Communication in Distributed Systems

10 LoRa(WAN)

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P4: Programming Protocol-Independent Packet Processors

Talking Points:

- What is the goal of this paper?
- What is the main motivation behind P4?
- What is the difference between P4 and OpenFlow?
- What do the authors want to show with the mTag example?

Low-Power Wide-Area Network (LPWAN) — Motivation

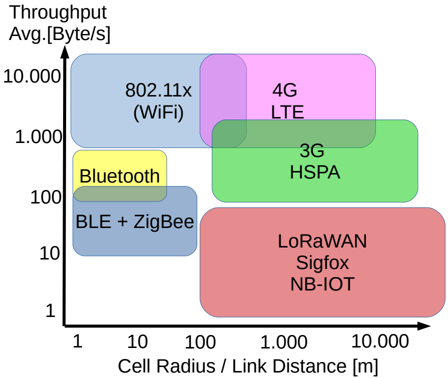
Motivation — Sensors for the IoT / Smart City

How many bytes do I need to transmit a position of a ship in a harbor?

- **GPS coordinates:**
- **Latitude** (between -90 und 90)
- **Longitude** (between -180 und 180)
- 6 Decimal places
  - Accuracy below one meter
- 2 int32_t = **8 bytes**

Transmission of **only 8 bytes** over **a long-distance** is needed.

Technologies

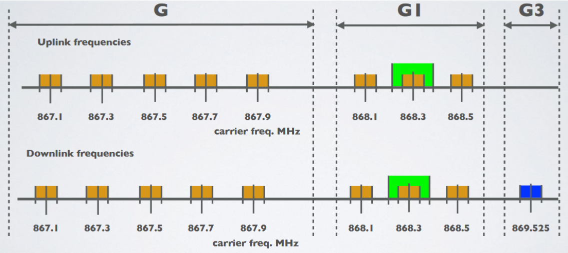


- LPWANs
  - Long range
  - Low power
  - Low cost

LoRa (Long Range)

LoRa (Long Range)

- License-free ISM frequency bands but regulated **duty cycle.** [5]:
  - g (863.0 - 868.0 MHz): 1%
  - g1 (868.0 - 868.6 MHz): 1%
  - g2 (868.7 - 869.2 MHz): 0.1%
  - g3 (869.4 - 869.65 MHz): 10%
  - g4 (869.7 - 870.0 MHz): 1%
- No license costs for the operation of a network (vs. 3GPP).
- The manufacturer (Semtech) finances the development by selling LoRa chipsets.
- Bi-Directional Communication (Up- and Downlink).



LoRa vs. LoRaWAN

LoRa

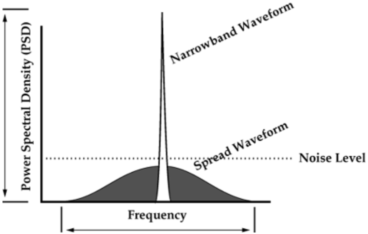
- Is a wireless communication technique
  - Physical layer: No specified encryption, routing, topology, ...
- Uses a spread spectrum modulation technique patented by the company Semtech [4].
- Builds upon the general idea of Chirp Spread Spectrum (CSS) [6].
- Goal: become THE LPWAN standard

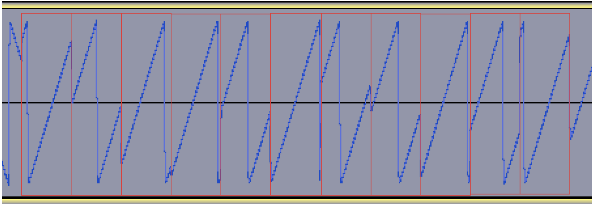
LoRaWAN

- Is an open specification developed and maintained by the LoRa Alliance for the upper layers [2].
- Defines protocols to manage and route the communication between sensors and applications.
- Typical components in the hierarchy of these networks are sensors, gateways, network server and application server.

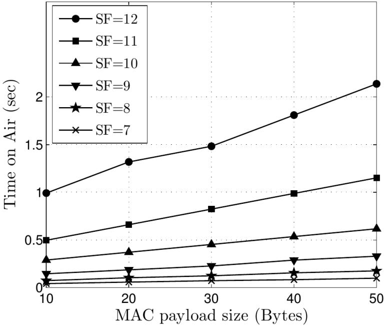
LoRa - Chirp Spread Spectrum

- A chirp is a signal whose frequency increases or decreases over time.
- A full up-chirp is a signal sweeping from the lowest to the highest frequency of the allocated bandwidth.
- Information can be encoded by conducting certain frequency jumps in these chirps.
- Spread Spectrum is great for low SNR's ($\frac{S}{N}$)
  - $C = B * log_2(1 + \frac{S}{N})$
  - Bandwith: 125 kHz, 250 kHz, 500 kHz
  - Spreading Factor (SF): 7... 12 bits per symbol (symbol=chirp)
  - Useful bit rate: $R_b = SF * \frac{BW}{2^{SF}} * CR$ [3]
  - Receiver sensitivity: $RXLevel_{min} = -174 + 10 * log_{10}(BW) + NF + SNR$





LoRa - Limitations



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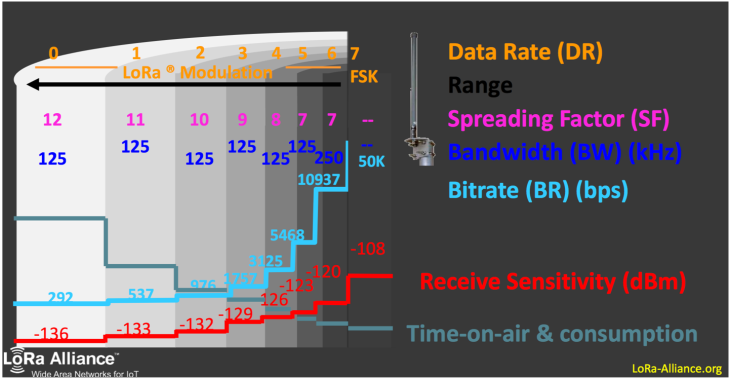
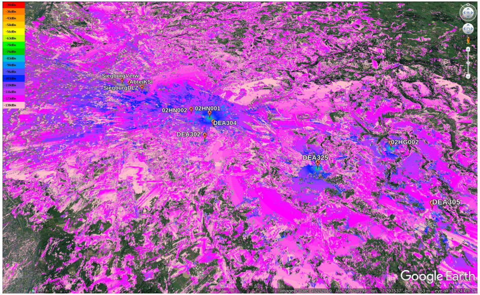


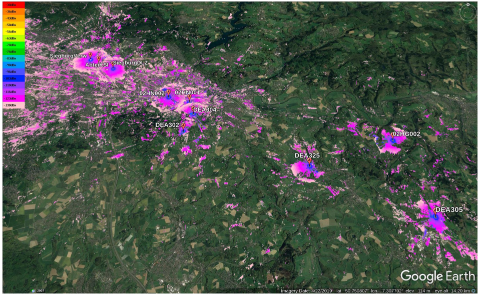
LoRaWAN 101 (LoRa Alliance)

- Airtime in magnitude of **seconds** and Bitrate in the magnitude of **kbps**.
- Duty cycle limitations: Especially for the Gateways.
- Spreading Factor: Trade throughput/latency vs. range.
- Bandwith: Trade throughput vs. range.

LoRa link budget example

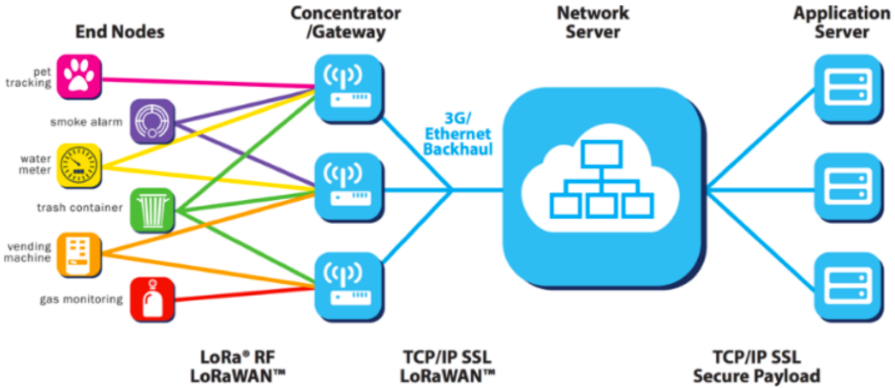
Spreading Factor	12	9	7
Transmitter:			
P_{TX} [dBm]	12	12	12
$L_{C,TX}$ [dB]	1	1	1
G_{TX} [dBi]	2	2	2
EIRP [dBm]	*14*	*14*	*14*
Receiver:			
G_{RX} [dBi]	1	1	1
$L_{C.RX}$ [dB]	1	1	1
$RXLevel_{min}$[dBm] (125 kHz)	-137	-131	-122
Path 15 km:			
FSPL [dB]	115	115	115
Link Budget:			
$RXLevel_{pred}$[dBm]	*-101*	*-101*	*-101*
Link Budget	***36***	***30***	***21***





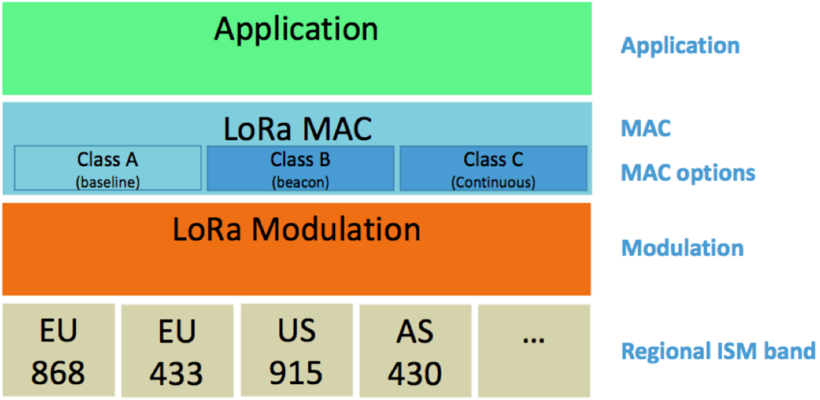
LoRaWAN

LoRaWAN - Network overview



- **A sensor (End Nodes)** gathers data which is transmitted to one or multiple gateways via LoRa.
- **Gateways** simply decode and forward the data to a network server using an arbitrary backhaul technology.
- **Network server**: security checks, dynamic adoption of the SF or handling of redundant packages.
- Afterwards encapsulates the messages and forward it to the final destination called **application sever**.
- A topology can be described as several interconnected stars with multiple gateways as center of these stars.

LoRaWAN - Network layers



LoRaWAN - Network Classes

Class A

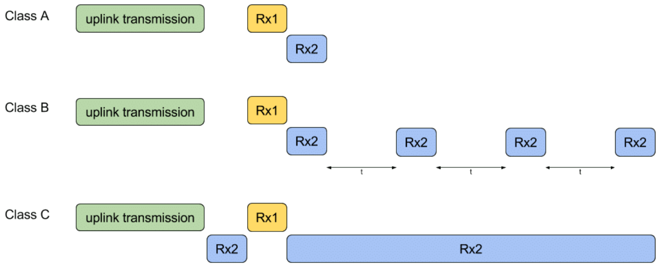
- Initiated only by the end devices
- Send and listen for a response during two short times
- High Latency in the downlink
- Battery powered Sensors

Class B

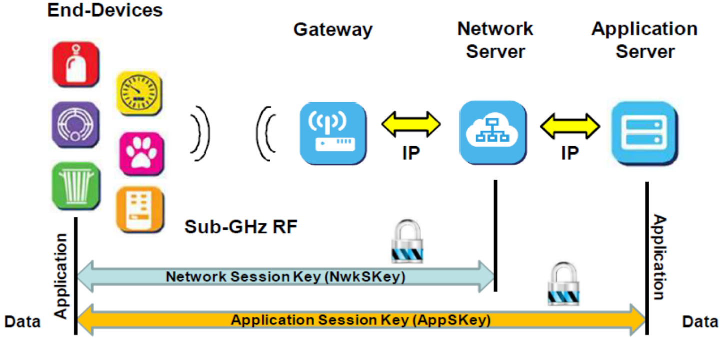
- Similar to Class A but with multiple RX times
- Time synchronization needed (i.e RTC or GPS)
- Low latency
- Multicast possible

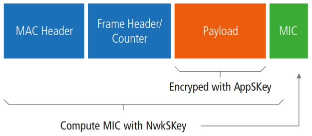
Class C

- Continuous RX time
- No additional downlink latency
- High energy consumption — end device never sleeps
- Low latency
- Multicast possible



LoRaWAN - Security





- Two different layers of security.
  1. Between sensors and the network sever to ensure the authenticity/integrity (MIC)
  2. End-to-end encryption between the sensor and the user application.
- The exchange of the required key material for both layers is one of the main challenges.

LoRaWAN - Activation Methods

Every End-Device needs to join a network. There are two different possibilities:

Activation by Personalization (ABP)

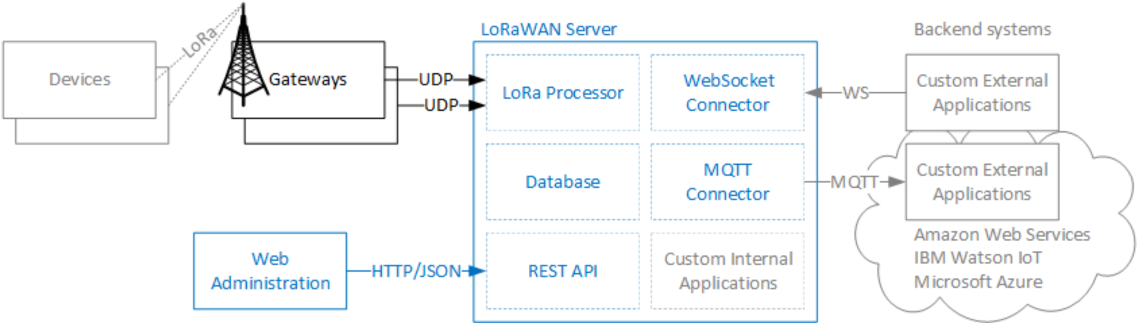
- The network session key, application session key and device address are build in when the device is manufactured.
- Devices can not change the network.
- Key material can not be updated.
- No downlink required.

Over-The-Air-Activation (OTAA)

- A DevEuI, an APPEuI and an AppKey are build in when the device is manufactured.
- When the device is turned on it will start a join procedure where it negotiates a new set of keys based on the existing AppKey.
- More complex and consumes airtime.
- Dynamic allocation of addresses and key material

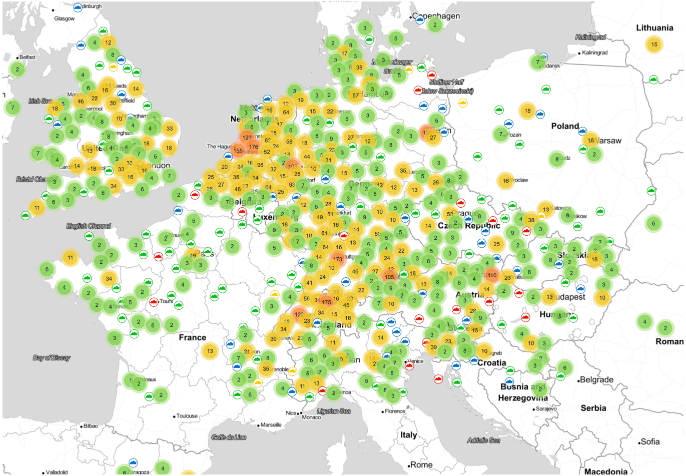
LoRaWAN Server - example architecture

- There are multiple Backendsystems (Network Server) available
- A community driven project is called **The Things Networks**



https://github.com/gotthardp/lorawan-server

The Things Network Map

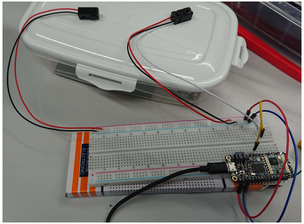


- TTN is a **community based** system in which everyone can participate ("Freifunk for IoT").
- The operators of the gateways charge no costs for receiving the data.
- Only the duty cycle is limited to 30 seconds per day per device and only a maximum number of 10 downlinks per day can be sent to each device.

Example LoRa projects in our research group

Flood protection:

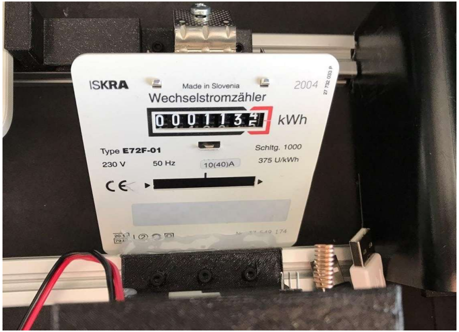
Mailbox:

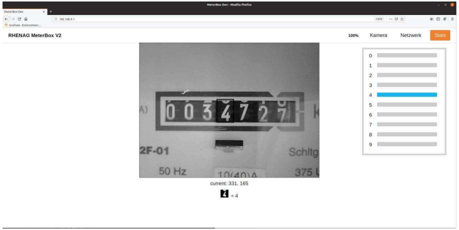


Bicycle lock:

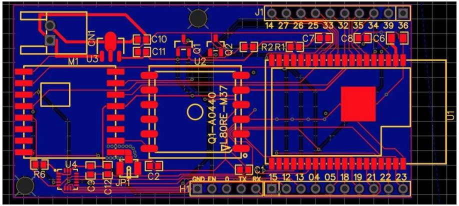
Example LoRa projects in our research group

Meterbox:





GPS + Accelerometer:



Thank you for your attention.
Are there any questions left?

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