LoRaWAN Telecommunication Chain

Theory

LoRa (Long Range) defines the physical layer including communication modulation utilizer for the long-range communication. LoRa[1,2] derives its spread-spectrum modulation from the Chirp Spread Spectrum (CSS) modulation, which maintains the same low power characteristics as the frequency shifting keying (FSK) while significantly increasing the communication range in comparison to the FSK. One of the key parameters is Spreading Factor (SF)[3], that determines how many chips represent a symbol. LoRa has a possibility of trade-off between data rate and sensitivity with a fixed channel bandwidth by selecting SF (a selectable radio parameter from 7 to 12). Lower SF means lower number of chirps are required per symbol, which results in higher data rate at a cost of lower sensitivity. Higher SF implies higher number of chirps per symbol, which results in lower data rate but leads to better sensitivity. In addition, LoRa uses forward error correction coding to improve resilience against interference. LoRa operates at 433MHz and 868MHz in Europe and 915MHz in North America and Australia. The communication bandwidth in the uplink is either 125 kHz or 500 kHz, while in downlink the bandwidth is 500 kHz. LoRa's data rates vary from 250 bit/s to 50 kbit/s in Europe and enables communication up to 5 kms in urban areas (cities), while up to 15 kms in rural areas (achieving line of sight). LoRa exploits ALOHA for medium access, thus, due to the bandwidth, low energy consumption and wide coverage it makes suitable protocol for transferring small sparse data, e.g., sensor data.

Long Range Wide Area Network (**LoRaWAN**) defines the communication protocol and system architecture for the network based on the LoRa physical layer and enables the long-rage, low power communication. The whole LoRaWAN protocol stack is shown in Figure 1.

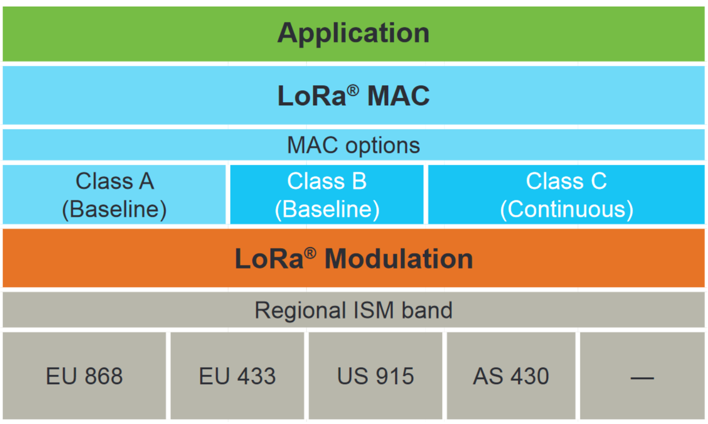

Figure 1. LoRaWAN protocol stack[2].

LoRaWAN for the long-range communication exploits the star architecture that enables preserving battery lifetime, as shown in Figure 2. In the LoRaWAN network, nodes are not associated with a

[1] https://lora-developers.semtech.com/library/tech-papers-and-guides/lora-and-lorawan/
[2] https://lora-alliance.org/wp-content/uploads/2020/11/what-is-lorawan.pdf
[3] https://josefmtd.com/2018/08/14/spreading-factor-bandwidth-coding-rate-and-bit-rate-in-lora-english/

specific gateway, instead, transmitted data are received at multiple gateways, that forward the received packet to the designed application server.

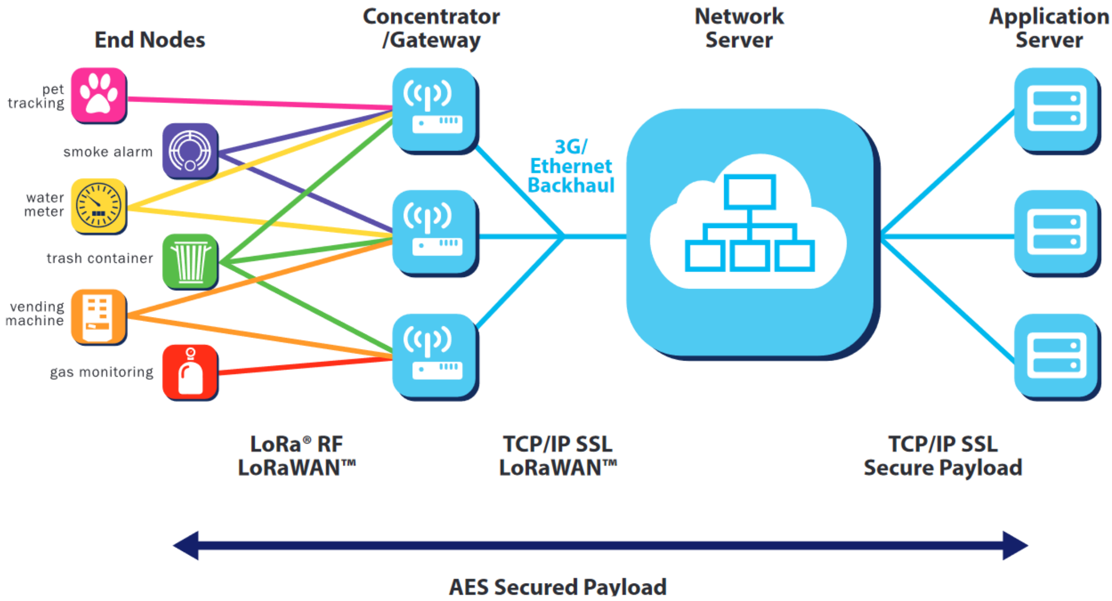

Figure 2. LoRaWAN network architecture.

The devices need to be able to connect to the network, called device activation. To achieve this, there are two ways: Over-the-Air Activation (OTAA) and Activation by Personalization (ABP). The ABP provides an easy way to connect to the network as no network interaction is necessary due to storing all necessary keys on the device. In the OTAA the network key is generated and assigned by the network, thus initial interaction is necessary. Moreover, for OTAA good signal quality is necessary in downlink in order to successfully activate the device.

LoRaWAN Device Classes

To fit the needs of serving various applications, multiple device classes are defined, as shown in Figure 3.

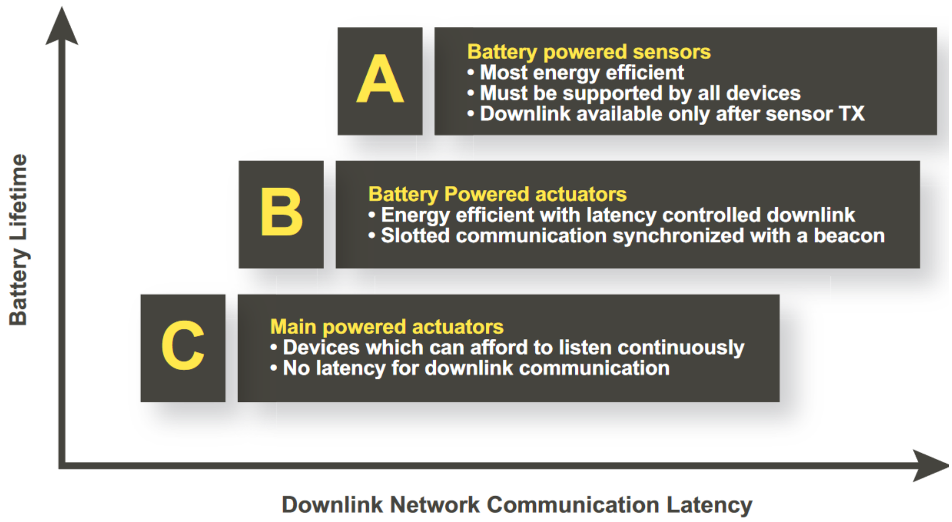

Figure 3. LoRaWAN device classes.

Class A

This is the default class which must be supported by all LoRaWAN devices. Communication is always initiated by the end-device and is **fully asynchronous**. Each uplink transmission can be sent at any time and is followed by a two short downlink windows, giving the opportunity for the **bi-directional communication**, or **network control commands** if needed. This is an **ALOHA type of protocol**. The end-device is able to enter low-power sleep mode for as long as defined by it's own application, i.e., there is no network requirement for periodic wake-ups. This makes class A the **lowest power operating mode**, while still allowing uplink communication at any time. Because downlink communication must always follow an uplink transmission with a schedule defined by the end-device application, downlink communication must be buffered at the network server until the next uplink event.

Class B

In addition to the class A initiated receive windows, class B devices are **synchronized** to the network **using periodic beacons**, and **open downlink 'ping slots'** at scheduled times. This provides the network the ability to send **downlink communications** with a **deterministic latency**, but at the expense of some **additional power consumption** in the end-device. The latency is programmable up to 128 seconds to suit different applications, and the additional power consumption is low enough to still be valid for battery powered applications.

Class C

In addition to the class A structure of uplink followed by two downlink windows, class C **further reduces latency** on the downlink by keeping the **receiver** of the end-device **open at all times** that the device is not transmitting (**half duplex**). Based on this, the **network** server can **initiate** a **downlink transmission** at **any time** on the assumption that the end-device receiver is open, so **no latency**. The **compromise** is the **power drain** of the receiver (up to ~50mW) and so class C is suitable for applications where **continuous power** is available for **devices**. For battery powered devices, temporary mode switching between classes A & C is possible and is useful for intermittent tasks such as firmware over-the-air updates.

Further information is available from the LPWAN/LPN protocols for IoT lecture.