LoRa

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Lora in the ISM bands channel spacing : 200kHz

- 433MHz Band
  - ✓ Max Tx power 10dBm
- EU 863-870MHz Band
  - ✓ Max Tx power : 20dBm, by default 14dBm
  - ✓ Rx channels for the *gateways*

Modulation	Bandwidth [kHz]	Channel Frequency [MHz]	FSK Bitrate or LoRa DR / Bitrate	Nb Channels	Duty cycle
LoRa	125	868.10 868.30 868.50	DR0 to DR5 / 0.3-5 kbps	3	<1%

  - ✓ *Duty cycle* is computed **per sub band**
  - ✓ Each gateway may listen to 16 canaux in parallel.

Specified to the *devices* when they associate

Lora in the ISM bands channel spacing : 200kHz (cont.)

DataRate	Configuration	Indicative physical bit rate [bit/s]
0	LoRa: SF12 / 125 kHz	250
1	LoRa: SF11 / 125 kHz	440
2	LoRa: SF10 / 125 kHz	980
3	LoRa: SF9 / 125 kHz	1760
4	LoRa: SF8 / 125 kHz	3125
5	LoRa: SF7 / 125 kHz	5470
6	LoRa: SF7 / 250 kHz	11000
7	FSK: 50 kbps	50000
8..15	RFU	

TXPower	Configuration
0	20 dBm (if supported)
1	14 dBm
2	11 dBm
3	8 dBm
4	5 dBm
5	2 dBm
6..15	RFU

- **Real world range : a few km NLOS, $\approx$ 20 km with LOS**
- Payload max size : from 59 to 230 B

(for *datarate* 4 and higher)

ISM 868MHz band

http://www.arcep.fr/uploads/tx_gsavis/14-1263.pdf

http://www.anfr.fr/fileadmin/mediatheque/documents/tnrbf/TNRBF_

Ed2013_Mod8_-_Version_du_19_février_2016.pdf

EIRP: 14dBm

Freq.	*Duty cycle*	other uses
863-865 MHz	0,1 %	Cordless microphones
865-868 MHz	1%	RFID – ??
868-868,6 MHz	1%	(802.15.4 Sub-GHz)
868.6-868,7 MHz	—	Alarms
868,7-869,2 MHz	0,1%	
869,2-869,7 MHz	—	Alarms
869,7-870 MHz	1%	air force

ERC Recommendation 70-03

`http://www.erodocdb.dk/docs/doc98/official/pdf/rec7003e.pdf`

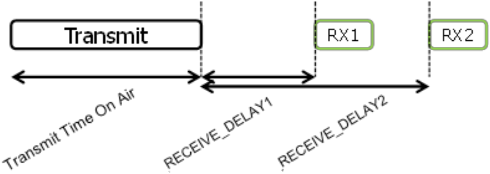
Sub band	Freq. (MHz)	Power	*Duty cycle*	BW (MHz)
h1.3	863-870	14 dBm	0.1%	7
h1.4	**868-868.6**	14 dBm	**1%**	0.6
h1.5	868.7-869.2	14 dBm	0.1%	0.5
h1.6	**869.4-869.65**	27 dBm	**10%**	0.25
h1.7	869.7-870	7 dBm	100%	0.3
h1.7	869.7-870	14 dBm	1 %	0.3

Duty cycles are computed per sub-band : a *device* may consume 1% in h1.4, 10% in h1.6, 1% in h1.7, during the same hour for instance

h1.4 encompasses the **3 defaults LoRa channels**,
h1.6 is used by the GW to respond to the devices (*cf.* RX2)

Transmissions

- Classe A (**A**ll devices)
  - ✓ Exchange **always initiated** by the *device* **Aloha** access
  - ✓ 2 rx windows follow the transmission
    at +1 s (same channel as TX) and +2 s (channel and SF fixed in advance)

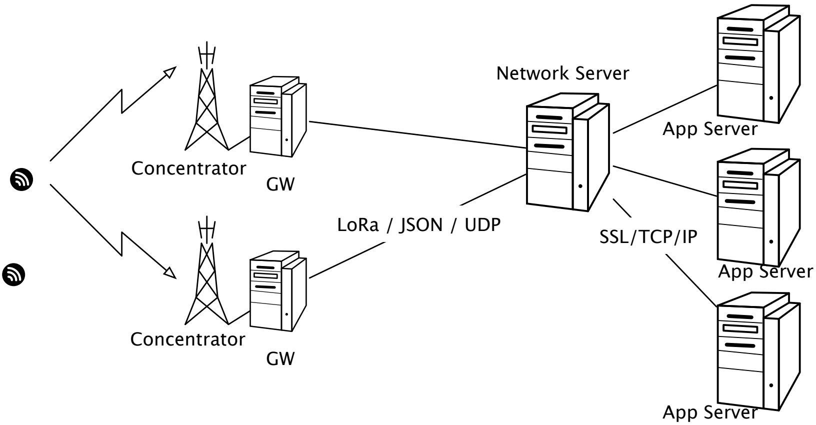


By default : RX2 at 869.525 MHz (center of h1.6), DR0 (SF12, 125 kHz)

  - ✓ Each frame carries the *Confirmed* bit: (expecting and ACK) or *unconfirmed*

- Classe B : ***B**eacons* Device listen periodically to beacons. Regular downlink slots are defined relative to the beacon
- classe C : **C**ontinuous reception

LoRaWAN



Network Server
App Server
Concentrator
GW
LoRa / JSON / UDP
SSL/TCP/IP
App Server
Concentrator
GW
App Server

LoRaWAN (cont.)

Radio PHY layer:

Preamble	PHDR	PHDR_CRC	PHYPayload	CRC*

Figure 5: Radio PHY structure (CRC* is only available on uplink messages)

PHYPayload:

1B	…	4B
MHDR	MACPayload	MIC

Figure 6: PHY payload structure

MACPayload:

	0 or 1B	…
FHDR	FPort	FRMPayload

Figure 7: MAC payload structure

FHDR:

4B	1B	2B	0…15B
DevAddr	FCtrl	FCnt	FOpts

Figure 8: Frame header structure

LoRaWAN (cont.)

- The frames only carry a single address, the *device* source/destination
- Application demultiplexing : “FPort” (0: pure MAC command)
- *Piggybacking* of MAC commands (power, data rate, channels, device state, rx delay[1] …) in the will typically get several copies of the same frame (they have a seq. number)
  The net. server selects the best GW for a reply (if applicable)
- In the core networks, the frames are forwarded with quite a bit of ancillary data (power, timestamp…)

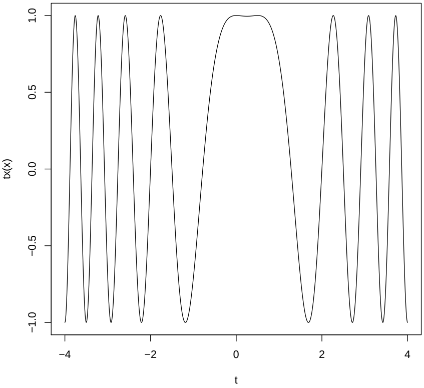
[1] RX2 is always 1 s behind RX1

Activation

- ABP — *Activation By Personalization*
- OTAA — *Over-The-Air Activation*
  - √ DevAddr allocation: the DevAddr is composed of 7 bits of Network ID and then a device-specific addr. (The DevAddr is assigned by the guest network. The real / immutable device identifiers are its NetEUI and AppEUI, which are stored in the device)
  - √ Computation of the session keys: AppSKey, NetSKey, from the AppKey (128 bits) stored in the *device*

What is a *chirp* ?
CSS : Chirp Spread Spectrum

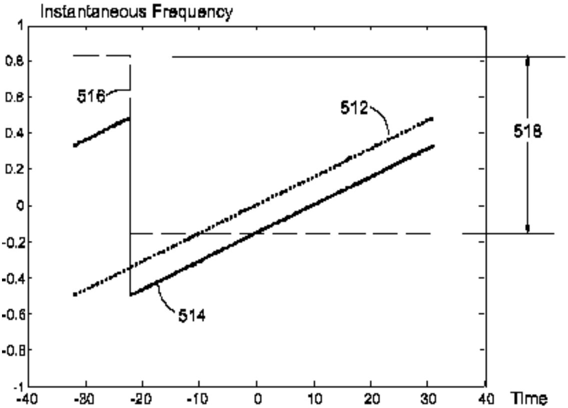
- A linear frequency sweep/ramp $-\frac{BW}{2} < f < \frac{BW}{2}$



- Used by radars, bats, dolphins…

Coding information on a chirp

- It is the start freq. offset that codes the information (line 514)



Reception

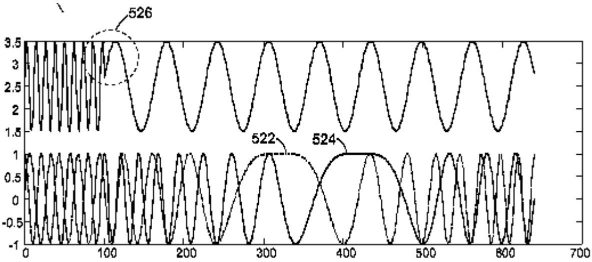
- Multiplication of rx signal with a complex conjugate chirp (down chirp)

$$e^{2\pi jt[f_0+(at+b) \bmod BW]} \times e^{-2\pi jt[f_0+(at) \bmod BW]}$$
$$= e^{2\pi jt[b \bmod BW]}$$

N.B. : $a = \frac{BW^2}{2^{SF}} \rightarrow$ sweep BW in time $\frac{2^{SF}}{BW}$

Reception (cont.)

- if both chirps are in sync, we get a constant, otherwise



FFT-based reception

- FFT after sampling at rate BW
- The symbol duration is N/BW $\rightarrow$ N samples
- By frequency aliasing, **a single frequency appears in the FFT** !

Spread spectrum

- Spreading factors from 7 to 12 $\Leftrightarrow$ N goes from 2^7 to 2^{12},
  7 to 12 bits per symbol
- The bigger the **SF** the longer the **chirp** — 33 ms @ SF12.
  For LoRa, **the preamble is also proportional to the SF**

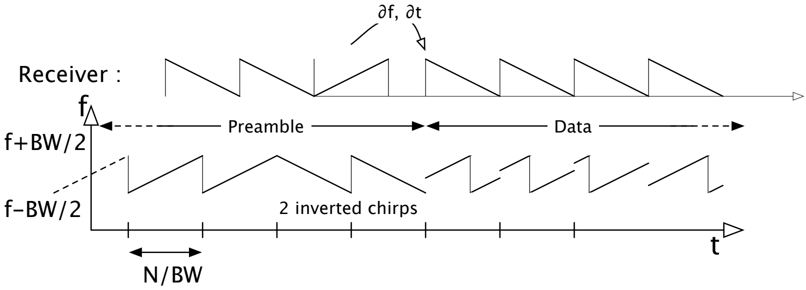
The actual SF dynamics are ≈ 20 $\qquad R_b = SF \times \frac{BW}{2^{SF}}$

- Error correcting codes $R = \frac{4}{5}$
- The actual max. SF is $\approx$ 340 ($2^{12}/12$), so a transmission may survive a collision with a node closer by a ratio of $\approx \sqrt{340}$

Frame sizes

- Depends on SF : 51B payload at SF12, 242 at SF8 and SF7…
- 51B @ SF12 $\rightarrow$ 1,3 s of continuous transmission!

Initial Synchronisation



- The *device* may quickly assess if there is a transmission $\rightarrow$ short rx1 and rx2 windows
- The inverted chips in the preamble allow to find the two unknown variable the transmitter **frequency** and the relative time **reference**

Localization

- The observed δt at several GW allow to compute relative time of arrival
- Trilateration
- Time ref. from GPS at the GWs

A few remarks

- A receiver can receive at several SF simultaneously ($\approx 30\,dB$)[2].
- It needs as many reception circuits as there are SFs
  7 channels (6 CSS + 1 FSK) on all LoRa GWs
- Localization is a by product of PHY initial sync.
- Cell breathing
  - ✓ Having more GWs allows :
    - Lower the SF for closer devices
    - lower the power

[2] C. Goursaud & J.M. Gorce : "Dedicated networks for IoT : PHY / MAC state of the art and challenges"