# Low-Power Wide-Area Networks

# Wireless Communication Ranges

- Many communication standards to build wireless LANs or PANs
  - IEEE 802.15.4, WiFi, Bluetooth
  - *Only work on short distances <100m*

- Technologies to build wireless WANs:
  - GSM/GPRS, UMTS, LTE/LTE-A
  - Laser links
  - Traditional radio networks (Aloha,...)
  - *Work on several kilometers*

- For larger distances (*thousands of km*): Satellite links

# Low-power WANs

- Until around 2010, there was no low-power technology for wireless WANs:
  - 802.15.4 only for PANs
  - UMTS (3G)/LTE (4G) require complex hardware: expensive and high power consumption. Same for satellite links
  - GSM/GPRS (2G) also has high power consumption, but at least it's relatively simple. Unfortunately, GSM/GPRS is being phased out

- That was a big problem for long-distance IoT/WSN applications
- Different groups and companies worked on this in the 2010s

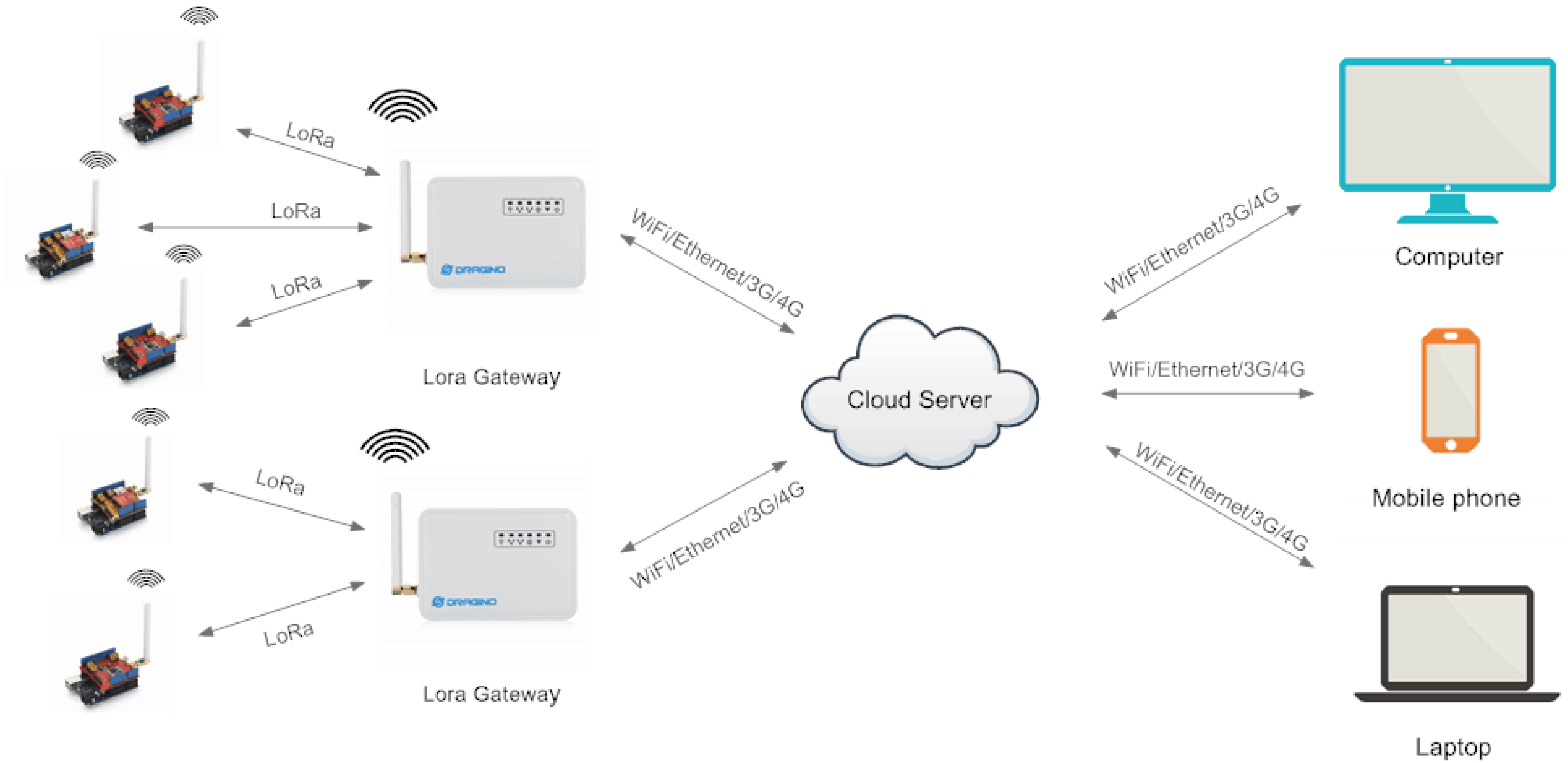
# LoRa

Consists of

- LoRa PHY (physical layer)
  - Proprietary modulation format owned by Semtech
  - Not documented. You have to buy their chips.
  - <u>Very</u> slow but robust, allows long-range communication with low power
- LoRaWAN (MAC layer)
  - Defines the MAC layer on top of LoRa
  - Open specification, managed by the LoRa Alliance

- Devices and applications have a 64-bit identifier
- Optional security with 128-bit keys (AES-128)

# Typical usage of LoRa




Source: www.antratek.com

# LoRa PHY

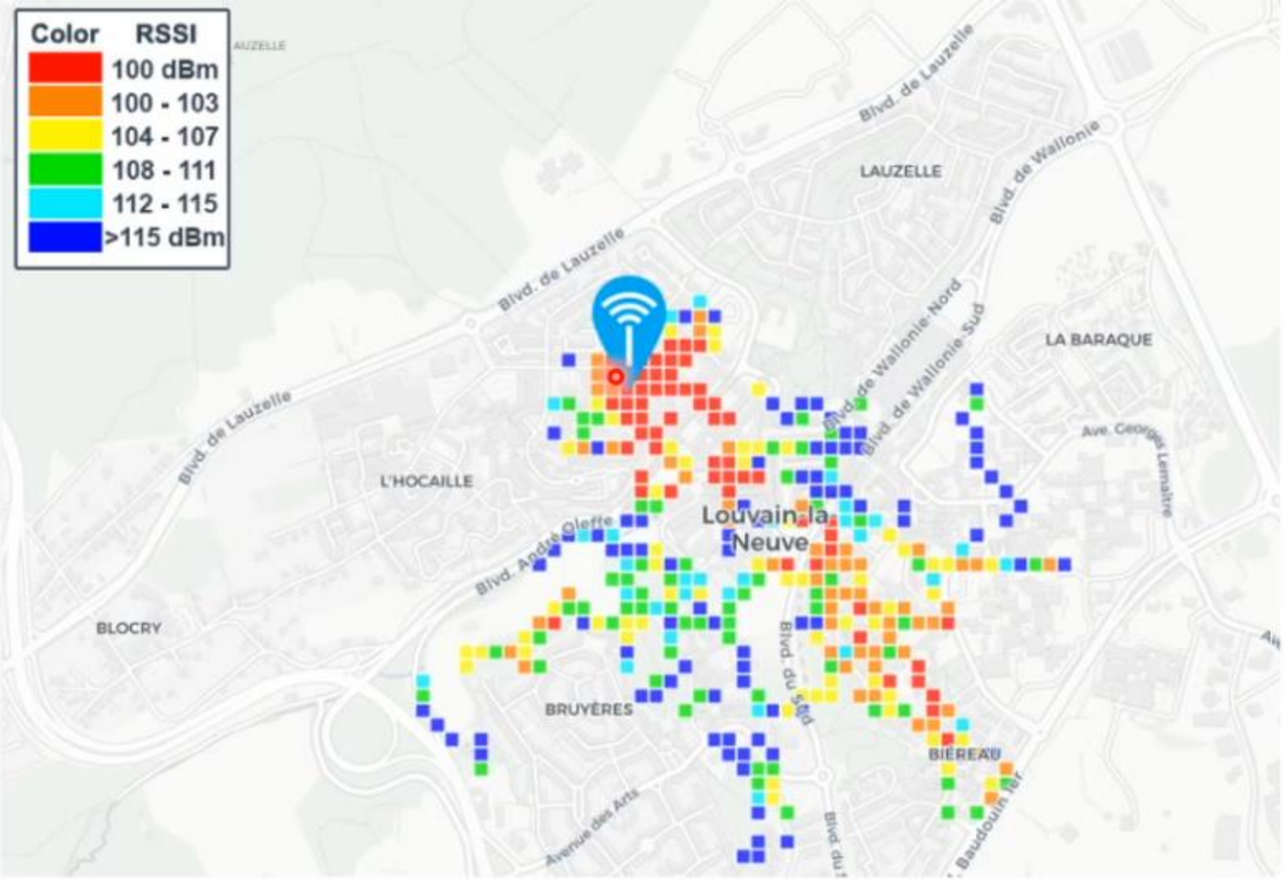
- Europe: Uses the free 863-870 MHz frequency band for sending and receiving, divided into 8 channels
- Different regulations outside Europe. Example USA: 902-928 MHz, separate uplink and downlink channels
- LoRa defines different spreading factors SF7 to SF12

$$spreading\ factor = \log_2 \frac{chip\ rate}{symbol\ rate}$$

- Several frames can be sent at the same time if they use different spreading factors
- Higher spreading factor = Slower, but very robust against noise, communication over longer distances possible (5 km urban, 20 km rural)
  - SF7:  27 kbit/s, max. 222 bytes payload per frame
  - SF12: 0.3 kbit/s, max. 51 bytes payload per frame

# Coverage example

- The picture shows the received signal strength (RSSI) with a <u>single</u> gateway placed in the north of LLN
(from the Master thesis of R. Schoenmaeckers at UCLouvain, 2019)

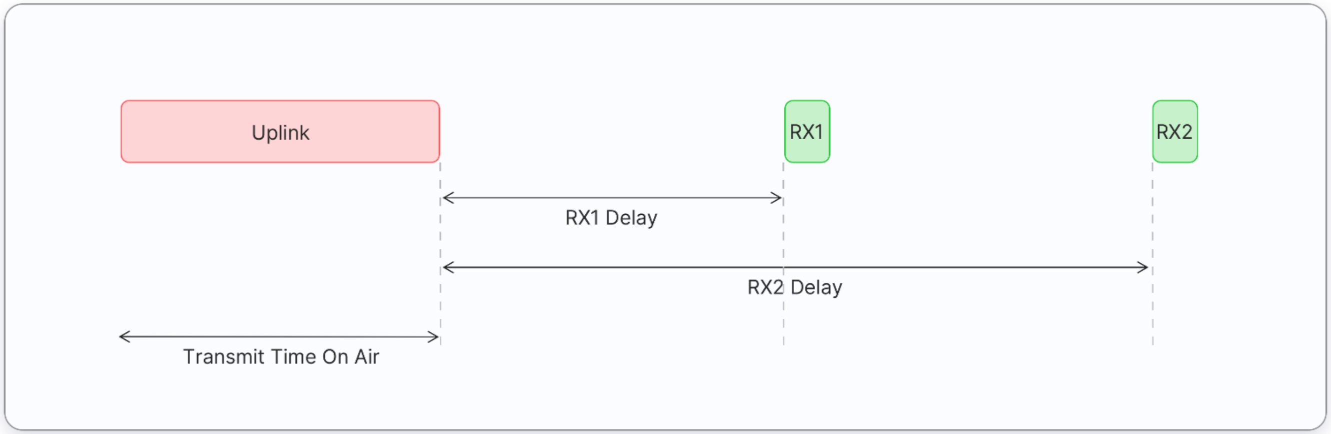


# LoRaMAC

- ALOHA-based: Random access
- Devices (nodes and also the gateway) must not exceed the 1% (resp. 0.1%) duty-cycle imposed by EU laws
  - Highly recommended to use less than 1% of your time budget, otherwise you could only have 800 stations per gateway (if you use all 8 channels and the same spreading factor)
- Devices can do channel hopping to increase their allowed time on air and to avoid losses if external interferences on one channel
- Performance:
  - Depends on number of devices, payload size, distance to gateway, background noise, number of channels a device can use
  - Rough estimation: 50,000 messages/day with 20 byte payload for a gateway (up to 700,000 in perfect conditions)

# LoRa: Device classes

- Different device classes: A, B, C
- Class A: device can send at any time and switch to receive mode during two small windows (1 or 2 seconds) after sending




- The server can respond in one of the two windows
- All devices must support class A

Source: https://www.thethingsnetwork.org/docs/lorawan/classes/

# LoRa: Device classes (2)

- Class B: device send and receive at specific times announced by a beacon sent by the gateway (similar to slotted mode of IEEE 802.15.4)
  - Advantage: application can be sure that device is reachable at specific times
  - Needs more energy than class A because device must be online at the specified times
- Class C: device can send at any time, can receive at any time (if not sending; half-duplex)
  - Advantage: low latency, device always reachable
  - Needs more energy than class A and B. Usually class C devices run on mains power, not on batteries.

# Building a LoRaWAN network

- Just buy a gateway and some nodes
  - Or build them (Raspberry + LoRa network interface)
  - Actually, quite cheap

- Or use the gateways of the The Things Network for free

  https://www.thethingsnetwork.org/

  (The website also contains a lot of useful information about LoRa and LoRaWAN)

  Their fair use policy: 30s uplink per day per device

# Sigfox

- Different business model to LoRa
- LoRa:
  - Open network: You can build your own network. Just buy a gateway and radio interfaces for your devices.
  - Closed hardware: If you want to build your own hardware, you need the Semtech chips
- Sigfox:
  - Closed network: You <u>must</u> use the Sigfox network infrastructure
  - Semi-open hardware: Chips are licensed to several manufacturers

# Sigfox: Infrastructure

- The Sigfox company has installed network infrastructure in several countries (Belgium: managed by EngieM2M)
- You have to pay to use it
- The messages that your devices send are forwarded to the Sigfox cloud where your application can read them

- Characteristics:
  - Same free frequency bands as LoRa
  - 140 messages/day per device uplink, 4 downlink
  - Payload: 12 bytes uplink, 8 bytes downlink
  - Like LoRA, very robust encoding and MAC layer: only 7 base stations for good coverage in entire Belgium!

# Narrow-Band LTE (NB-LTE)

- Uses LTE infrastructure in the licensed frequency bands
- Devices implement a simplified version of the LTE protocol
- 250kbps down, 250kbps up
- 1 km urban, 10 km rural
- Medium is controlled by the operator
  - Hardware more expensive: devices must co-exist with other 2G/4G devices and follow all rules
  - Higher power consumption
  - Infrastructure more expensive than Sigfox or LoRa
  - But: Quality of service can be guaranteed.
    Performance of Sigfox and LoRa depends on how other people use the free 868 MHz band
- We will see later a little bit more on 4G and 5G for IoT applications