Pervasive Systems

Ioannis Chatzigiannakis

Sapienza University of Rome
Department of Computer, Control, and Management Engineering (DIAG)

Lecture 17:
Low-Power Long-Range Connectivity

The Need for Low-Power Long-Range Connectivity

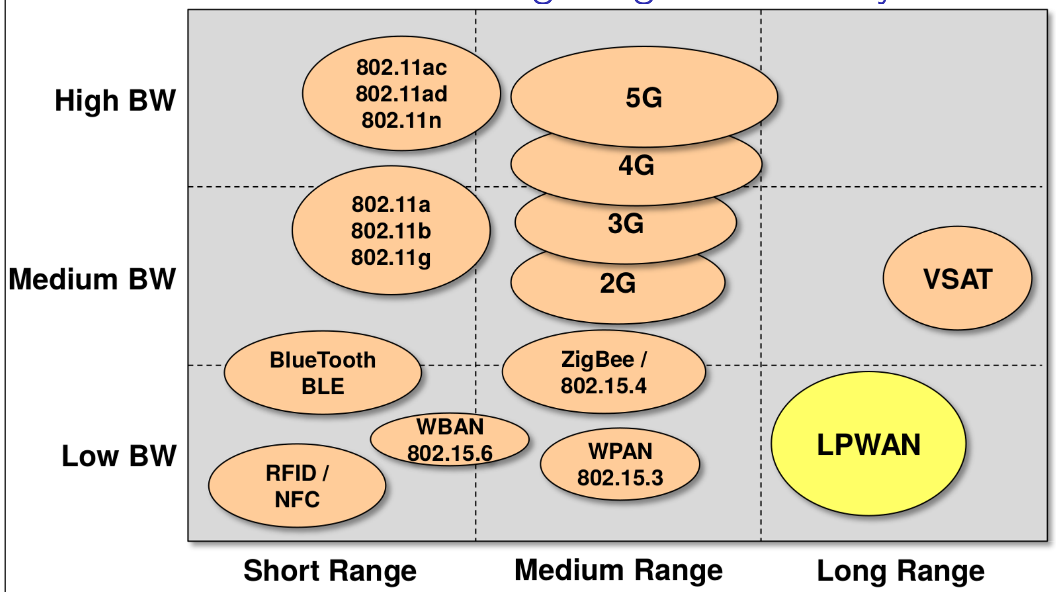
- $>$ 25 billion devices by 2020
- Bluetooth & Wi-Fi not well suited for many scenario
  $<$ 100m, high throughput & power consumption
- 3G/4G cellular not well suited as well
  $ hardware, $ SIMs/plans, high battery inefficiency, available spectrum.
- Endpoints costs need to be low
- Must be small for integration into everything
- Conserve wireless spectrum duty cycle policy
- Conservative power – run on a battery – i.e. mA
- Support really low bandwidth for Bytes not MB of data
- $ network plans

The Need for Low-Power Long-Range Connectivity

The emergence for IoT introduces new challenges that cannot be addressed by the current available connectivity protocol, such as:

- Bandwidth/Data Rate: In LPWAN, the data rate is selected by a trade-off between the communication range and the duration of the message.
- Battery Life: To maximize the life of the final device batteries, the LPWAN server controls the RF output and an output rate through an adaptive scheme for each end device.
- Range: LPWAN obtains about 2-5 km of coverage range in urban perimeters and about 45 km in rural areas.
- Latency: There is a trade-off between downlink communication latency versus battery life time that can be resolved through QoS classes in a LPWAN device.
- Throughput: Data rates between 290 bps and 50 kbps.

The Need for Low-Power Long-Range Connectivity



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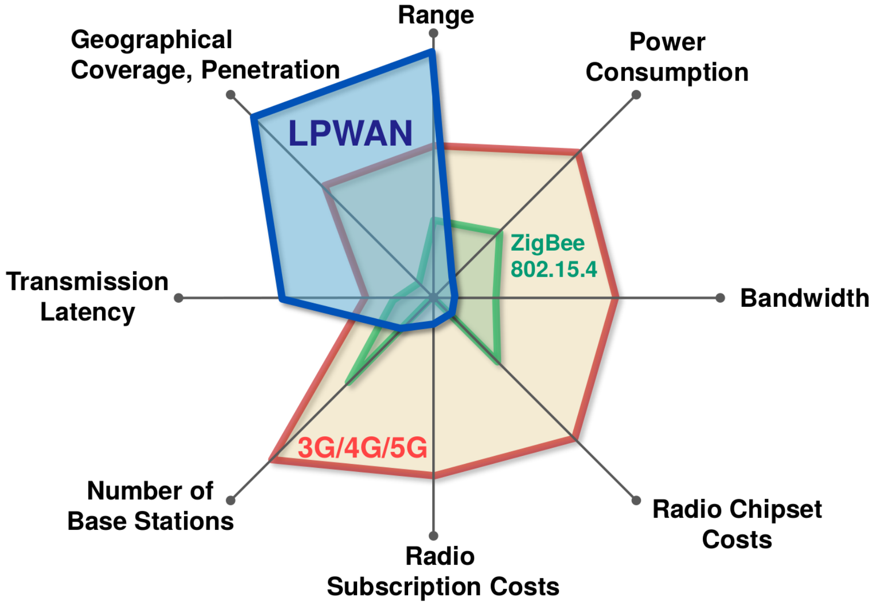

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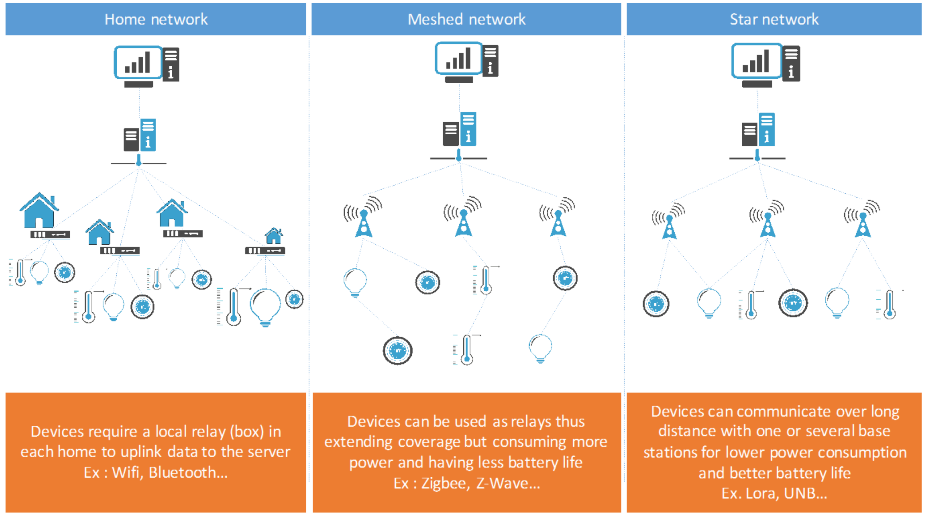


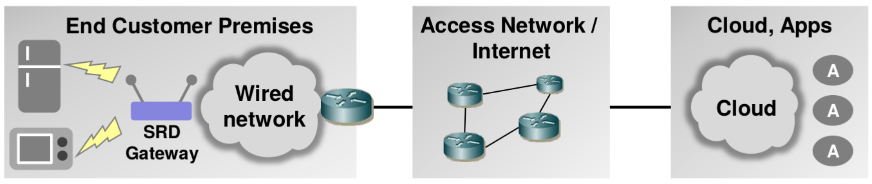
The Need for Low-Power Long-Range Connectivity

Characteristic	Target Value for LPWAN Technologies
Long range	5 – 40km in the open field
Ultra low power	Battery lifetime of 10 years
Throughput	$\sim$ a few hundred bps
Radio chipset costs	\$2 or less
Radio subscription costs	\$1 per device and year
Transmission latency	Not a primary requirement for LPWAN.
Required number of base stations for coverage	Very low. LPWAN base stations are able to serve thousands of devices.
Geographic coverage, penetration	Excellent coverage also in remote and rural areas. Good in-building and in-ground penetration (e.g. for reading power meters).

The Need for Low-Power Long-Range Connectivity

Short range radio connectivity for IoT devices:

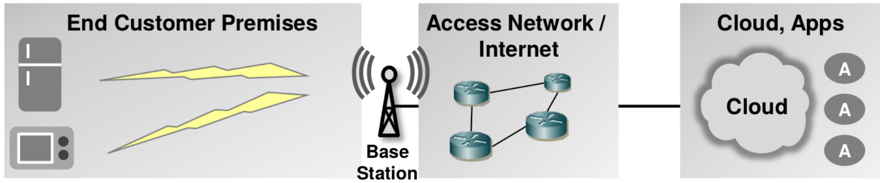
- Short range radio devices (SRD) such as ZigBee require using a gateway for long-range backhaul.
- The gateway is typically hooked up to some on-site wired network which is not under control of the IoT provider.



The Need for Low-Power Long-Range Connectivity

Direct long range connectivity (LPWAN) for IoT devices:

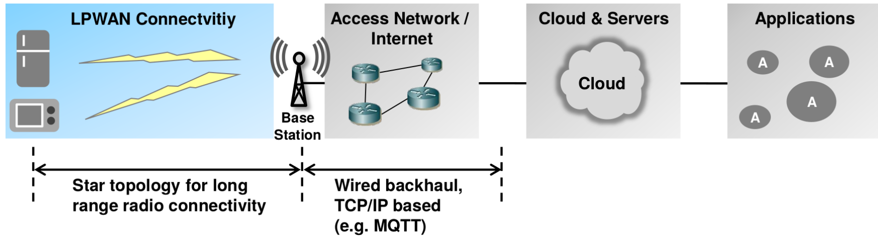
- Long range connectivity allows direct access to the devices in the field.
- The base station typically serves a large number of devices thus greatly reducing costs.



LPWAN Network Topology

Direct device connectivity (base station):

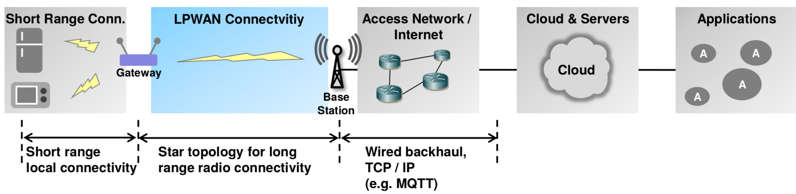
- A base station provides connectivity to a large number of devices.
- The traffic is backhauled to servers (cloud) through TCP/IP based networks (Internet).
- The base station is responsible for protocol translation from IoT protocols such as MQTT or CoAP to device application protocols.



LPWAN Network Topology

Indirect device connectivity through a LPWAN gateway:

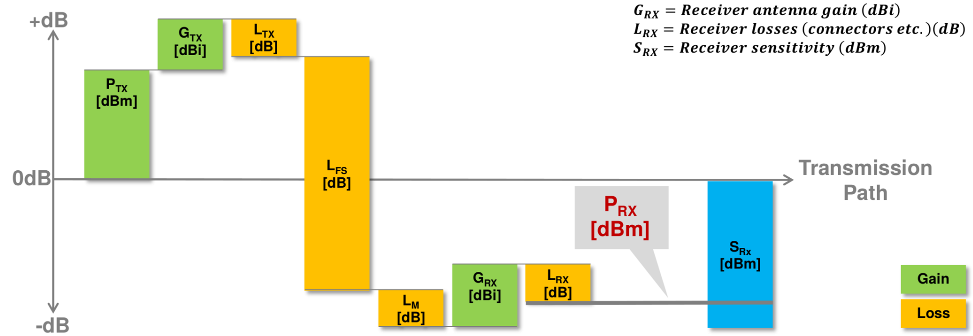
- Devices cannot be directly reached through LPWAN, a local gateway bridges LPWAN connectivity to some short range radio (SRD) technology (e.g. ZigBee, BLE).
- The gateway typically runs on mains power since it serves a larger number of devices and must convert between LPWAN and SRD radio technologies and protocols.
- Gateways may help to improve security since more powerful security algorithms can be implemented on the gateway than is possible on the constrained devices.



Link budget for LPWAN devices

$$P_{RX} = P_{TX} + G_{TX} - L_{TX} - L_{FS} - L_{M} + G_{RX} - L_{RX}$$

P_{RX} = Received power (dBm)
P_{TX} = Sender output power (dBm)
G_{TX} = Sender antenna gain (dBi)
L_{TX} = Sender losses (connectors etc.)(dB)
L_{FS} = Free space loss (dB)
L_{M} = Misc. losses (multipath etc.)(dB)
G_{RX} = Receiver antenna gain (dBi)
L_{RX} = Receiver losses (connectors etc.)(dB)
S_{RX} = Receiver sensitivity (dBm)

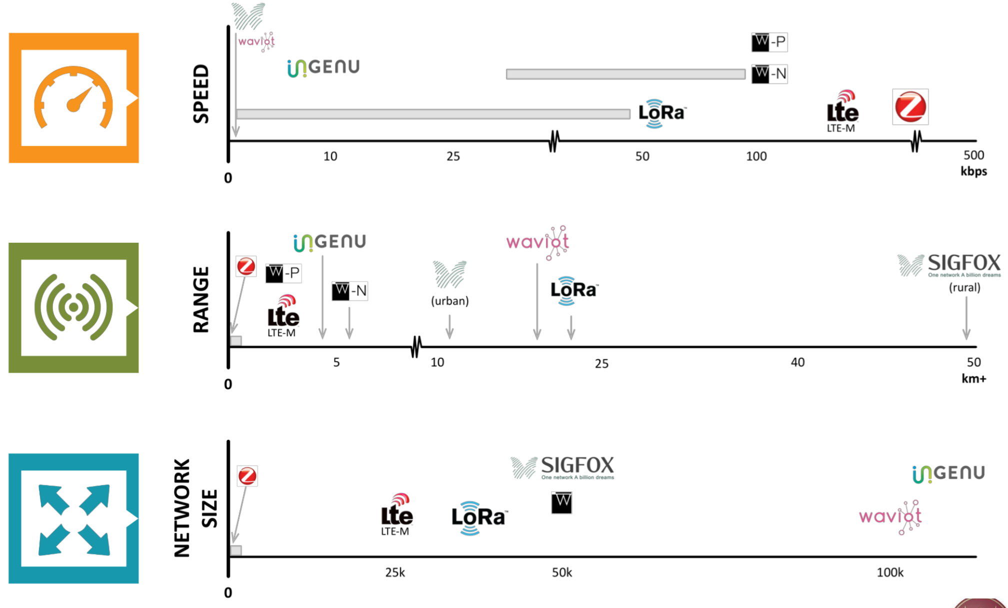


Receiver sensitivity: $\leq 140 dBm$

Available LPWAN Providers

LoRa	SIGFOX	waviot	INGENU
Pros	**Pros**	**Pros**	**Pros**
• Private and public networks • MAC & network layers are open • Good hardware availability • Flexible for broad uses • Inexpensive • Excellent battery life	• Easy/quick product development • Well capitalized and good network availability • Inexpensive	• Public and private networks • Great use of spectrum • Good hardware availability • Excellent link budget and performance in varied environments	• Private and public networks • Excellent bi–directional communication • Scalable base stations • Good bandwidth utilization
Cons	**Cons**	**Cons**	**Cons**
• Proprietary PHY layer • Transceivers only available from Semtech • High downstream latency	• Must use public network • Very limited data transfer • Use is limited and caters to sensor networks, status monitoring, etc.	• High latency • Very low speed • Less flexibility than LoRa, Weightless	• Works in crowded 2.4 GHz band • Higher frequency less penetrable

Available LPWAN Providers



SIGFOX

A French start-up company founded in 2009 and based in Toulouse.

Already deployed long range infrastructure worldwide

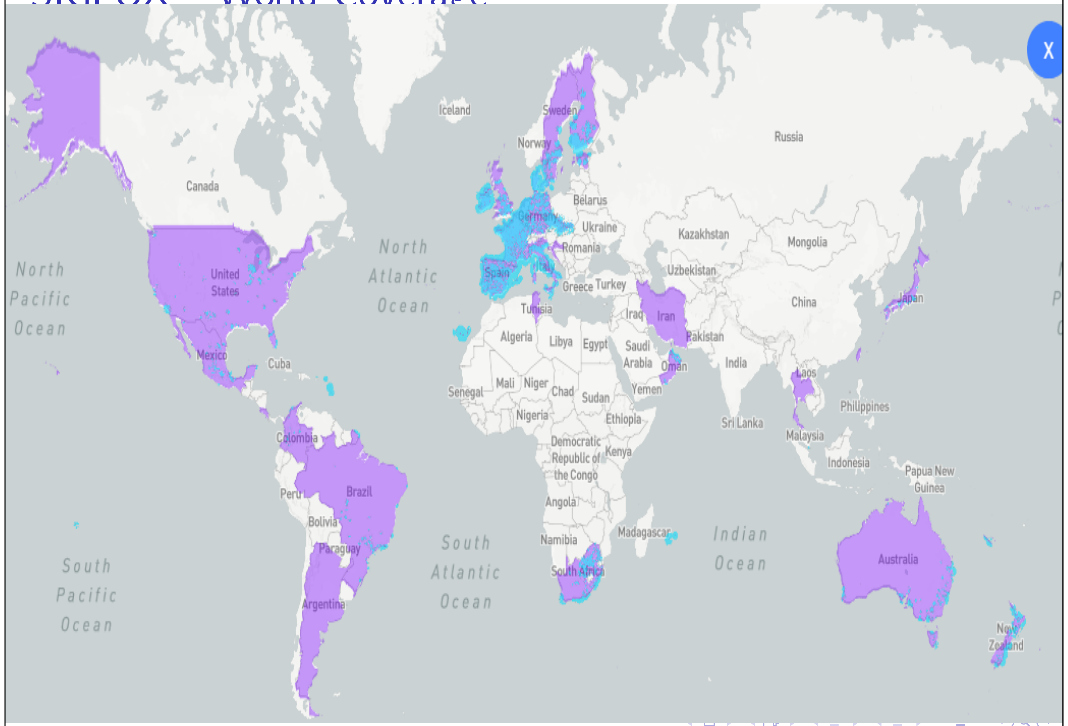
SIGFOX technology features modules able to send messages of 12 octets maximum, with a maximum frequency of 140 transmissions per day, and a datarate of 100 bits/s.

- Network operator model only (annual subscriptions/connected object)
- Deployment outside France by selected SNOs (Sigfox Network Operator). Eg: Arqiva in the UK, Aerea in the Netherlands, Abertis Telecom in Spain, EI Towers in Italy...)
- Integration to its capital of telecomunication operators and equipment manufacturer to influence normalization of the Narrow- Band IoT.

SIGFOX

- The transmission uses public, open but regulated ISM radio band (ISM 868 MHz in Europe, 902 MHz in the US/FCC).
- Within an actual bandwidth of 48 KHz and soon of 192 KHz, centred on the 862 MHz frequency, in France and Europe, each device transmits on a bandwidth of 100 Hz. A Sigfox modem cannot transmit more than overall 30s / hour (1% of time, i.e. roughly 6 messages max/hour).
- The base frequency and authorised bandwidth are set in accordance with each countrys regulations. This frequency range is public and can be shared with others users.

SIGFOX – World Coverage



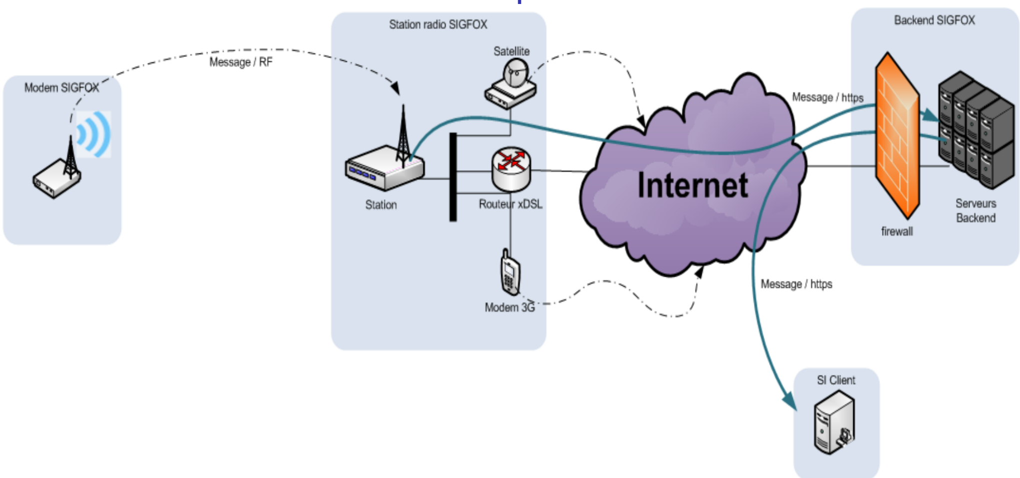
SIGFOX – Transmission over the network

- Each device and each station have a unique Sigfox ID. The message are transmitted and signed with this ID. This signature authenticate the Sigfox device.
- Transmission mode is fire and forget: the modem does not wait for any acknowledgement from the base stations receiving the message. The modem has no awereness of the base station within its reach. Its missions are:
  - Multiple times transmission of messages (3 transmissions of the same message on 3 different canals)
  - The choice of transmission frequencies.
  - The choice of reception frequency which is calculated according to the frequency used for the last transmission

SIGFOX – Bidirectional communication

- Uplink transmission (UL)
- Downlink transmission (DL)
  1. The user sends to the back-end the demand for control
  2. At the following UL connection of the Sigfox device, it is informed of the demand
  3. Transmission by a single Base station
  4. Delay in operation of transmission (asynchronous)
  5. Up to 4 messages downlink per day per device ("platinum" subscription)

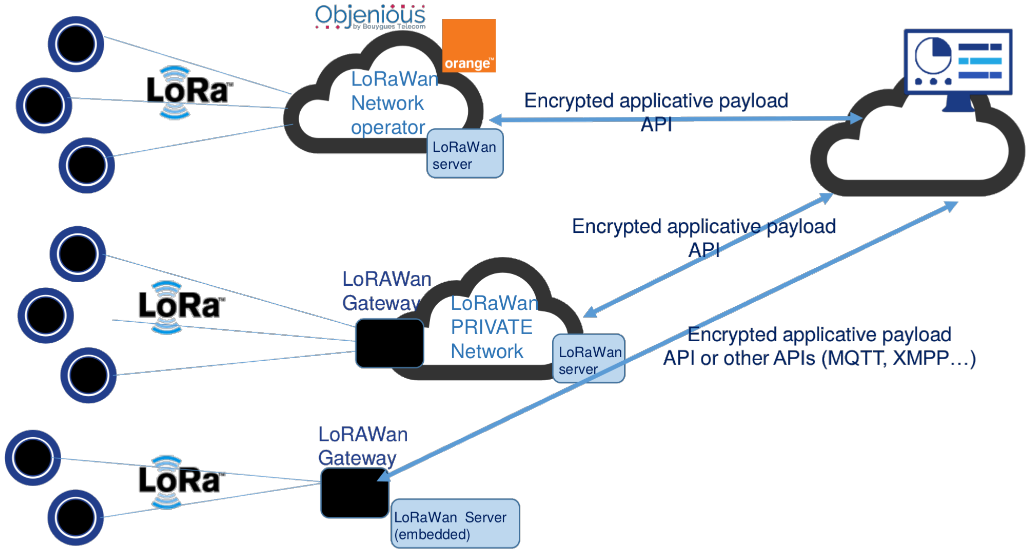
SIGFOX – Architecture Principles



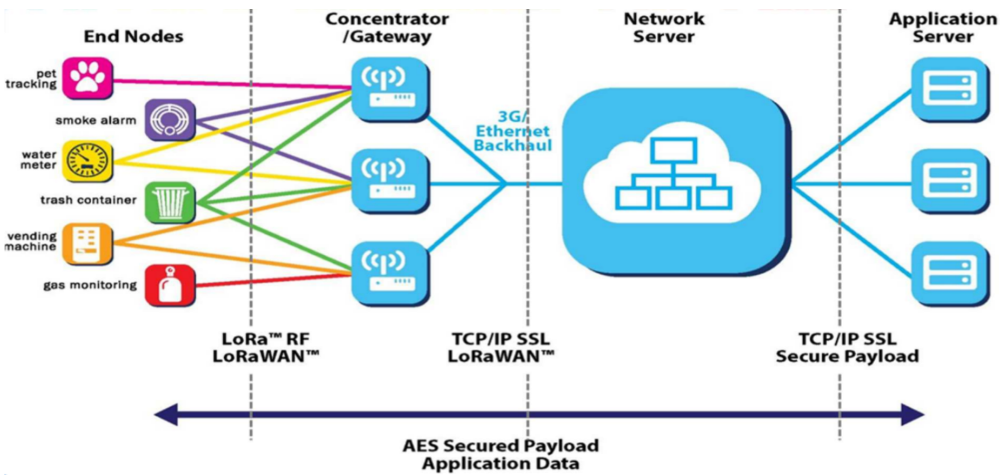
LoRa – Long Range

- Technology and protocol engineered by SEMTECH from a French technology (Cycleo)
- LoRa Alliance (founded in 2014, > 200 members in 2016)
- 2 successive versions of the protocol: LoRAMAC & LoRAWAN 1.1
- 3 classes of devices LoRAWan: A, B, C*
  - Classe A: Bi-directional end-devices
  - Classe B: Bi-directional end-devices with scheduled receive slots
  - Classe C: Bi-directional end-devices with maximal receive slots
- Chipsets exist in unidirectional (860 – 1020 MHz band) or bidirectional (High Band 860-960MHz & Low Band 169-510MHz) and for the moment are provided only by Semtech.
- End devices identification: IEEE EUI64 format

LoRa – Architecture Principles



LoRa – LoRaWAN protocol

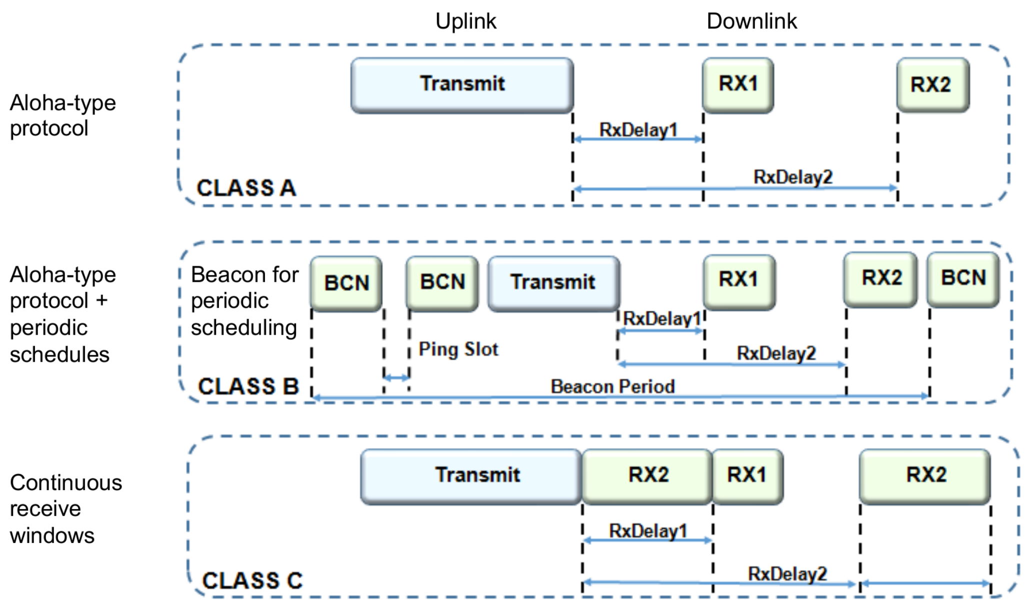


- Long range star network (same as telecom cellular networks)
- Centrally managed multi-tenant network

LoRa – LoRaWAN protocol

- End devices identification: IEEE EUI64 format
- Datarate of 0.3 to 50 Kb/s
- Encryption AES128 device server & end-node user app
- Stars of stars architecture
- 3 classes of devices (bidirectionnal communication)
  - Classe A
  - Classe B (beacon)
  - Classe C (continuous)

LoRa – LoRaWAN protocol



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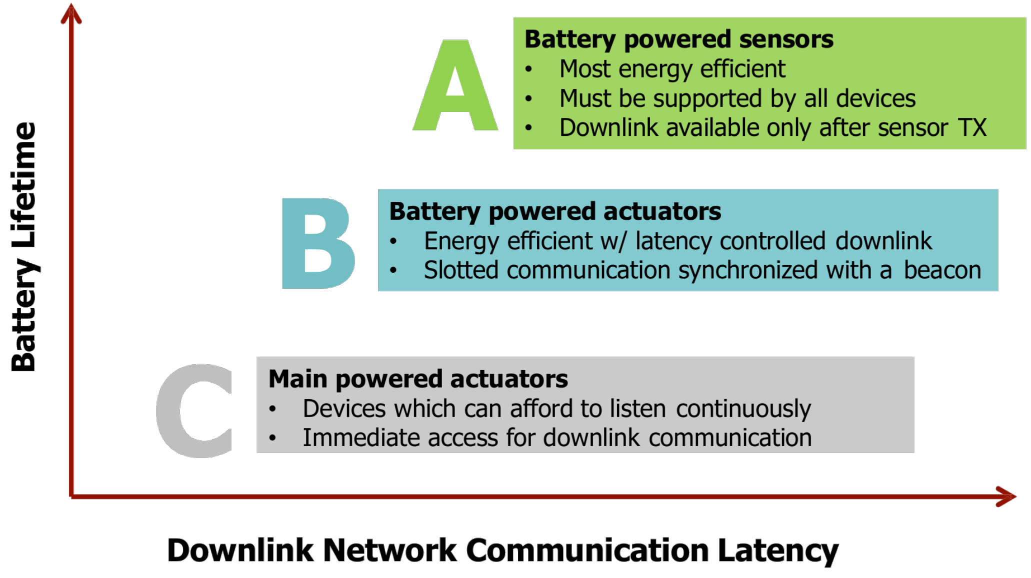
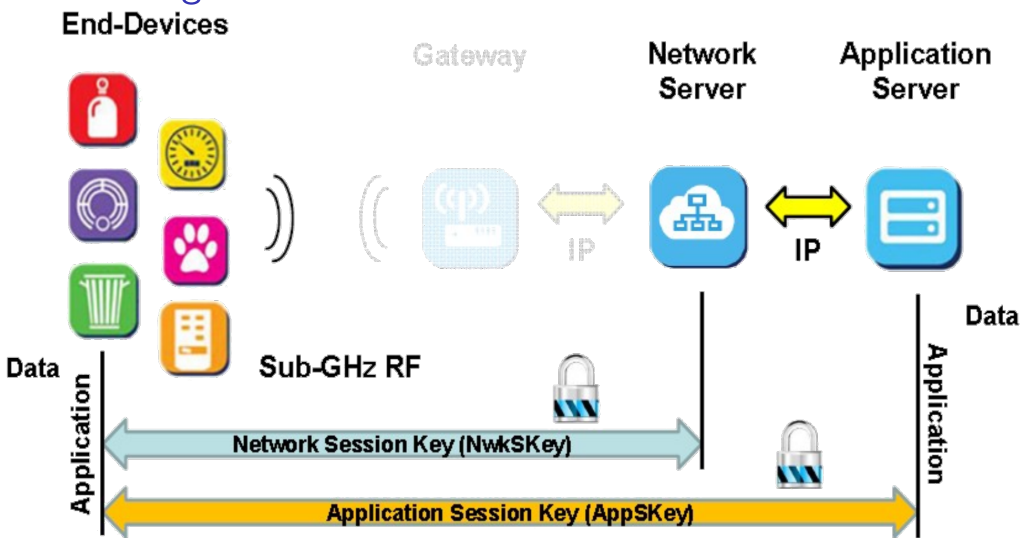


LoRa – Logical Model



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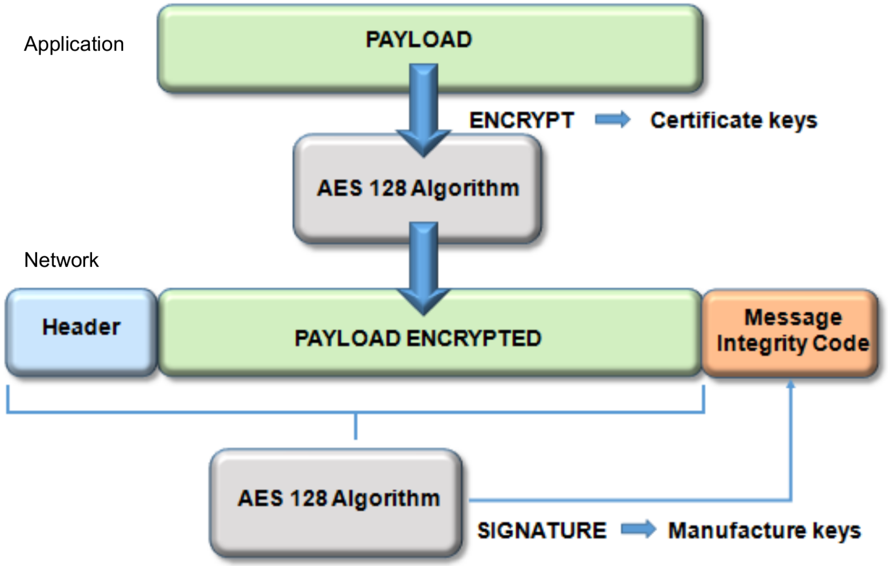

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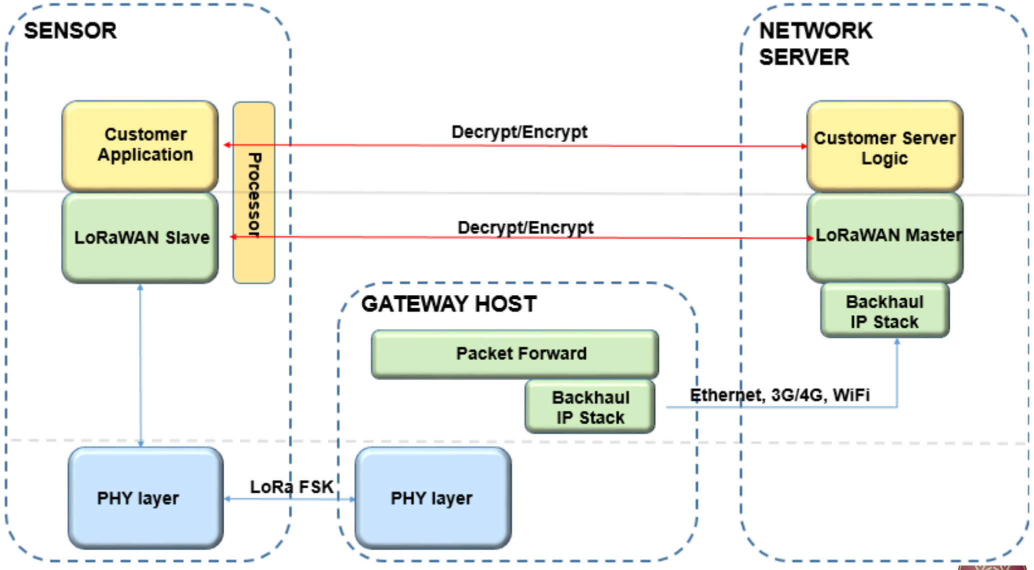

LPWAN Network Stack