LoRa
Overview

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Partner for a smarter future

CERN 7/11-17,
Jorgen Mortensen

ABOUT ORBIWISE

- **Headquartered in Geneva, Switzerland.**
  - Offices in India, Macedonia, USA – soon Asia.
- **Extensive experience in wireless communication, especially cellular.**
- **Industry leading LoRaWAN™ Network Server Software - OrbiWAN™.**
- **Customers - any company wanting to deploy a LPWA network, e.g.**
  - ICondor/Yeap!: Argentinian Nationwide LoRa™ NW.
  - Eleven-X: Canadian Nationwide LoRa™ NW.
  - Tata Communications: Indian Nationwide LoRa™ NW.
  - Pervasive Nation: Irish Nationwide LoRa™ NW.

  ..
  - Private networks / Enterprise segment

LoRa Alliance
Contributor Member

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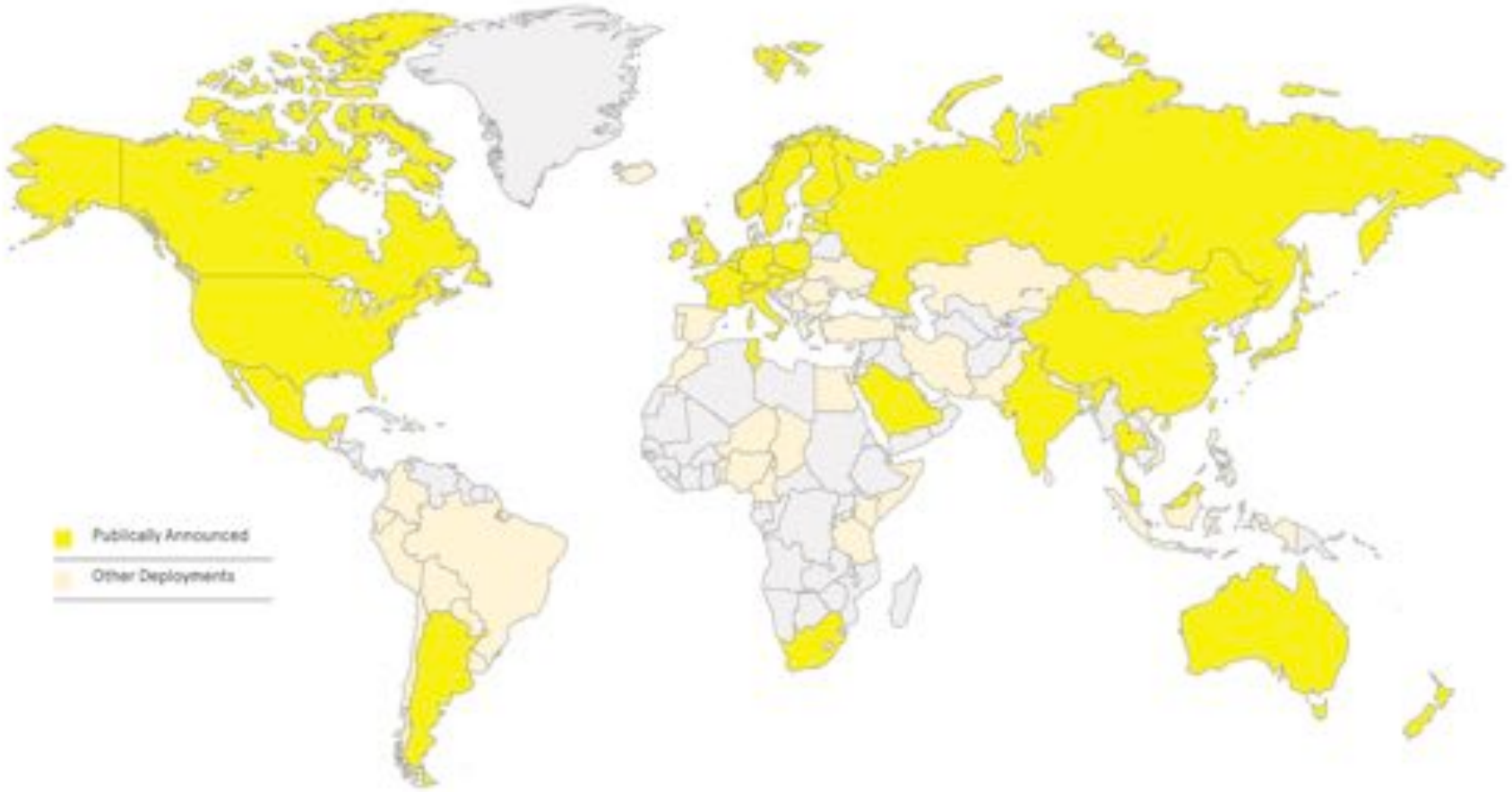
LoRa™

Overview

- **LoRa™ : Physical Layer for LOng RAnge communication, defined by Semtech.**
- **LoRaWAN™ : MAC Protocol Layer on top of LoRa™, defined by the LoRa-Alliance, for for Low Power Wide Area Networks (LPWAN).**
- **LoRa-Alliance: Eco-system around the LoRa™ Technology**
  - 500+ companies including: Applications & devices makers, Network operators, GW manufacturers, Core network SW providers, etc
- **An open, non-profit association of members (http://lora-alliance.org/)**
- **Defines the LoRaWAN specifications**
- **Defines Device certification program**
- **Organizes events and promotion of the eco-system**

LoRaWAN™ Network Coverage

- 57 Announced Public Network Operators
- 49 Alliance Member Operators
- Over 100 Countries
- 350+ on-going trials & city deployments
- 500+ members in the Alliance



November 2017

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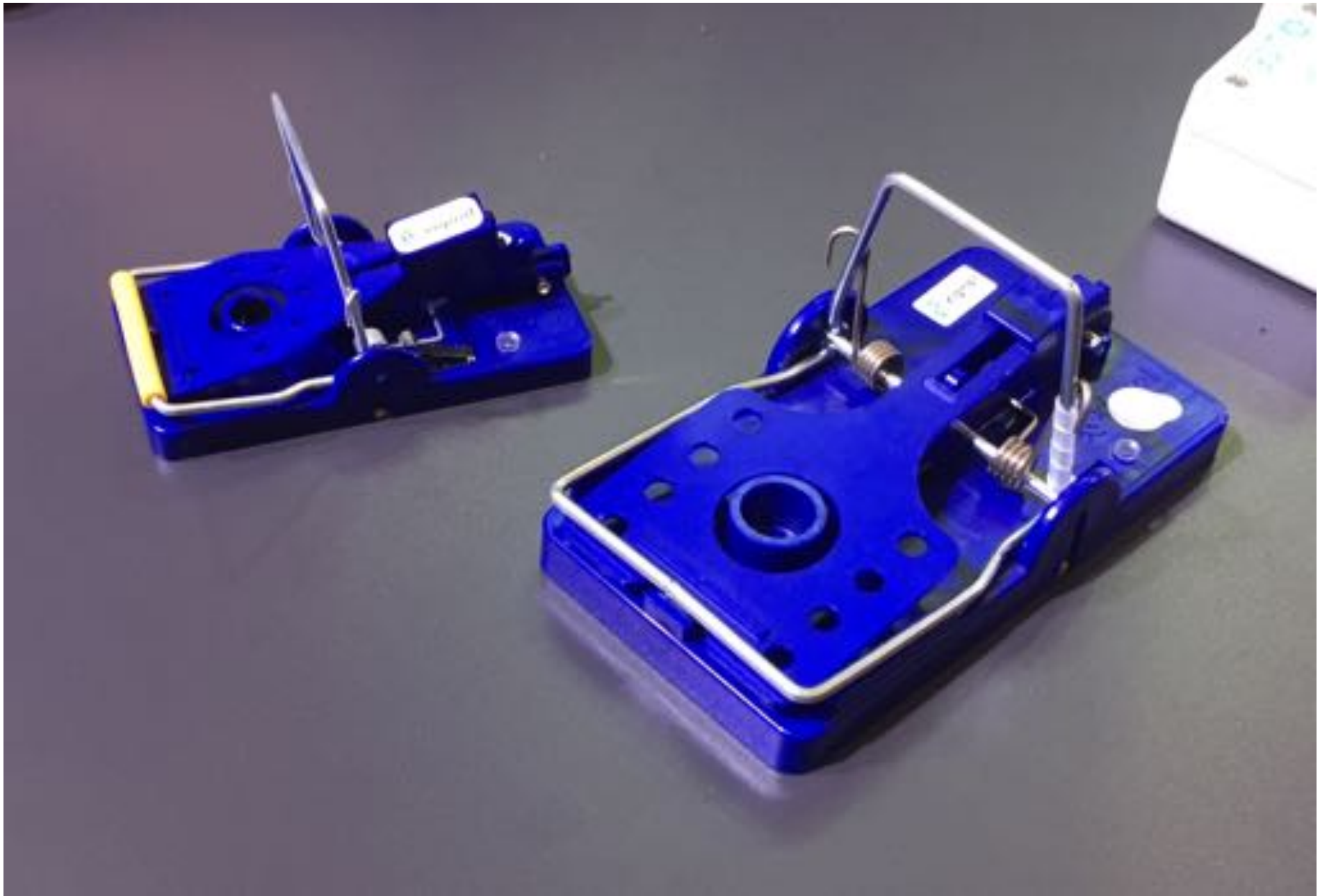
IoT use-cases, How to generate "data"



LoRaWAN™ Network Features

Long Range

- Greater than cellular
- Deep indoor coverage

Max Lifetime

- Low-power
- >10yr on AA cell
- >10x vs cellular M2M

Low Cost

- Minimal infrastructure
- Low-cost end-devices
- ISM RF band

Advanced Radio

- Adaptive Radio
- Multiple Device Classes
- Roaming
- Geo-location
- Multicast

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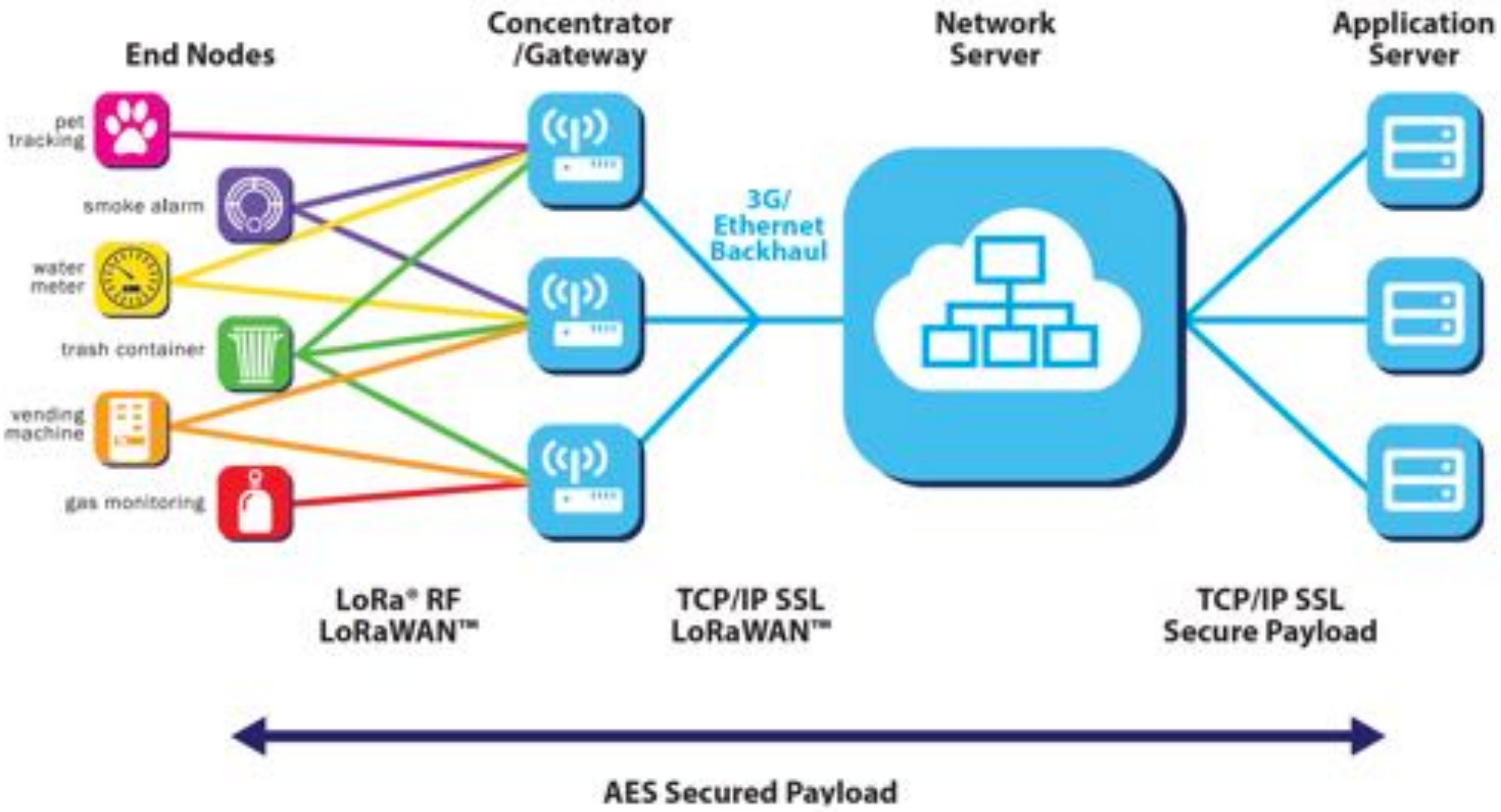
LoRaWAN network



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LoRa Air Interface

Modulation: Chirp Spread Spectrum (& FSK).

- Constant envelope
- Relative "Wide-band", less sensitive to multipath fading
- Less sensitive to frequency error and Doppler effect

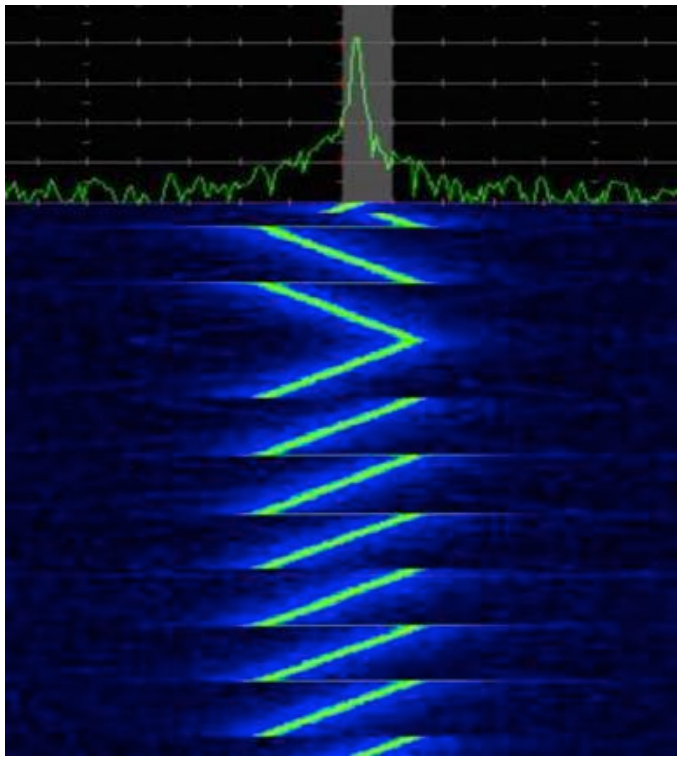
Spreading factors: SF7 - SF12

- 2^{SF} chirps/symbol
- Chirp rate = BW
- demodulation possible down to -20dB below noise floor (< -143dBm)

Multiple Bandwidth:

- 125KHz, 250KHz and 500KHz (not used EU)

Forward error correction and CRC



(Image source: Link Labs

Long Range – and low data-rates.

Range between gateways and devices

- 3-5km in urban areas on average, depending gateway position.
- typical > 10km in rural areas.

Example of message transmission time (UL) for 20 byte payload (including header, FEC, CRC, etc)

- SF7 => Transmission time = 57mSec.
- SF12 => Transmission time = 1.3Sec.

Maximum payload size per message (EU):

- 59 bytes – 250 bytes depending on Spreading Factor used.

LoRa

Device Adaptive Data-Rate to optimize battery life & radio resource

- **SF , TX power, TX repetition**
- **Controlled by the network server**

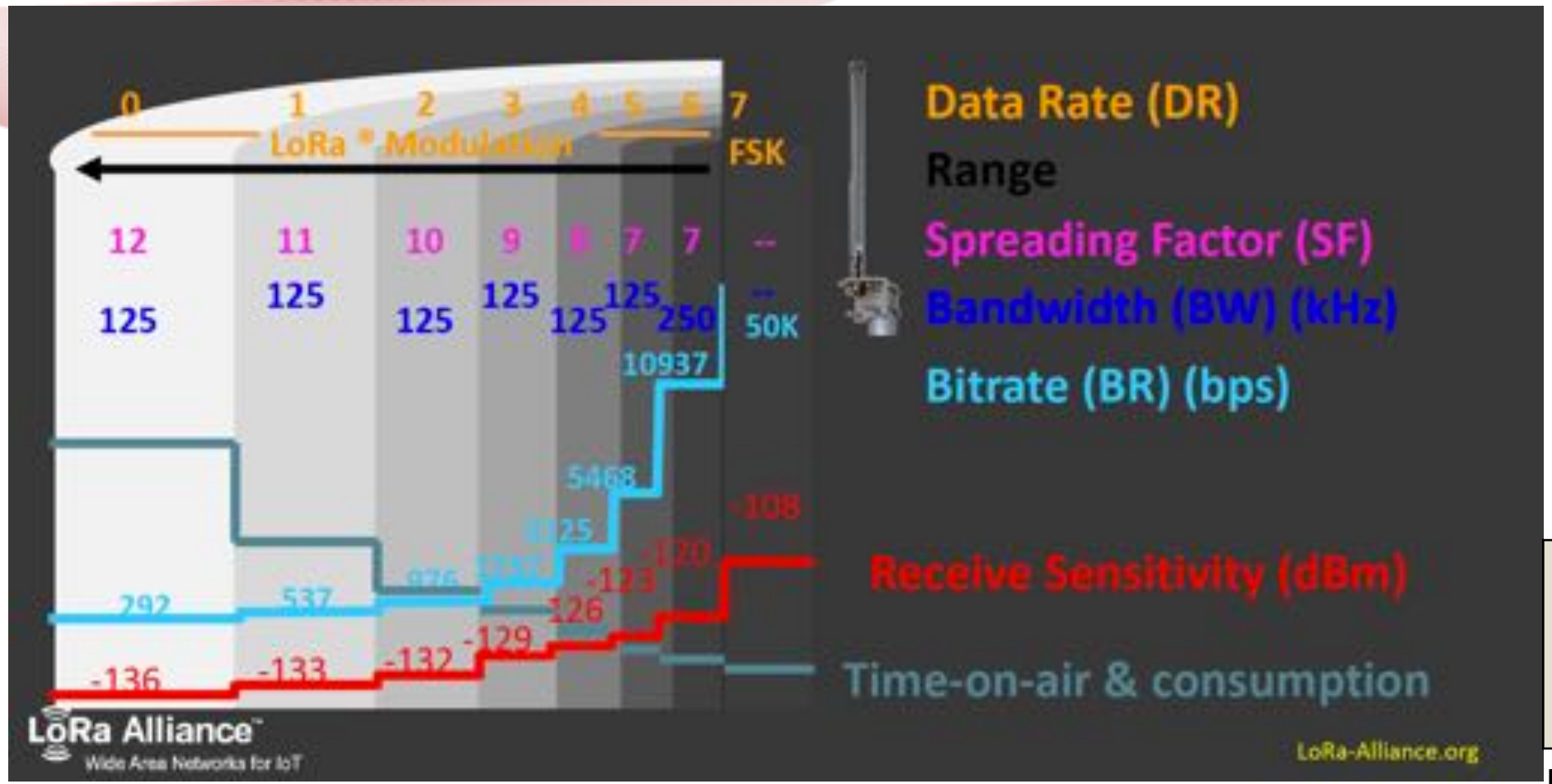
Encryption (AES)

- **End to End Payload encryption**
- **Network Protocol Communication authentication/encryption**

ISM Band (i.e. region dependent), For EU region:

- **ISM band: 863-870MHz (433-434MHz)**
- **Maximum TX power**
  - 14dBm,
  - 27dBm for 869.525MHz 27dBm (used for DL only)
- **Duty-cycle limitations 0.1% - 10% depending on channel**

Optimizing transmission with Adaptive Data-Rate



Battery usage coefficient

Tx Power [dBm]	SF 7	SF 8	SF 9	SF 10	SF 11	SF 12
2	1.0	1.8	3.2	5.6	11.2	22.4
5	1.0	1.8	3.2	5.6	11.2	22.4
8	1.1	2.0	3.5	6.1	12.3	24.6
11	1.3	2.4	4.2	7.3	14.7	29.4
14	1.6	3.0	5.3	9.2	18.4	36.9
17	2.2	4.0	7.2	12.6	25.1	50.2

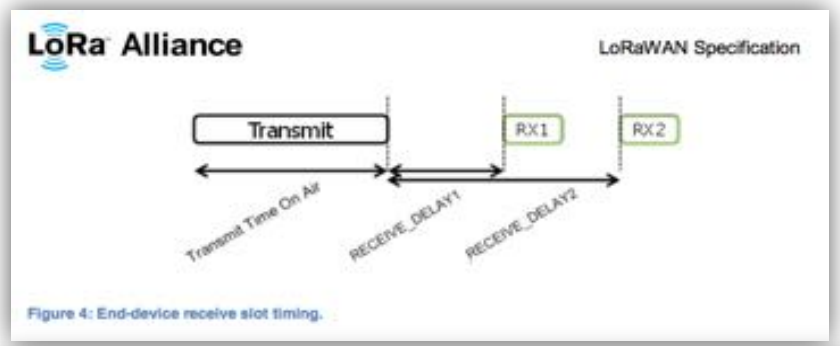
From IMST datasheet for current consumption & LoRa™ calculator for time on air

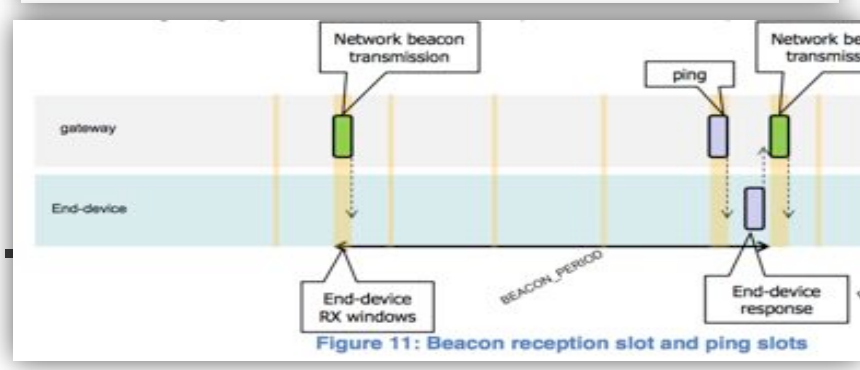
Device classes – for low power

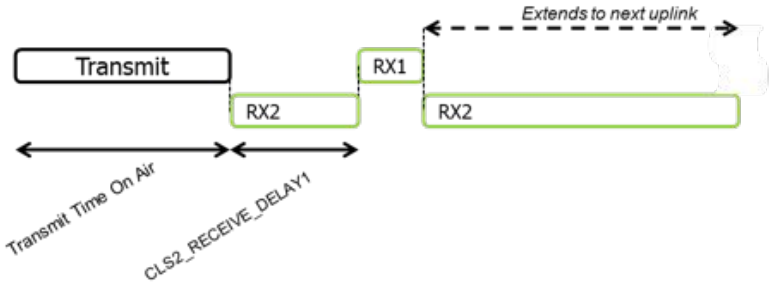
End Device classes:

- A : Device initiated communication. Downlink (to device) only possible after Uplink. Lowest power devices. (Aloha)
- B: Device time-synchronized to a common beacon. Additional downlink possible in scheduled `ping-slots`.
- C: Downlink always possible. No downlink latency.

Multicast is possble for class B & C devices







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LoRa-Based Geo-location

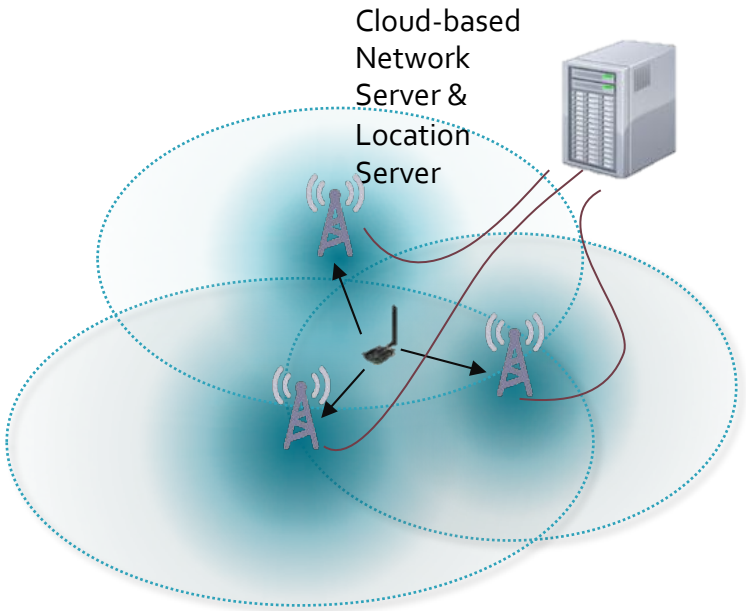
Zero-Cost Geolocation

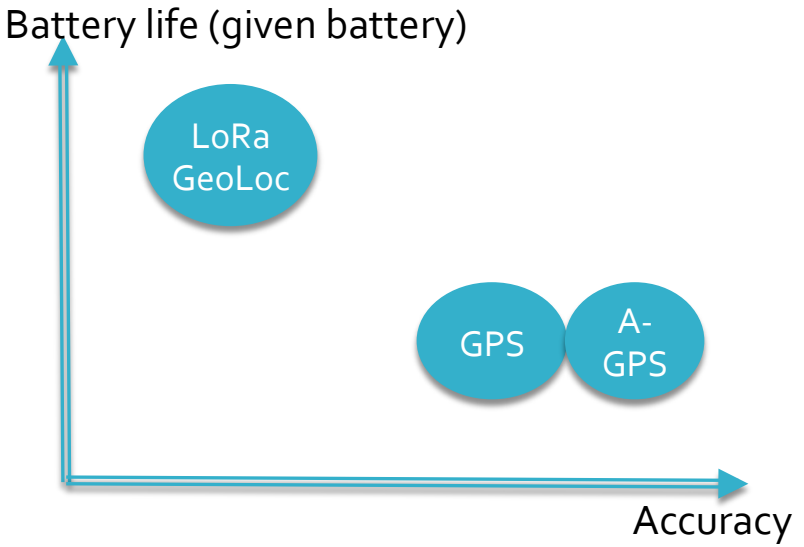
Any LoRa device can be geolocated. No need for additional HW or SW in device.

Lowest power consumption. Devices can survive on small battery for years.

Location server using TDOA, RSSI and other data to locate devices via advanced algorithms.

Spatial diversity and ” high” GW position important for good results.





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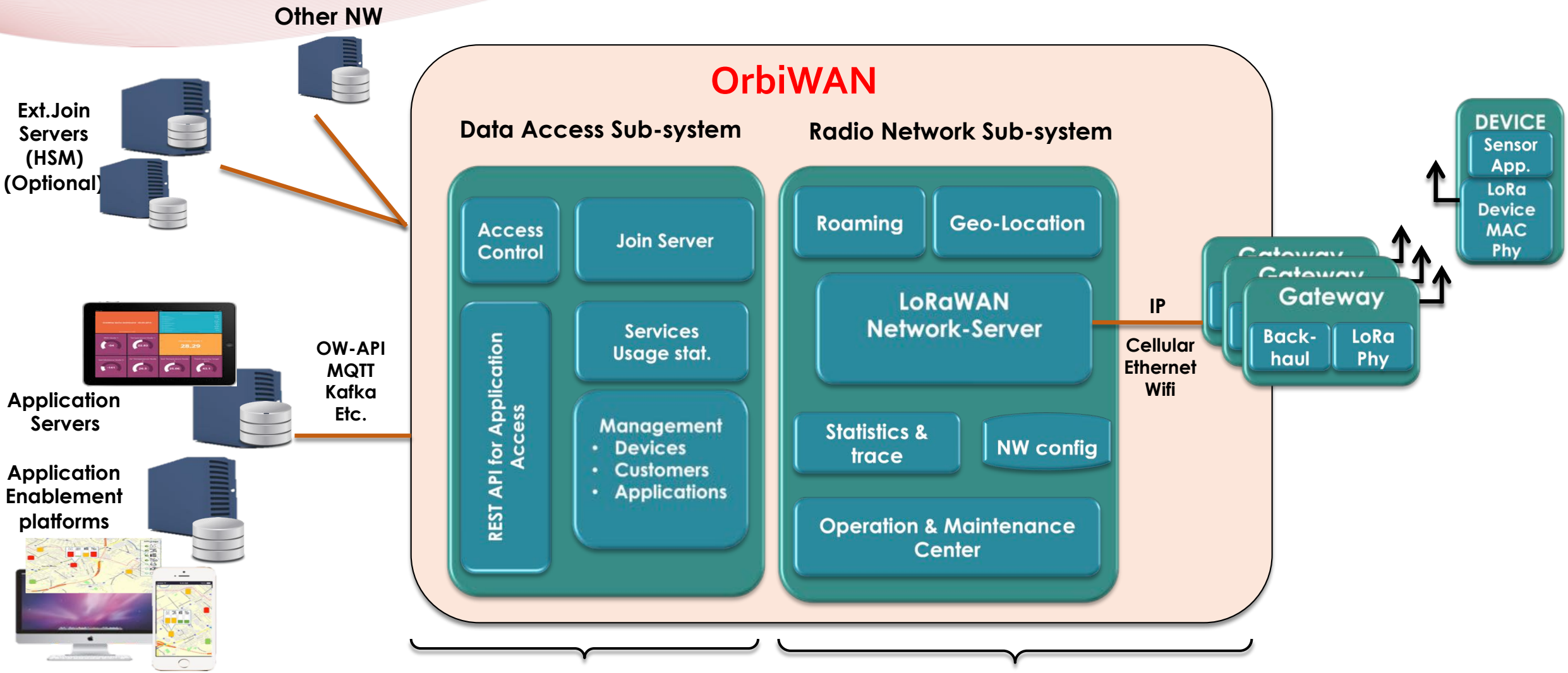
LoRa Network Server



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ORBIWAN LORA SERVER FEATURES

Support for all LoRaWAN™ v1.0.2 features - LoRaWAN™ v1.1 soon!

Support for device all Classes A, B and C

Full Multi-tenancy support

Monitoring & Management of Devices, Gateways, Servers, Application/AEP Interfaces

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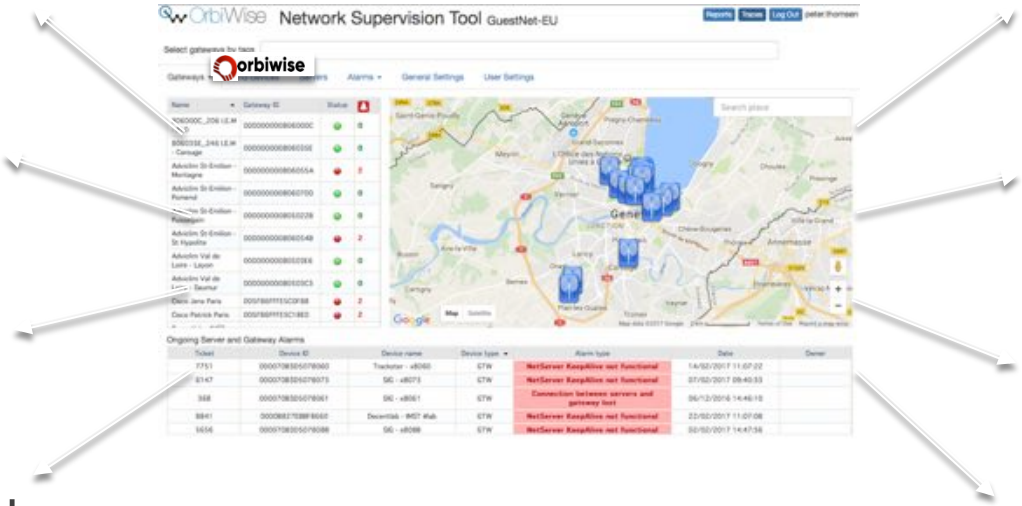

World-Class, Carrier-Grade LoRaWAN™ Network Server Solution

Additional Security and Software (JS, AEPs, Billing) Partner Solutions available.

Gateway connection via cellular (e.g. LTE/ 3G/2G) or Ethernet

Comprehensive Trace & Reporting system

LoRa™-based Localization/ Geolocation fully supported!

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LoRa is here

- A proven viable solution for LPWAN IoT solutions
- Devices, Gateways, Network servers, Applications are avaliable
- Very Active Eco-system
- Networks rolling out

Use-cases innovate !!

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FOR A SMARTER FUTURE

PHY layer definition

- **European regulation: ETSI [EN300.220]**
- **Frequency bands from 863 to 870 MHz without license but with limitation on the duty cycle (average transmit time per unit of time)**
  - 10% duty cycle / 500mW from 869,4 to 869,7MHz
  - 1% duty cycle / 25 mW from 868 to 868.6 MHz
  - 0.1% ducy cycle / 10mW from 863 to 870 MHz
- **Default frequency channels: 868.1 868.3 868.5 MHz**
- **Default Rx2 Window: 869.525MHz with SF12**
- **Other bands supported for other regions (US, Asia, …)**

Types of messages & commands

- **Uplink / downlink messages**
  - Uplink messages are sent by end-devices to the network server
  - Downlink messages are sent by the network server to the end-devices.
- **Message types : Confirmed / unconfirmed / proprietary**
  - Data messages (both downlink & uplink) can be confirmed or unconfirmed. A confirmed message has to be acknowledged by the receiver.
  - Proprietary messages type can be used to implement no-standard message formats.
- **MAC commands**
  - Network commands added to a message or sent in a separate frame, based on request/answer between end-device and network server

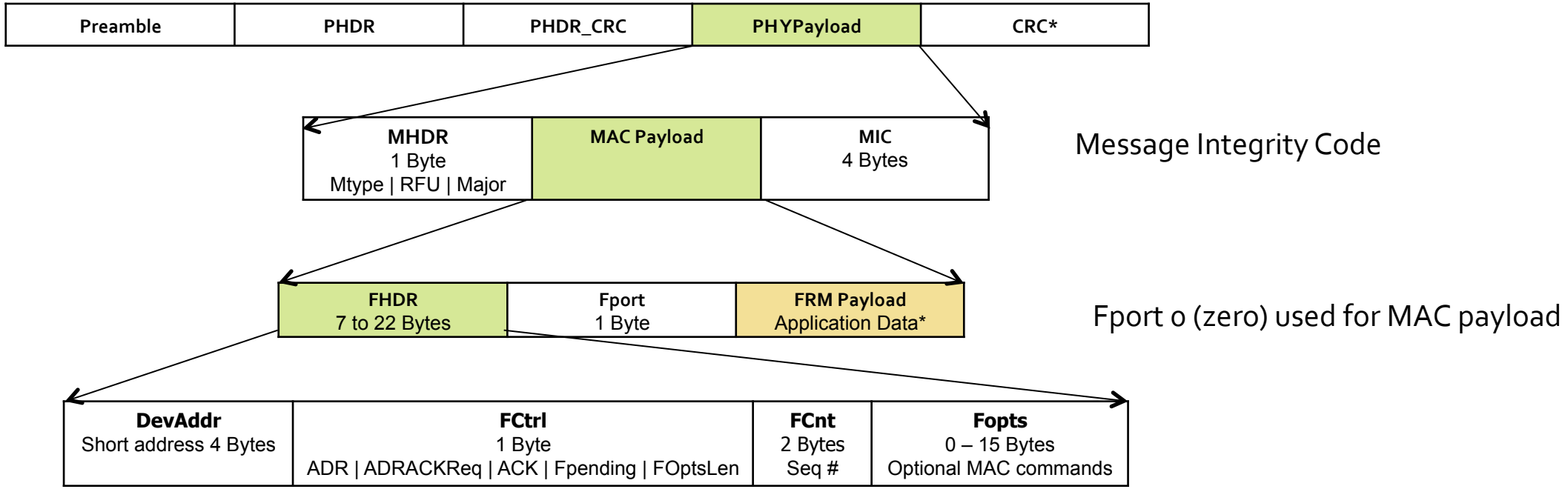
LinkCheckReq / LinkCheckAns
LinkADRReq / LinkADRAns
DutyCycleReq / DutyCycleAns
RXParamSetupReq / RXParamSetupAns
DevStatusReq / DevStatusAns

NewChannelReq / NewChannelAns
RXTimingSetupReq / RXTimingSetupAns

TxParamSetupReq /TxParamSetupAns
DlChannelReq / DlChannelAns

PingSlotInfoReq / PingSlotInfoAns
PingSlotChannelReq / PingSlotFreqAns BeaconTimingReq / BeaconTimingAns BeaconFreqReq / BeaconFreqAns

LoRaWan Message Format



Note: Max size of application payload data depends on spreading factor used and regional restrictions. If the application use payloads larger than the max size for current SF (or MAX SF), the application and the device must handle the packet segmentation and assembly.

* Only in uplink

MAC commands in Messages

- **MAC commands can be transported either in:**
  - Fops field of the Frame Header
    - This is the case if the MAC command is smaller or equal to 15 bytes
  - The frame payload and encrypted with NwkSKey
    - This is the case if the MAC command is larger than 15 bytes

Device identification & authentication

- **DevEUI – Unique End-Device Identifier**

  Unique identifier of the end-device – format: IEEE EUI64

  Kind of MAC address

- **AppKey – Application Key**

  AES-128 application key specific for the end-device used to derive the session keys : AppSKey & NwkSKey

- **AppEUI – "Application" identifier (JoinEUI in v1.1)**

  Join Server Identifier, currently not used

  Pointing to an optional external Join Server (standardized in LoRaWan 1.1)

Device identification & authentication

- **DevAddr – End-Device Address**

  Kind of local IP address

  Identification of the device on the current network, used in each frame to and from the end-device, generated by OrbiWAN during the join process.

- **NwkSKey – Network Session Key**

  Device specific key for message calculating the integrity code (MIC) and for encryption MAC payload messages. Generated from AppKey and two random numbers (renewed at every join session).

- **AppSKey – Application Session Key**

  Device specific encryption key for application payload messages. Generated from AppKey and two random numbers (renewed at every join session).

- **MIC – Message Integrity Code**

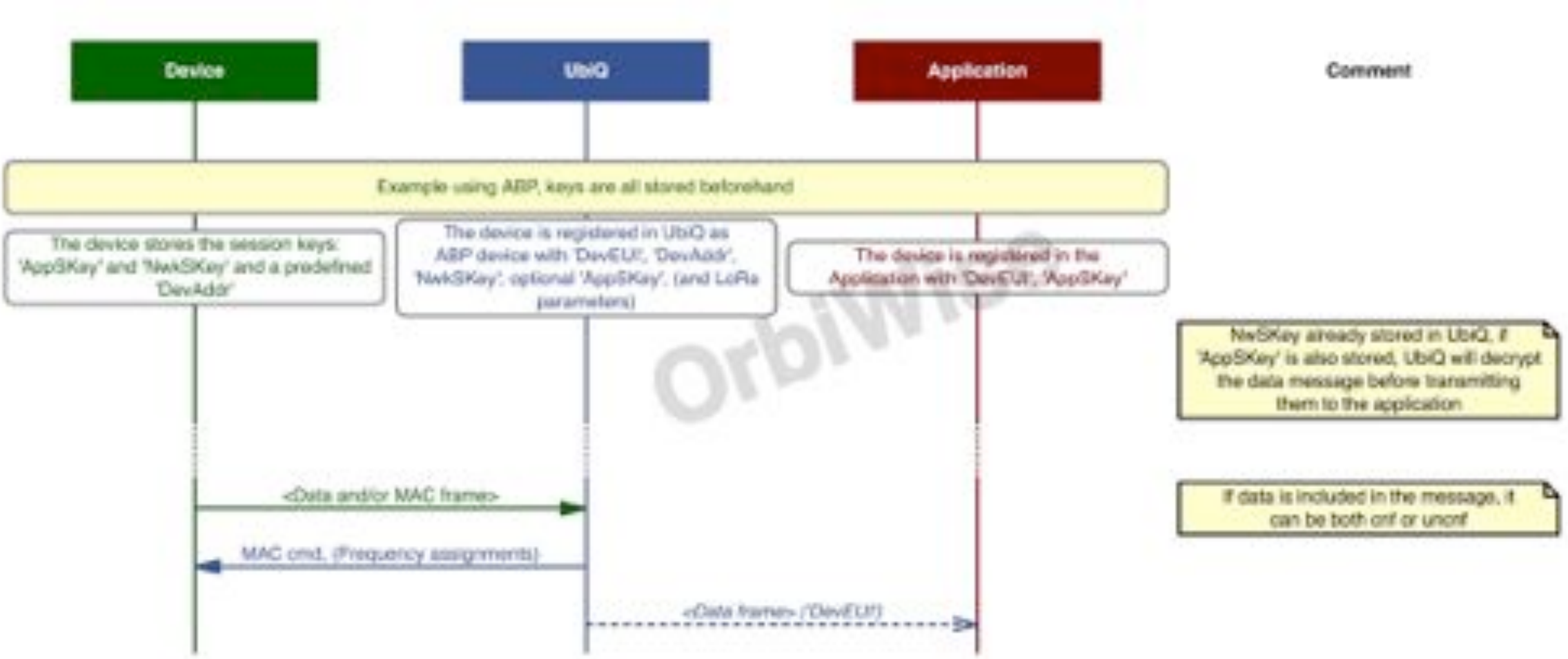
  Signature calculated over the "NW" part of the message using the NwkSKey, DevAddr, FCNT , etc

Device activation on the network

- **Over The Air Activation (OTAA)**
  - End-device follows a join procedure prior exchanging data with the network server.
  - Pros: device can attach any LoRa network, security keys can be updated from time to time (session based). Device reboot easily detected.
  - Cons: application server has to answer to join requests each time a device (re)starts, generating more downlink traffic.

- **Activation By Personalization (ABP)**
  - The end-device is already pre-registered on the network. DevAddr, NwkSKey & AppSKey are stored in the end-device and Network Server.
  - Pros : simpler from application server point of view
  - Cons : node tied to a particular network or must be registered with exactly the same keys.

Device „Join“ by ABP, class A, B & C



Join procedure, Application, OTAA