LoRa
APPLICATIONS

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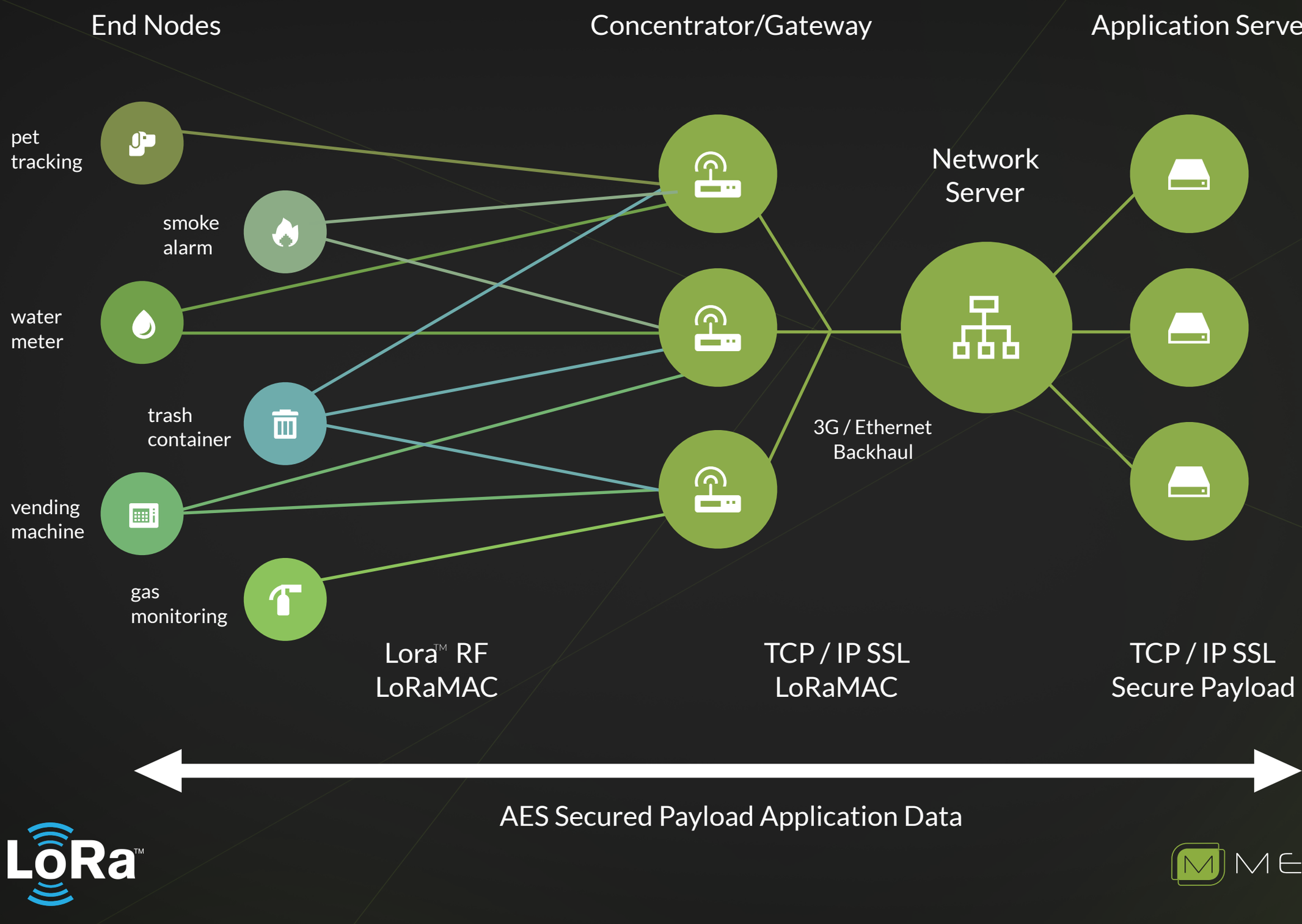
LoRa NETWORK



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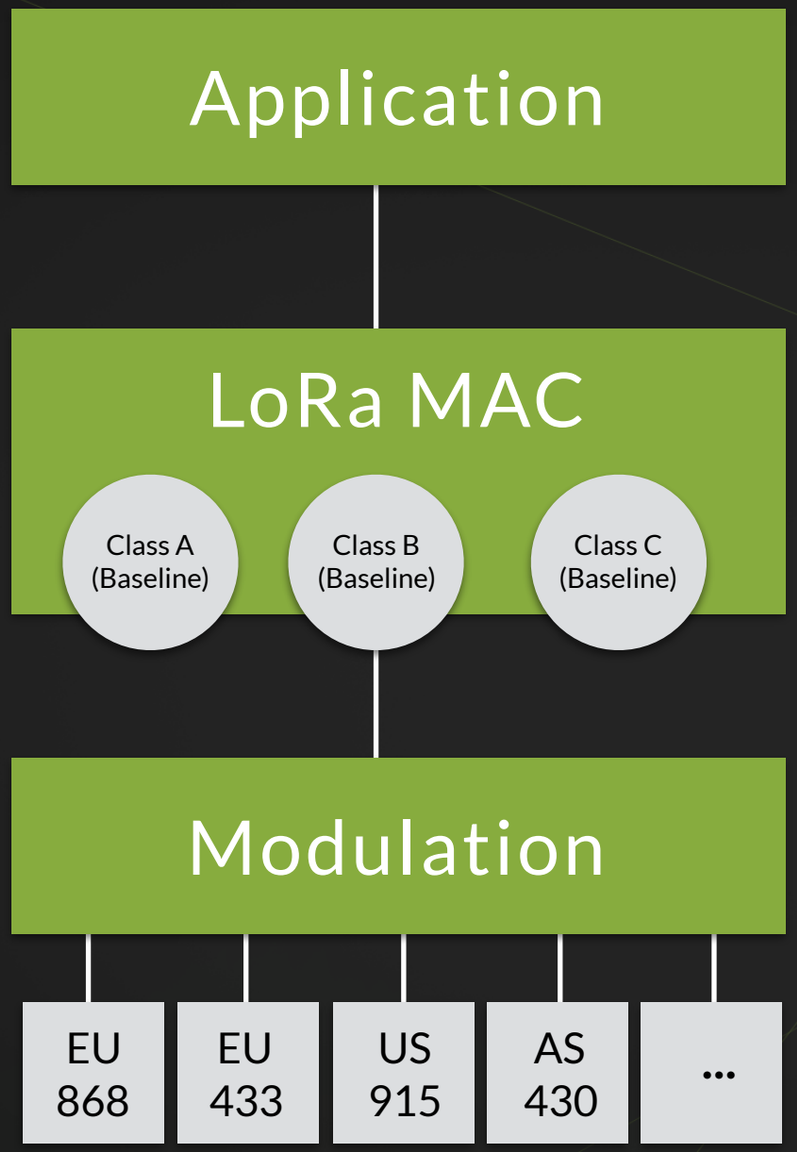
LoRa ARCHITECTURE OVERVIEW



- High level application layer that handles business logic
- Application layer implements open source LoRaMAC library and communication layer with LoRa transceiver
- Transceiver transmits using proprietary LoRa modulation
- Utilizes regional ISM bands
- Devices communicate with Gateways via LoRa RF protocol
- Multiple gateways communicate with a single Network Server via Cellular or Ethernet backhaul
- End to End Encryption
- Single Network Server has many Application Servers

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LoRa MODULATION

- Properties
  - Bandwidth scalable
  - Constant Envelope
  - Multipath Resistant
  - Doppler Resistant
  - Long Range
  - Enhanced Network Capacity
  - Ranging and Localization
- Proprietary modulation scheme, not a lot of details available
- Looks to use a “Chirp” Spread Spectrum with pulsed FM “sweeping frequency” rather than traditional DSSS or FHSS

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DEVICE CLASSES

LoRa Class A	LoRa Class B	LoRa Class C
Battery Powered	Low Latency	No Latency
Bidirectional Communications	Bidirectional with scheduled received slots	Bidirectional Communications
Unicast Messages	Unicast & Multicast Messages	Unicast & Multicast Messages
Small Payloads, Long Intervals	Small Payloads, Long Intervals, Periodic beacon from gateway	Small Payloads
End-Device initiates Communication (uplink)	Extra Receive Window (ping slot)	Server can initiate Transmission at anytime
Server communication with end-device (downlink) during predetermined response windows	Server can initiate transmission at fixed intervals	End-Device is constantly Receiving

- Controlled and deployed by application subscriber
- Use regionally designated ISM radio frequency band
- Device's application layer controls the interval at which it communicates with the network
- Stack supported commands
- Support for custom downlink commands
- Class A, B, and C

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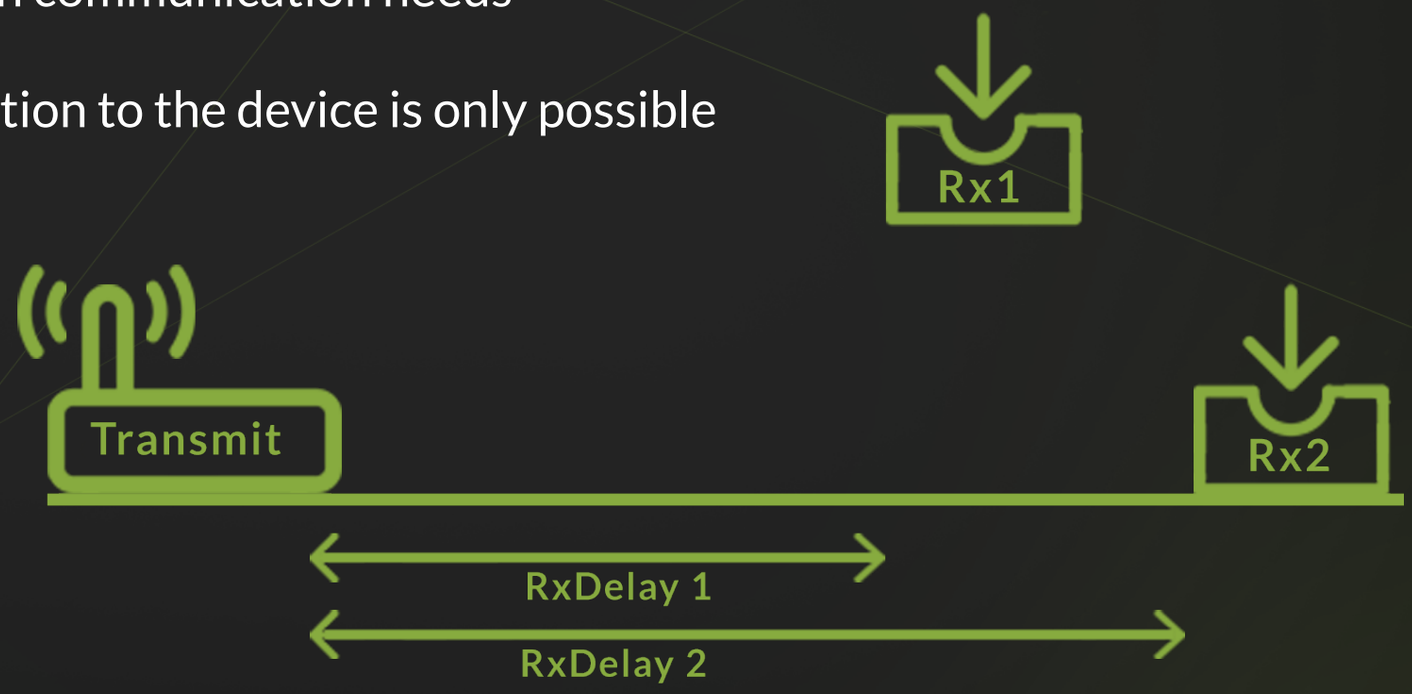
CLASS A DEVICES

- Lowest power option
- Each uplink transmission is followed by two short downlink receive windows
- RXDelay1 is 1 second from the end of the transmission
- RXDelay2 is 2 seconds from the end of the transmission
- Transmission slot is based on your own communication needs
- This means that downlink communication to the device is only possible once the device transmits an uplink
- Timing in Class A is critical



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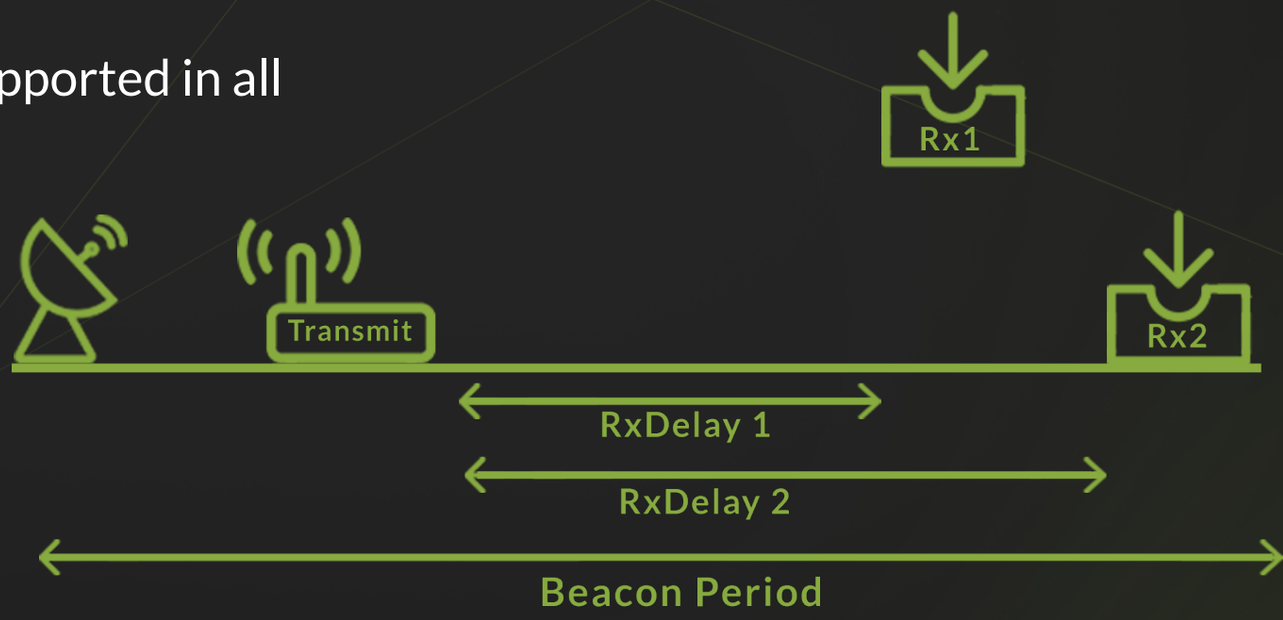
CLASS B DEVICES

- Mid-level power option
- Class B devices open extra receive windows at scheduled times
- In order for the end-device to open the receive window at the scheduled time, it receives a time-synchronized beacon from the gateway
- Unicast and Multicast
- GPS required in gateway (this is not supported in all microcell gateways)



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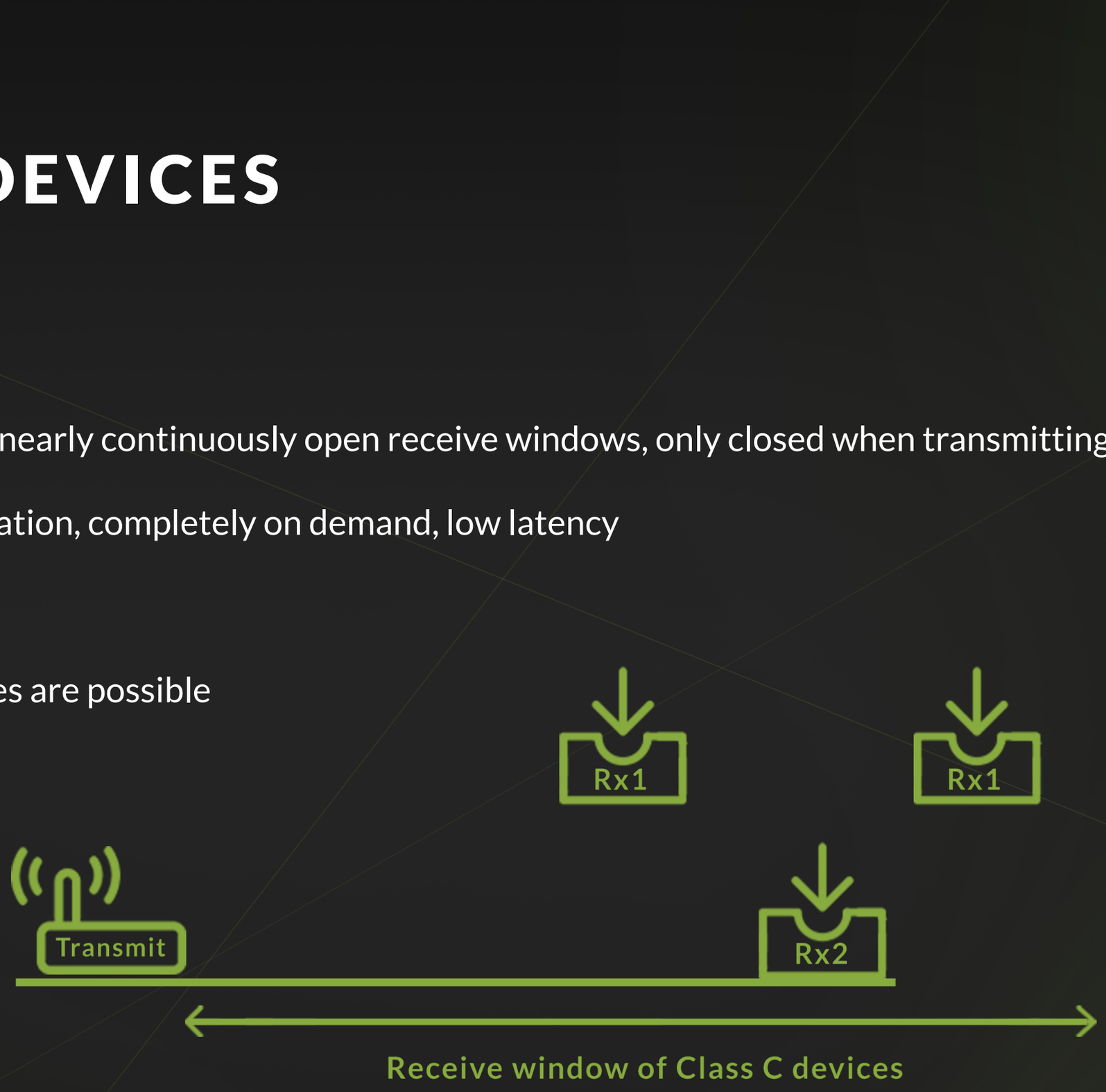
CLASS C DEVICES

- Heavy power option
- Class C devices have nearly continuously open receive windows, only closed when transmitting
- Full 2 way communication, completely on demand, low latency
- Multicast support
- OTA firmware updates are possible



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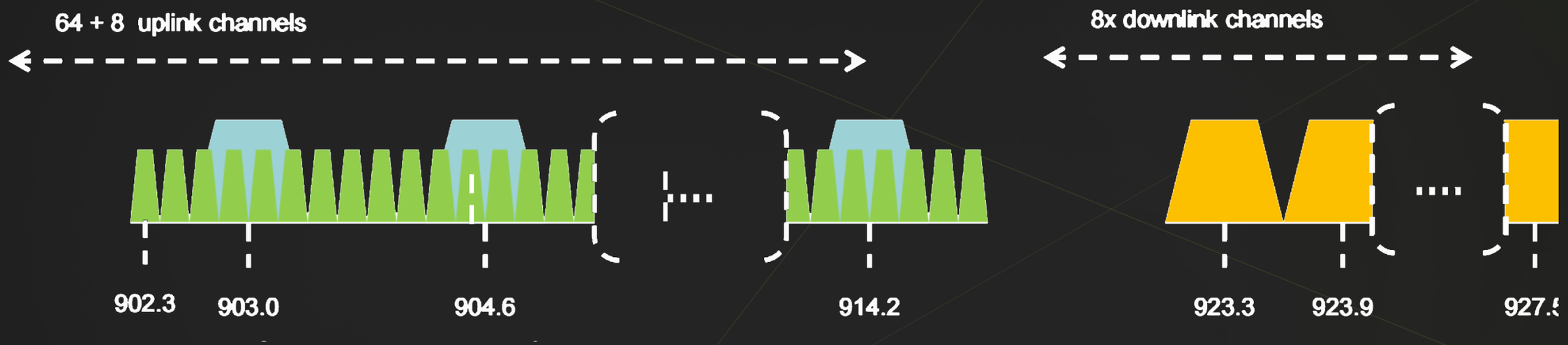
LoRa RF SPECTRUM

Uplink and downlink frequencies used for US 915 ISM Band



- channels used when transmitting at DR0-DR3
- DR4 channels
- receive channels at the end of the ISM spectrum

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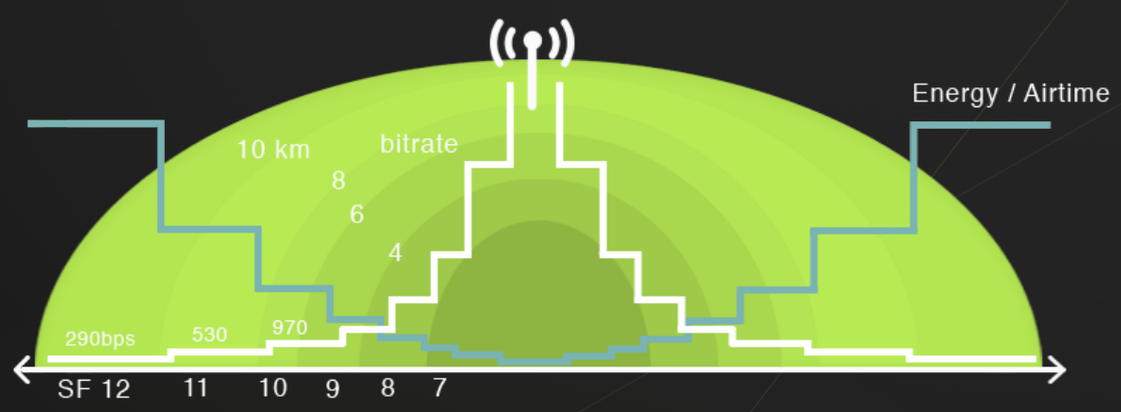
DATA RATES & ADAPTIVE DATA RATE (ADR)

- Enabled on a per device basis - most providers require or pay higher cost
- Multiple data rates supported
- Used to balance range and bit rate
- The lower the data rate, the longer the range, the smaller the payload



Data Range	Configuration	Indicative Physical Bit Rate (bit/sec)
0	LoRa: SF10 125 kHz	980
1	LoRa: SF9 125kHz	1760
2	LoRa: SF8 125kHz	3125
3	LoRa: SF7 125kHz	5470
4	LoRa: SF8 500kHz	12500
5:7	RFU	
8	LoRa: SF12 500kHz	980
9	LoRa: SF11 500kHz	760
10	LoRa: SF10 500kHz	3900
11	LoRa: SF9 500kHz	7000
12	LoRa: SF8 500kHz	12500
13	LoRa: SF7 500kHz	21900
14:15	RFU	

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LoRa PHYSICAL (PHY) LAYER

- LoRa physical layer includes:
    - 8 preamble symbols
    - 2 synch symbols
    - physical payload and optional CRC.
- SF8 takes exact twice the time of SF7 and SF9 takes exact twice time of SF8.
- Symbol Rate(Rs), Bandwidth(BW) and Spreading Factor(SF) relation:
    - Rs = BW / (2^SF)
- Higher the Spreading Factor -> Higher the over-the-air time.
- Lower the Spreading Factor -> Higher the Bit Rate.

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PACKET SIZE CONSIDERATIONS

Date Rate	Payload Size	Customer Payload Size
0	19	11
1	61	53
2	134	126
3	250	242
4	250	242
5:7	Not Defined	

- Smallest payload is only 11 bytes
- MAC command responses take up payload space, use wisely

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DATA RATES, SF, PAYLOAD SIZE

Uplink DR	SF	Bandwidth	Bitrate	Max Payload
0	10	125kHz	980	11
1	9	125kHz	1760	53
2	8	125kHz	3125	129
3	7	125kHz	5470	242
4	8	500kHz	12500	242
Downlink DR				
8	12	500kHz	122	53
9	11	500kHz	244	129
10	10	500kHz	488	242
11	9	500kHz	976	242
12	8	500kHz	1953	242
13	7	500kHz	3906	242

Longer range
smaller payload

Larger payload
tighter download link

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MAC COMMANDS

CID	Command	Short Description	Transmitted By End Device	Gateway
0 x 02	LinkCheckReq	Used by end-Device to validate it's connectivity a network	x	
0 x 02	LinkCheckAns	Answer to LinkCheckReq. Contains the received signal power estimation indicating to the end-device the quality of reception (link margin)		x
0 x 03	LinkADRReq	Request end-device to change data rate, transmit power, repetition rate or channel		x
0 x 03	LinkADRAns	Acknowledges the LinkRateRea	x	
0 x 04	DutyCycleReq	Sets the maximum aggregated transmit duty-cycle of a device		x
0 x 04	DutyCycleAns	Acknowledges a DutyCycleReq	x	
0 x 05	RxParamSetupReq	Sets the reception slot parameters		x
0 x 05	RxParamSetupReq	Acknowledges the RxSetup command	x	
0 x 06	DevStatusReq	Request the status of an end-device		x
0 x 06	DevStatusAns	Returns the status of an end device, namely it's battery level and demodulation margin	x	
0 x 07	NewChannelReq	Creates of modifies the definition of a radio channel		x
0 x 07	NewChannelAns	Acknowledges a NewChannelReq command	x	
0 x 08	RxTimingSetupReq	Sets the timing of the reception slots		x
0 x 08	RxTimingSetupAns	Acknowledges RxTimingSetupReq command	x	
0 x 08 to 0 x FF	Proprietary	Reserved for proprietary network command ext.	x	x

- Media Access Control (MAC)
- Each command expects an answer
- Controlled by the network provider
- Commands can be initiated by the server or device

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GATEWAYS

MultiTech MultiConnect Conduit

KONA Macro IoT Gateway

Kerlink LoRa IoT Station

- Controlled and managed by the network operator
- Relays communication between devices and network network server
- Uses same regional ISM RF band to communicate with end devices
- Backhaul to network server over ethernet or cellular
- Network server determines which gateway to utilize when communicating with device, if a device is heard by multiple Gateways
- 8 channel and 72 channel gateways

GATEWAY METADATA

Data and RF parameters recorded for each received uplink

- Signal to Noise Ratio
- RSSI
- Channel / Frequency
- Bandwidth
- SF/Datarate
- Timestamp

This data is forwarded to the network server, some is shared within application server (this is up to the provider)

SERVERS

Network Server

- Accepts connections from multiple gateways, protocols vary per product
- Sends packets along to multiple Application Servers
- Unable to decrypt device payloads
- Handles LoRa stack commands
- Controls network performance - data rate, power levels, etc.

Application Server

- Accepts connections from multiple gateways, protocols vary per product
- Sends packets along to multiple Application Servers
- Unable to decrypt device payloads
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SECURITY OVERVIEW

Devices

- Devices have globally unique IDs (from IEEE)
- Con only join specific server (App EUI)
- Nonce is random seed
- AES-128 encryption (ECB not so great)

Server

- Sessions keys are generated and used instead of actual encryption keys
- The session keys are generated on a successful join procedure and known to both sides
- Only the join request is sent unencrypted
- All other uplink and downlinks are encrypted with session keys
- MAC commands can be sent unencrypted, but a valid MIC is required to act on the command
- The MIC is generated via the session keys

THANK YOU!