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Mobile and Wireless Computing
CITS4419
Week 4: LoRa

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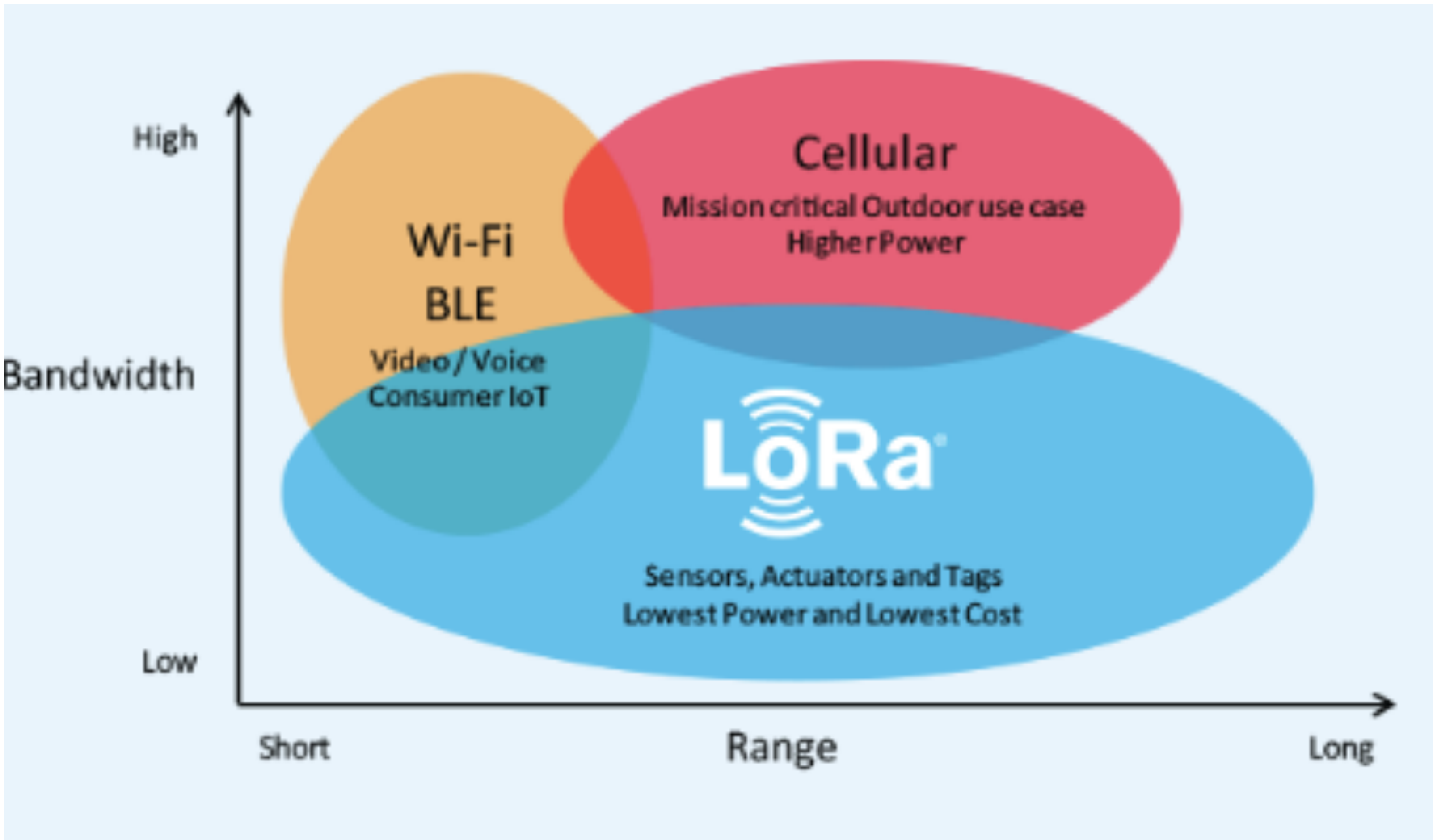
Low Power Wide Area Networks

LPWAN

- Short range wireless technologies
  - WiFi, Bluetooth Low Energy, IEEE 802.15.4
- Low power wide area networks (LPWAN)
  - **Spread-spectrum eg LoRa**
  - Ultra-narrowband eg Sigfox, Weightless-N, NB-IoT
  - Long range comms so simple star topology
  - Trade throughput for range and vice versa
  - Good for IoT applications (low data rate, long dist)

www.semtech.com/lora/why-lora



LoRa

- Spreads the signal over a wider frequency band – so resilient to jamming and interference
- LoRa proprietory PHY layer from Semtech
- You can fine tune performance by selecting from over 6000 parameter settings

Which LoRa

- LoRa Physical Layer
  - Patented Technology by Semtech (2012)
  - Settable parameters to trade throughput with range
- LoRa MAC Layer = LoRaWAN
  - LoRa Alliance lora-alliance.org
  - 500 companies, Standardisation of LoraWAN
  - Open source
  - Eg. The Things Network: globally distributed, crowd sourced network

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LoRa Parameters

LoRa Parameters [source: Cattani et al]

Setting	Values	Effects
Bandwidth	$125 \ldots 500\,\text{kHz}$	Higher bandwidths allow for transmitting packets at higher data rates (1 kHz = 1 kcps), but reduce receiver sensitivity and communication range.
Spreading Factor	$2^6 \ldots 2^{12} \frac{\text{chips}}{\text{symbol}}$	Bigger spreading factors increase the signal-to-noise ratio and hence radio sensitivity, augmenting the communication range at the cost of longer packets and hence a higher energy expenditure.
Coding Rate	$4/5 \ldots 4/8$	Larger coding rates increase the resilience to interference bursts and decoding errors at the cost of longer packets and a higher energy expenditure.
Transmission Power	$-4 \ldots 20\,\text{dBm}$	Higher transmission powers reduce the signal-to-noise ratio at the cost of an increase in the energy consumption of the transmitter.

Carrier Frequencies

- 137 MHz, 433, 868 and 915 MHz (depends on country)
- HopeRF (Dragino board) and SX1272 (Semtech) support 860-1020 MHz programmable in steps of 61 Hz
- Country regulations define useable channels

Transmission Power

- HW dependent, but typically -2 to 20 dBm
- Increasing Tx power increases energy use
- Increasing Tx power also increases range
- For Tx power > 17 dBM, hardware limitations and legal regulations limit duty cycle (<1%)

Bandwidth

- LoRa bandwidth can be set to 125 kHz, 250 kHz or 500 kHz
- Higher bandwidth gives lower receiver sensitivity (so weaker pkts can be received)
- Higher bandwidth increases the data rate
- So increasing bandwidth reduces time on air and energy use

```
# Receiver sensitivity floor depends on bandwidth
  if(BWidth==125):
    RSF={6:-121,7:-124,8:-127,9:-130,10:-133,11:-135,12:-137}
  elif(BWidth==250):
    RSF={6:-118,7:-122,8:-125,9:-128,10:-130,11:-132,12:-135}
  else: #500
    RSF={6:-111,7:-116,8:-119,9:-122,10:-125,11:-128,12:-129}
```

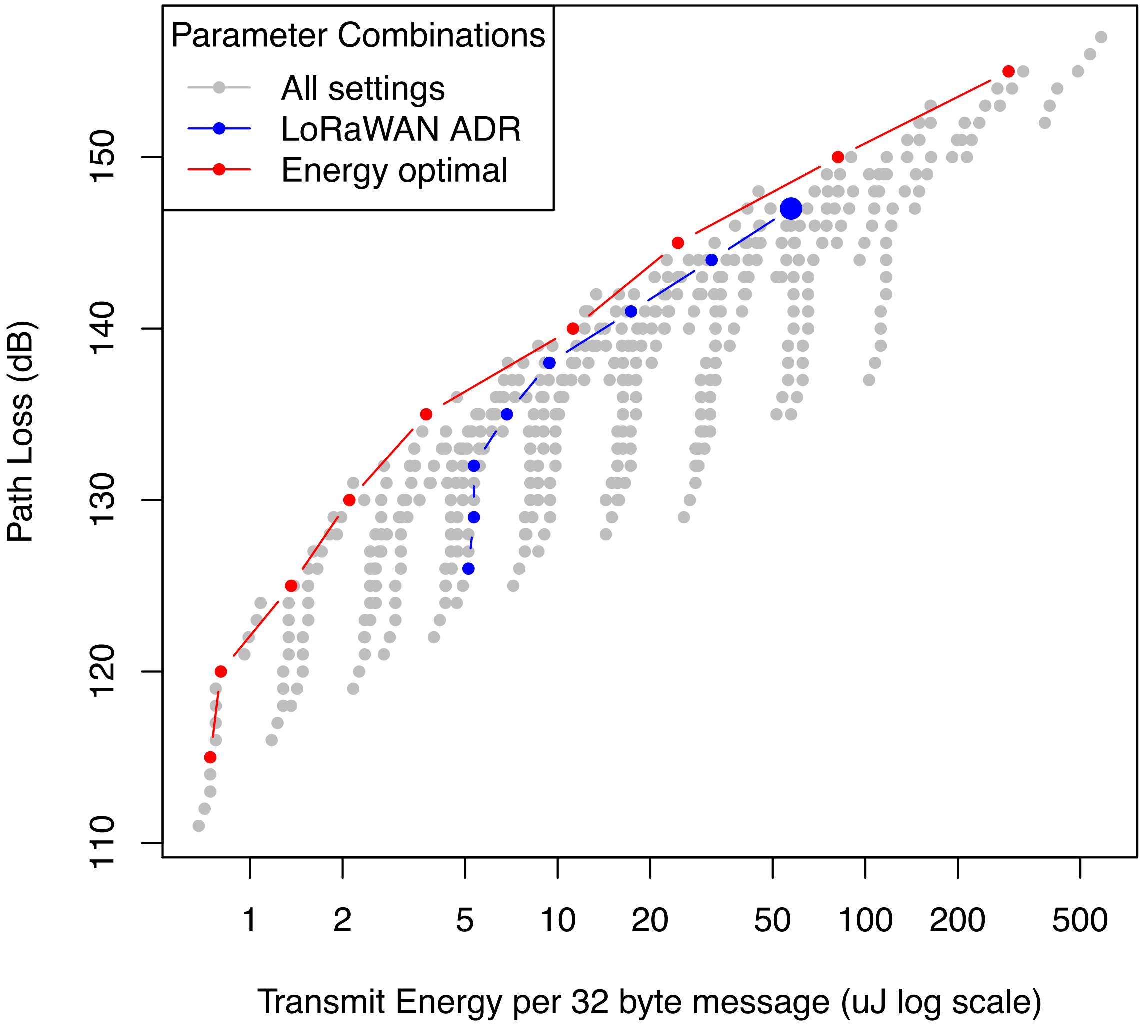
Coding Rate

- Inbuilt Forward Error Correction
- For protection from bursts of interference
- Adds from 1..4 redundant bits
- Called SF 4/5, 4/6, 4/7 and 4/8
- Increasing CR provides protection against burst interference
- Increased CR increases the message length, so time on air and so energy use

Spreading Factor

- Spreading factor values from 6 to 12
- Each symbol has 2^{SF} chirps
- Bit rate depends on SF, BW and Coding rate
- Increase SF halves the tx rate, so increases (doubles) tx time and so energy use
- Channels with different SF are orthogonal, so can tx at the same time

Parameter Choices



LoRa Simulator

- Python code by Ben Dix-Matthews
- Supports experimentation of LoRa parameters
- Download from github.com/websense/lorasimulator

- For this week's lab

Bor & Roedig

- What is the impact of LoRa parameter settings on energy consumption and communication reliability?
- How effective is an adaptive protocol using link probing to overcome frame loss?

- Martin Bor and Utz Roedig. 2017. LoRa Transmission Parameter Selection. In Proceedings of the 13th IEEE International Conference on Distributed Computing in Sensor Systems (DCOSS), Ottawa, ON, Canada. 5–7

Cattani et al

- Is it worth selecting PHY settings to reduce the data rate in order to increase the link quality?
- If and how much does temperature affect LoRa's communication performance

- Marco Cattani, Carlo Boano, and Kay Römer. 2017. An Experimental Evaluation of the Reliability of LoRa Long-Range Low-Power Wireless Communication. Journal of Sensor and Actuator Networks 6, 2 (jun 2017), 7. https://doi.org/10. 3390/jsan6020007

Marcelis et al

- What are the properties of LoRaWAN channels in mobile and stationary scenarios?
- How well can application layer coding (DaRe) recover lost frame data?

- P. J. Marcelis, V. Rao, and R. V. Prasad. 2017. DaRe: Data Recovery through Application Layer Coding for LoRaWAN. In Proceedings of the Second International Conference on Internet-of-Things Design and Implementation - IoTDI ’17. 97–108. https://doi.org/10.1145/3054977.3054978

Dix-Matthews et al

- What are the energy-optimal parameter settings for LoRa?
- What are the properties of LoRa channels in mobile and stationary scenarios?
- How well does data-aware replication fare in these settings?

- LoRa Parameter Choice for Minimal Energy Usage, Under review

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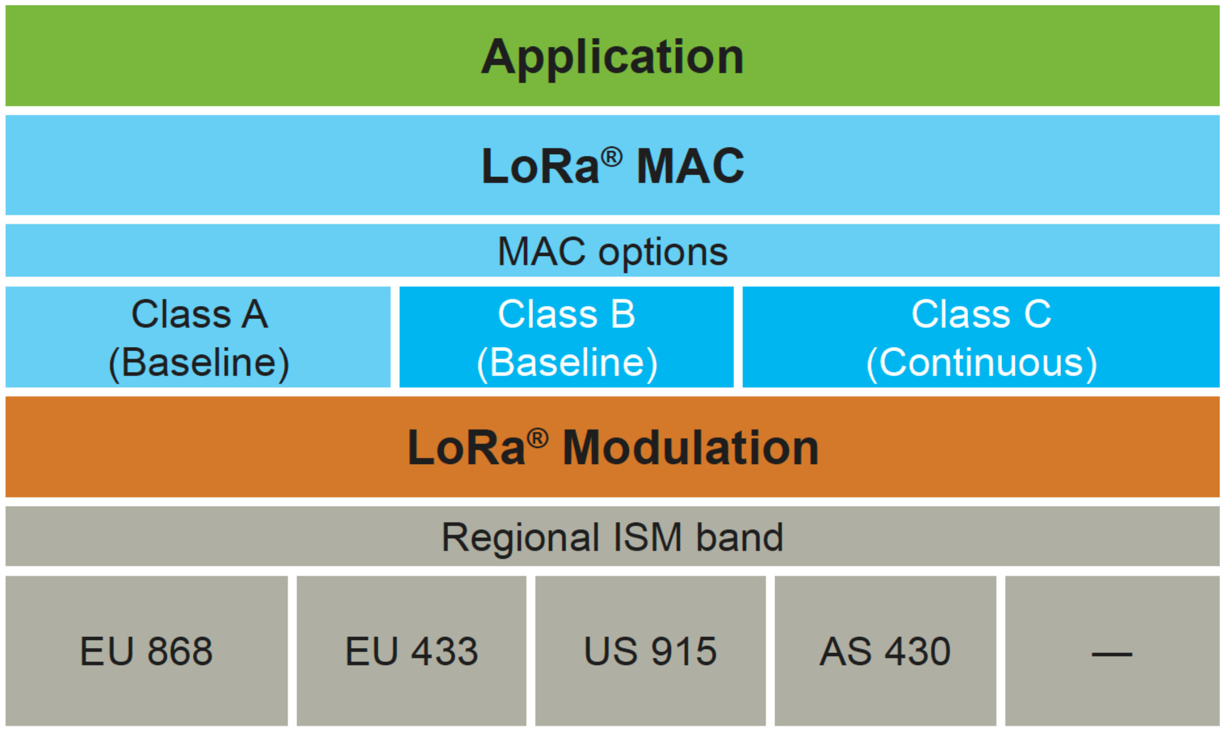
LoRaWAN

LoraWAN

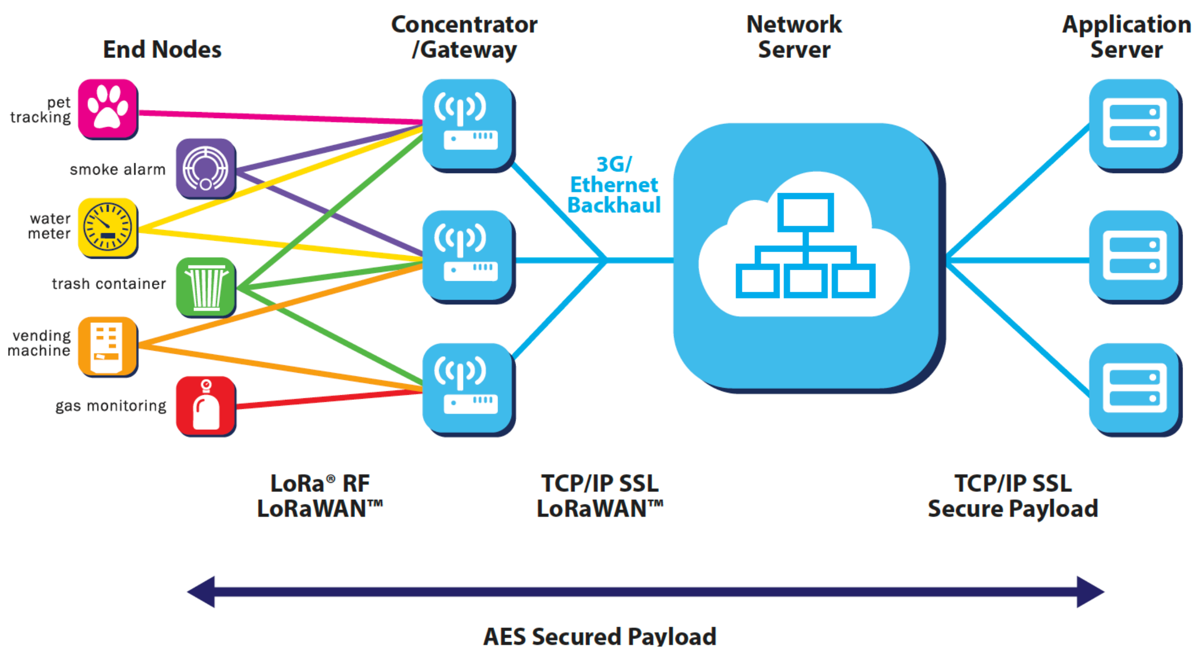

Application
LoRa® MAC
MAC options
Class A
(Baseline)
Class B
(Baseline)
Class C
(Continuous)
LoRa® Modulation
Regional ISM band
EU 868
EU 433
US 915
AS 430
—

Mesh Network

- Mesh network: individual end-nodes forward the information of other nodes to increase the communication range and cell size of the network. While this increases the range, it also adds complexity, reduces network capacity, and reduces battery lifetime

Star Network

- Single hope from sensor nodes to a gateway
- Long range star architecture makes the most sense for preserving battery lifetime when long-range connectivity can be achieved



LoRa-Alliance.org

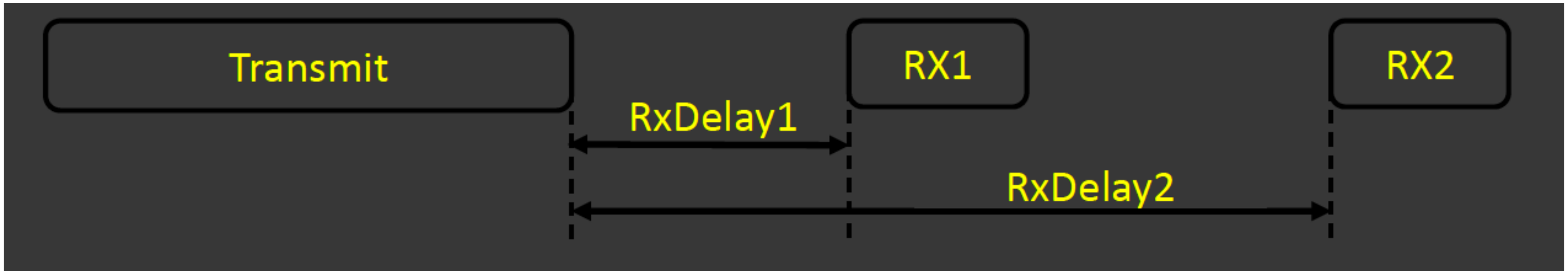
End-devices

Each end-device class has different behavior depending on the choice of optimization:

- Battery Powered – Class A
- Low Latency – Class **B**
- No Latency – Class **C**

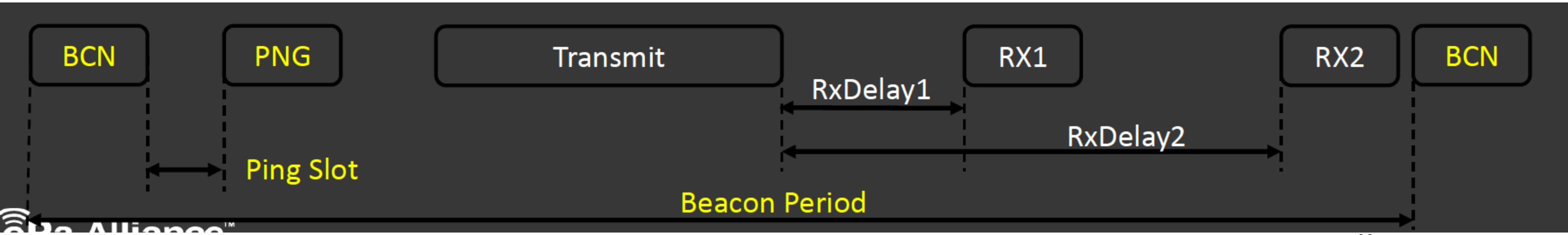
Battery Powered – Class A

- Bidirectional communications
- Unicast messages
- Small payloads, long intervals
- End-device initiates communication (uplink)
- Server communicates with end-device (downlink) during predetermined response windows:



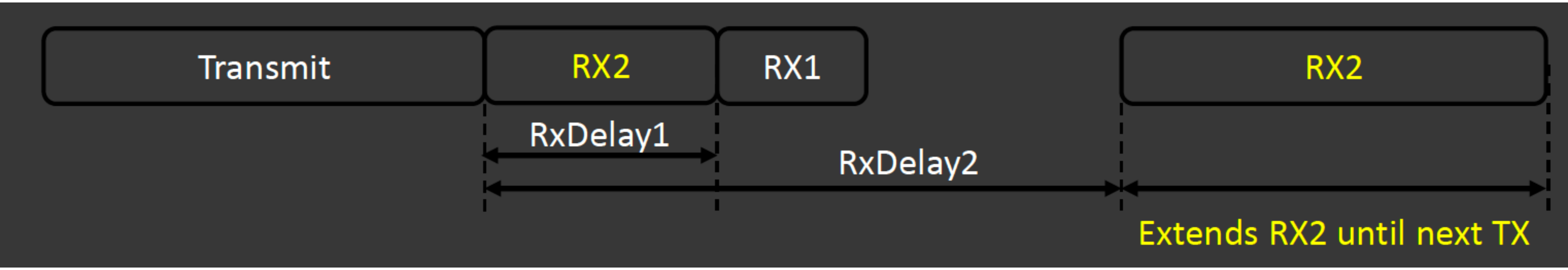
Low Latency – Class B

- Bidirectional with scheduled receive slots
- Unicast and Multicast messages
- Small payloads, long intervals
- Periodic beacon from gateway
- Extra receive window (ping slot)
- Server can initiate transmission at fixed intervals



No Latency – Class C

- Bidirectional communications
- Unicast and Multicast messages
- Small payloads
- Server can initiate transmission at any time
- End-device is constantly receiving



Device Activation

- Before an end-device can communicate on the LoRaWAN network, it must be activated
- The following information is required:
  - Device Address (DevAddr)
  - Network Session Key (NwkSKey)
  - Application Session Key (AppSKey)
- We won't go into the details of activation in this unit