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LoRa Technologies

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LPWAN

- **L**ow **P**ower **W**ide **A**rea **N**etwork
- Multi-year battery lifetime
- Send small amounts of data over long distances by sensor nodes
- A few times per hour

Technology comparison

	Local Area Network Short Range Communication	**Low Power Wide Area** (LPWAN) Internet of Things	**Cellular Network** Traditional M2M
	40%	**45%**	**15%**
☺	Well established standards In building	Low power consumption Low cost Positioning	Existing coverage High data rate
☹	Battery Live Provisioning Network cost & dependencies	High data rate Emerging standards	Autonomy Total cost of ownership
	Bluetooth 4.0 · ZigBee · Wi Fi	LoRa	GSM · 3G+ / H+ · 4G

LoRa®

LoRa Alliance
Wide Area Networks for IoT

https://www.lora-alliance.org/what-is-lora

- LoRa = **Lo**ng **Ra**nge
- Physical layer (wireless modulation) for long range communication
- spread spectrum- based modulation
  - Most legacy wireless systems use FSK modulation for low power
  - LoRa uses Chirp spread spectrum modulation
    - Maintain same low power as FSK
    - But significantly increases the communication range

LoRa

- signals are practically orthogonal to each other for different spreading factors
- As the spreading factor changes, the effective data rate also changes
- A single gateway
  - can cover entire cities or hundreds of square kilometers
  - can receive multiple different data rates on the same channel at the same time

LoRa

- LoRa® and LoRaWAN™ have a **Link Budget** (in dB) greater than any other standardized communication technology
  - Link budget = the primary factor in determining the range in a given environment

Link Budget

Link Budget Calculation

Training materials for wireless trainers

The Abdus Salam International Centre for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization

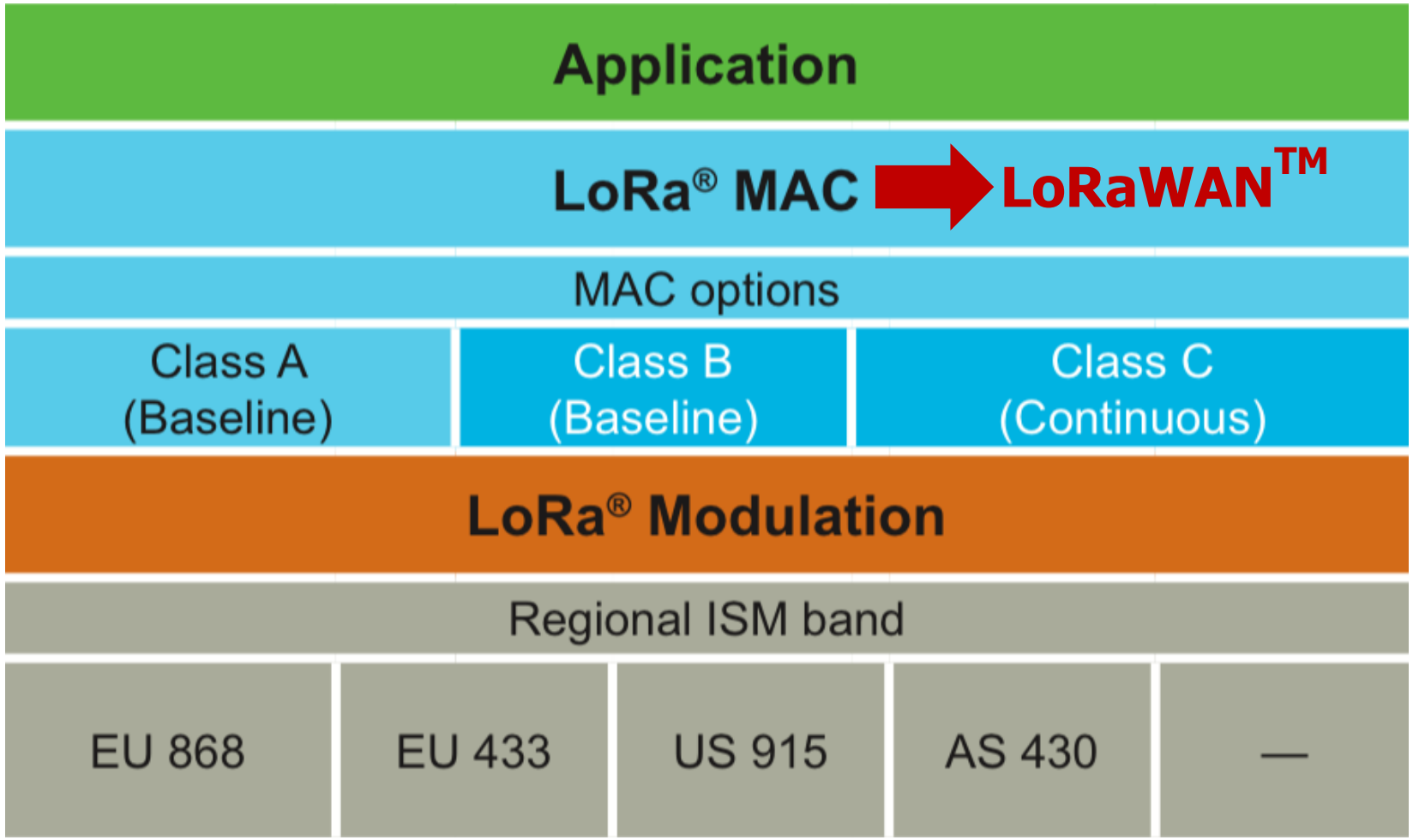
Chirp spread spectrum

- Used in military and space communication for decades
  - long communication distances
  - robustness to interference
- LoRa® is low cost implementation for commercial usage

LoRaWAN™

- LoRa®
  - Define **physical layer** for long-range communication link
- LoRaWAN™
  - Define communication **protocol and system architecture** for the network
    - battery lifetime
    - network capacity
    - quality of service
    - security

LoRaWAN™


Application
LoRa® MAC
LoRaWAN™
MAC options
Class A (Baseline)
Class B (Baseline)
Class C (Continuous)
LoRa® Modulation
Regional ISM band
EU 868
EU 433
US 915
AS 430
—

Battery lifetime

- Aloha-like method
  - Asynchronous
  - Send as data (event-driven or scheduled)
  - No need for synchronization as Mesh or Cellular (consumes more energy)
  - 3 - 5 times more energy save

Network Capacity

- For a long range star network
  - High volume messages from nodes → Requires high capacity GW
- @Gateway:
  - Implement adaptive data rate
  - Use a multichannel multi-modem transceiver → simultaneous messages on multiple channels can be received
- Critical factors
  - the number of concurrent channels
  - data rate (time on air)
  - payload length
  - how often nodes transmit

Adaptive data rate

- Once close to a gateway
  - use high data rate
    (make more available spectrum)
- By shifting the data rate higher
  - time on air is shortened
  - opening up more potential space for other nodes to transmit
- also optimizes the battery lifetime

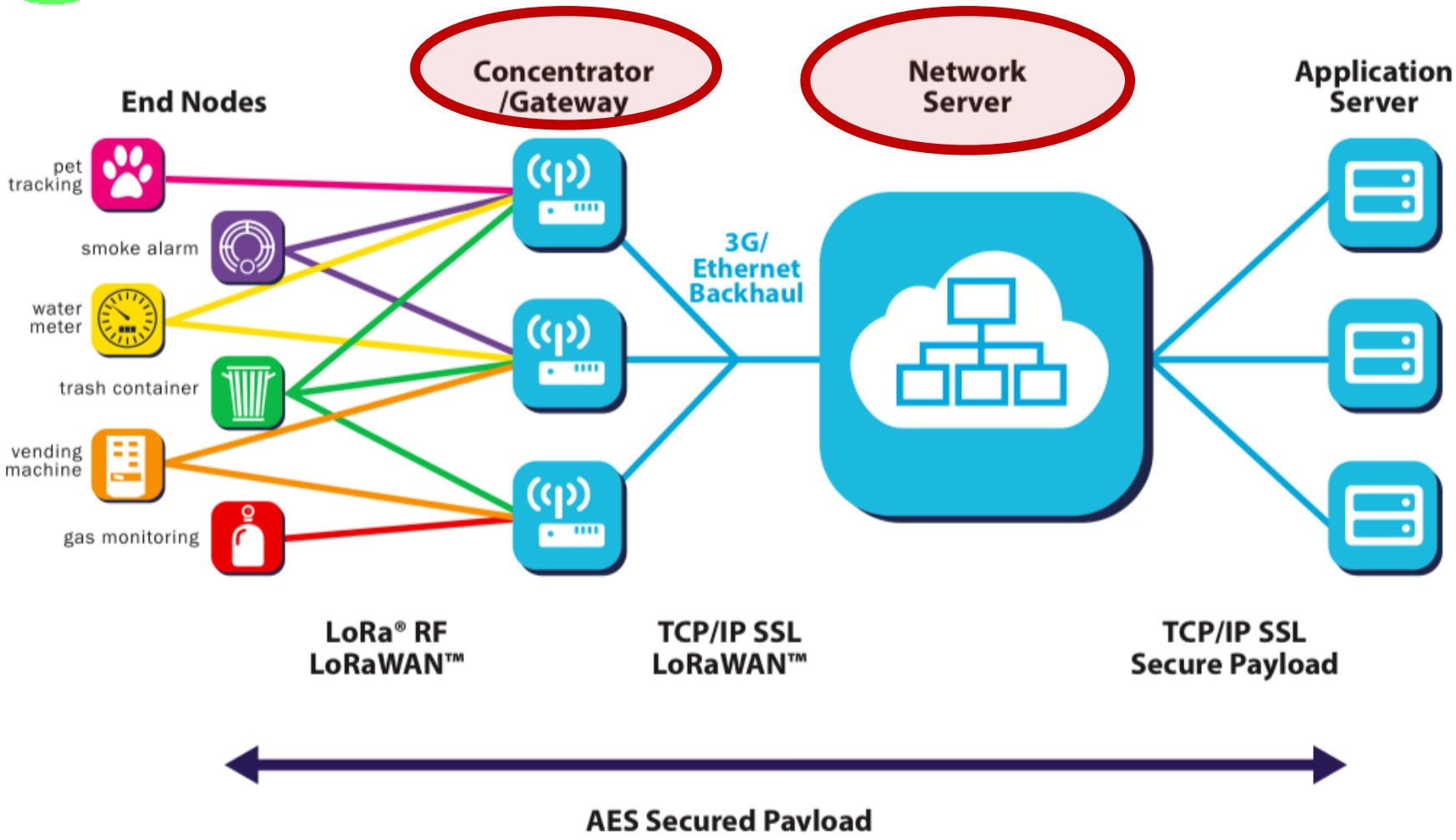
Adaptive data rate

- symmetrical up link and down link is required with sufficient downlink capacity ??
- More capacity
  - install more GW
  - shifting up the data rates
  - reducing the amount of overhearing to other gateways
- Other LPWAN cannot due to
  - limit downlink capacity or make the downlink range asymmetrical to the uplink range ??

Long Range Wireless Network architecture

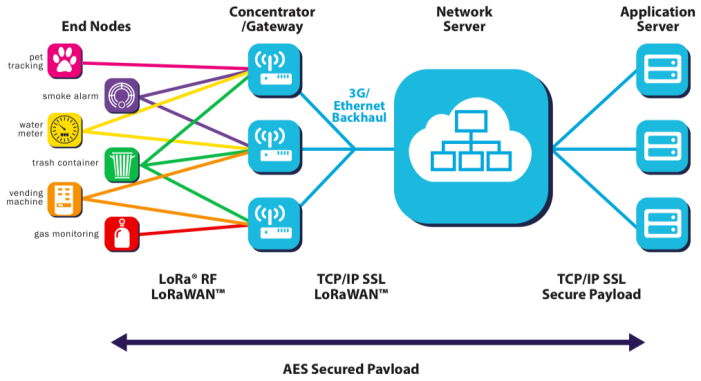
- Usually achieved by
  - **mesh network** architecture
  - individual end-nodes forward info. of other nodes to increase range and cell size
  - Increase Complexity
  - Reduces network capacity and battery lifetime
- If possible, **star architecture** makes more sense

LoRaWAN™ architecture



LoRaWAN™ architecture

- Nodes may associate with multiple gateways
- Each gateway will forward packets to the cloud-based **network server** via some backhaul (either cellular, Ethernet, satellite, or Wi-Fi)
- Network server
  - intelligence and complexity part
  - filter redundant received packets
  - perform security checks
  - schedule ack through the optimal gateway
  - perform adaptive data rate
  - no handover needed from gateway-to-gateway
    - critical feature to enable asset tracking applications (IoT)

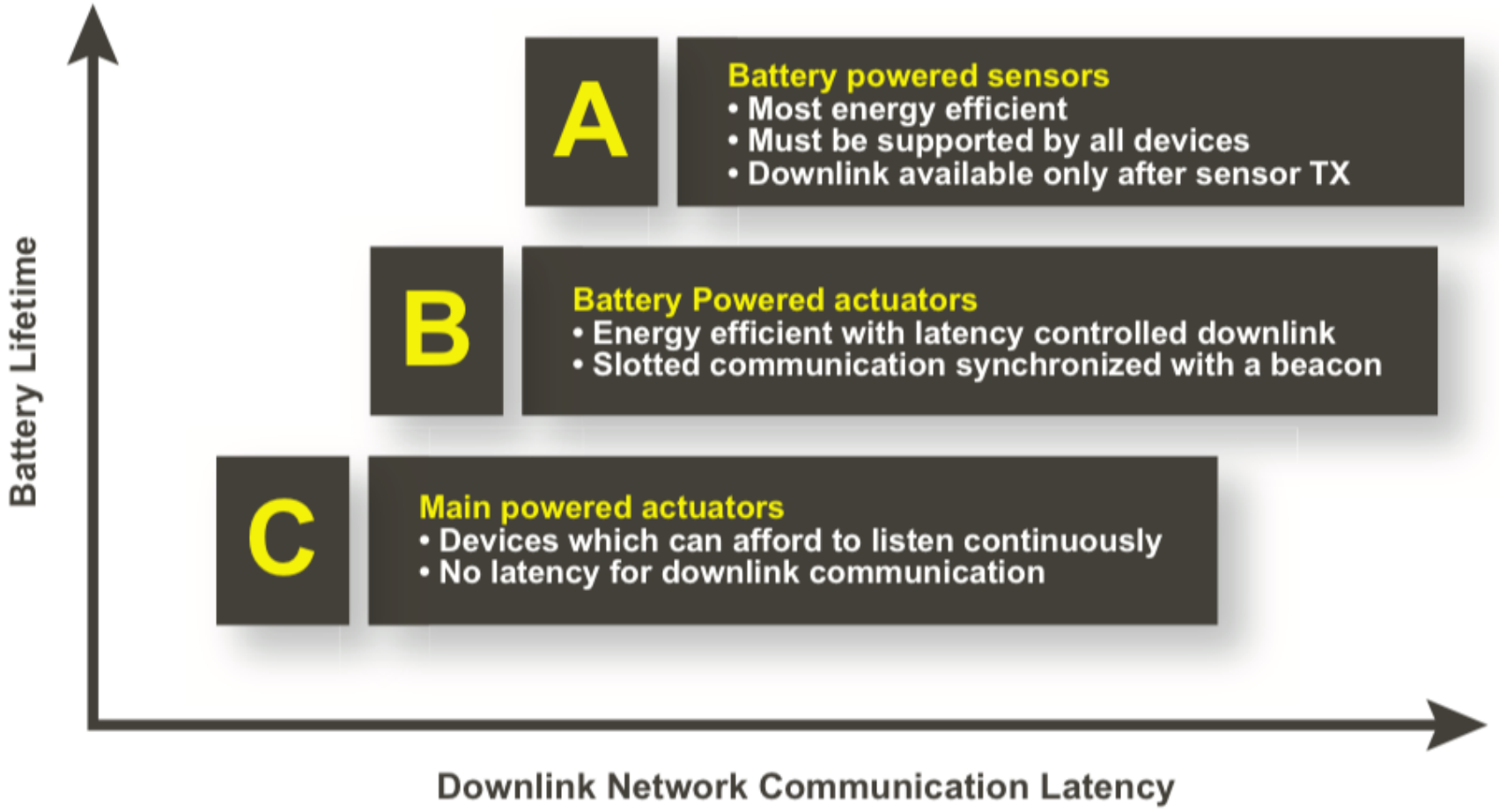


Device Classes

- Different requirements/application for End-devices
  - Different classes
  - Trade off downlink communication latency **versus** battery lifetime
- downlink communication latency is critical for a control or actuator-type application

3 Device Classes

Support for different applications/requirements



Class A

- bi-directional communications
- each end-device's uplink transmission is followed by two short downlink receive windows
- Downlink communications from the server at any other time will have to wait until the next scheduled uplink
- transmission slot scheduled by the end-device is based on its own communication needs with a small variation based on a random time basis (ALOHA-type of protocol)
- the lowest power end-device

Class B

- Bi-directional end-device with scheduled receive slots
- In addition to the Class A random receive windows
  - Class B devices open extra receive windows at scheduled times
- Requires time-synchronized beacon from the gateway

Class C

- Bi-directional end-device with maximal receive slots
- almost continuously open receive windows
- only closed when transmitting

LoRaWAN™ Security

- utilizes two layers of security
  - @network layer: ensures authenticity of the node in the network
  - @application layer: ensures the network operator does not have access to the end user's application data
- AES encryption is used with the key exchange (IEEE EUI64 identifier)

LoRaWAN™ Channal

OFDMA

Comparing LPWAN

2015

Feature	LoRaWAN	Narrow-Band	LTE Cat-1 2016 (Rel12)	LTE Cat-M 2018 (Rel13)	NB-LTE 2019(Rel13+)
Modulation	SS Chirp	UNB / GFSK/BPSK	OFDMA	OFDMA	OFDMA
Rx bandwidth	500 - 125 KHz	100 Hz	20 MHz	20 - 1.4 MHz	200 KHz
Data Rate	290bps - 50Kbps	100 bit/sec 12 / 8 bytes Max	10 Mbit/sec	200kbps – 1Mbps	~20K bit/sec
Max. # Msgs/day	Unlimited	UL: 140 msgs/day	Unlimited	Unlimited	Unlimited
Max Output Power	20 dBm	20 dBm	23 - 46 dBm	23/30 dBm	20 dBm
Link Budget	154 dB	151 dB	130 dB+	146 dB	150 dB
Batery lifetime - 2000mAh	105 months	90 months		18 months	
Power Efficiency	Very High	Very High	Low	Medium	Med high
Interference immunity	Very high	Low	Medium	Medium	Low
Coexistence	Yes	No	Yes	Yes	No
Security	Yes	No	Yes	Yes	Yes
Mobility / localization	Yes	Limited mobility, No loc	Mobility	Mobility	Limited Mobility No Loc

References

- “Introduction to LoRaWAN” by Martin Haas (11.01.2017)