LoRa for wireless sensor network

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Physical Layer

Physical Layer - Frequency, range and bitrate

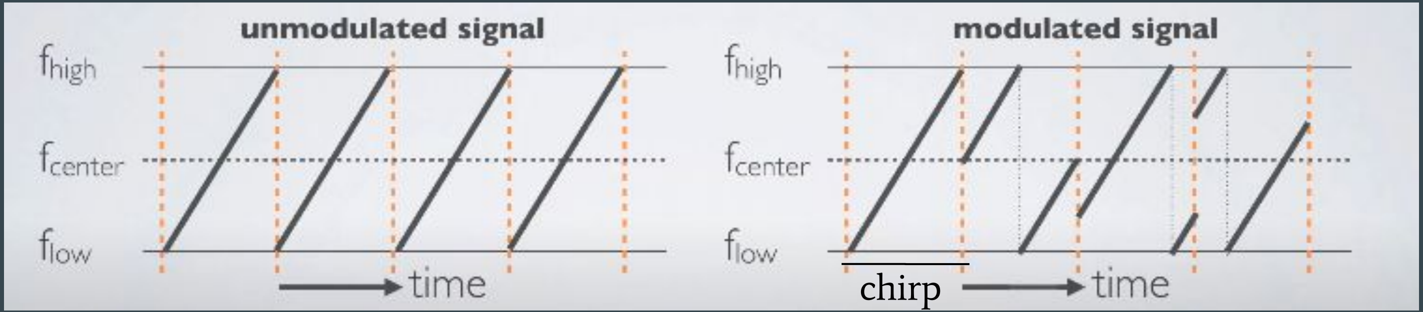
- low power communication
- Range: Up to 15 kilometers
- Can be used 433 MHz 868 MHz or 915-MHz bands (Europe -> 868MHz)
- Payload: reach up to 255 bytes
- Bitrate: can reach 50kBps

Physical Layer - Modulation

- Chirp spread spectrum (CSS) modulation
- Proprietary modulation (not open)

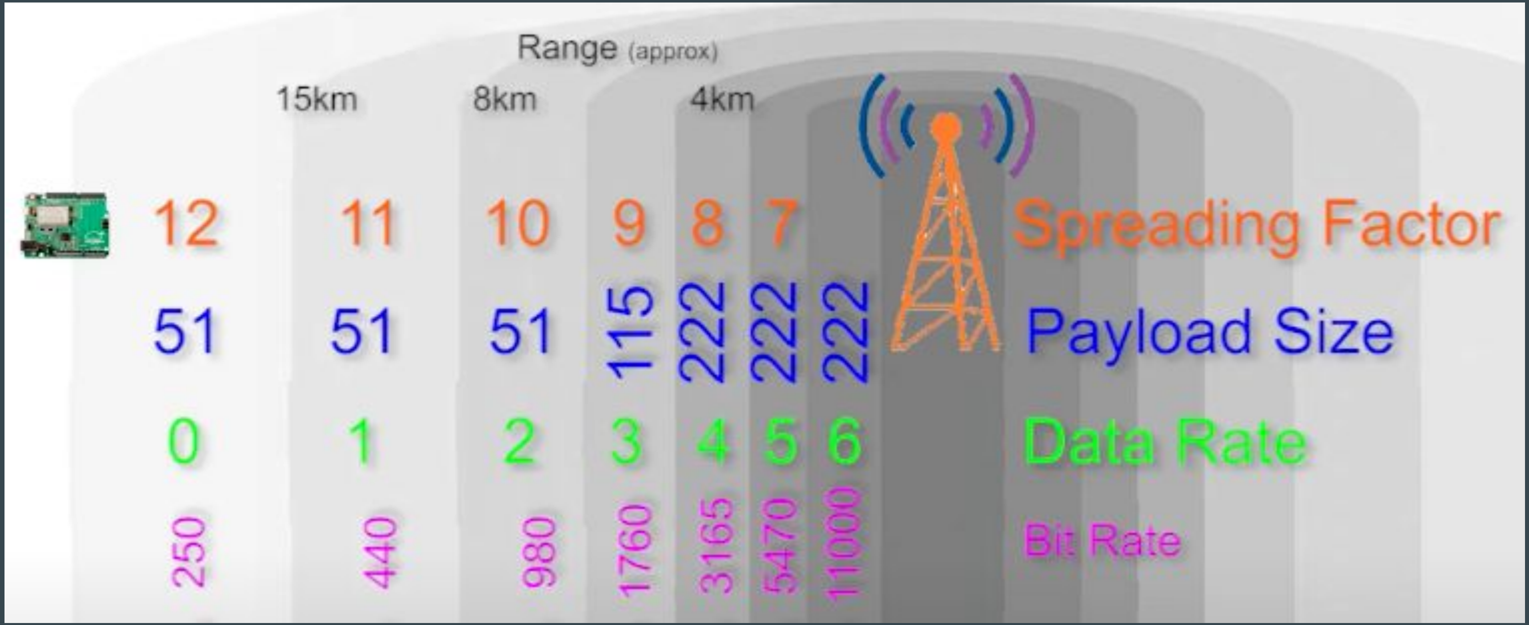
Physical Layer - CSS Modulation

→ spread spectrum technique : wideband frequency to encode information



Physical Layer - Spreading Factor

→ The Spreading Factor (SF) decides on how many chirps, the carrier of the data, are sent per second



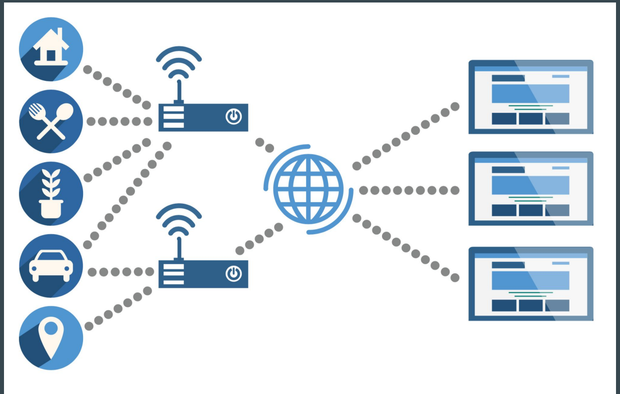
MAC Layer - LoRaWAN

MAC Layer - LoRaWAN Protocol - Basis

- MAC Protocol
- Open Protocol
- Half-Duplex (bidirectional but not simultaneously)
- Used both on end devices (connected objects) and gateways
- Asymmetric (uplink, downlink messages)

MAC Layer - LoRaWAN Protocol - How it works

- Gateways in listening mode
- End devices decides to transmit something :
  - every gateways in range receives it
  - they add an RSSI information to the data received (RSSI = Received Signal Strength Indication)
  - they send the data + RSSI to the server
- The server responds to the gateway that send the data with the best RSSI
- Gateway transmits the response packet to the end device

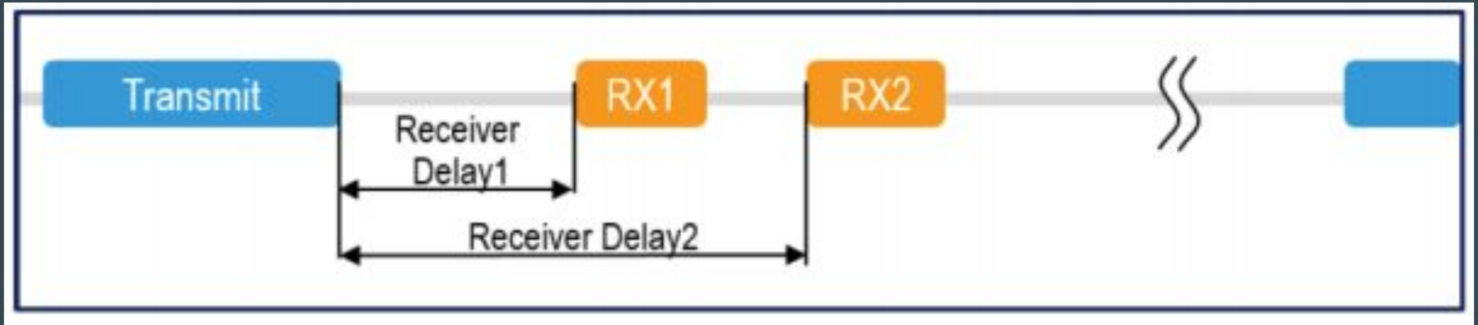


MAC Layer - LoRaWAN Protocol - How it works

- 3 classes of transmission (A,B,C), each allowing a given time to the server to respond after a transmission.
- Each class have its pros and cons.
  - When a class is really effective (low delay, long response time window for the server), it is more energy consuming.
  - At the opposite, is the class is low energy consuming, it won’t be as effective.

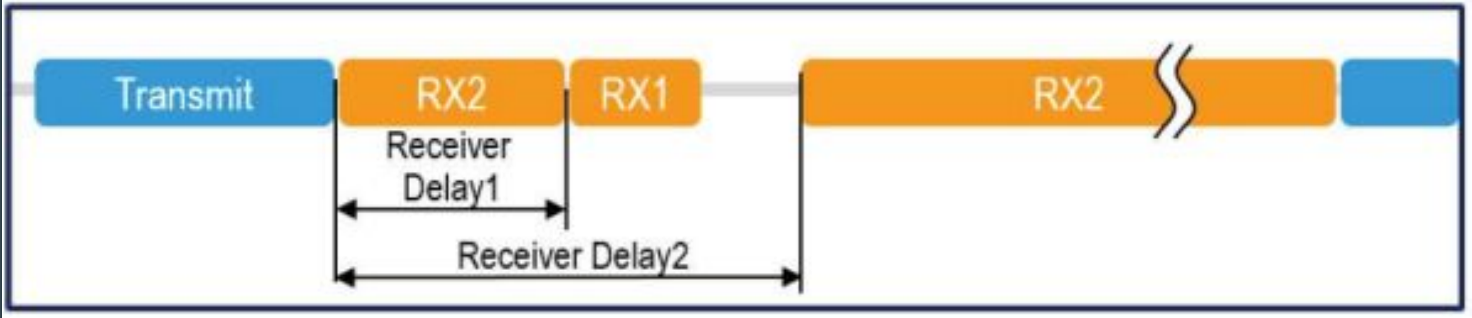
MAC Layer - LoRaWAN Protocol - Class A

- The end device transmit a message
- 2 temporal windows are reserved during which the server can respond after a given delay.



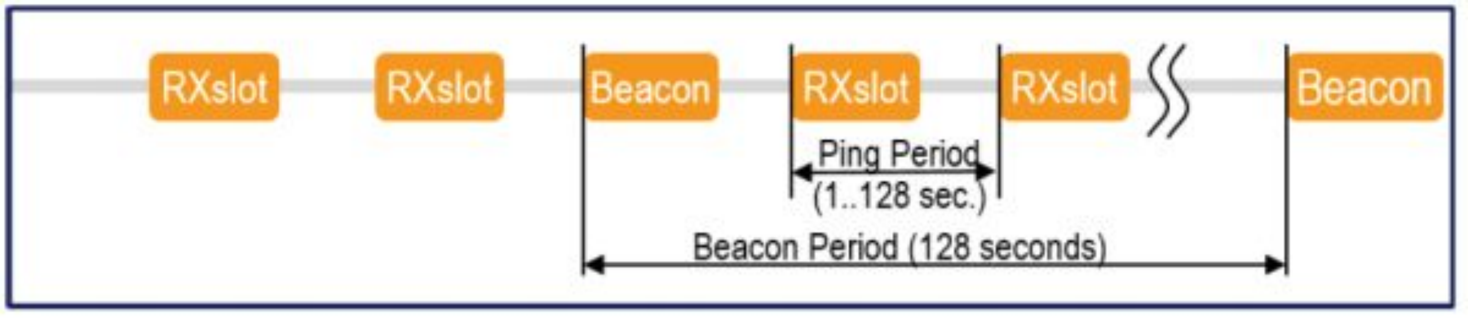
MAC Layer - LoRaWAN Protocol - Class B

- Same as class A (2 temporal windows reserved)
- The server can, in addition, transmit a “Beacon synchronization frame” to get additional transmission window.



MAC Layer - LoRaWAN Protocol - Class C

- The end device is constantly in reception mode, expect when it is sending a data.
- The server can, with this class of transmission, transmit at any time to the end device, without delay.
- Really effective but really energy consuming (end device ALWAYS listening).



MAC Layer - LoRaWAN Protocol - MAC Commands

- MAC Commands are used for network administration between server/gateway and end devices.

- Applications cannot see them.

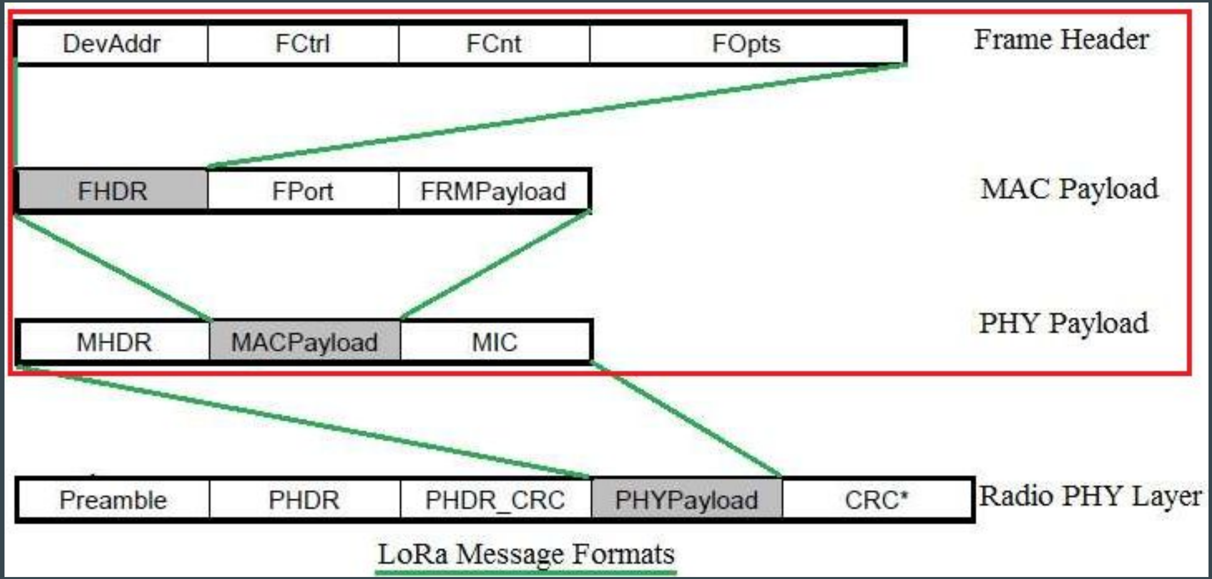
- Multiple MAC commands can be send into a single dataframe.

- Standardized with CID (command identifier).

CID	Command	Transmitted by End-device	Transmitted by Gateway	Short Description
0x02	*LinkCheckReq*	x		Used by an end-device to validate its connectivity to a network.
0x02	*LinkCheckAns*		x	Answer to LinkCheckReq command. Contains the received signal power estimation indicating to the end-device the quality of reception (link margin).
0x03	*LinkADRReq*		x	Requests the end-device to change data rate, transmit power, repetition rate or channel.
0x03	*LinkADRAns*	x		Acknowledges the LinkRateReq.
0x04	*DutyCycleReq*		x	Sets the maximum aggregated transmit duty-cycle of a device
0x04	*DutyCycleAns*	x		Acknowledges a DutyCycleReq command
0x05	*RXParamSetupReq*		x	Sets the reception slots parameters
0x05	*RXParamSetupAns*	x		Acknowledges a RXSetupReq command
0x06	*DevStatusReq*		x	Requests the status of the end-device
0x06	*DevStatusAns*	x		Returns the status of the end-device, namely its battery level and its demodulation margin
0x07	*NewChannelReq*		x	Creates or modifies the definition of a radio channel
0x07	*NewChannelAns*	x		Acknowledges a NewChannelReq command
0x08	*RXTimingSetupReq*		x	Sets the timing of the of the reception slots
0x08	*RXTimingSetupAns*	x		Acknowledges RXTimingSetupReq command
0x09	*TxParamSetupReq*		x	Used by the network server to set the maximum allowed dwell time and Max EIRP of end-device, based on local regulations
0x09	*TxParamSetupAns*	x		Acknowledges TxParamSetupReq command
0x0A	*DlChannelReq*		x	Modifies the definition of a downlink RX1 radio channel by shifting the downlink frequency from the uplink frequencies (i.e. creating an asymmetric channel)
0x0A	*DlChannelAns*	x		Acknowledges DlChannelReq command
0x0B to 0x0C	*RFU*			
0x0D	*DeviceTimeReq*	x		Used by an end-device to request the current date and time
0x0D	*DeviceTimeAns*		x	Sent by the network, answer to the DeviceTimeReq request
0X0E to 0x7F	RFU			
0x80 to 0xFF	Proprietary	x	x	Reserved for proprietary network command extensions

MAC Layer - LoRaWAN Protocol - MAC message format

- MAC Commands contained into FRMPayload of MAC Payload.
- MHDR (Mac Header) containing message type (connection establishment, ack message, ...etc).

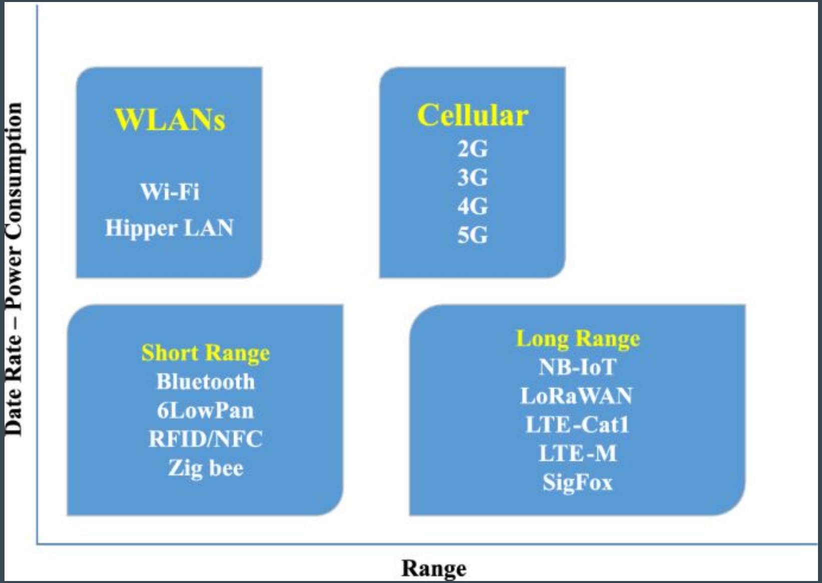


Energy Consumption- LoRaWAN

Energy Consumption

Several parameters to take in consideration:

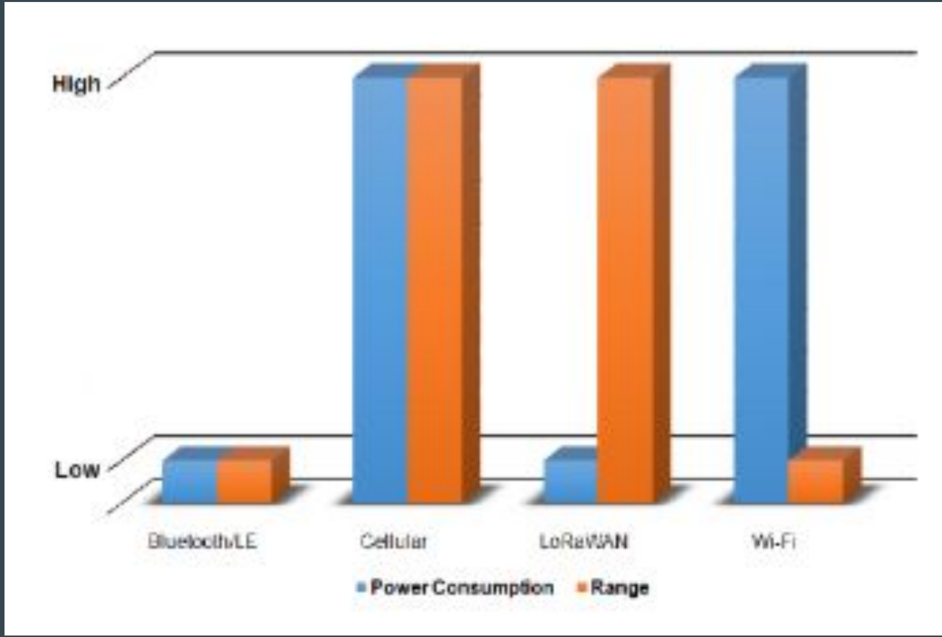
- Used mode (emission, reception, sleep and wait),
- The transmission,
- The power emission…



Energy Consumption - LoRaWAN, a low power consumption

LoRaWAN:

- asynchronous events
- a technology covering a long range
- with the less power consumption



Power Consumption vs Range for several technologies

Energy Consumption Model

➢ The total consumed energy:

$E_{Total} = E_{Sleep} + E_{Active}$

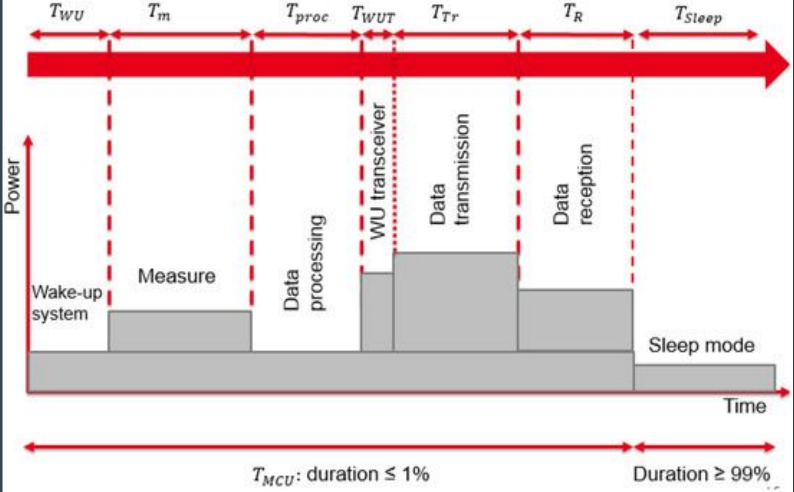
➢ The energy per useful bit:

$E_{bit} = E_{Total} / (8 \cdot PL) = P_{cons}(P_{Tr}) \cdot T_{Packet} / (8 \cdot PL)$

with PL: the payload size
and $P_{cons}(P_{Tr})$: the total consumed power which depends on transmission power

$$E_{bit} = P_{cons}(P_{Tr}) \cdot (N_{Payload} + N_P + 4.25) \cdot 2^{SF} / (8 \cdot PL \cdot BW)$$

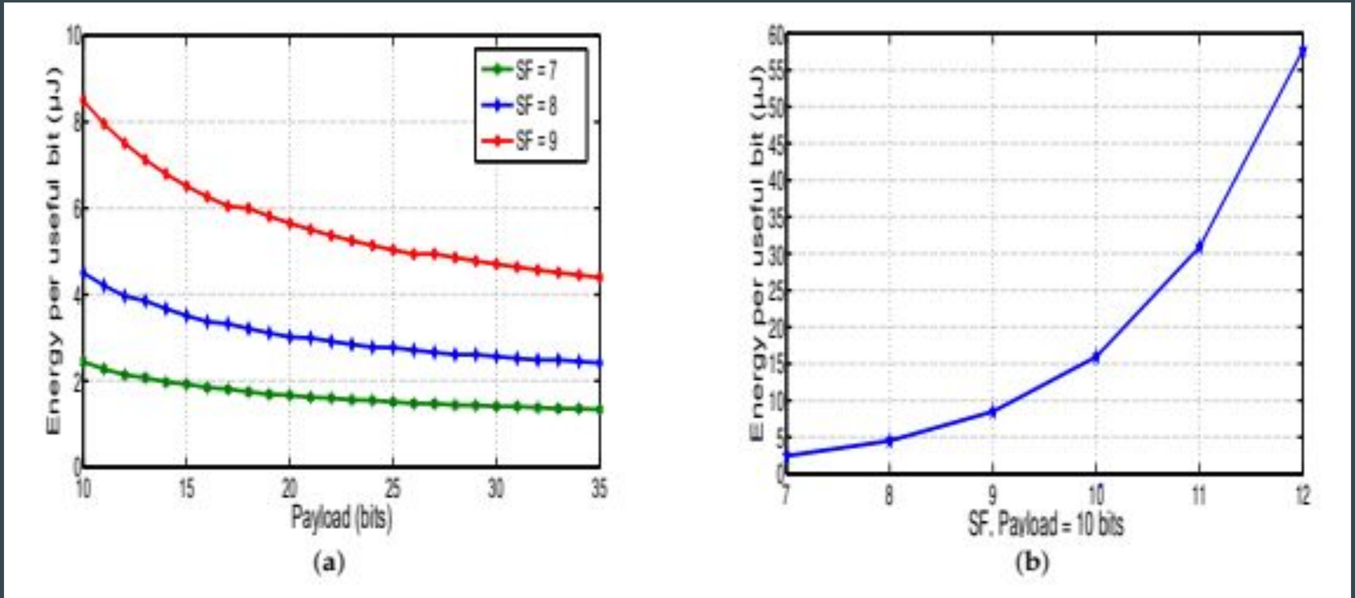
➢ The bitrate: $R_b = SF . BW . CR / 2^{SF}$



Sensor working scenario

Energy Consumption - LoRa parameters: example 1

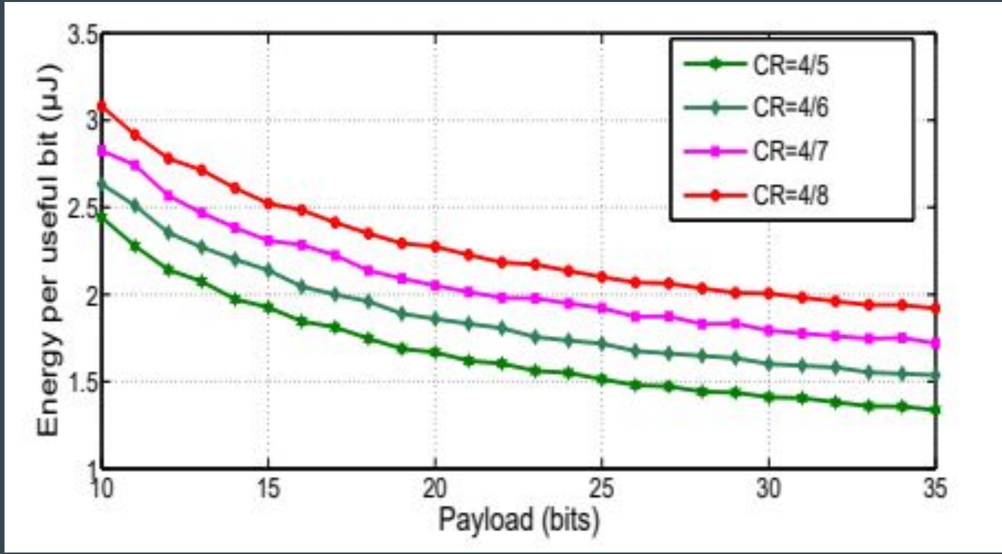
Spreading factor and payload size parameters



(a): Effect of SF on the consumed energy, CR = 4/5 ; and (b): Energy per useful bit evolution as a function of SF

Energy Consumption - LoRa parameters: example 2

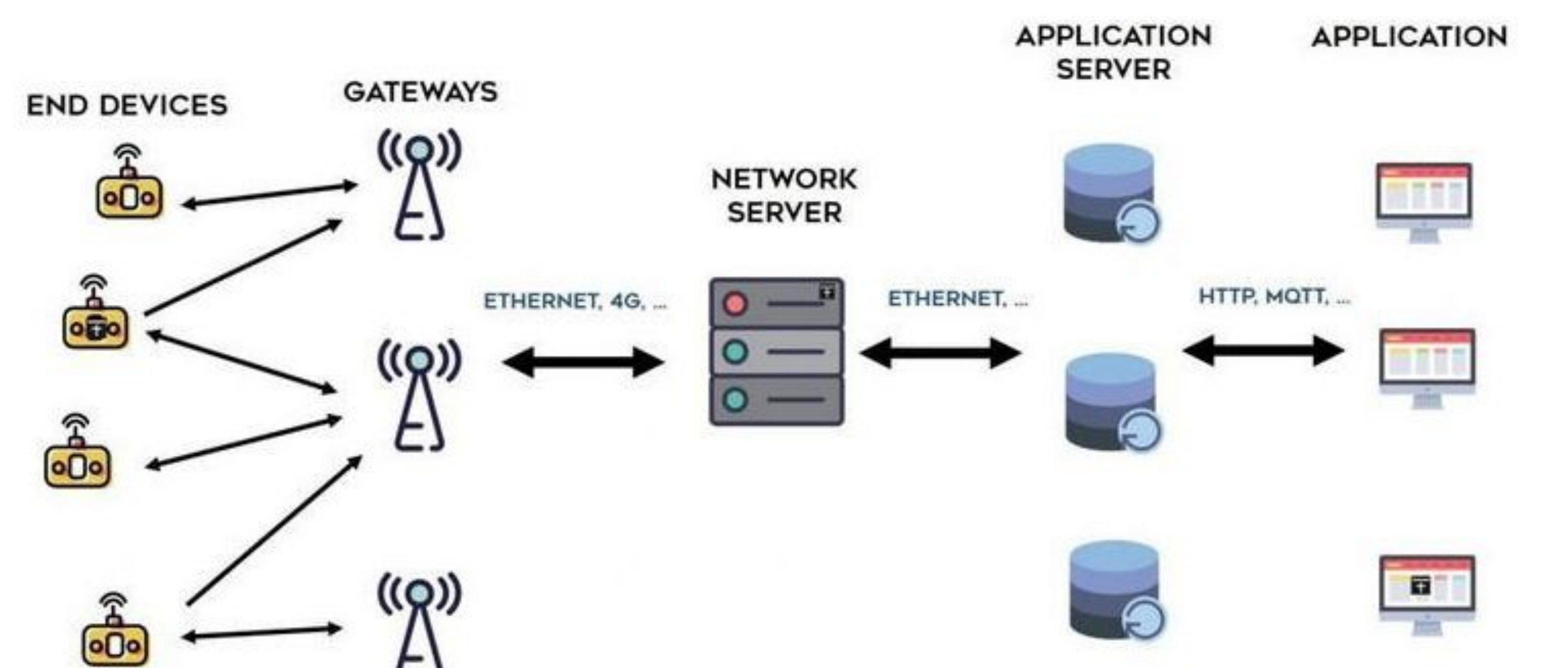
Coding rate parameter



Effect of CR on the consumed energy, SF = 7 and BW = 500 KHz

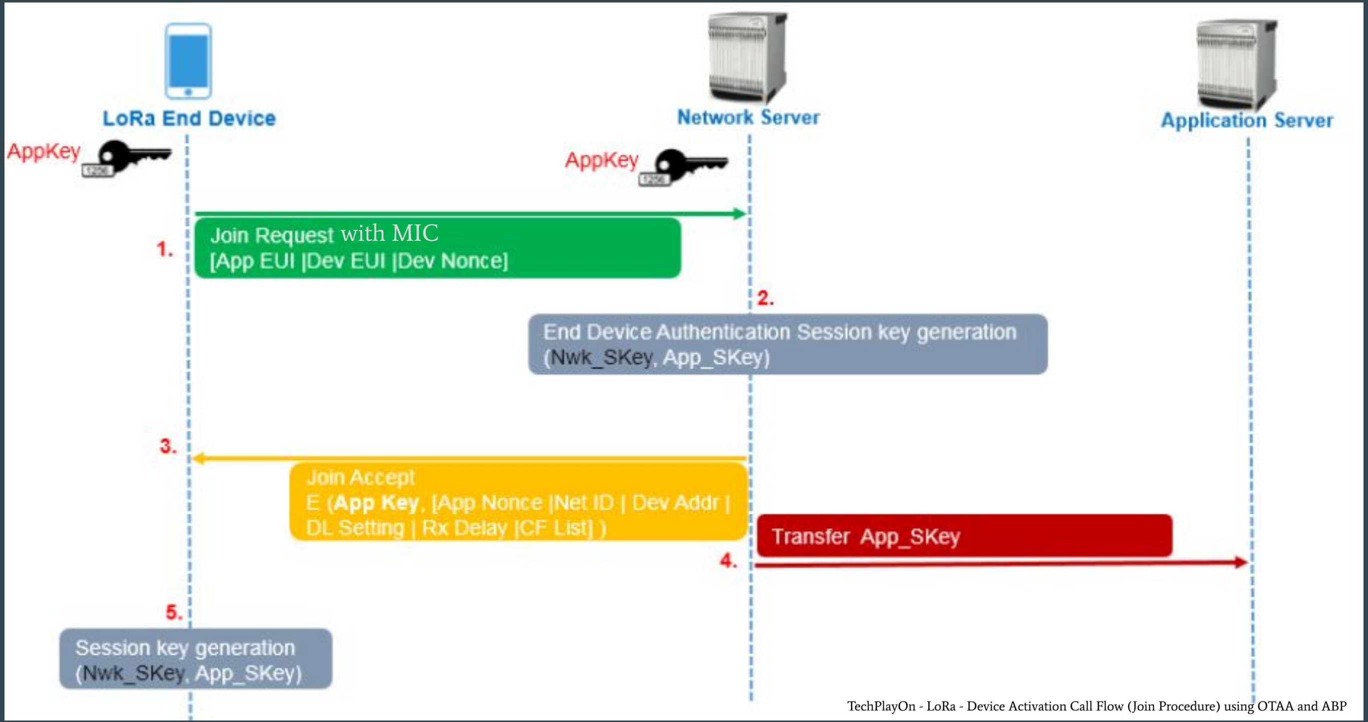
Security - LoRaWAN

Security - LoRa architecture



Architecture d'un réseau LoRaWAN, FrugalPrototype : De la technologie LoRa au réseau LoRaWAN

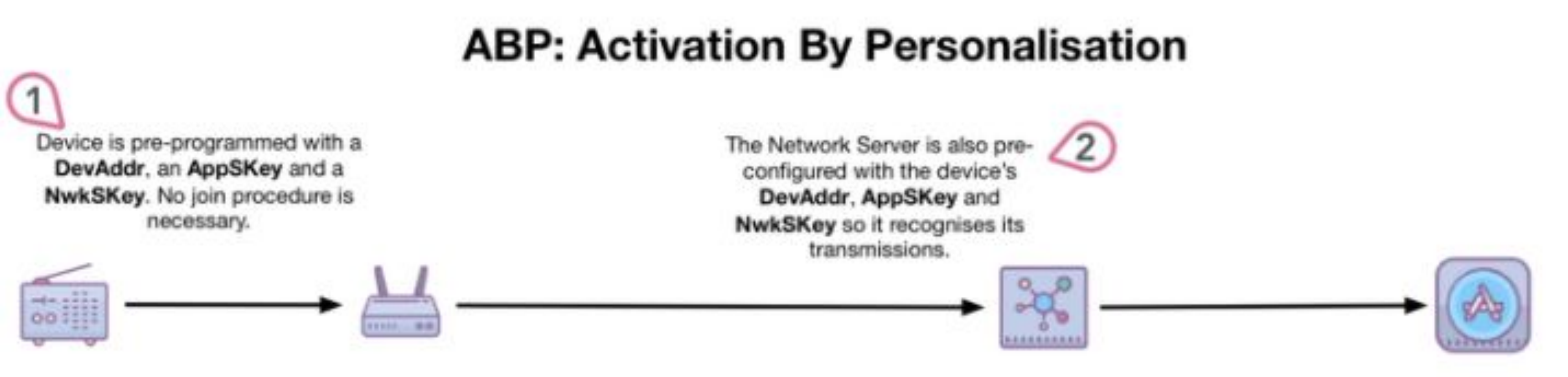
Security - Over-The-Air Activation (OTAA)




```
mac=aes128_cmac(AppKey, MHDR | AppEUI | DevEUI | DevNonce)
MIC = mac[0..3]
```

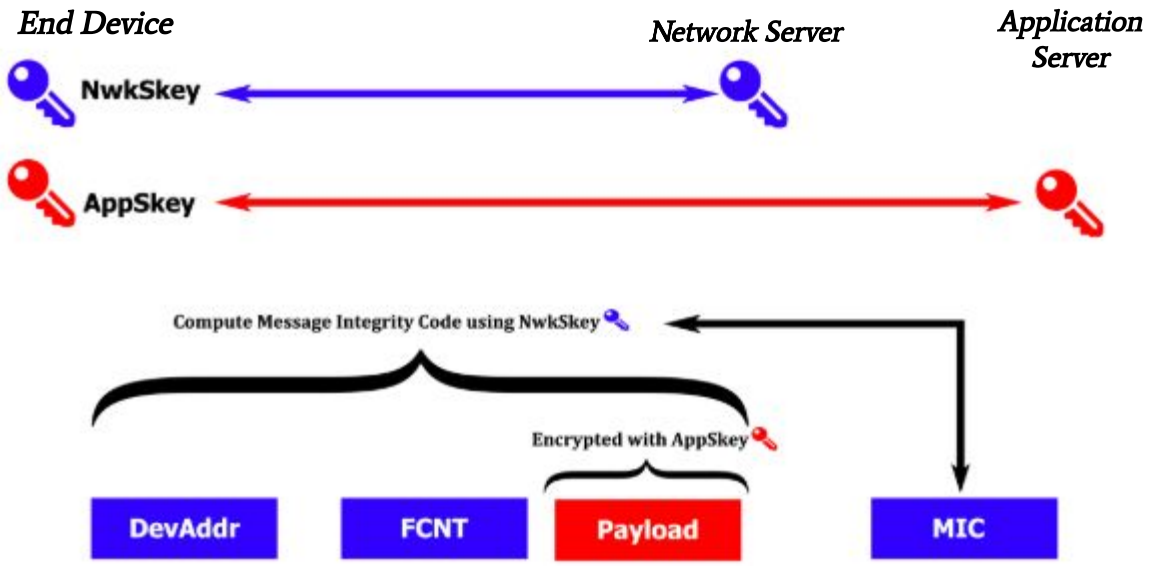
```
NwkSKey = aes128_encrypt(AppKey, 0x01 | AppNonce | NetID | DevNonce | pad16)
AppSKey = aes128_encrypt(AppKey, 0x02 | AppNonce | NetID | DevNonce | pad16)
```

Security - Activation by Personalization (ABP)



Newieventures - LoRaWAN : OTAA or ABP ?

Security - Message Encryption



Medium - LPWAN, LoRa, LoRaWan and the Internet of things - Prashant Ram

Thanks for your attention

References:

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- Analysis of LoRaWAN v1.1 Security, Ismail Butun, Nuno Pereira, Mikael Gidlund, June 2018