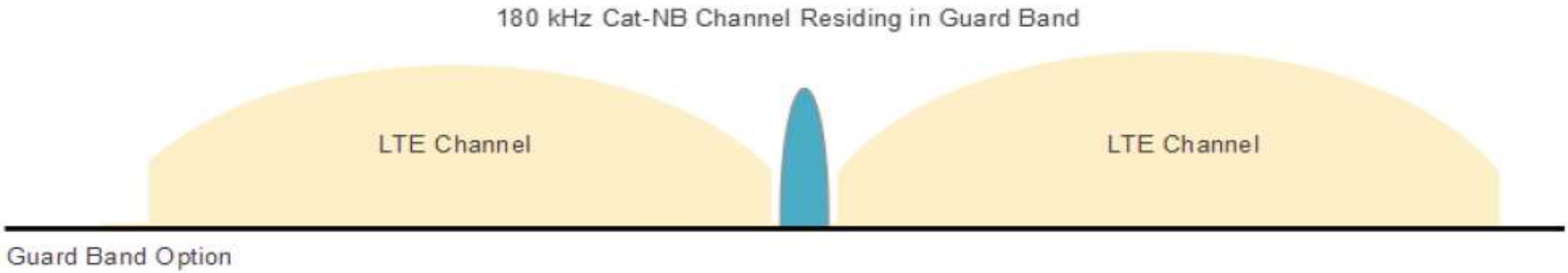
- Since the channel width is so small (180 kHz), it allows for the opportunity to bury the Cat-NB signal
  1. inside a larger LTE channel (**In-band**)
  2. replace a **GSM channel**,
  3. even exist in **the guard channel** of regular LTE signals.

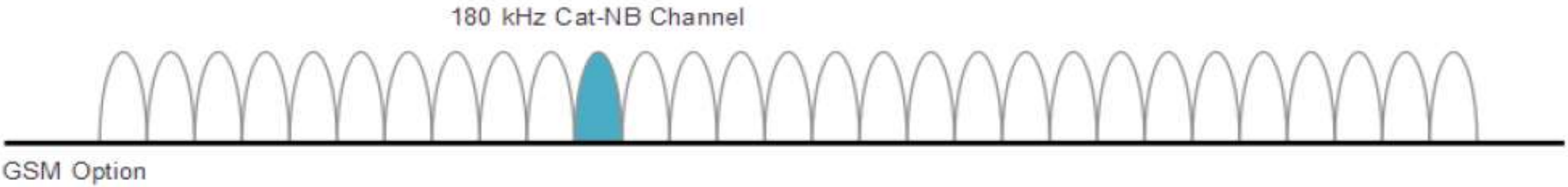
- ***In-band*** provides a massive amount of spectrum to use as the LTE bands are much larger than the 180 kHz band. This allows for deployments of up to 200,000 devices in theory per cell. In this configuration, the base cell station will multiplex LTE data with Cat-NB traffic.

- Using Cat-NB as the LTE ***guard band*** is a unique and novel concept. Since the architecture re-uses the same 15 kHz subcarriers and design, it can be accomplished with existing infrastructure.

- The GSM option is simplest and fastest to market. Some portions of the ***existing GSM traffic*** can be replaced with NB-IoT

NB-IoT Deployment Options





Other Wireless Protocols

- LTE Cat-M
  - use cellular channels for long range, limited bandwidth communication
  - still in development or with limited coverage
- Satellite
  - huge coverage
  - extremely expensive