LoRa knowledge sharing session

Almere, the Netherlands

January 19,   2016

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Version 0.3

Agenda

- What modules are we using
- How to connect them
- How to configure the Gateway
- How to configure the Mote
- Antenna considerations
- The internet of things server
- Using the sensor data within an App
- More about LoRa Radio

What modules are we using: The LoRa gateway

Thanks to @nestorayuso for the detailed instructions.

Based on Multitech mCard-LORA, containing:

- 1x Semtech SX1301 Concentrator and
- 2x Semtech SX1257 I/Q Transceivers
- USB/SPI interface

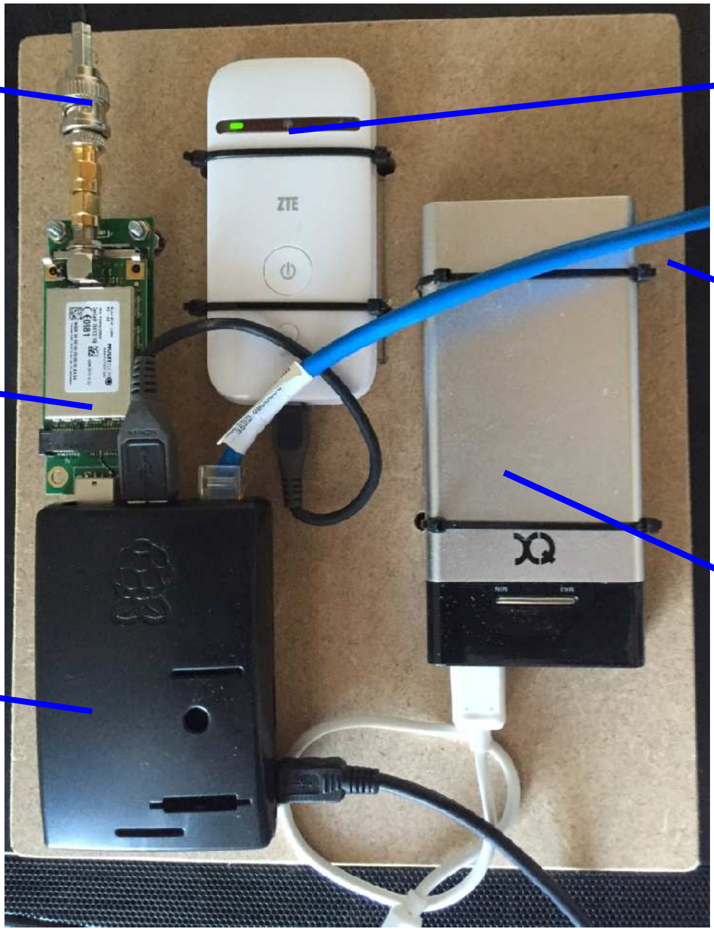
More information:

https://github.com/mirakonta/lora_gateway/wiki
http://www.digikey.com/product-detail/en/MTAC-LORA-868/881-1243-ND/5322991

Costs: 200 Euro

The LoRa gateway assembled

The mCard module is controlled by a Linux server, e.g. Raspberry Pi.
For a complete “mobile” gateway, a 3G modem and Battery Pack can be added. This results in:



RG58MIL coax cable to 868 MHz GP antenna

Multitech mCard-Lora Gateway module

Raspberry Pi 2 Model B

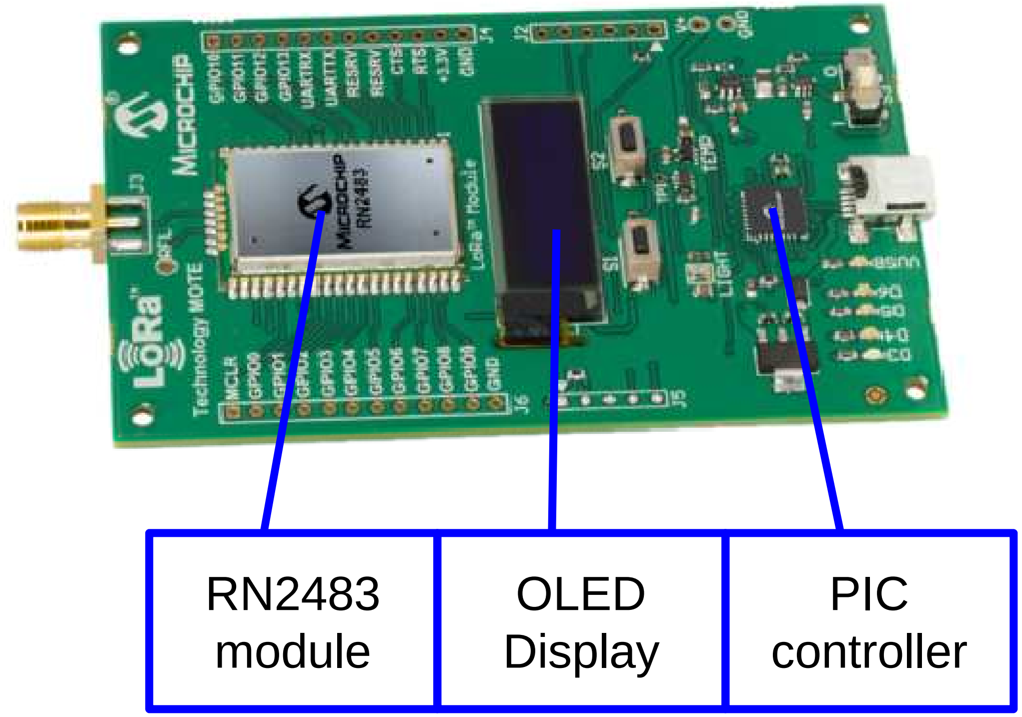
ZTE 3G data modem (and WiFi AP)

UTP cable, (removed during mobile operations)

Xquisit Battery Pack 10 Ah

What modules are we using: The LoRa sensor

868MHz RN2483 LoRa(TM) Technology Mote
Based on the RN2483 MicroChip module and PIC controller.



RN2483 module

OLED Display

PIC controller

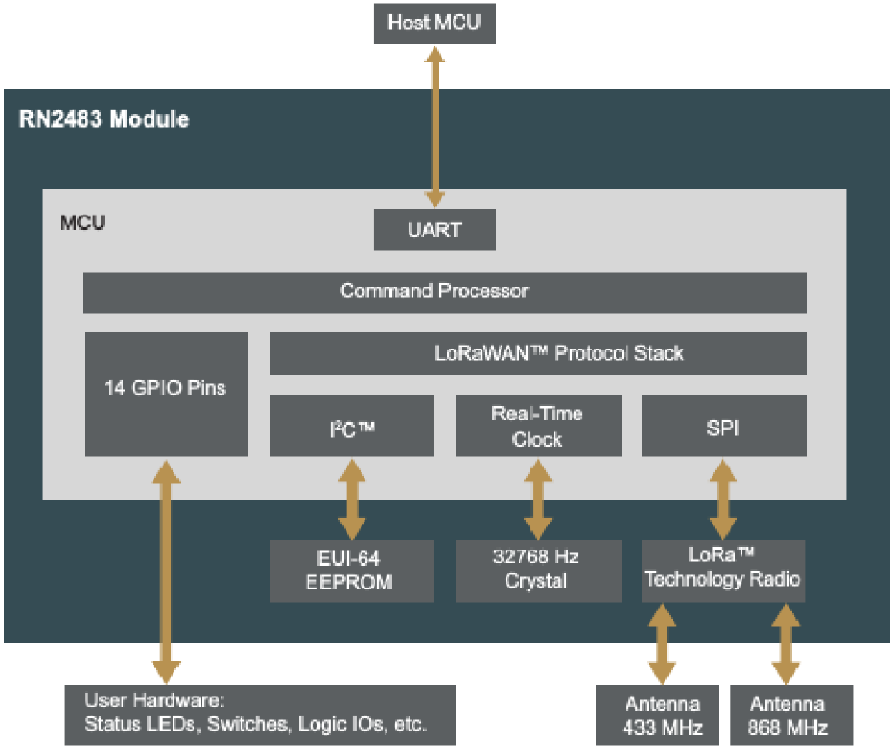
More information:

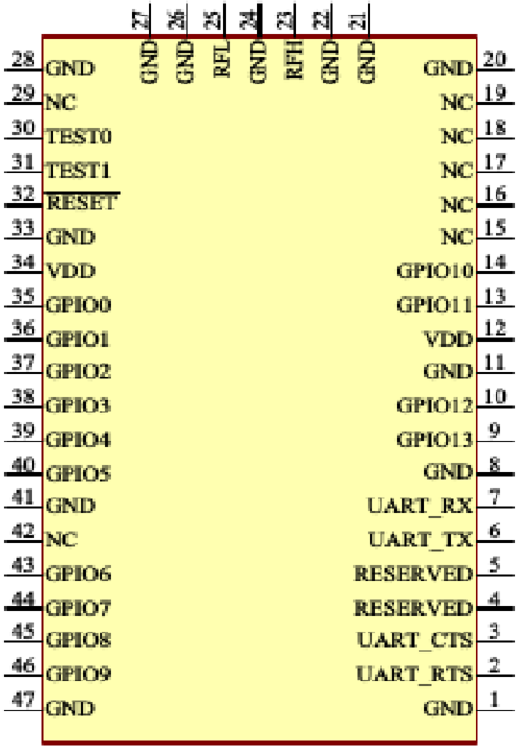
http://www.microchip.com/DevelopmentTools/ProductDetails.aspx?PartNO=dm164138

Costs: 60 Euro

The LoRa sensor: inside

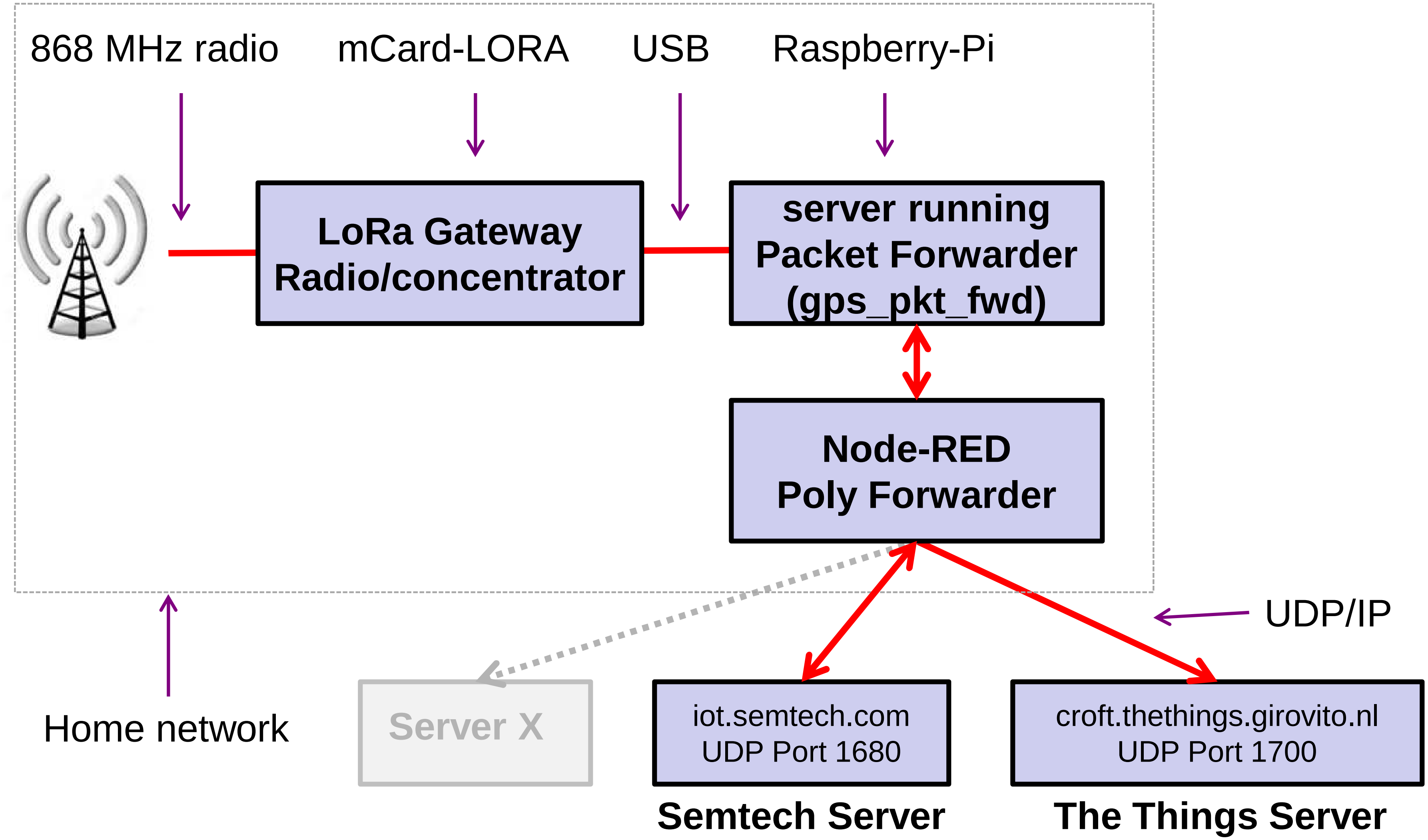
- Microchip RN2483 LoRa module:





- Microchip PIC18LF25K50 (works in USB/UART bridge or application mode),
- 4-line OLED display,
- Thermometer, Light intensity meter, 2x push button switches, LED’s,
- USB 2.0 interface to communicate with RN2483 module,
- Holder for 2x AAA batteries,
- 868 MHz antenna, mini-USB cable

How to connect them together: The LoRa Gateway



868 MHz radio

mCard-LORA

USB

Raspberry-Pi

LoRa Gateway Radio/concentrator

server running Packet Forwarder (gps_pkt_fwd)

Node-RED Poly Forwarder

UDP/IP

Home network

Server X

iot.semtech.com
UDP Port 1680

croft.thethings.girovito.nl
UDP Port 1700

Semtech Server

The Things Server

How to configure the Gateway

Install packet forwarder; this forwards data received by the gateway to a defined destination.

https://github.com/Lora-net/packet_forwarder/

```
#  cd     packet_forwarder/gps_pkt_fwd
#  cat    local_conf.json
{
        "gateway_conf": {
        "gateway_ID": "008000000000A465",
        "serv_port_up": 1700,
        "serv_port_down": 1700,
        "server_address": "croft.thethings.girovito.nl",
        "forward_crc_valid": true,
        "forward_crc_error": false,
        "forward_crc_disabled": true,
        "fake_gps": true,
        "ref_latitude": 52.216434,
        "ref_longitude": 5.467384,
        "ref_altitude": -1
    }
}
```

Gateway ID – defined by the GW

UDP Port forward 1700 on your router to your server.

Forward the mote data to this address

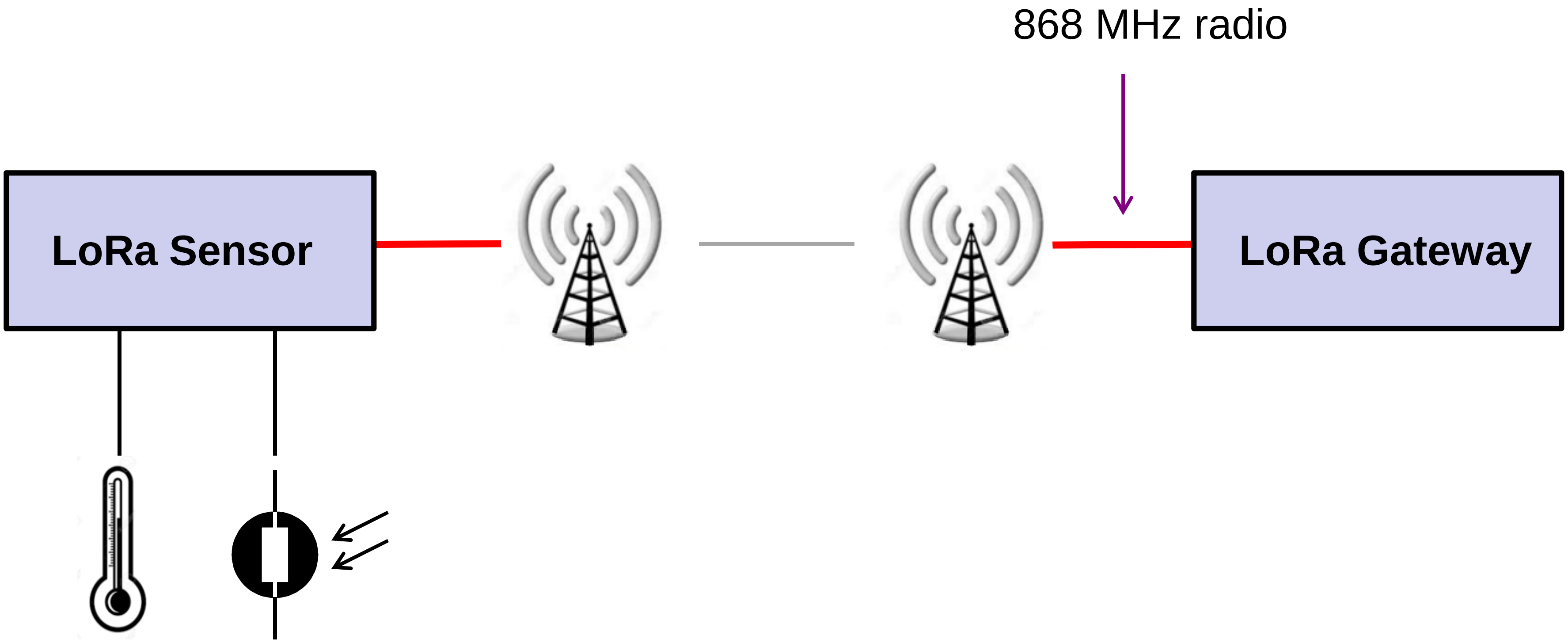
Or… your server address and port for node-red

The LoLa of your gateway

Also edit the **global_conf.json** file;   update the gateway_ID parameter.

Run the forwarder :   sudo gps_pkt_fwd

How to connect them together: The LoRa Sensor



868 MHz radio

LoRa Sensor

LoRa Gateway

Temperature and Light sensor

How to configure the Sensor

The Microchip sensor RN2483 has a USB connector

Install YAT on your Windows PC to setup USB communication

Port type: Serial Port (Com), Serial Port: COM4 (but could be different)
type: text, 9600/8/none/1, flow control: none. Text settings, add 500ms after the CrLf)

Enter the next settings on the mote

```
mac set appskey 2B7E151628AED2A6ABF7158809CF4F3C     ← agreed open key
mac set nwkskey 2B7E151628AED2A6ABF7158809CF4F3C
mac set ch dcycle 0 9
mac set ch dcycle 1 9
mac set ch dcycle 2 9
mac set adr off
mac set devaddr 02013D20   ← your mote id, please consult the IOT forum for guidelines
mac join abp
mac set dr 0
mac save
```

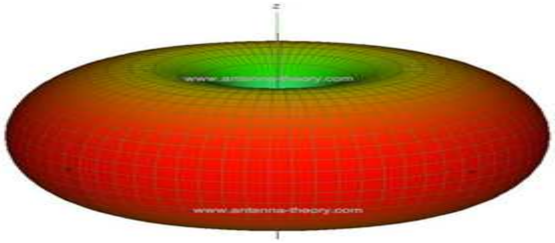
Optionally you may want to update the radio parameters ‘radio set pwr 15’ and ‘radio set sf sf12’

More information regarding command and parameter can be found in the LoRaWAN specifications:
https://www.lora-alliance.org/portals/0/specs/LoRaWAN%20Specification%201R0.pdf

Antenna considerations

The recommended gateway antenna is a ground plane antenna (omni-directional)
For example: Aurel 650200599

Costs: 35 Euro (conrad.nl), including 2.5 m RG58MIL coax cable
Cable has F-connector at antenna side and BNC connector at Gateway side.

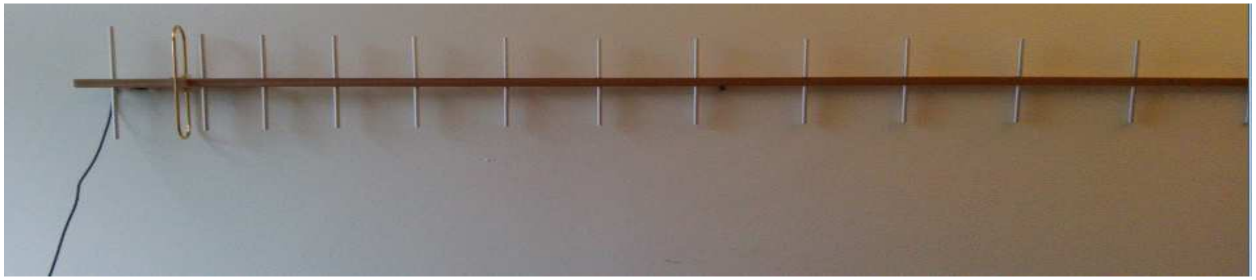


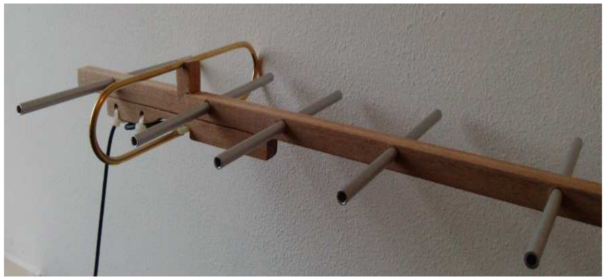
Attenuation: about 4 dBi (10^0.4 = 2.5x)

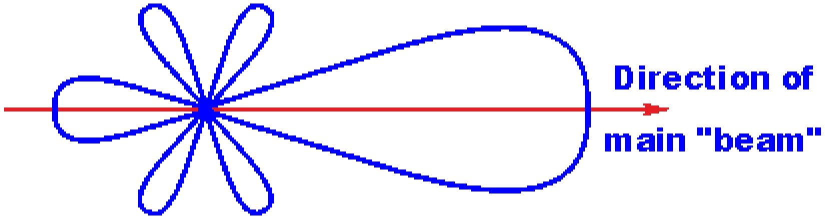
Antenna considerations

You can also make your own antenna…Yagi, highly directional

Estimated costs: 7 Euro

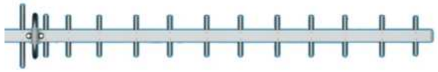






Attenuation: 14.2 dBi (10^1.42 = 25x)

Antenna considerations



- Place the antenna as high as possible to improve the line of sight

- Place the antenna vertically polarized

- Avoid metal obstacles nearby since it will take away radio-sight

- Make use of high quality HF cable (e.g. RG58)

- The gateway impedance is 50 Ω, do not connect another impedance or you will get a bad SWR.

- Keep the cable as short as possible to avoid loss.

- Consider to mount the gateway device as close as possible to the antenna and transport the data via a USB cable to the packet-forwarder server or use UTP cable from server to internet, PoE is an option.

The Things Network (TTN) server

Receives sensor records from the gateways
Stores the records in a database
Provides API access to received records from sensors
Provides API access to the gateway information.

http://thethingsnetwork.org/api/v0/nodes/02013D20/
http://thethingsnetwork.org/api/v0/gateways/008000000000A465/

Sample of recorded sensor (node) data:

```
{
        "data_raw": "QCA9AQIAAAB0EnOyqi04FEZyN3Xs",
        "gateway_eui": "008000000000A465",
        "node_eui": "02013D20",
        "frequency": 868.3,
        "data_plain": "00750018",
        "time": "2016-01-16T07:24:20.025Z",
        "rssi": -59,
        "snr": 11.2,
        "datarate": "SF11BW125",
        "data": "MDA3NTAwMTg="
},
```

Using the TTN sensor data within an Application

Using the API of the TTN server, an application has been developed called ‘MyLoraSensors’.

The MyLoraSensors application obtains records from the TTN server and shows the data in a graphical way.

The application can subscribe to a maximum of 6 sensors (mote ids) and show the temperature and light intensity curve.

With the recent update of the TTN server software to also store the radio parameters, the application also shows these parameters in a curve (RSSI, SNR)

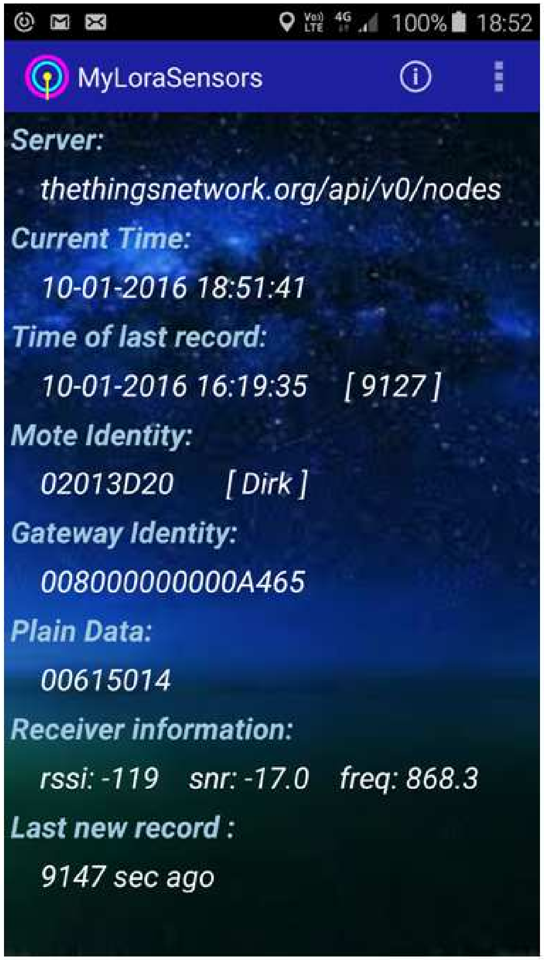
The application also features a MAP to show the geographical location of the app. If the sensor is nearby, the MAP shows the radio parameters and in this way a plot can be made of where the sensors can still be received and also with which gateway it is connected.

Optionally, with every new received record, the current (smartphone) coordinates are being forwarded to a dedicated server which presents the data on a web site.

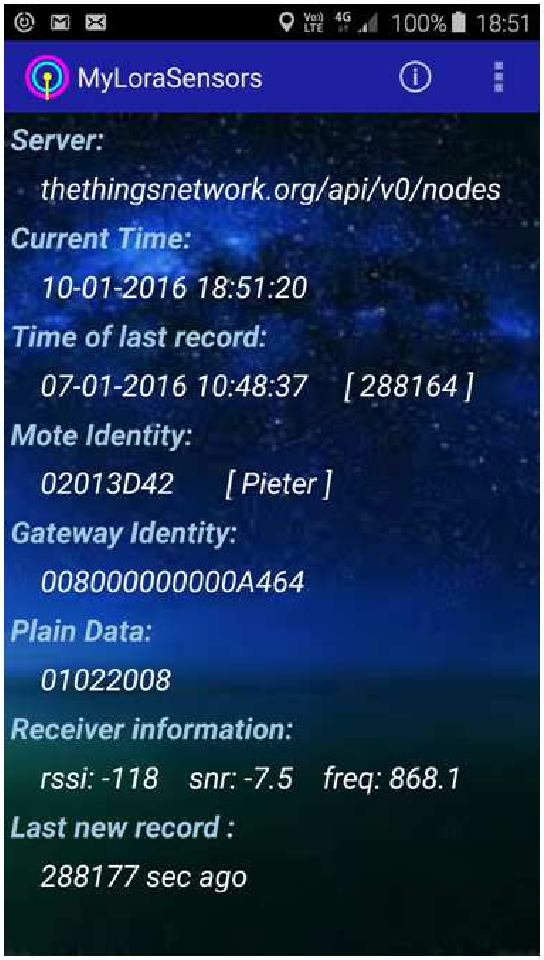
The next slides show screenshots of the app.

The MyLoraSensors application – screenshot samples

Main Screen



Server:
thethingsnetwork.org/api/v0/nodes
Current Time:
10-01-2016 18:51:41
Time of last record:
10-01-2016 16:19:35 [9127]
Mote Identity:
02013D20 [Dirk]
Gateway Identity:
008000000000A465
Plain Data:
00615014
Receiver information:
rssi: -119 snr: -17.0 freq: 868.3
Last new record :
9147 sec ago

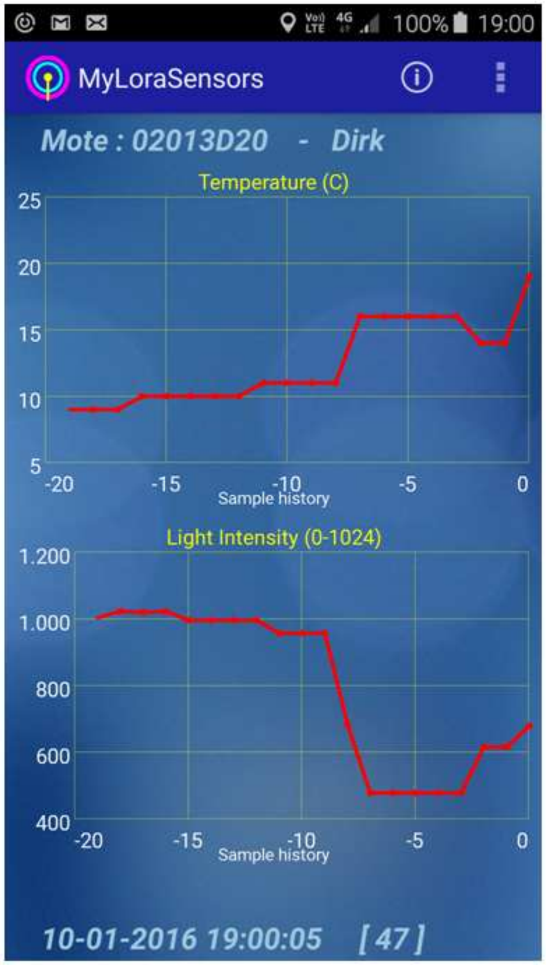


Server:
thethingsnetwork.org/api/v0/nodes
Current Time:
10-01-2016 18:51:20
Time of last record:
07-01-2016 10:48:37 [288164]
Mote Identity:
02013D42 [Pieter]
Gateway Identity:
008000000000A464
Plain Data:
01022008
Receiver information:
rssi: -118 snr: -7.5 freq: 868.1
Last new record :
288177 sec ago

Main screen cycles through the specified mote identities. Cycle time is user definable

The MyLoraSensors application – screenshot samples

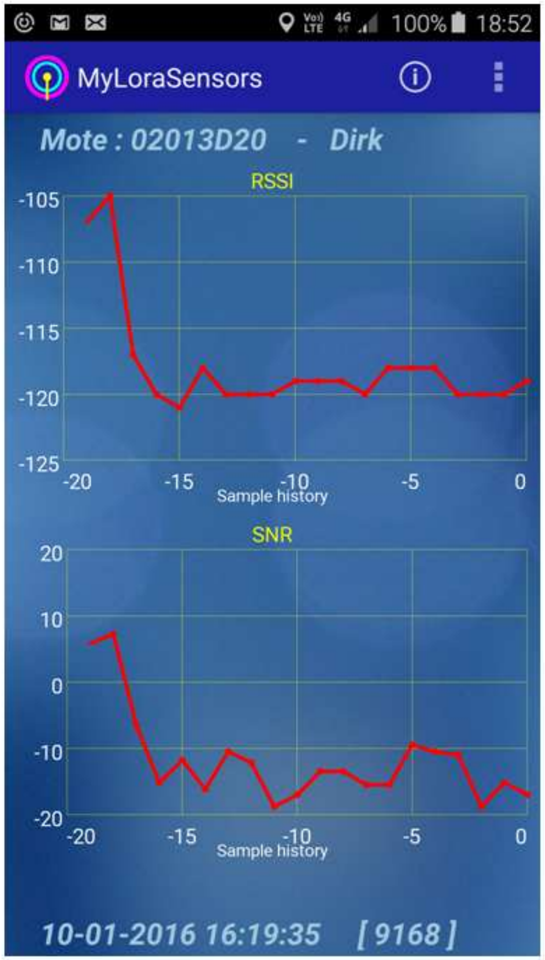
Temperature and Light intensity measurements in a graph.
Also the radio parameters can be shown



MyLoraSensors

Mote : 02013D20 - Dirk

10-01-2016 19:00:05 [47]



MyLoraSensors

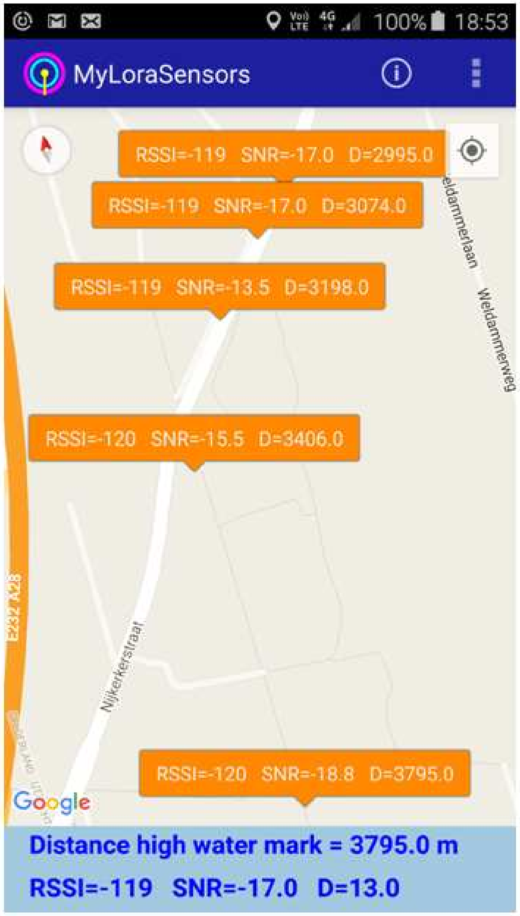
Mote : 02013D20 - Dirk

10-01-2016 16:19:35 [9168]

By swiping, the next mote can be selected.

The MyLoraSensors application – screenshot samples

Location of the Mote can be showed in a geo map
(if sensor and smartphone app are nearby)



RSSI=-119 SNR=-17.0 D=2995.0

RSSI=-119 SNR=-17.0 D=3074.0

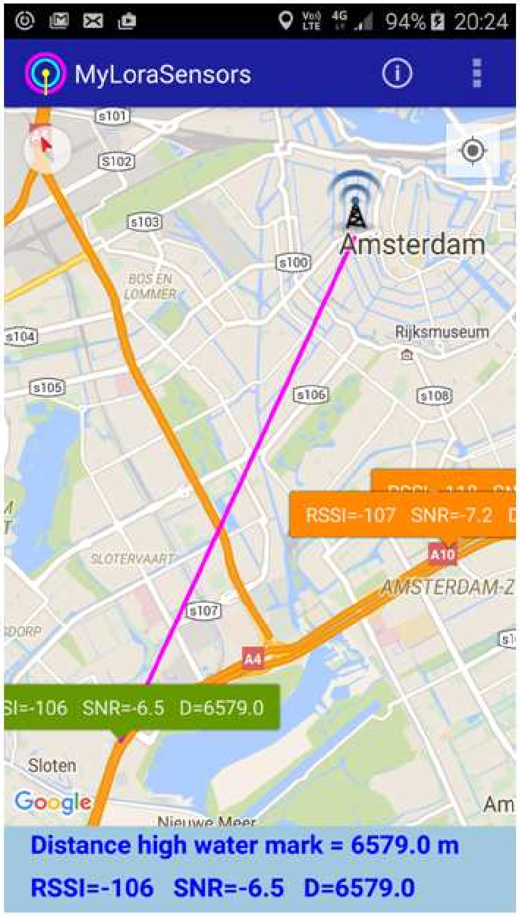
RSSI=-119 SNR=-13.5 D=3198.0

RSSI=-120 SNR=-15.5 D=3406.0

RSSI=-120 SNR=-18.8 D=3795.0

Distance high water mark = 3795.0 m

RSSI=-119 SNR=-17.0 D=13.0



RSSI=-107 SNR=-7.2 D

SI=-106 SNR=-6.5 D=6579.0

Distance high water mark = 6579.0 m

RSSI=-106 SNR=-6.5 D=6579.0

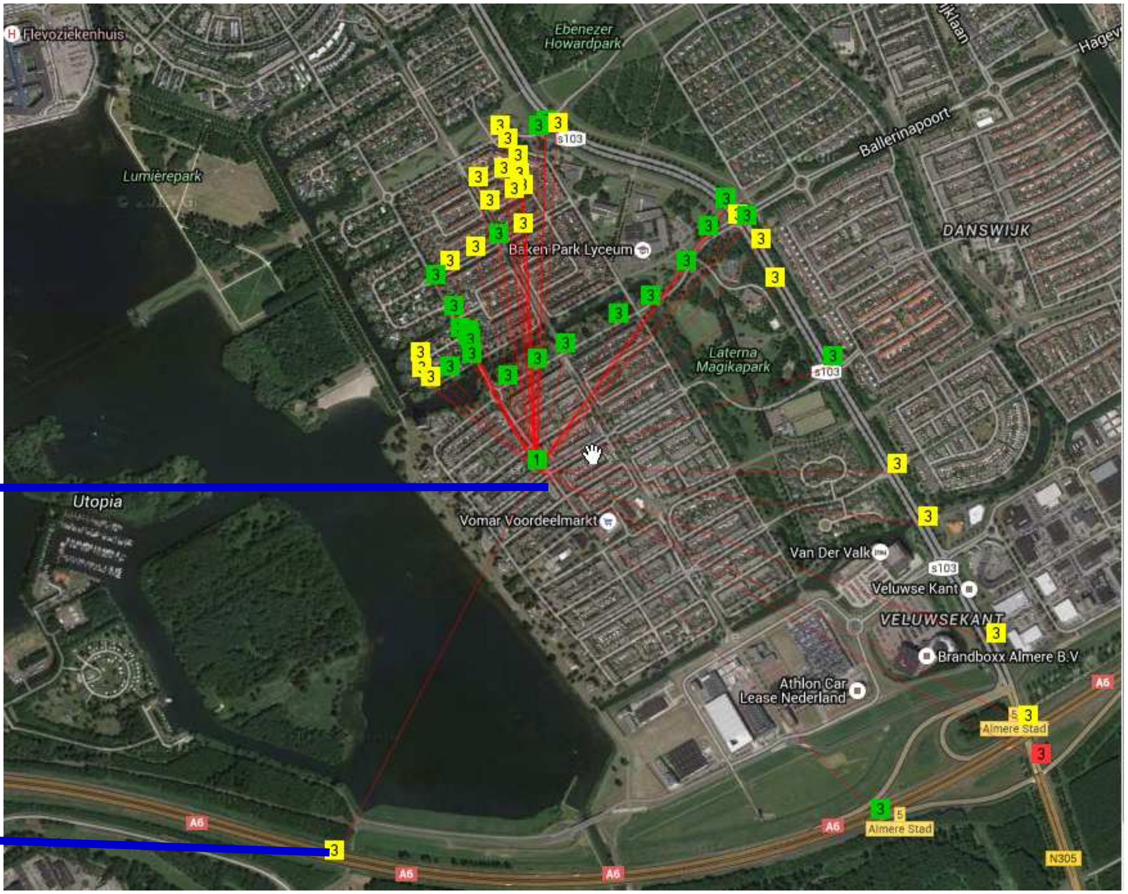
War-driving on the A4 in Amsterdam appears to have a connection with gateway id 0000024B08060112 (Rockstart)

Distance : ~ 6.6 Km

The green marker is the latest sample location, the orange ones are previous sample locations.

A web based application using sensor GPS coordinates

War-driving data of collected data visualized on a web based application.
Website under construction.



Gateway

This LoRA sensor has GPS module

Colored squares indicate the signal to noise ratio. Each square shows detailed balloon information all extracted from the stored record (not depicted here). The red lines show the connection with the current gateway. The MyLoraSensors app optionally feeds the web server with LoLa data to plot the coordinates. This map example uses data from @batilan.

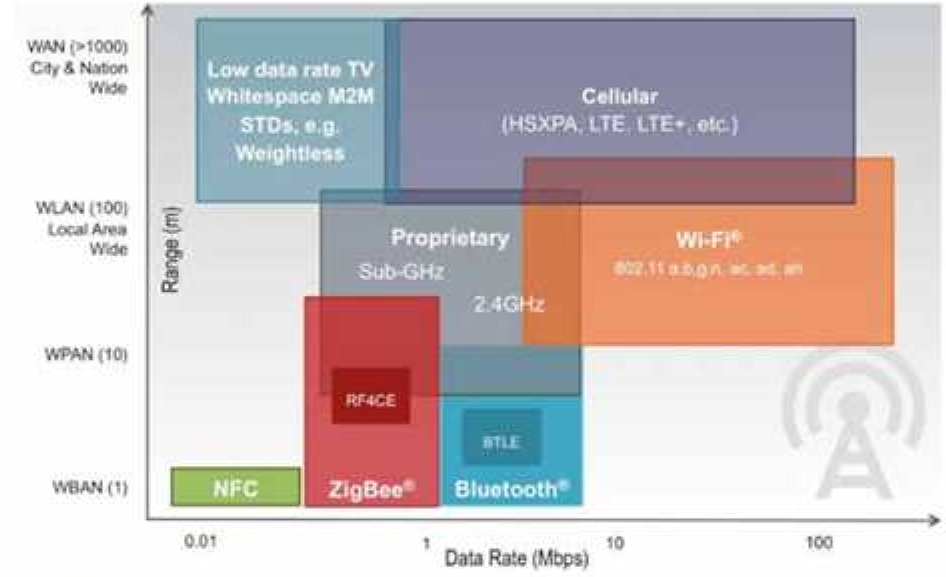
More about LoRa Radio

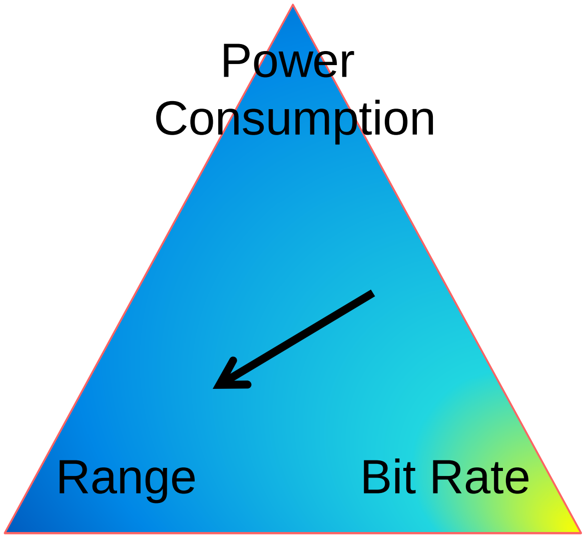
Section that explains the LoRa details with regards to Radio.

Topics will be addressed:

What is Spreading Factor
Which frequencies are being used
What happens during a concurrent mote sending data
What parameters on the sensor are important for the radio connection.
What can we do to improve the radio coverage
What does ‘confirmed’ mode mean
…

Why LoRa Radio Modulation for IoT?

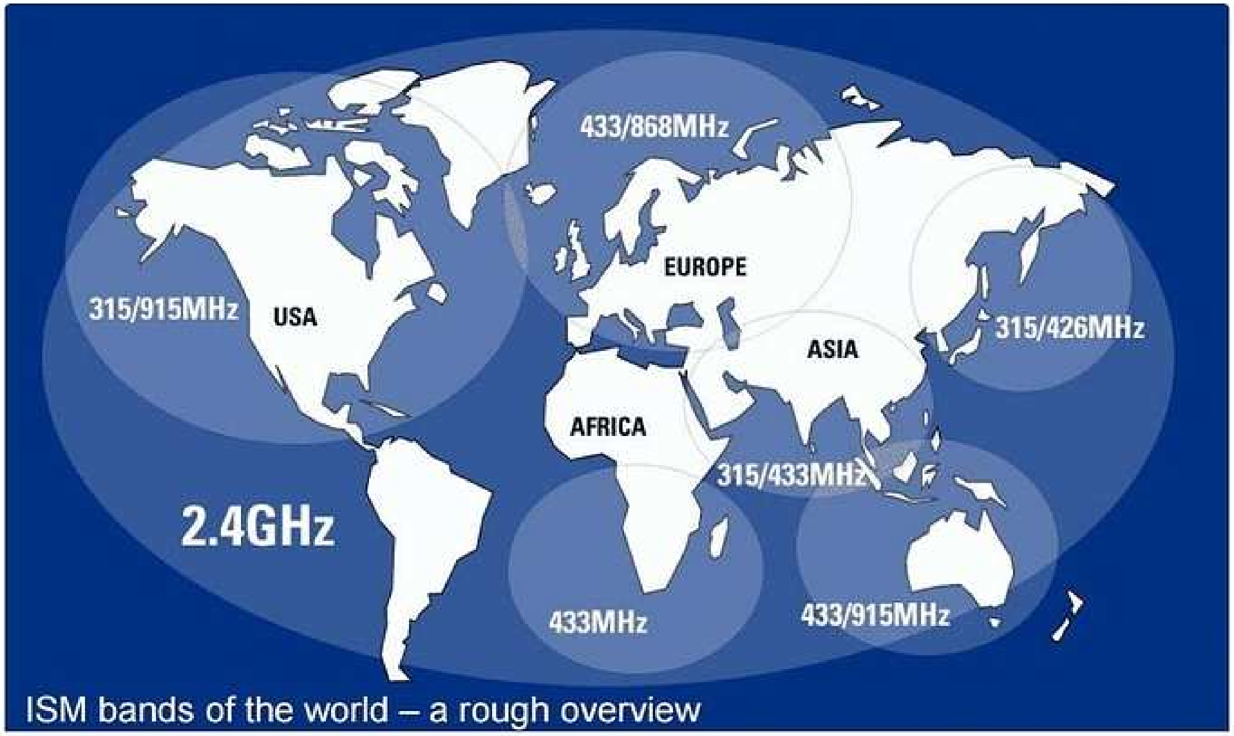




Power Consumption

Range

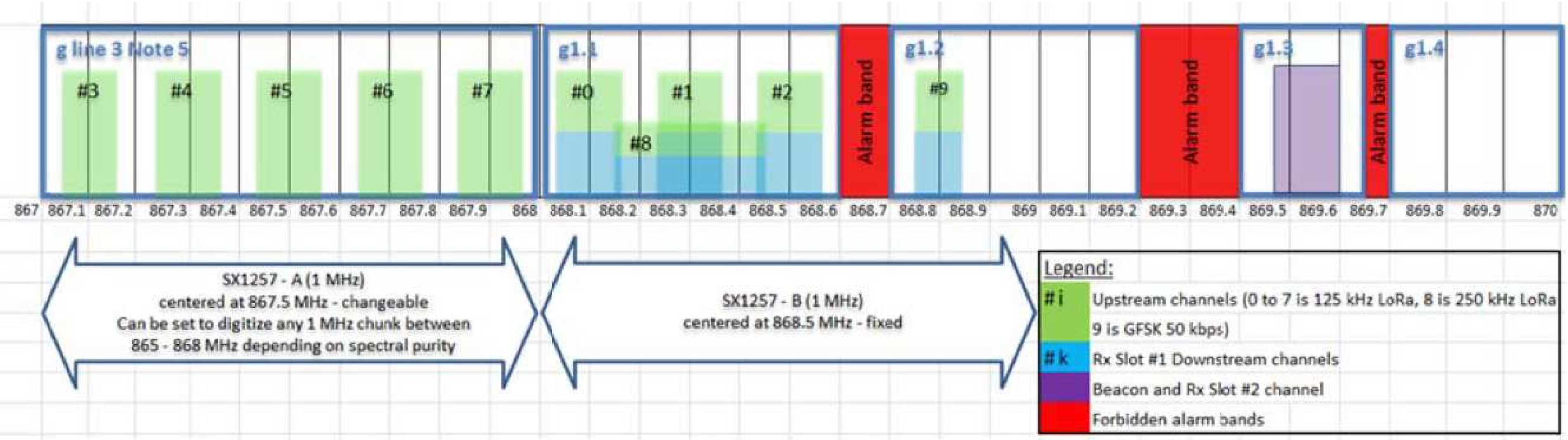
Bit Rate



ISM bands of the world – a rough overview

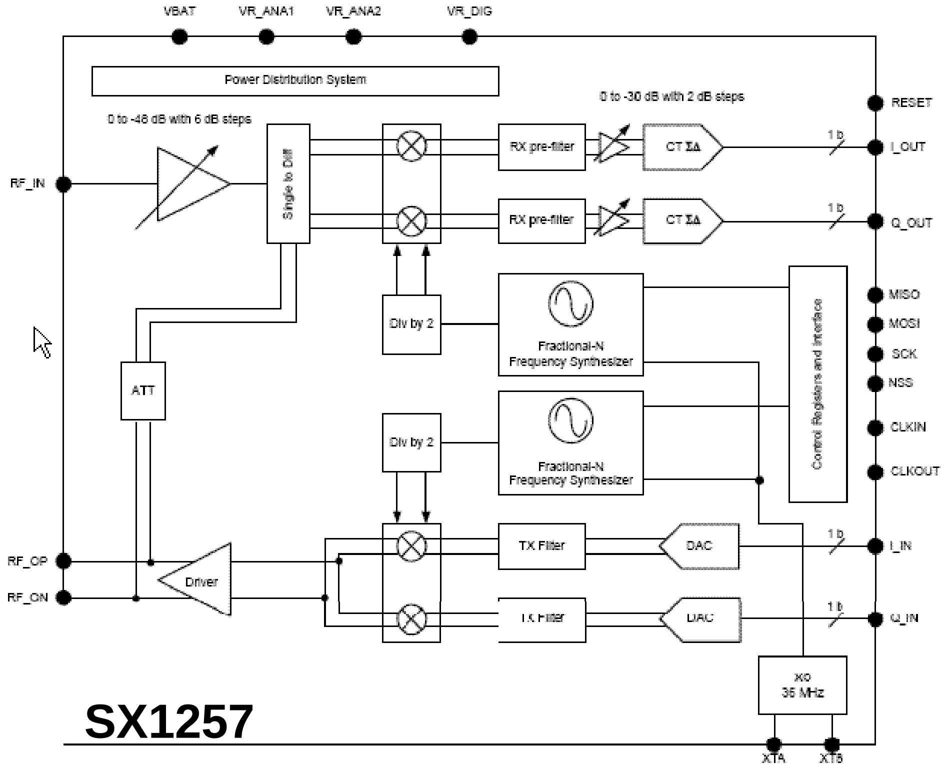
LoRa Spectrum at 868 MHz according to ETSI spec

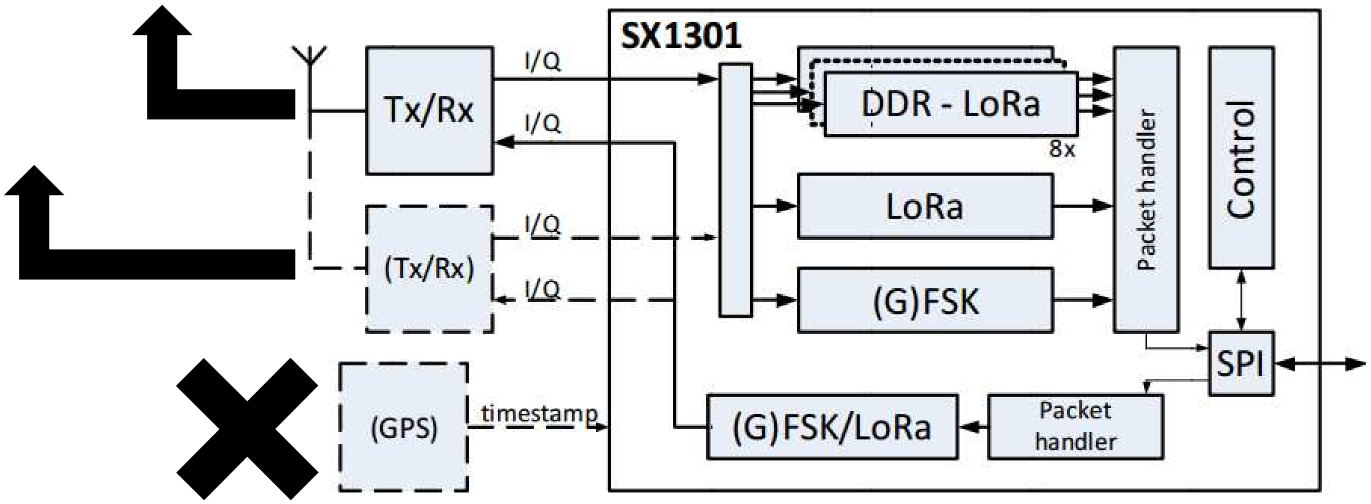
LoRa is a FM chirped spread spectrum (CSS) radio modulation format patented by Semtech. LoRa is only the Physical Layer (PHY – OSI Layer 1)
Note: a single SX1257 I/Q transceiver can handle only a 1 MHz baseband



#	Freq (MHz)	LoRa BW	SF Range	Time allowed on this Channel per hour	Time allowed	Regulatory Regime	Max ERP
0	868.1	125	SF7-12	t1=36s - t2-t3-t9	t1+t2+t3+t9 < 36s/hour	g1.1	25mW or +14dB
1	868.3			t2=36s - t1-t3-t9			
2	868.5			t3=36s - t2-t1-t9			
3	867.1			t4=36s - t5-t6-t7-t8	t4+t5+t6+t7+t8 < 36s/hour	g line 3	
4	867.3			t5=36s - t4-t6-t7-t8			
5	867.5			t6=36s - t4-t5-t7-t8			
6	867.7			t7=36s - t4-t5-t6-t8			
7	867.9			t8=36s - t4-t5-t6-t7			
8	868.3	250k	SF7	t9=36s - t1-t2-t3	t1+t2+t3+t9 < 36s/hour	g1.1	
9	868.8	GFSK 50kbps		t10=3.6s	t10<3.6s/hour	g1.2	

LoRa Gateway Internals

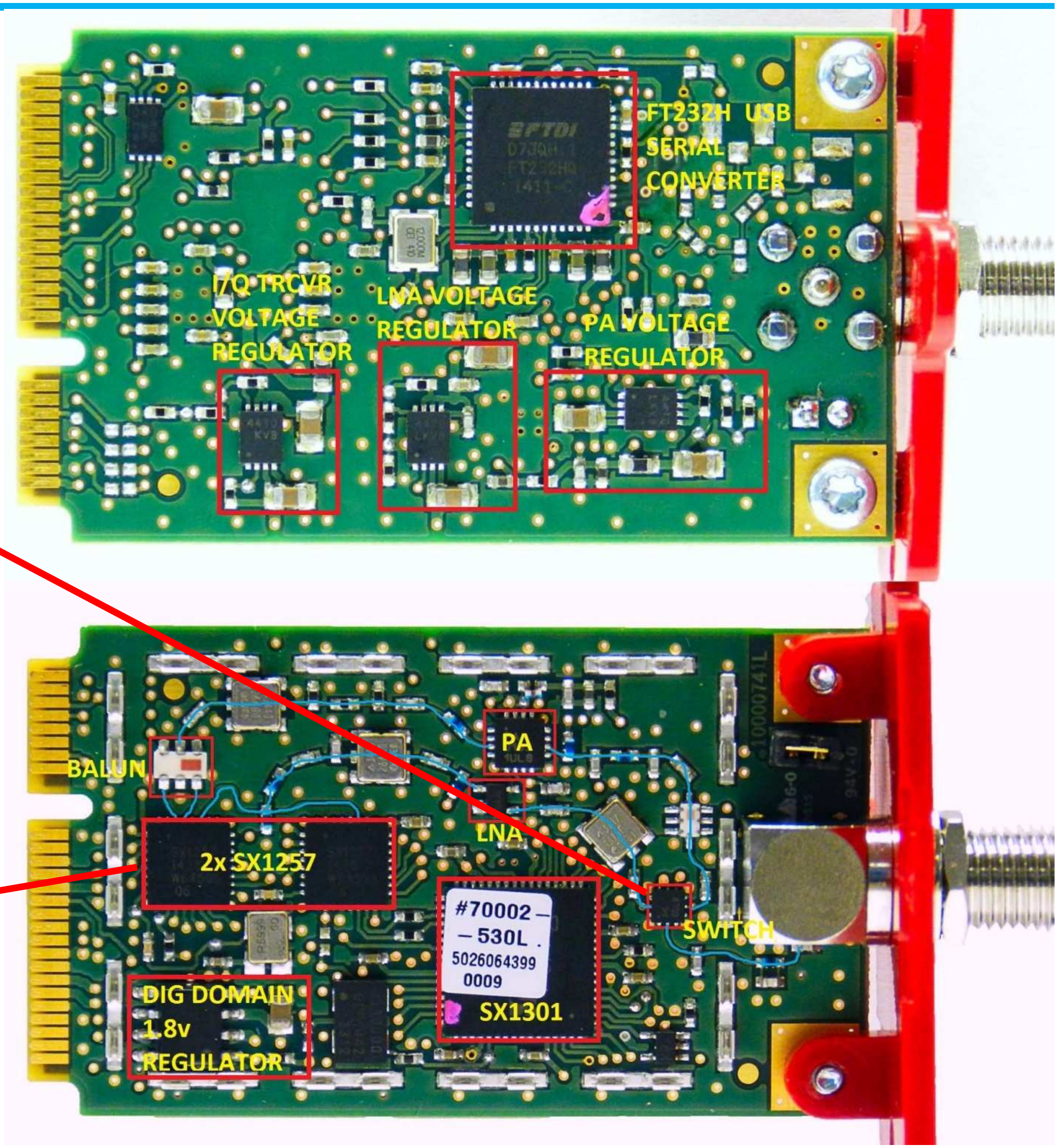




LoRa Gateway – a closer look

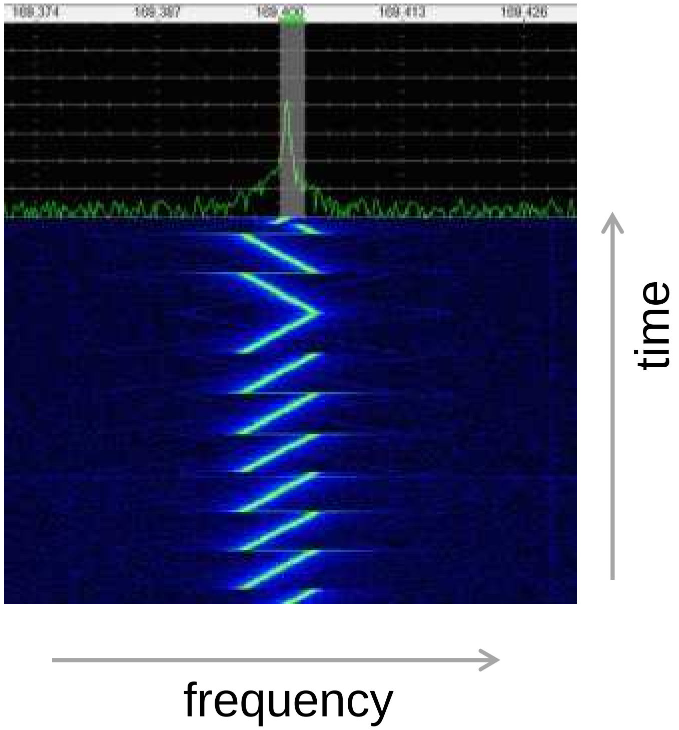
Tx/Rx switch prevents transmit power from Power Amplifier to destroy sensitive Low Noise Amplifier receiver. As a result, only half-duplex is possible.

Because of the transceiver constraints and the required 868 MHz frequency band coverage, two transceivers are needed.

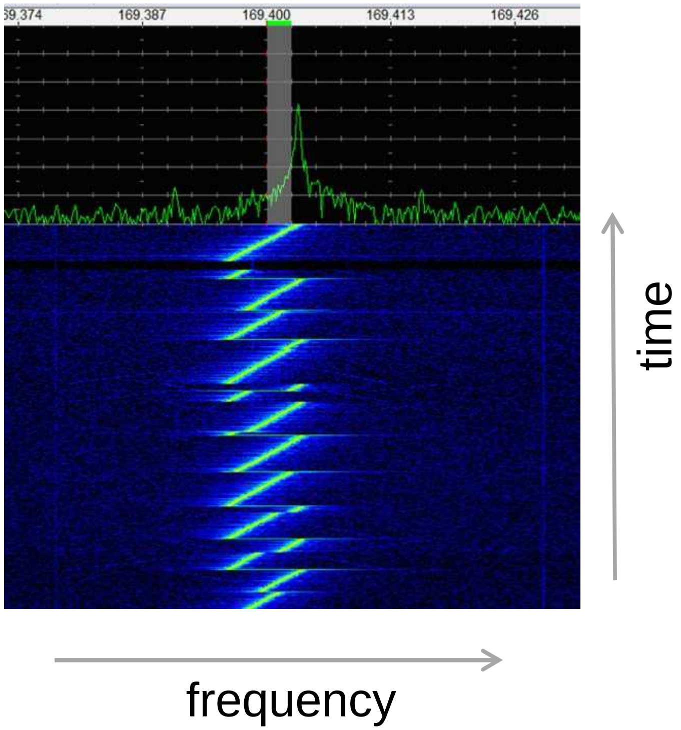

FT232H USB SERIAL CONVERTER
I/Q TRCVR VOLTAGE REGULATOR
LNA VOLTAGE REGULATOR
PA VOLTAGE REGULATOR
BALUN
PA
LNA
2x SX1257
SWITCH
#70002 – – 530L . 5026064399 0009
SX1301
DIG DOMAIN 1.8v REGULATOR

More about LoRa Radio

LoRa pre-amble signal:
8 symbols or “chirps”,
1 reverse “chirp”.



LoRa data signal:
A symbol is a “chirp” with
a frequency “hop”.



The change in frequency per time unit is the spreading factor.
SF12 has the slowest rate of change.
Slower rate of change helps the receiver to detect the signal, but transmission of data is slower.

Additionally: Forward Error Correction

Information Theory – how to improve the S/N budget

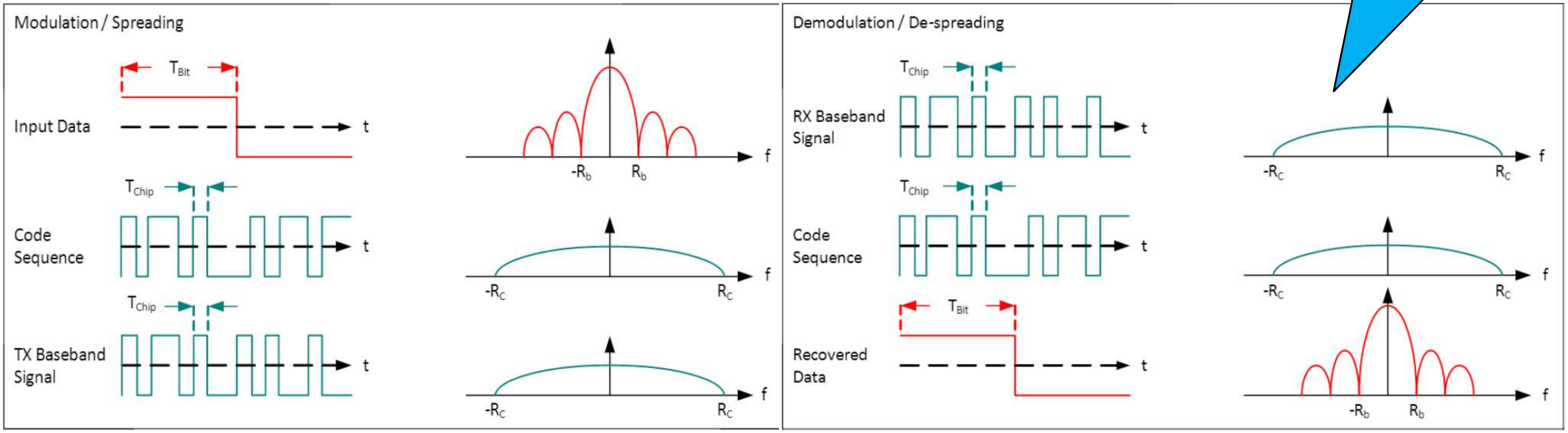
Shannon/Hartley Theorem: C/B = 1.433 * S/N

C = Channel Capacity (bits/s)
B = Channel Bandwidth (Hz)
S = Signal Power (W)
N = Noise Power (W)
S/N = Signal to Noise ratio

For spread spectrum applications, S/N << 1, so C/B ≈ S/N or N/S ≈ B/C
In a channel with a fixed N/S ratio to achieve error free transmission, only the transmitted **bandwidth need to be increased**.

Spread Spectrum technology:
Frequency of Input Data << Frequency of Code Sequence
Modulation by multipliction of input data with code sequence.
Demodulation by multiplication of baseband signal with code sequence

Rb = bit-rate (bits/s)
Rc = chirp-rate (chirps/s)
Rb << Rc
Gp = 10 * log (Rc/Rb) (dB)



More about LoRa Radio

Conclusion: with Spread Spectrum technology, we can improve the S/N ratio by increasing the BW.
For IoT, we need a cheap and practical implementation. So no highly accurate clocks but simple FM modulation and simple/fast synchronization.

For LoRa:

$$R_b = \frac{SF * BW}{2^{SF}}$$

Where:

Rb = Bit Rate (bits/s)
SF = Spreading Factor (7..12)
BW = Bandwidth (Hz)

And:

$$R_s = \frac{BW}{2^{SF}}$$

Chirp:

$$R_c = R_s * 2^{SF}$$

Rs = Symbol Rate (symbols/s)
Rc = Chip Rate (chirps/s)

Then:

Rc = BW (chirps/s) → one chirp is sent per second per Hz of bandwidth

More details in:
Semtech
AN1200.22

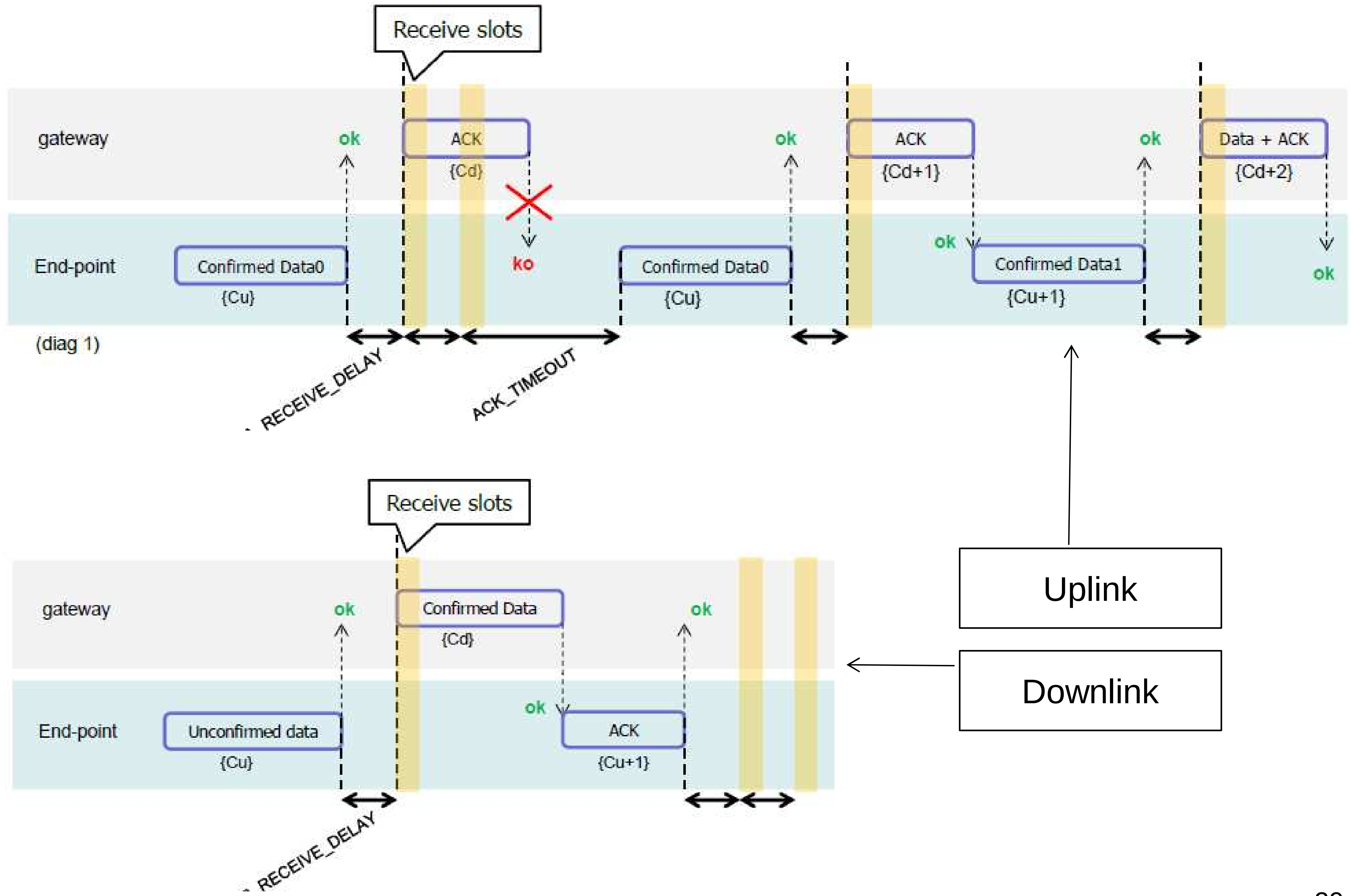
More about LoRa Radio – confirmed messages

For Class A devices, radio communication is always initiated from the sensor. Using Confirmed communication, the gateway has a chance to acknowledge the correct reception of the sensor data and also to send data to the sensor.
In this diagram, the ACK for the first packet Data0 is not received. The sensor re-transmits the packet. After reception of the ACK, the sensor listens for the Data packet from the gateway.

In LoRaWAN for 868 MHz ISM band,

receive_delay1 = 1 s
receive_delay2 = 2 s (must be receive_delay1 + 1 s)
join_accept_delay1 = 5 s
join_accept_delay2 = 6 s
adr_ack_limit = 64
adr_ack_delay = 32
ack_timeout = 2 ± 1 s (so 1 … 3 seconds, randomly)

More about LoRa Radio – confirmed messages



Thank You !

Version 0.3