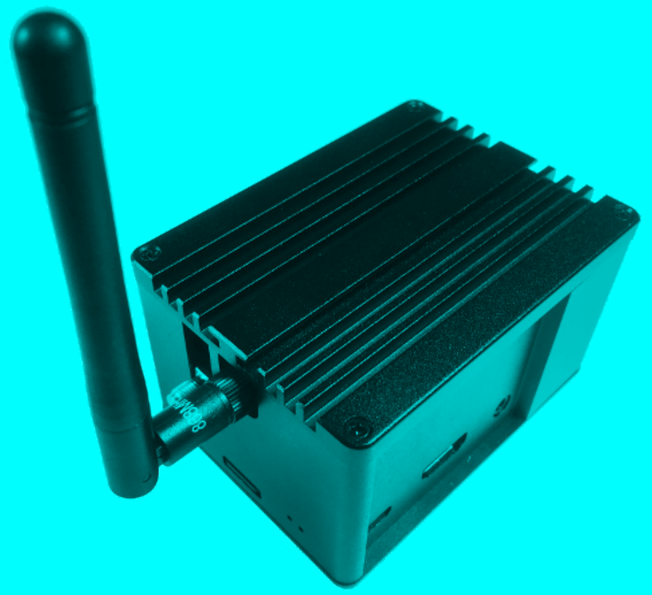
mobilefish.com

LORA / LORAWAN TUTORIAL 30

Semtech UDP Packet Forwarder Configuration Files Explained



← global_conf.json
local_conf.json

v1.1.0

INTRO

- In this tutorial I will give a simplified explanation of what the parameters mean in the global and local JSON configuration files.

PACKET FORWARDER CONFIGURATION FILES

- The Semtech UDP Packet Forwarder (https://github.com/Lora-net/packet_forwarder) is configured by the global configuration file global_conf.json.

- It has two sections: the radio settings (SX1301_conf) and server settings (gateway_conf).

```
{
    "SX1301_conf": {...},
    "gateway_conf": {...}
}
```

PACKET FORWARDER CONFIGURATION FILES

- The radio settings (SX1301_conf) should contain the parameters for the Lora concentrator board (e.g. RF channels definition, modem parameters, etc).
- The server settings (gateway_conf) should contain the gateway parameters (e.g. IP address of the server, keep-alive time, etc).
- If parameters are defined in both the global and local configuration file, the local definition overwrites the global definition.
- Recommended is to make changes in the local configuration file (local_conf.json).

PACKET FORWARDER CONFIGURATION FILES

- Here is an example of a global and local configuration file:
  - https://github.com/robertlie/RAK831-LoRaGateway-RPi/blob/master/configuration_files/EU-global_conf.json
  - https://github.com/robertlie/RAK831-LoRaGateway-RPi/blob/master/configuration_files/local_conf.json

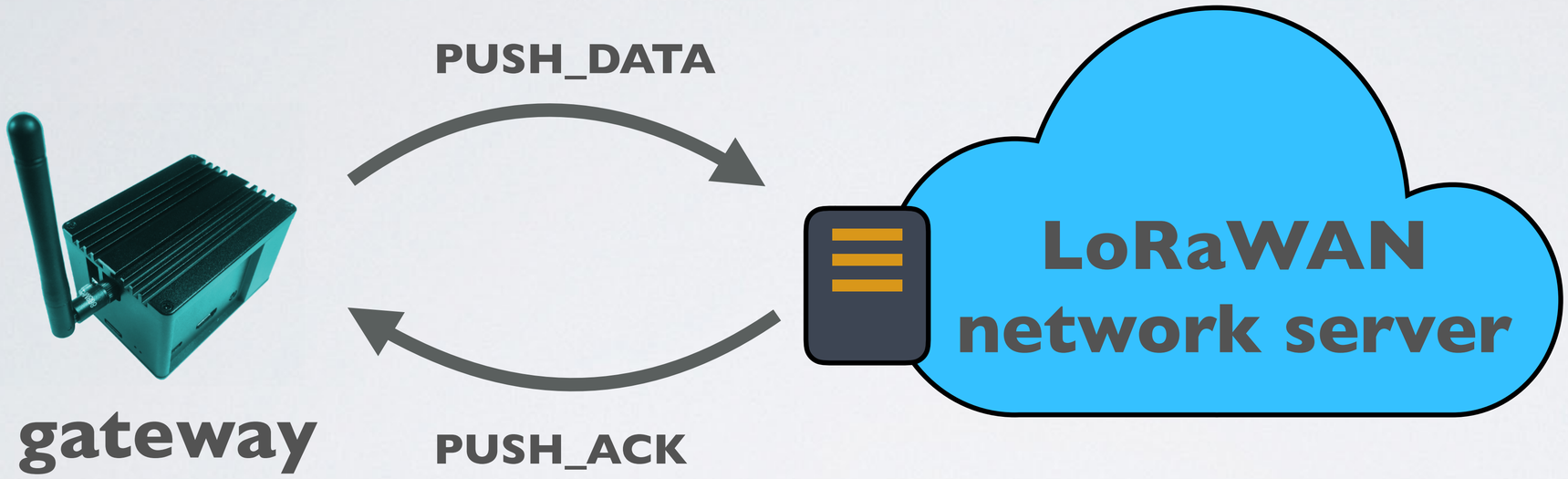
GLOBAL_CONF.JSON: GATEWAY_CONF

Name	Type	Function
gateway_conf Configure the gateway.		
gateway_ID	string	The gateway ID or gateway EUI is based on the MAC address. The gateway identifier is sent in each message to the network server. Default value: 0 More information: Tutorial 28
server_address	string	Network server hostname or IP address. Default value: 127.0.0.1 More information: Tutorial 28
serv_port_up	unsigned integer	Network server port for uplinks. Default value: 1780 More information: Tutorial 29
serv_port_down	unsigned integer	Network server port for downlinks. Default value: 1782 More information: Tutorial 29

GLOBAL_CONF.JSON: GATEWAY_CONF

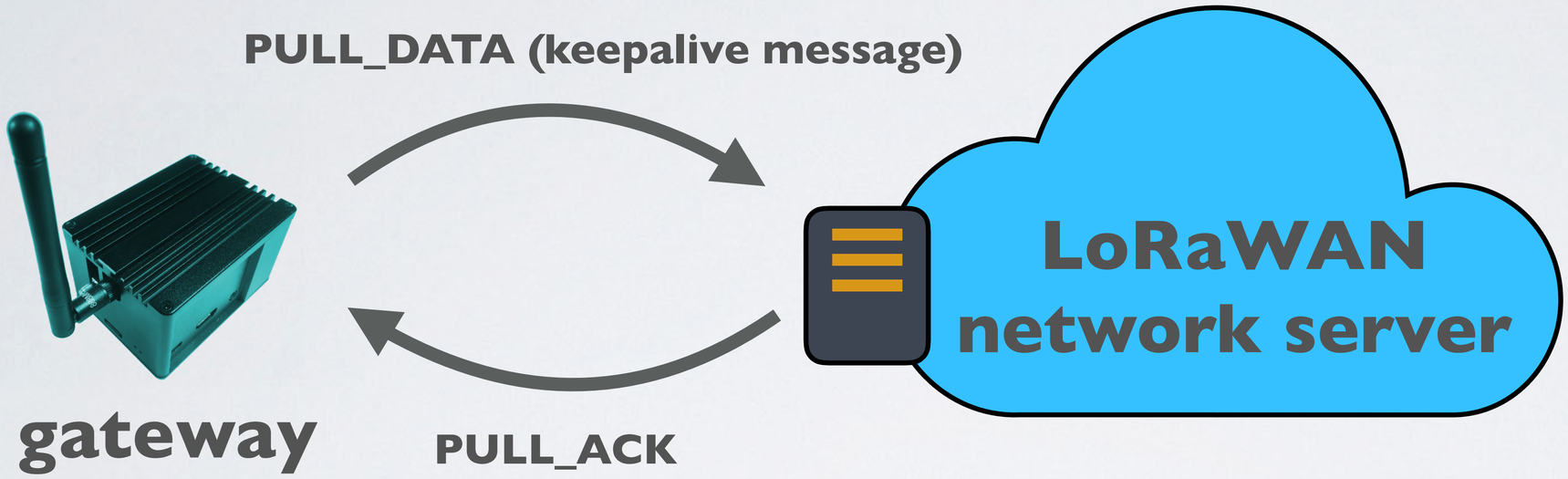
Name	Type	Function
gateway_conf Configure the gateway.		
keepalive_interval	signed integer	Keep-alive interval in seconds for downlinks. Sends a keepalive message (PULL_DATA packet) every X seconds from gateway to the network server to ensure downlinks. Default value: 5 More information: Tutorial 29
push_timeout_ms	signed integer	Time-out value in ms for uplinks (PUSH_DATA). Default value: 100
autoquit_threshold	unsigned integer	Auto-quit threshold. If the number of non-acknowledged PULL_DATA packets exceeds the threshold, auto-quit. Default value: 0

PUSH_TIMEOUT_MS EXPLAINED



push_timeout_ms specifies the timeout limit in milliseconds on how long the LoRaWAN network server waits for the PUSH_DATA operation to complete.
More information about PUSH_DATA, see Tutorial 29.

AUTOQUIT_THRESHOLD EXPLAINED



For example: autoquit_threshold = 5

An autoquit counter (autoquit_cnt) counts the number of PULL_DATA packages sent since the latest PULL_ACK.

If autoquit_cnt > autoquit_threshold, the concentrator will be stopped.
More information about PULL_DATA & PULL_ACK, see Tutorial 29.

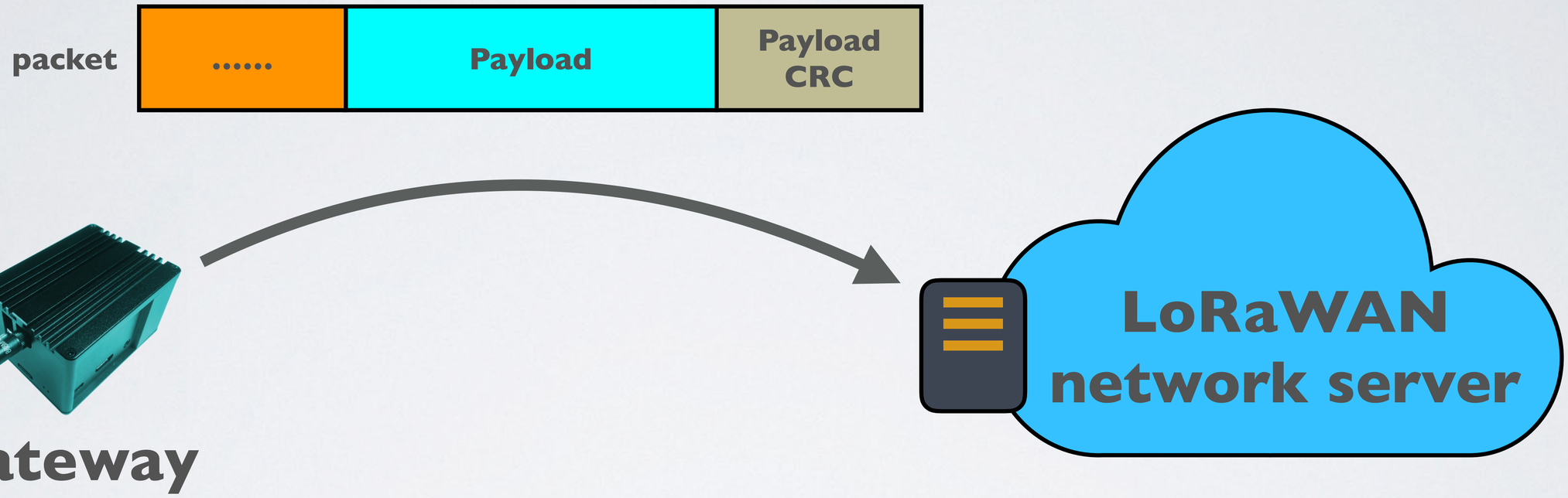
GLOBAL_CONF.JSON: GATEWAY_CONF

Name	Type	Function
gateway_conf Configure the gateway.		
stat_interval	unsigned integer	Interval in seconds for status information / statistics display. Default value: 30 Every X seconds: - The gateway statistics information is logged in /var/log/syslog The start of statistics information: ##### 2019-01-29 12:12:44 GMT ##### The end of statistics information: ##### END ##### - A stat JSON object with gateway status information is sent to the network server. More information: Tutorial 29 - The Last Seen message in the TTN console is updated. More information: Tutorial 29

GLOBAL_CONF.JSON: GATEWAY_CONF

Name	Type	Function
gateway_conf Configure the gateway.		
forward_crc_valid	bool	If true, packets received with a valid CRC will be forwarded. CRC stands for **C**yclic **R**edundancy **C**heck and is an error-detecting code to detect accidental changes to raw data. Default value: true
forward_crc_error	bool	If true, packets received with CRC error will be forwarded. Default value: false
forward_crc_disabled	bool	If true, packets received with no CRC will be forwarded. Default value: false

FORWARD_CRC_NNN EXPLAINED



Should the packet be forwarded if payload CRC = OK and forward_crc_valid = true: Yes
Should the packet be forwarded if payload CRC = NOK and forward_crc_error = true: Yes
Should the packet be forwarded if payload has no CRC and forward_crc_disabled = false: No

More information about payload CRC, see Tutorial 17.

GLOBAL_CONF.JSON: GATEWAY_CONF

Name	Type	Function
gateway_conf Configure the gateway.		
gps_tty_path	string	The GPS module TTY path. If the path is set, the GPS module is enabled. If this parameter is not found, GPS is disabled for this gateway and the TTY port is not opened for GPS synchronisation. For example for the RAK831 concentrator: gps_tty_path="/dev/ttyAMA0"
ref_latitude	float	The gateway reference latitude in degrees.
ref_longitude	float	The gateway reference longitude in degrees.
ref_altitude	signed integer	The gateway reference altitude in meters.
fake_gps	bool	If true, the gateway will use the hardcoded (aka. fake) ref_latitude, ref_longitude and ref_altitude instead of the real GPS coordinates.

The 5 keys mentioned above are explained in Tutorial 28.

GLOBAL_CONF.JSON: GATEWAY_CONF

Name	Type	Function
gateway_conf Configure the gateway.		
beacon_period	unsigned integer	The beacon signal period in seconds. Default value: 0 Allowed values: >= 6
beacon_freq_hz	unsigned integer	The beaconing signal will be emitted at specified TX frequency in Hz. Default value: 869525000
beacon_freq_nb	unsigned integer	The number of beacon channels. Default value: 1
beacon_freq_step	unsigned integer	The frequency step between beacon channels in Hz. Default value: 0
beacon_datarate	unsigned integer	The beacon datarate (Spreading Factor) Default value: 9

The keys mentioned above will be explained in a future video when demonstrating class B devices.

GLOBAL_CONF.JSON: GATEWAY_CONF

Name	Type	Function
gateway_conf Configure the gateway.		
beacon_bw_hz	unsigned integer	The beacon modulation bandwidth in Hz. Default value: 125000
beacon_power	unsigned integer	The beaconing TX power in dBm. Default value: 14
beacon_infodesc	unsigned integer	The beacon information descriptor. Default value: 0

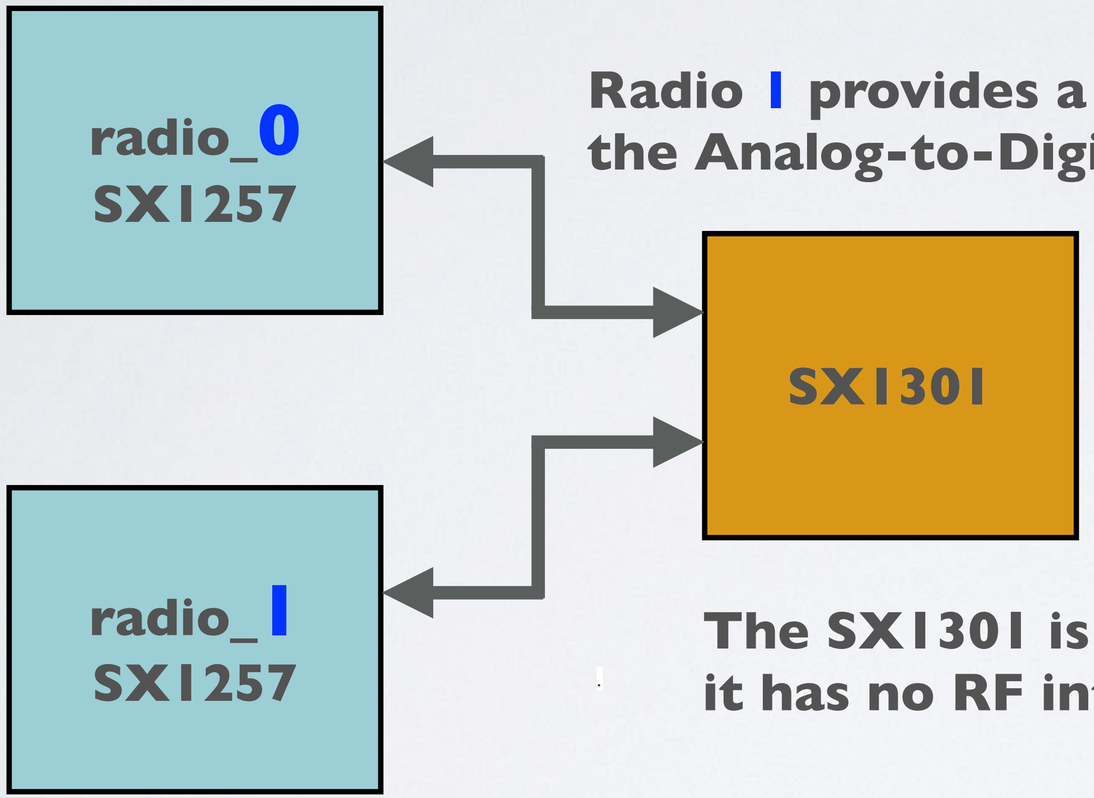
The keys mentioned above will be explained in a future video when demonstrating class B devices.

GLOBAL_CONF.JSON: SX1301_CONF

Name	Type	Function
SX1301_conf Configure the gateway board.		
lorawan_public	bool	Enable ONLY for public networks using the LoRa MAC protocol. If false, sync word (preamble) = 0x12. If true, sync word = 0x34. Default value: false.
clksrc	unsigned integer	Index of the radio (radio_N, where N=0 or 1), which provides the clock to the concentrator. Default value: 0. Note: radio_1 provides the clock to the concentrator for most devices except MultiTech. For MultiTech set to 0.
antenna_gain	signed integer	Antenna gain in ~~dBi~~ dBd. More information about dBd, see Tutorial 5. Antenna gain value is subtracted from TX power value which the network server requests from the gateway. It affects the downlink, not the uplink. Default value: 0. A more detailed explanation of the antenna gain will be given when explaining the Lookup Table keys.

CLKSRC EXPLAINED

For example: clksrc=1



Radio 1 provides a clock to the SX1301 for the Analog-to-Digital Converter.

The SX1301 is a baseband processor and not a radio, it has no RF interface.

GLOBAL_CONF.JSON: SX1301_CONF.LBT_CFG

Name	Type	Function
SX1301_conf.lbt_cfg Make sure the concentrator supports the Listen-Before-Talk (LBT) feature and LBT is supported in your region. If LBT is enabled, the gateway continuously monitors the channels (Listen). The gateway will only transmit when a channel is not in use (Talk). If the lbt_cfg parameter is not found, LBT is not set.		
enable	bool	Enable or disable LBT. If true, LBT is enabled. Default value: false.
rssi_target	signed integer	The RSSI threshold in dBm to detect if the channel is busy or not. Below this threshold, TX will be allowed. If enable=true, set the rssi_target. Default value: 0. More information about RSSI: Tutorial 10
sx127x_rssi_offset	signed integer	The RSSI offset in dBm to apply to RSSI reading from the radio front end. If enable=true, set the sx127x_rssi_offset. Default value: 0.

GLOBAL_CONF.JSON: SX1301_CONF.LBT_CFG

Name	Type	Function
SX1301_conf.lbt_cfg.chan_cfg If enable=true, check if chan_cfg is set. "chan_cfg":[{ "freq_hz": 867100000, "scan_time_us": 128 },{…},..] Each LBT channel has the parameters freq_hz and scan_time_us. Maximum 8 LBT channels can be configured.		
freq_hz	unsigned integer	Center frequency to track for LBT. Default value: 0.
scan_time_us	unsigned integer	Channel scan time in microseconds to track RSSI before TX. Allowed values: 128 or 5000. Default value: 0.

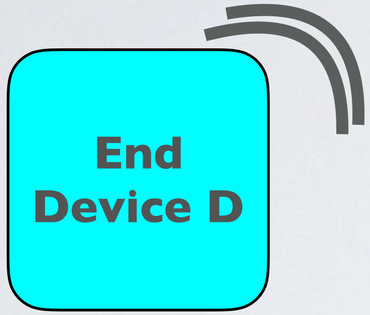
GLOBAL_CONF.JSON: SX1301_CONF.LBT_CFG

- Listen-Before-Talk (LBT) is a mandatory requirement in some countries, such as South Korea. See LoRaWAN 1.0.2 Regional Parameters document [Ref 4].

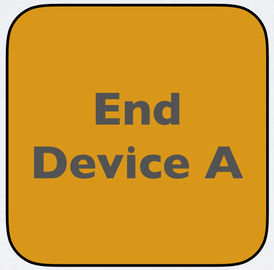
- LBT prevents end devices from transmitting at the same time on the same channel.

- LBT means the end device checks (=Listen) if the intended channel is free.
  If the channel is not free, the end device changes to another channel and repeats the LBT procedure.
  If the channel is free it transmits (=Talk).

RSSI_TARGET EXPLAINED



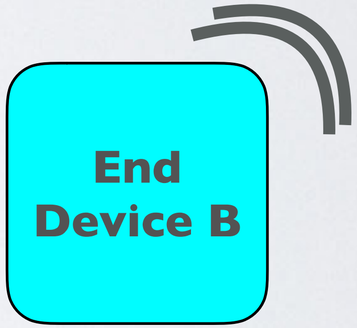
4. Tx @ 923.0 MHz



1. Select freq to Tx, e.g. freq 922.4 MHz
2. Scan freq 922.4 MHz
5. Read RSSI (Dev B: scanned RSSI=-50 dBm)
6. Compare with rssi_target = -80 dBm
   scanned RSSI < rssi_target: DO NOT USE FREQ
7. Select another freq to Tx, e.g. 922.6 MHz

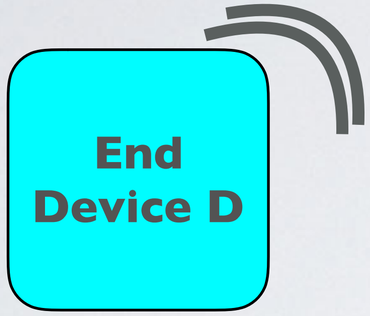
Max. 8 channels

Freq (MHz)	Scan Time (us)
923.2	128
923.4	128
922.2	128
922.4	128
922.6	128
922.8	128
923.0	128
922.0	128

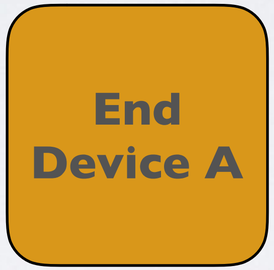


3. Tx @ 922.4 MHz

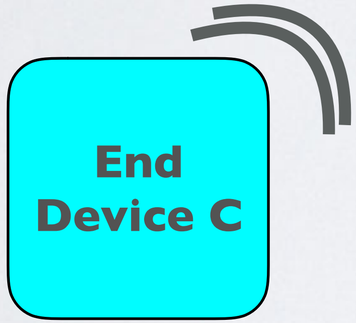
RSSI_TARGET EXPLAINED



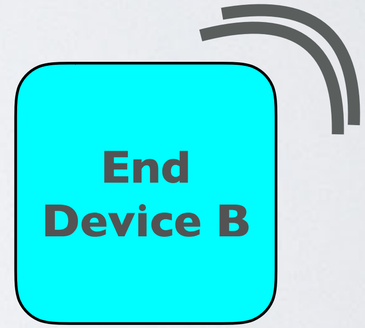
4. Tx @ 923.0 MHz



1. Select freq to Tx, e.g. freq 922.4 MHz
2. Scan freq 922.4 MHz
5. Read RSSI (Dev B: scanned RSSI=-50 dBm)
6. Compare with rssi_target = -80 dBm
   scanned RSSI < rssi_target: DO NOT USE FREQ
7. Select another freq to Tx, e.g. 922.6 MHz
9. Scan freq 922.6 MHz (Dev C: scanned RSSI=-100 dBm)
10. Compare with rssi_target = -80 dBm
    scanned RSSI < rssi_target: USE FREQ
11. Device A Tx @ 922.6 MHz



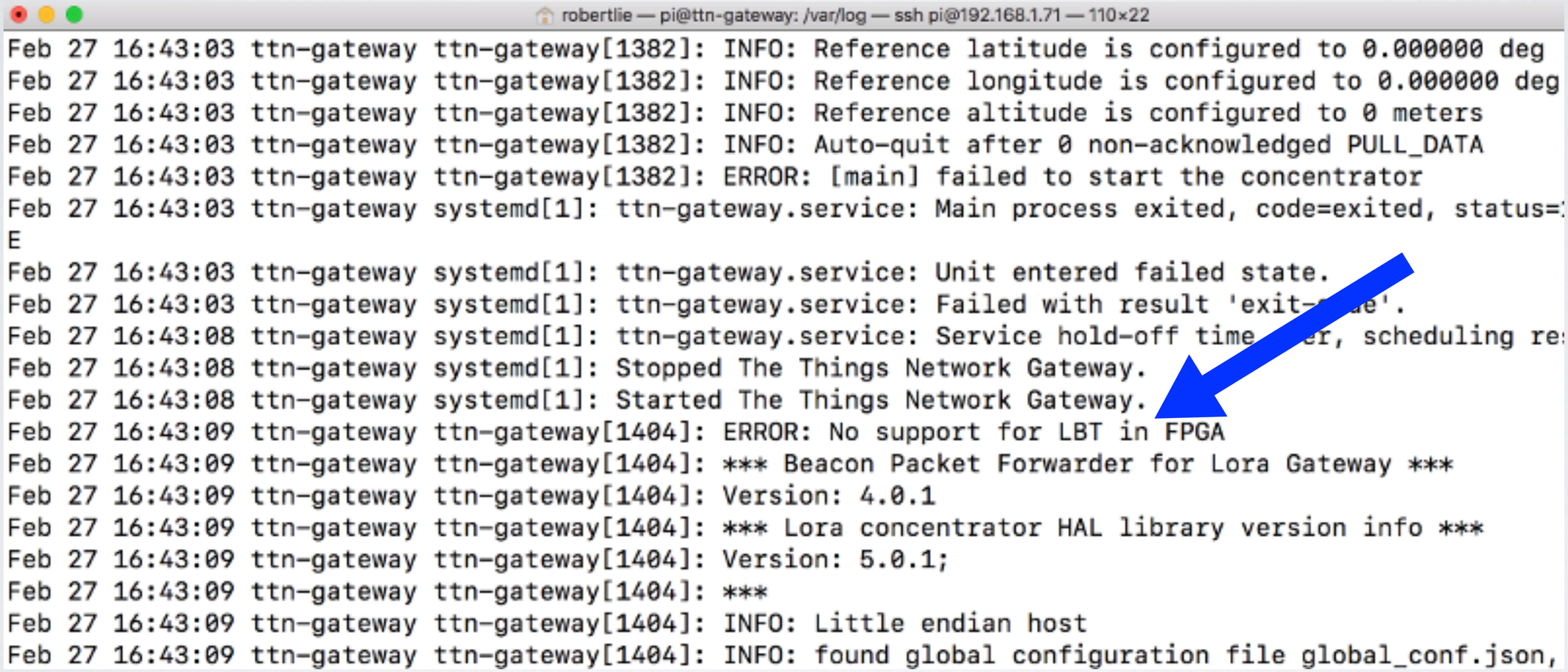
8. Tx @ 922.6 MHz



3. Tx @ 922.4 MHz

CHECK LBT SUPPORT

- The RAK831 concentrator does not support LBT.



CHECK LBT SUPPORT

- In case you wonder how I got previous log message, I have done the following:

- For **DEMONSTRATION PURPOSE** I have copied the "lbt_cfg" values from https://github.com/robertlie/RAK831-LoRaGateway-RPi/blob/master/configuration_files/AS1-global_conf.json into my global_conf.json file (Region: EU), and set lbt_cfg.enable=true.

- Next I have set DEBUG_LBT=1 in the library.cfg file and compiled the code, see Tutorial 28.2.

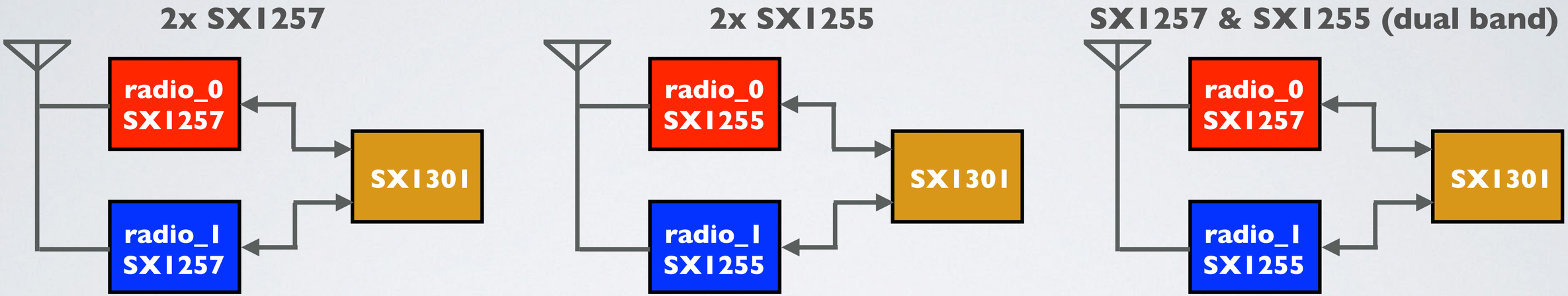
GLOBAL_CONF.JSON: SX1301_CONF.RADIO_N

Name	Type	Function
SX1301_conf.radio_N (N=0 or 1) Configure the concentrator RF chain aka radio channels.		
enable	bool	Enable or disable the radio. If true, radio is enabled for use. Default value: false.
freq	unsigned integer	Center frequency of the radio in Hz to listen for packets. The exact frequency the gateway transmits on is specified by the network server. If enable=true, set freq.
rssi_offset	signed float	Board dependant RSSI offset in dBm to adjust the radio RSSI reading. If enable=true, set rssi_offset.
type	string	Radio type (SX1255 or SX1257). If enable=true, set type.

GLOBAL_CONF.JSON: SX1301_CONF.RADIO_N

Name	Type	Function
SX1301_conf.radio_N (N=0 or 1) Configure the concentrator radio channels.		
tx_enable	bool	Enable or disable TX on the radio. If enable=true and tx_enable=true, the radio can be used for transmissions. Default value: false.
tx_notch_freq	unsigned integer	TX notch filter frequency in Hz. If enable=true and tx_enable=true, set tx_notch_freq. This is used by FPGA. Allowed values:126000-250000
tx_freq_min	unsigned integer	The minimum frequency allowed for transmissions. If enable=true and tx_enable=true, set tx_freq_min. Acts as a fail safe if the network server tells to use a freq. that falls outside the tx_freq_min and tx_freq_max range.
tx_freq_max	unsigned integer	The maximum frequency allowed for transmissions. If enable=true and tx_enable=true, set tx_freq_max. Acts as a fail safe if the network server tells to use a freq. that falls outside the tx_freq_min and tx_freq_max range.

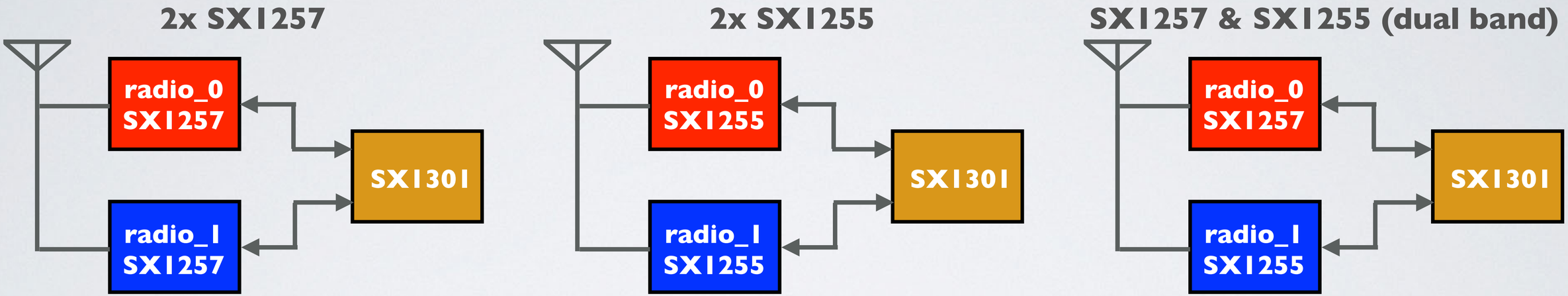
RADIO TYPE EXPLAINED



- The SX1257/55 radios captures the LoRa uplink packets and sends the digital signal to the SX1301 digital baseband chip which demodulates the signal.
  This processed signal is used by the Micro Controller Unit (MCU).

- The SX1257 chip can be configured to any frequency inside the 868/900 MHz ISM band. The SX1255 chip can be configured around the 433MHz ISM band.

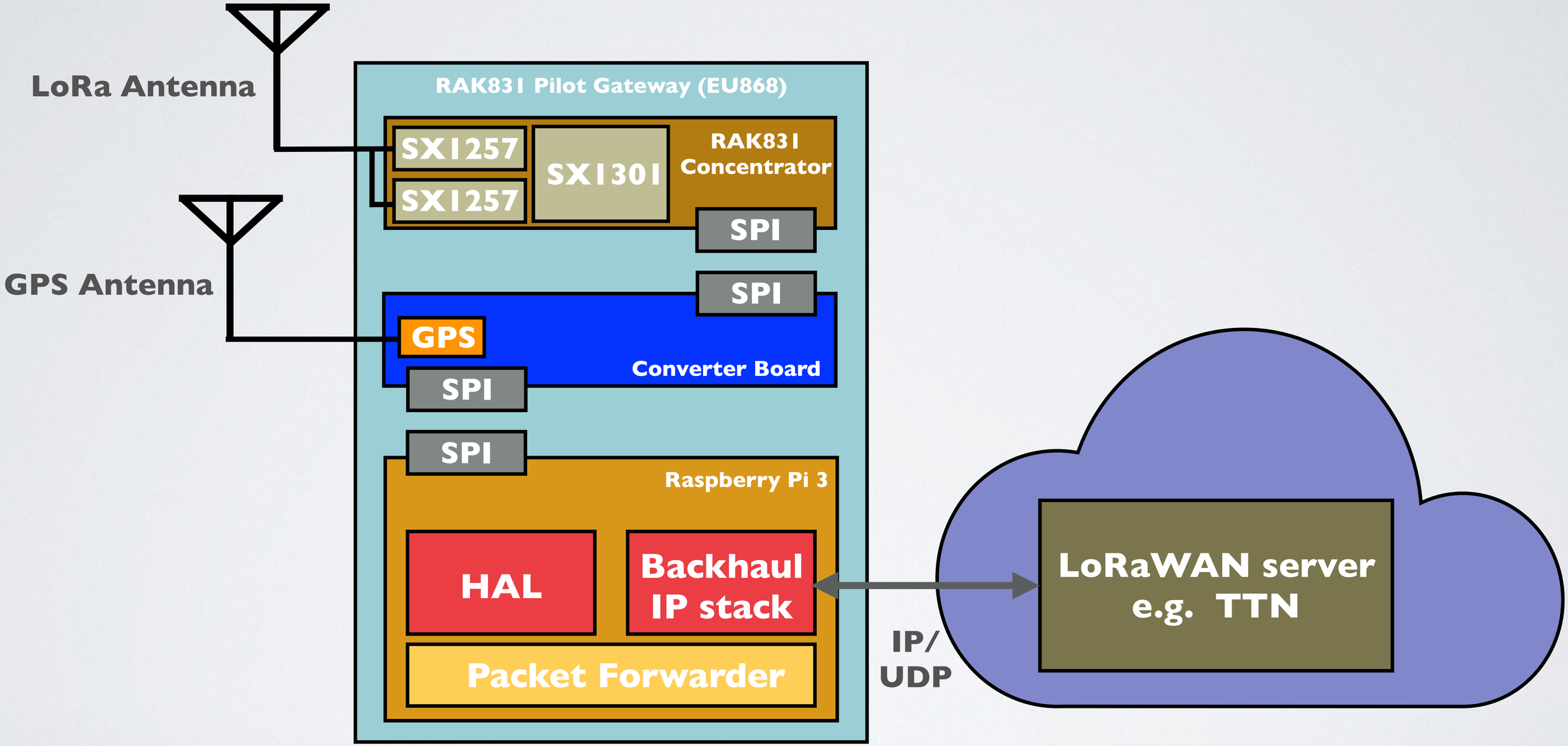
RADIO TYPE EXPLAINED



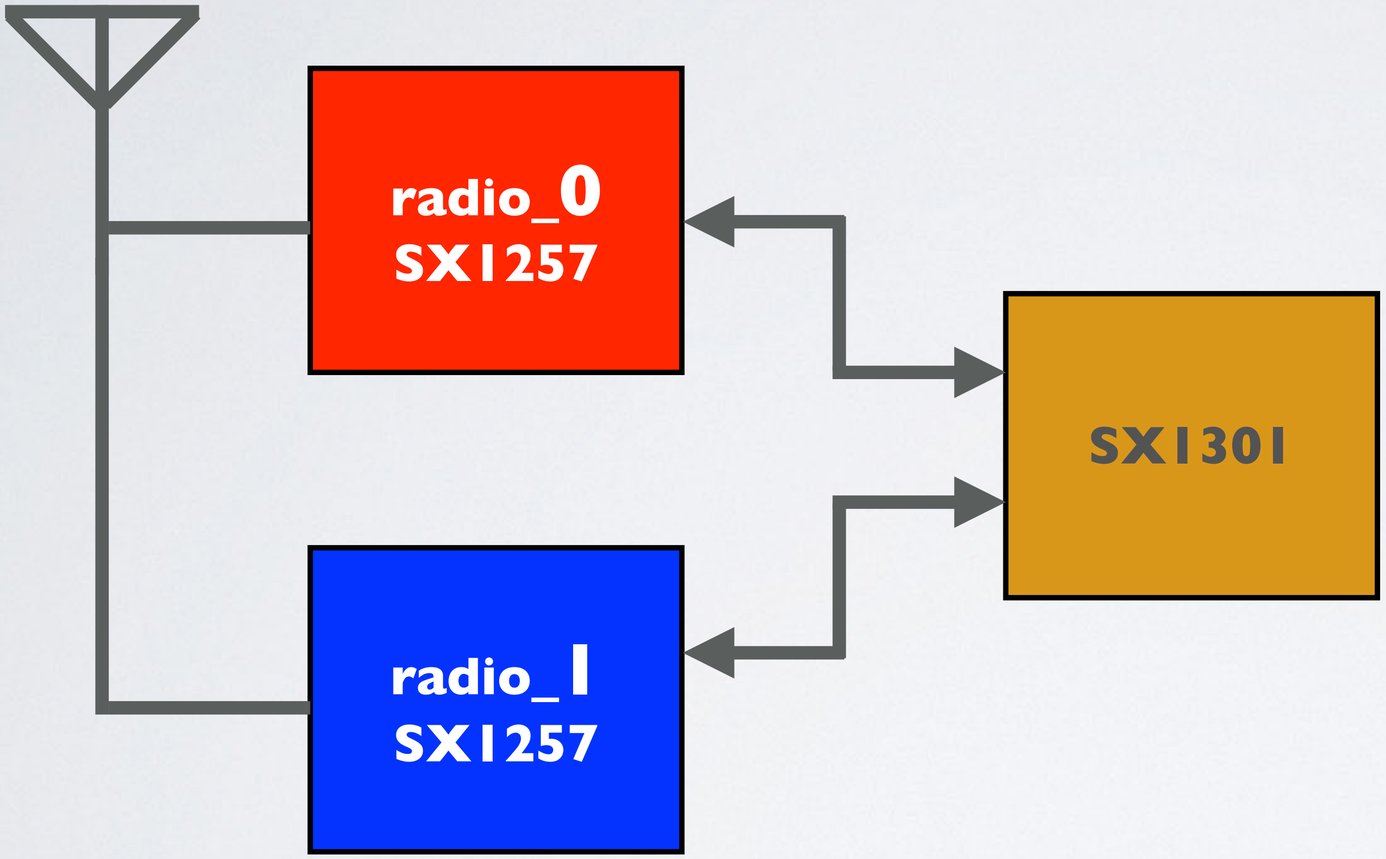
- Most commercial concentrators, using the SX1301 chip is build according to one of the three above mentioned configurations.

- For example if you buy the RAK831 Pilot Gateway (EU868 freq. range 865MHz-872 MHz), the concentrator uses two SX1257 radio's.

RADIO TYPE EXPLAINED



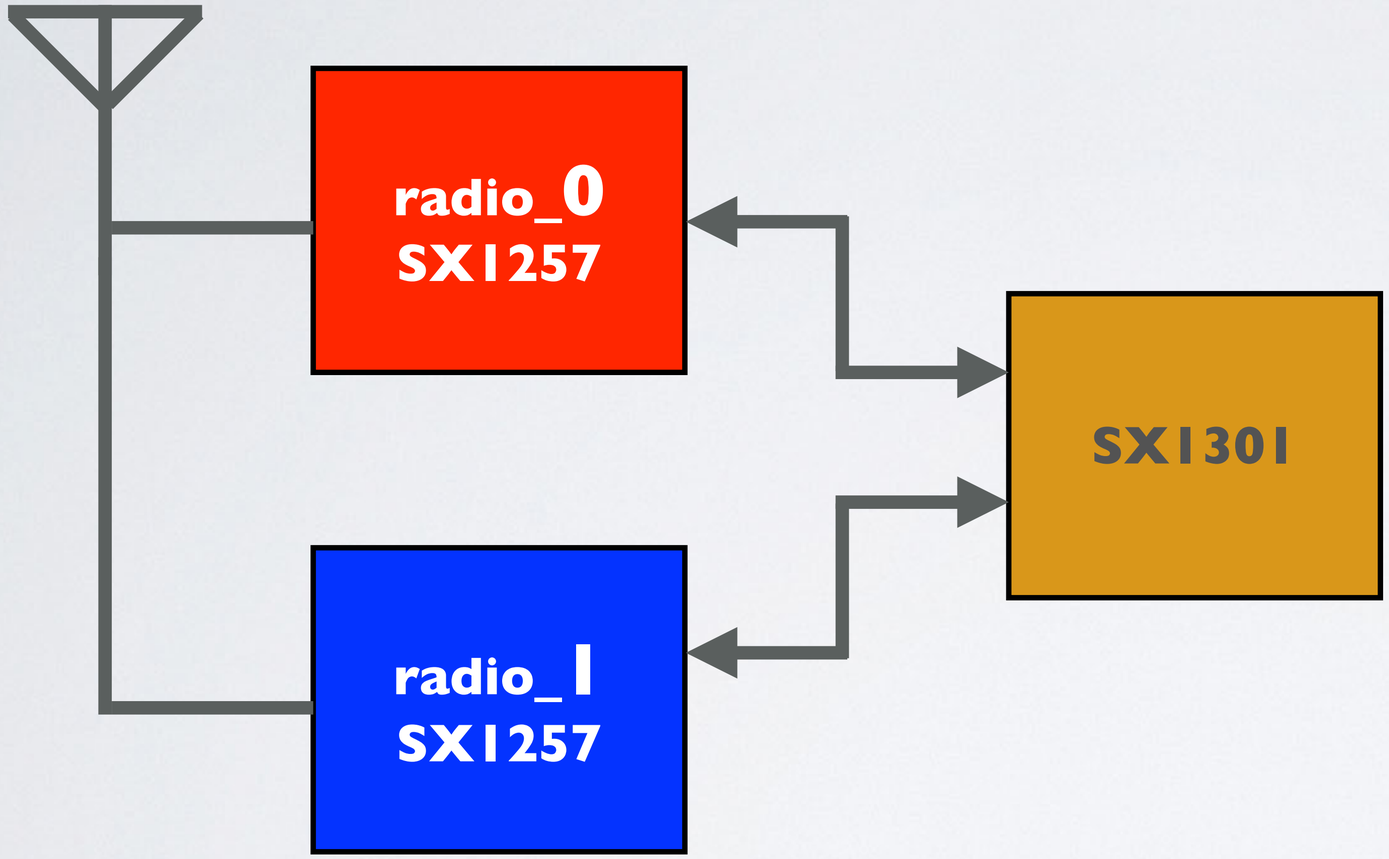
SEVERAL RADIO_N PARAMETERS EXPLAINED




```
radio_0
enable=true
type=SX1257
freq=867.5MHz
rssi_offset=-166.0 dBm
tx_enable=true
tx_freq_min=863.0 MHz
tx_freq_max=870.0 MHz
```

```
radio_1
enable=true
type=SX1257
freq=868.5MHz
rssi_offset=-166.0 dBm
tx_enable=false
```

SEVERAL RADIO_N PARAMETERS EXPLAINED

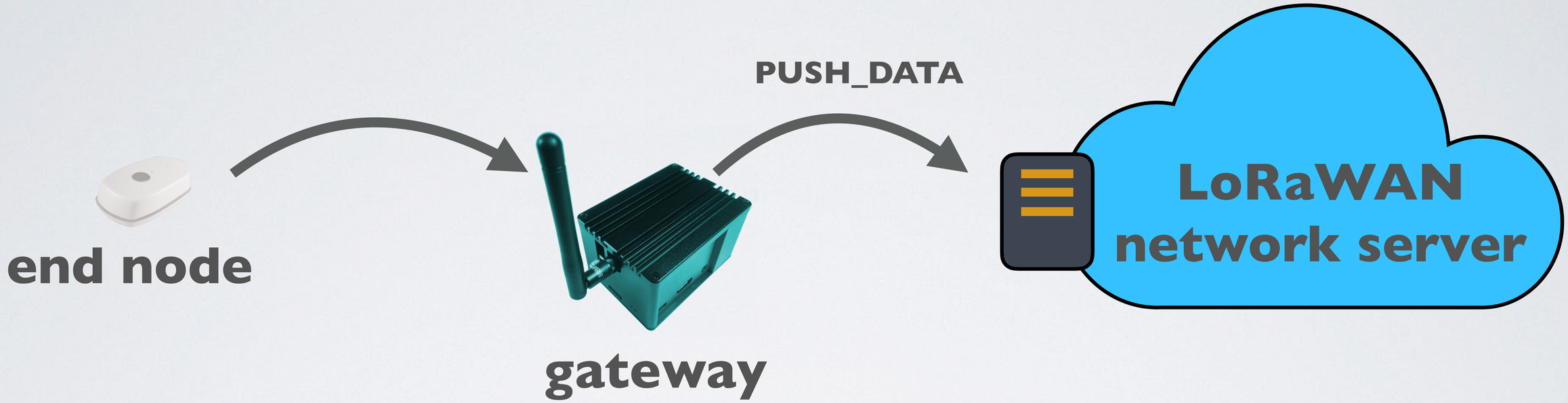


radio_0
enable=true
tx_enable = true
This radio is used to transmit data.

Only if tx_enable = true, then tx_freq_min, tx_freq_max and tx_notch_freq are used.

radio_1
enable=true
tx_enable = false
This radio is not used to transmit data.

RSSI_OFFSET EXPLAINED



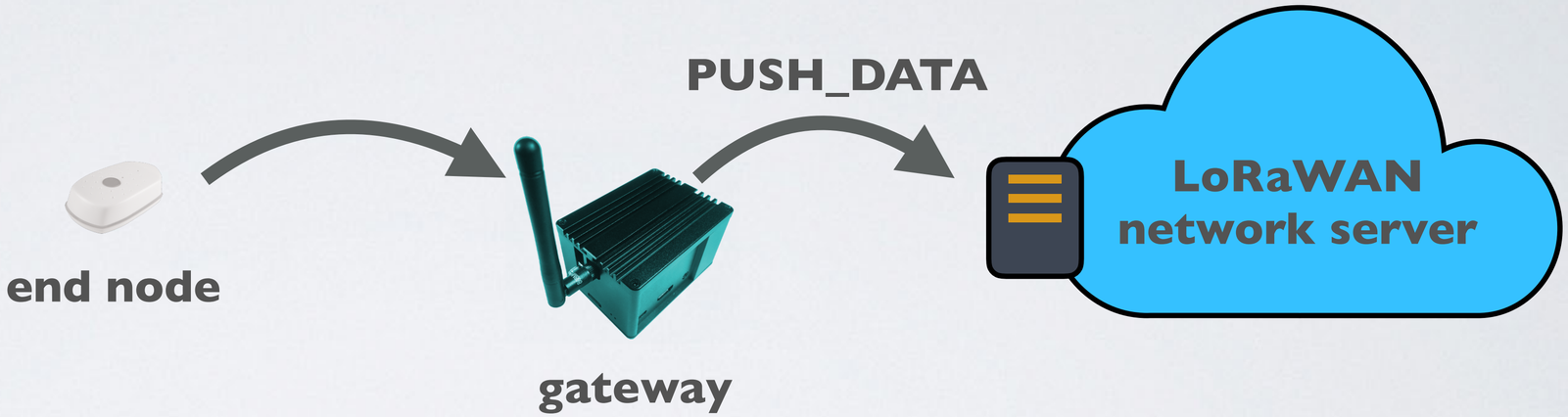
1. The end node transmits a message.
2. The gateway receives the message. It also measures the RSSI.
3. The measured RSSI will be adjusted by rssi_offset and additional offset.
4. The gateway creates a PUSH_DATA packet containing the adjusted RSSI which is sent to LoRaWAN network server.

More information about RSSI, see Tutorial 10.
More information about PUSH_DATA, see Tutorial 29.

RSSI_OFFSET EXPLAINED

PUSH_DATA

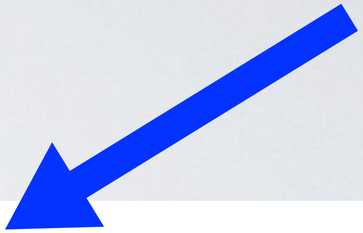
```
{"rxpk":
 [{
 "tmst":2675812,
 "chan":5,
 "rfch":0,
 "freq":867.500000,
 "stat":1,
 "modu":"LORA",
 "datr":"SF7BW125",
 "codr":"4/5",
 "lsnr":7.0,
 "rssi":-57,
 "size":17,
 "data":"QGojASaABAABpItDC2C3H8k="
 }]}
```



Adjusted rssi = measured rssi + **rssi_offset** - additional offset
Note: additional offset (RSSI_MULTI_BIAS=-35)

TX_NOTCH_FREQ EXPLAINED

- Notch filtering (tx_notch_freq) is performed by an FPGA.
  The RAK831 concentrator has no FPGA.



```
Mar  7 15:03:47 ttn-gateway systemd[1]: Started The Things Network Gateway.
Mar  7 15:03:48 ttn-gateway ttn-gateway[1090]: lgw_connect:532: INFO: no FPGA detected or version not supported (v0)
Mar  7 15:03:48 ttn-gateway ttn-gateway[1090]: Note: success connecting the concentrator
Mar  7 15:03:48 ttn-gateway ttn-gateway[1090]: lgw_setup_sx125x:407: Note: SX125x #0 version register returned 0x48
Mar  7 15:03:48 ttn-gateway ttn-gateway[1090]: lgw_setup_sx125x:415: Note: SX125x #0 clock output disabled
Mar  7 15:03:48 ttn-gateway ttn-gateway[1090]: lgw_setup_sx125x:469: Note: SX125x #0 PLL start (attempt 1)
Mar  7 15:03:48 ttn-gateway ttn-gateway[1090]: lgw_setup_sx125x:469: Note: SX125x #0 PLL start (attempt 2)
Mar  7 15:03:48 ttn-gateway ttn-gateway[1090]: lgw_setup_sx125x:469: Note: SX125x #0 PLL start (attempt 3)
Mar  7 15:03:48 ttn-gateway ttn-gateway[1090]: lgw_setup_sx125x:407: Note: SX125x #1 version register returned 0x90
Mar  7 15:03:48 ttn-gateway ttn-gateway[1090]: lgw_setup_sx125x:412: Note: SX125x #1 clock output enabled
Mar  7 15:03:48 ttn-gateway ttn-gateway[1090]: lgw_setup_sx125x:469: Note: SX125x #1 PLL start (attempt 1)
Mar  7 15:04:41 ttn-gateway ttn-gateway[1090]: *** Beacon Packet Forwarder for Lora Gateway ***
Mar  7 15:04:41 ttn-gateway ttn-gateway[1090]: Version: 4.0.1
Mar  7 15:04:41 ttn-gateway ttn-gateway[1090]: *** Lora concentrator HAL library version info ***
Mar  7 15:04:41 ttn-gateway ttn-gateway[1090]: Version: 5.0.1;
Mar  7 15:04:41 ttn-gateway ttn-gateway[1090]: ***
```

- To check if a concentrator supports FPGA, set DEBUG_REG=1 in the library.cfg file, see Tutorial 28.2. Unfortunately I can not provide you more information about notch filtering.

GLOBAL_CONF.JSON: SX1301_CONF.CHAN_MULTISF_N

Name	Type	Function
SX1301_conf.chan_multiSF_N (N=0-7) Configure the concentrator IF (Intermediate Frequency) channels.		
enable	bool	Enable or disable the IF channel. If true, IF channel is enabled. Default value: false.
radio	unsigned integer	To which radio is the IF channel associated with to listen for packets. If enable=true, set radio.
if	signed integer	Centre frequency of the IF channel in Hz, relative to the associated radio frequency. IF allowed values: [-400000 to +400000]

The Semtech packet forwarder v4.0.1 does not allow the user to set the bandwidth and SpreadFactor for LoRa multi-SF channels.
Bandwidth (BW) is always 125 kHz and the SpreadFactor is always 7-12

GLOBAL_CONF.JSON: SX1301_CONF.CHAN_LORA_STD

Name	Type	Function
SX1301_conf.chan_Lora_std Configure the concentrator Lora standard channel.		
enable	bool	Enable or disable Lora standard channel configuration. If true, Lora standard channel configuration is enabled. Default value: false.
radio	unsigned integer	To which radio is the Lora std channel associated with to listen for packets. If enable=true, set radio.
if	signed integer	The Intermediate Frequency (IF) of the Lora standard channel in Hz. The channel frequency is the freq. setting of the associated radio plus the if setting.
bandwidth	unsigned integer	Bandwidth of the Lora standard channel in Hz. Allowed values: 125000, 250000 and 500000.
spread_factor	unsigned integer	Spread Factor of the Lora standard channel. Allowed values: 7-12

GLOBAL_CONF.JSON: SX1301_CONF.CHAN_FSK

Name	Type	Function
SX1301_conf.chan_FSK Configure the concentrator modem.		
enable	bool	Enable or disable modem configuration. If true, modem configuration is enabled. Default value: false.
radio	unsigned integer	To which radio is the modem associated with to listen for packets. If enable=true, set radio.
if	signed integer	Centre frequency of the modem in Hz.
bandwidth	unsigned integer	Bandwidth of the modem in Hz. Allowed values: 0-500000.
freq_deviation	unsigned integer	Freq deviation of the modem. If bandwidth is set, it has priority over freq_deviation
datarate	unsigned integer	Data rate of the modem in bps.

RULES AND REGULATIONS

- In the global_conf.json file you can find the Intermediate Frequency channels (IF).
- All gateways must comply to certain rules and regulations when using the ISM band frequencies. These rules and regulations determines how the Intermediate Frequency channels came about.
- As already explained in Tutorial 3, in Europe, the European Telecommunications Standards Institute (ETSI) creates these standards which are used by the local regulatory authorities.
- In the US the Federal Communications Commission (FCC) creates these standards.
- Most countries are using the standards sets by either ETSI or FCC.

RULES AND REGULATIONS

- In the following demonstration I assume the gateway is operated in the Netherlands, an European country.

- In Europe the ISM band frequency range is between 863-870 MHz.

- Therefore the Intermediate Frequency channels mentioned in https://github.com/robertlie/RAK831-LoRaGateway-RPi/blob/master/configuration_files/EU-global_conf.json must comply with the rules and regulations set by the Dutch Authority, ETSI and others. In the next slides I will demonstrate this.

ETSI EN 300220

- For LoRa related ETSI documentation, search for standard number **300220**-2 at https://www.etsi.org/.
  Number 2 means the second part of this multipart document.

- The document of interest (ETSI EN 300 220-2) is called: *Short Range Devices (SRD) operating in the frequency range 25 MHz to 1000 MHz; Part 2: Harmonised Standard for access to radio spectrum for non specific radio equipment*

- In ETSI EN 300 220-2 v3.2.1 (2018-06), Annex B, table B.1, you can find the allowed power and duty cycles for the 863-870 MHz frequency range.

ETSI EN 300220

Ref.	Freq Range [MHz]	ERP [mW]	Duty Cycle [%]
K	863.00-865.00	25	<0.1
L/M	865.00-868.60	25	<1
N	868.70-869.20	25	<0.1
P	869.40-869.65	500	<10
Q	869.70-870.00	25	<1

DUTCH LAWS AND REGULATIONS

- Dutch laws and regulations regarding LoRa, see: *Regulation on the use of frequency space without a license and without reporting obligation 2015*
  https://wetten.overheid.nl/BWBR0036378/2016-12-28

- In attachment 11, subcategory 1, you can find the allowed power and duty cycles for the 863-870 MHz frequency range.

DUTCH LAWS AND REGULATIONS

No.	Freq Range [MHz]	ERP [mW]	Duty Cycle [%]
H1	863.00-865.00	25	<0.1
H2	865.00-868.60	25	<1
H3	868.70-869.20	25	<0.1
H4	869.40-869.65	500	<10
H7	869.70-870.00	25	<1

COMPARISON DUTCH REGULATIONS & ETSI EN 300220

Dutch law and regulations

No.	Freq Range [MHz]	ERP [mW]	Duty Cycle [%]
H1	863.00-865.00	25	<0.1
H2	865.00-868.60	25	<1
H3	868.70-869.20	25	<0.1
H4	869.40-869.65	500	<10
H7	869.70-870.00	25	<1

ETSI EN 300220

Ref.	Freq Range [MHz]	ERP [mW]	Duty Cycle [%]
K	863.00-865.00	25	<0.1
L/M	865.00-868.60	25	<1
N	868.70-869.20	25	<0.1
P	869.40-869.65	500	<10
Q	869.70-870.00	25	<1

If I comply with the regulations set by ETSI EN 300220, I comply with the Dutch law and regulations.

LORAWAN REGIONAL PARAMETERS (EU863-870)

- The LoRa Alliance (https://lora-alliance.org) created a set of standards ensuring interoperability of all LoRaWAN products and technologies.
  For example they created the LoRaWAN Regional Parameters document, see:
  https://lora-alliance.org/lorawan-for-developers

- Search for this document in the Resource Hub and filter on Technical Documentation:
  https://lora-alliance.org/resource-hub

- In the LoRaWAN 1.0.2 Regional Parameters Revision B (2017 Feb), for the EU863-870 ISM band the following is specified:

  - The EU863-870 ISM Band channel frequencies applies to any region where the ISM radio spectrum use is defined by the ETSI 300220 standard.

LORAWAN REGIONAL PARAMETERS (EU863-870)

- For the EU863-870 ISM frequency band a maximum of 16 channels is supported.

- Three default channels **must** be implemented in every EU868MHz end-device. Those channels are the minimum set that all network gateways should always be listening on.

Modulation	BW [kHz]	Channel Freq. [MHz]	FSK Bitrate or LoRa Data Rate	Duty Cycle [%]
LoRa	125	868.10, 868.30, 868.50	DR0 – DR5 / 0.3-5 kbps	<1

- The remaining 13 channels can be freely attributed by the network operator.

LORAWAN REGIONAL PARAMETERS (EU863-870)

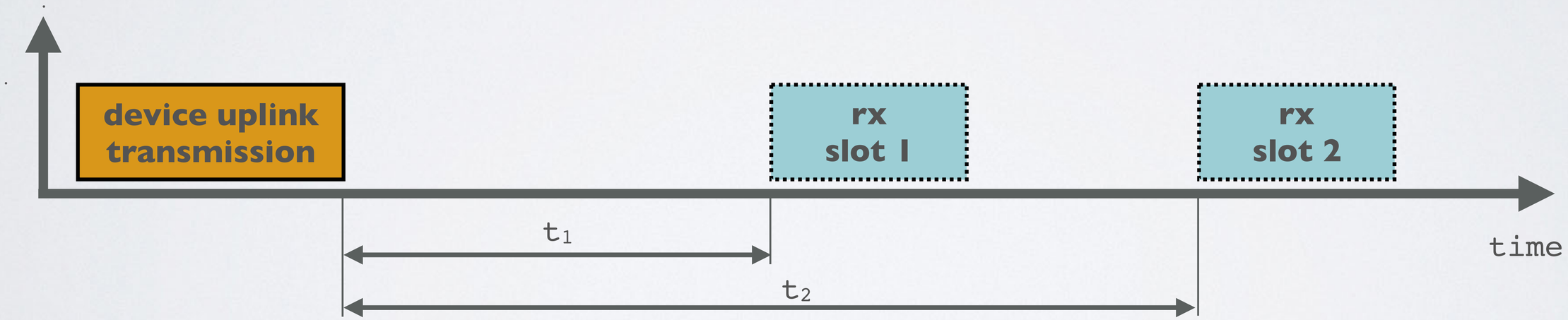
- For the EU863-870 ISM frequency band the following encoding is used for Data Rate (DR):

Data Rate	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	Reserved for Future Usage	

LORAWAN REGIONAL PARAMETERS (EU863-870)

- The RX1 receive window uses the same channel as the preceding uplink and the data rate is a function of the uplink data rate and an offset. To keep this tutorial short I will not elaborate on this.

- The RX2 receive window uses a fixed frequency and data rate.
  The default parameters are 869.525 MHz / DR0 (SF12, 125 kHz).

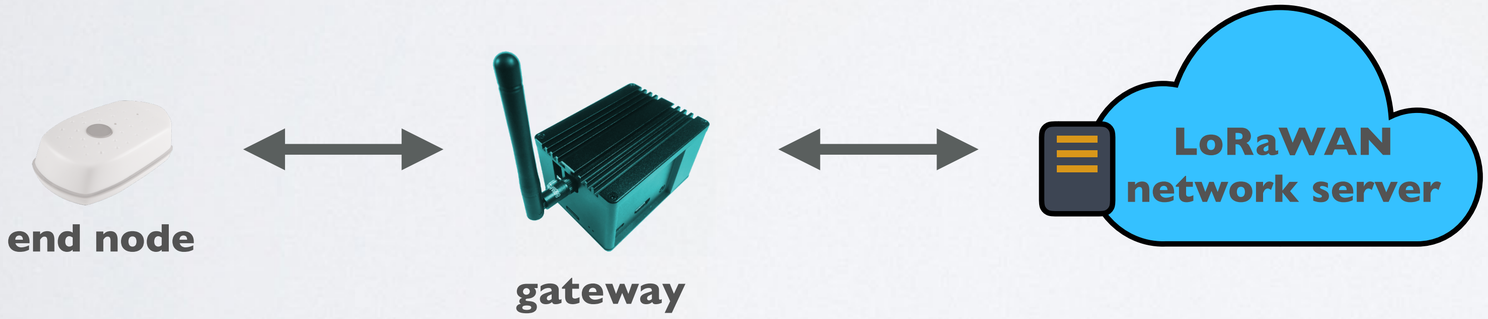


THE THINGS NETWORK EU863-870 FREQUENCY PLAN

- A list of frequency plan definitions used by The Things Network, see: https://www.thethingsnetwork.org/docs/lorawan/frequency-plans.html

- These frequency plans are based on what is specified in the LoRaWAN regional parameters document.

- It is important to understand that the frequency plan is intended for the LoRaWAN network server but also applies to the gateway and end node otherwise these 3 entities cannot communicate with each other.



THE THINGS NETWORK EU863-870 FREQ PLAN

Uplink

Nr	Channel Freq. [MHz]	Data Rate
1	**868.1**	**SF7BW125 to SF12BW125**
2	**868.3**	**SF7BW125 to SF12BW125** and SF7BW250 (DR 6)
3	**868.5**	**SF7BW125 to SF12BW125**
4	867.1	SF7BW125 to SF12BW125
5	867.3	SF7BW125 to SF12BW125
6	867.5	SF7BW125 to SF12BW125
7	867.7	SF7BW125 to SF12BW125
8	867.9	SF7BW125 to SF12BW125
9	868.8	FSK

Downlink

Uplink channels 1-9 (RX1)
869.525 MHz - SF9BW125 (RX2 downlink only)

Note 1: The Things Network uses the non-standard SF9BW125 data rate for RX2 in Europe instead of SF12BW125.
If your devices use OTAA, this will be configured automatically when they join. If your devices use ABP, you'll need to program this RX2 data rate into the devices in order to make them work with TTN.
This will be explained in another tutorial.

Note 2: The RX1 Data Rates complies with the LoRaWAN EU863-870 regional parameters document.

Note 3: The bold values are mandatory according to the LoRaWAN EU863-870 regional parameters document.

Note 4: More information about receive window 1 (RX1) and receive window (RX2), see Tutorial 4.

Note 5: There is one channel with a fixed SF and BW.
This channel is called "standard LoRa channel".
See channel frequency 868.3 MHz, SF7BW250.

COMPARISON TTN EU863-870 & ETSI EN 300220

TTN EU863-870 UPLINK

Nr	Channel Freq. [MHz]	Data Rate
1	**868.1**	**SF7BW125 to SF12BW125**
2	**868.3**	**SF7BW125 to SF12BW125** and SF7BW250 (DR 6)
3	**868.5**	**SF7BW125 to SF12BW125**
4	867.1	SF7BW125 to SF12BW125
5	867.3	SF7BW125 to SF12BW125
6	867.5	SF7BW125 to SF12BW125
7	867.7	SF7BW125 to SF12BW125
8	867.9	SF7BW125 to SF12BW125
9	868.8	FSK

ETSI EN 300220

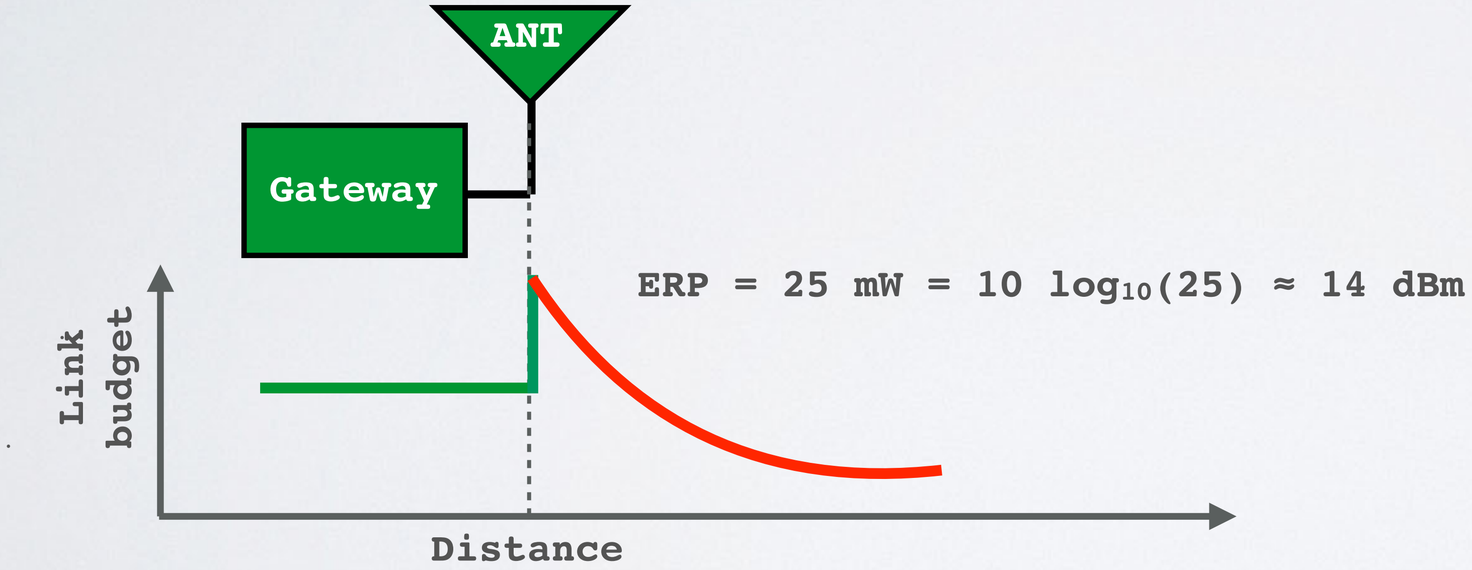
Ref.	Freq Range [MHz]	ERP [mW]	Duty Cycle [%]
K	863.00-865.00	25	<0.1
L/M	865.00-868.60	25	<1
N	868.70-869.20	25	<0.1
P	869.40-869.65	500	<10
Q	869.70-870.00	25	<1

TTN EU863-870 uplink complies with ETSI EN 300220

MAXIMUM ALLOWED ERP

- According to previous table (for uplink), for frequency range 865.00-868.60 MHz and 868.70-869.20 MHz, the maximum allowed ERP = 25 mW.
  More information about ERP, see Tutorial 9.

- 25 mW ERP is approximately 14 dBm (see Tutorial 5).



COMPARISON TTN EU863-870 & ETSI EN 300220

TTN EU863-870 DOWNLINK (**RX1**)

Nr	Channel Freq. [MHz]	Data Rate
1	868.1	SF7BW125 to SF12BW125
2	868.3	SF7BW125 to SF12BW125 and SF7BW250 (DR 6)
3	868.5	SF7BW125 to SF12BW125
4	867.1	SF7BW125 to SF12BW125
5	867.3	SF7BW125 to SF12BW125
6	867.5	SF7BW125 to SF12BW125
7	867.7	SF7BW125 to SF12BW125
8	867.9	SF7BW125 to SF12BW125
9	868.8	FSK
	869.525	SF9BW125 **(RX2)**

ETSI EN 300220

Ref.	Freq Range [MHz]	ERP [mW]	Duty Cycle [%]
K	863.00-865.00	25	<0.1
L/M	865.00-868.60	25	<1
N	868.70-869.20	25	<0.1
P	869.40-869.65	500	<10
Q	869.70-870.00	25	<1

TTN EU863-870 downlink complies with ETSI EN 300220

TTN EU863-870 & LORAWAN REGIONAL PARAMETERS

TTN EU863-870 (Uplink & Downlink)

Nr	Channel Freq. [MHz]	Data Rate
1	868.1	SF7BW125 to SF12BW125
2	868.3	SF7BW125 to SF12BW125 and SF7BW250
3	868.5	SF7BW125 to SF12BW125
4	867.1	SF7BW125 to SF12BW125
5	867.3	SF7BW125 to SF12BW125
6	867.5	SF7BW125 to SF12BW125
7	867.7	SF7BW125 to SF12BW125
8	867.9	SF7BW125 to SF12BW125
9	868.8	FSK
	869.525	SF9BW125 (RX2)

LoRaWAN Regional Parameters (EU863-870)

Data Rate	Configuration
0	LoRa: SF12 /125 kHz
1	LoRa: SF11 /125 kHz
2	LoRa: SF10 /125 kHz
3	LoRa: SF9 /125 kHz
4	LoRa: SF8 /125 kHz
5	LoRa: SF7 /125 kHz
6	LoRa: SF7 /250 kHz
7	FSK: 50 kbps
8-15	Reserved for Future Usage

LoRaWAN Regional Parameters (EU863-870)

Modulation	BW [kHz]	Channel Freq. [MHz]	FSK Bitrate or LoRa Data Rate	Duty Cycle [%]
LoRa	125	868.10, 868.30, 868.50	DR0 – DR5 / 0.3-5 kbps	<1

SEMTECH DATASHEET

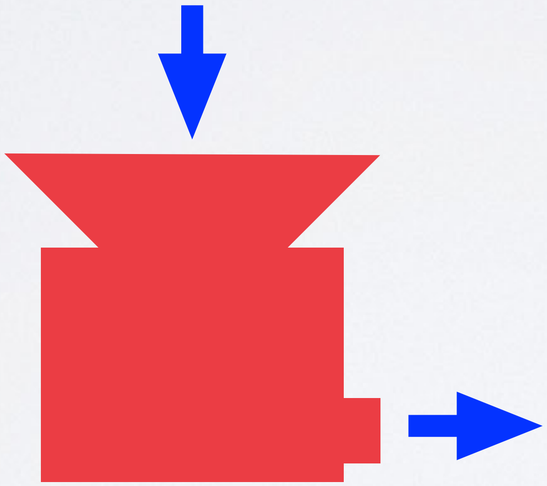
- Commercial LoRa gateways uses the SX1301 or SX1308 chip (March 2019):
  The SX1301 is intended for outdoor usage.
  The ambient operating temperature is -40 to 80°C and it has a -142 dBm sensitivity.
  The SX1308 is intended for indoor usage.
  The ambient operating temperature is 0 to 70°C and has a -139 dBm sensitivity.

- According to the Semtech datasheets, both the SX1301 [Ref. 7] and SX1308 [Ref. 8] can scan up to 8 LoRa channels for preambles of all data rates at all times.

- Because of this TTN defined 8 uplink LoRa channels for the EU863-870 frequency plan.

GLOBAL_CONF.JSON FOR EU863-870

European Telecommunications Standards Institute: ETSI 300220-2
Dutch Authority: Dutch Laws and Regulations
LoRa Alliance: LoRaWAN Regional Parameters (EU863-870)
Network Operator eg. TTN: The Things Network EU863-870 freq. plan
Semtech datasheet: Hardware capabilities



global_conf.json

radio_N
chan_multiSF_N
chan_Lora_std
chan_FSK

STOP THIS
BORING TALK!
AND GET DOWN TO BUSINESS!

GLOBAL_CONF.JSON FOR EU863-870

radio	Center freq. [MHz]	TX	chan_multiSF_N (if) [MHz]								chan_Lora_std (if) [MHz]	chan_FSK (if) [MHz]
			0	1	2	3	4	5	6	7		
0	867.5	Y				-0.4 **867.1**	-0.2 **867.3**	0 **867.5**	0.2 **867.7**	0.4 **867.9**		
1	868.5	N	-0.4 **868.1**	-0.2 **868.3**	0 **868.5**						-0.2 **868.3**	0.3 **868.8**
			Hardcoded: BW=125kHz Hardcoded: SF=7-12								BW=250kHz SF=7	BW=125kHz dataRate=50kpbs

```
"radio_0": {
        "enable": true,
        "type": "SX1257",
        "freq": 867500000,
        "rssi_offset": -166.0,
        "tx_enable": true,
        "tx_freq_min": 863000000,
        "tx_freq_max": 870000000
},
```

```
"radio_1": {
        "enable": true,
        "type": "SX1257",
        "freq": 868500000,
        "rssi_offset": -166.0,
        "tx_enable": false
},
```

Note:
Both radios will be used for receiving packages,
but only one radio will be used for transmitting packages.

GLOBAL_CONF.JSON FOR EU863-870

radio	Center freq. [MHz]	TX	chan_multiSF_N (if) [MHz]								chan_Lora_std (if) [MHz]	chan_FSK (if) [MHz]
			0	1	2	3	4	5	6	7		
0	867.5	Y				-0.4 **867.1**	-0.2 **867.3**	0 **867.5**	0.2 **867.7**	0.4 **867.9**		
1	868.5	N	-0.4 **868.1**	-0.2 **868.3**	0 **868.5**						-0.2 **868.3**	0.3 **868.8**
			Hardcoded: BW=125kHz Hardcoded: SF=7-12								BW=250kHz SF=7	BW=125kHz dataRate=50kpbs

```
"chan_multiSF_0": {
        "desc": "Lora MAC, 125kHz, all SF, 868.1 MHz",
        "enable": true,
        "radio": 1,
        "if": -400000
},
```

```
"chan_multiSF_1": {
        "desc": "Lora MAC, 125kHz, all SF, 868.3 MHz",
        "enable": true,
        "radio": 1,
        "if": -200000
},
```

```
"chan_multiSF_3": {
        "desc": "Lora MAC, 125kHz, all SF, 867.1 MHz",
        "enable": true,
        "radio": 0,
        "if": -400000
},
```

chan_multiSF_N
IF allowed values: -400000 to +400000 Hz
User can not set the BW and SF, hardcoded: BW=125 kHz, SF=7-12

GLOBAL_CONF.JSON FOR EU863-870

radio	Center freq. [MHz]	TX	chan_multiSF_N (if) [MHz]								chan_Lora_std (if) [MHz]	chan_FSK (if) [MHz]
			0	1	2	3	4	5	6	7		
0	867.5	Y				-0.4 **867.1**	-0.2 **867.3**	0 **867.5**	0.2 **867.7**	0.4 **867.9**		
1	868.5	N	-0.4 **868.1**	-0.2 **868.3**	0 **868.5**						-0.2 **868.3**	0.3 **868.8**
			Hardcoded: BW=125kHz Hardcoded: SF=7-12								BW=250kHz SF=7	BW=125kHz datarate=50kpbs

```
"chan_Lora_std": {
        "desc": "Lora MAC, 250kHz, SF7, 868.3 MHz",
        "enable": true,
        "radio": 1,
        "if": -200000,
        "bandwidth": 250000,
        "spread_factor": 7
},
```

```
"chan_FSK": {
        "desc": "FSK 50kbps, 868.8 MHz",
        "enable": true,
        "radio": 1,
        "if": 300000,
        "bandwidth": 125000,
        "datarate": 50000
},
```

GLOBAL_CONF.JSON FOR EU863-870

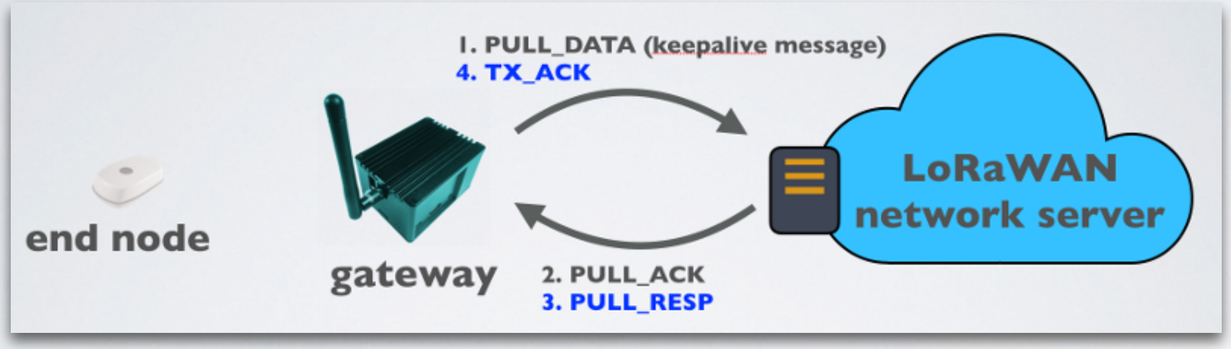
radio	Center freq. [MHz]	TX	chan_multiSF_N (if) [MHz]								chan_Lora_std (if) [MHz]	chan_FSK (if) [MHz]
			0	1	2	3	4	5	6	7		
0	867.5	Y				-0.4 **867.1**	-0.2 **867.3**	0 **867.5**	0.2 **867.7**	0.4 **867.9**		
1	868.5	N	-0.4 **868.1**	-0.2 **868.3**	0 **868.5**						-0.2 **868.3**	0.3 **868.8**
			Hardcoded: BW=125kHz Hardcoded: SF=7-12								BW=250kHz SF=7	BW=125kHz datarate=50kpbs

- The frequencies mentioned in the table are **uplink frequencies**.
  It means the gateway *scans* these frequencies to check if there are end nodes sending packets at these frequencies.

- A gateway can also create downlinks whereby packets are transmitted from the gateway to end nodes.

GLOBAL_CONF.JSON FOR EU863-870

- But these downlink frequencies are set by the LoRaWAN network server in the PULL_RESP messages, see Tutorial 29.

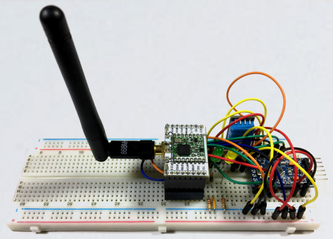


- The gateway only checks if the downlink frequency is within a certain frequency range specified in the global_conf.json file.

```
"radio_0": {
        "enable": true,
        "type": "SX1257",
        "freq": 867500000,
        "rssi_offset": -166.0,
        "tx_enable": true,
        "tx_freq_min": 863000000,
        "tx_freq_max": 870000000
},
```

```
"radio_1": {
        "enable": true,
        "type": "SX1257",
        "freq": 868500000,
        "rssi_offset": -166.0,
        "tx_enable": false
},
```

GLOBAL_CONF.JSON & TTN EU863-870



end node

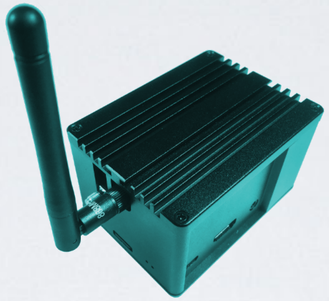
Arduino LMIC

End node uses these freq.

868.1 (TX, RX1)
868.3 (TX, RX1)
868.5 (TX, RX1)
869.525 (RX2)

When registring the end node, using OTAA, during Join Accept these freq. are set by the LoRaWAN network server.

867.1 (TX, RX1)
867.3 (TX, RX1)
867.5 (TX, RX1)
867.7 (TX, RX1)
867.9 (TX, RX1)



gateway

global_conf.json

Gateway scans these frequencies.

868.1
868.3
868.5
867.1
867.3
867.5
867.7
867.9
868.8 (FSK)

Gateway transmits at frequencies which are set by the LoRaWAN network server (PULL_RESP).

In this setup:
- The end node sends data to TTN.
- The end node uses Arduino LMIC.
  https://github.com/matthijskooijman/arduino-lmic
- The gateway uses the Semtech software:
  https://github.com/Lora-net/lora_gateway
  https://github.com/Lora-net/packet_forwarder

PULL_RESP
For example: 869.525, 868.1 etc.

GLOBAL_CONF.JSON & TTN EU863-870

radio	Center freq. [MHz]	TX	chan_multiSF_N (if) [MHz]								chan_Lora_std (if) [MHz]	chan_FSK (if) [MHz]
			0	1	2	3	4	5	6	7		
0	867.5	Y				-0.4 **867.1**	-0.2 **867.3**	0 **867.5**	0.2 **867.7**	0.4 **867.9**		
1	868.5	N	-0.4 **868.1**	-0.2 **868.3**	0 **868.5**						-0.2 **868.3**	0.3 **868.8**
			Hardcoded: BW=**125kHz** Hardcoded: **SF=7-12**								**BW=250kHz** **SF=7**	**BW=125kHz** **dataRate=50kpbs**

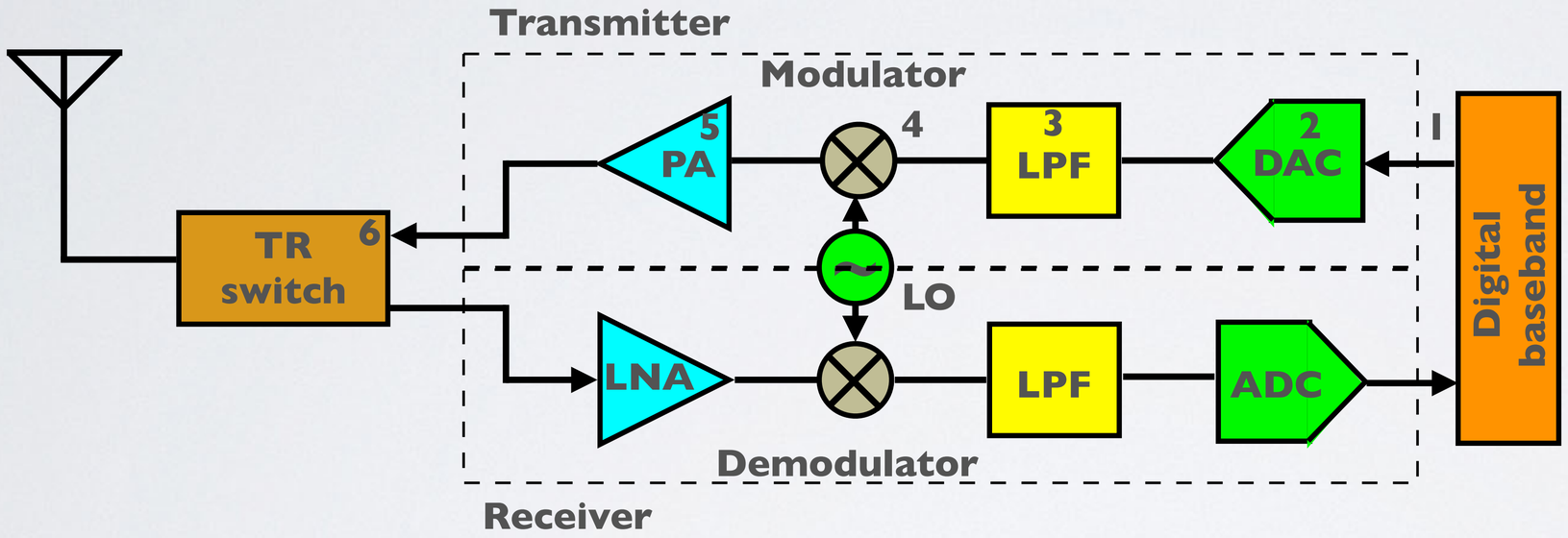
Nr	Channel Freq. [MHz]	Data Rate
1	**868.1**	**SF7BW125 to SF12BW125**
2	**868.3**	**SF7BW125 to SF12BW125 and SF7BW250**
3	**868.5**	**SF7BW125 to SF12BW125**
4	**867.1**	**SF7BW125 to SF12BW125**
5	**867.3**	**SF7BW125 to SF12BW125**
6	**867.5**	**SF7BW125 to SF12BW125**
7	**867.7**	**SF7BW125 to SF12BW125**
8	**867.9**	**SF7BW125 to SF12BW125**
9	**868.8**	**FSK**
	869.525	SF9BW125 (RX2)

The **uplink** frequencies, bandwidths and Spreading Factors specified in the global_conf.json (radio_N, chan_multiSF_N, chan_lora_std and chan_FSK) complies with the TTN EU863-870 frequency plan.

Uplink channels: 1-9
Downlink channels: 1-9 (RX1) and 869.525, SF9BW125 (RX2).

DIGITAL RADIO TRANSCEIVER

- In the most basic form a LoRaWAN gateway is just a digital radio transceiver, and in general this is what a digital radio transceiver looks like:



- It has a transmitter and a receiver path.

- Lets look at the transmitter path.

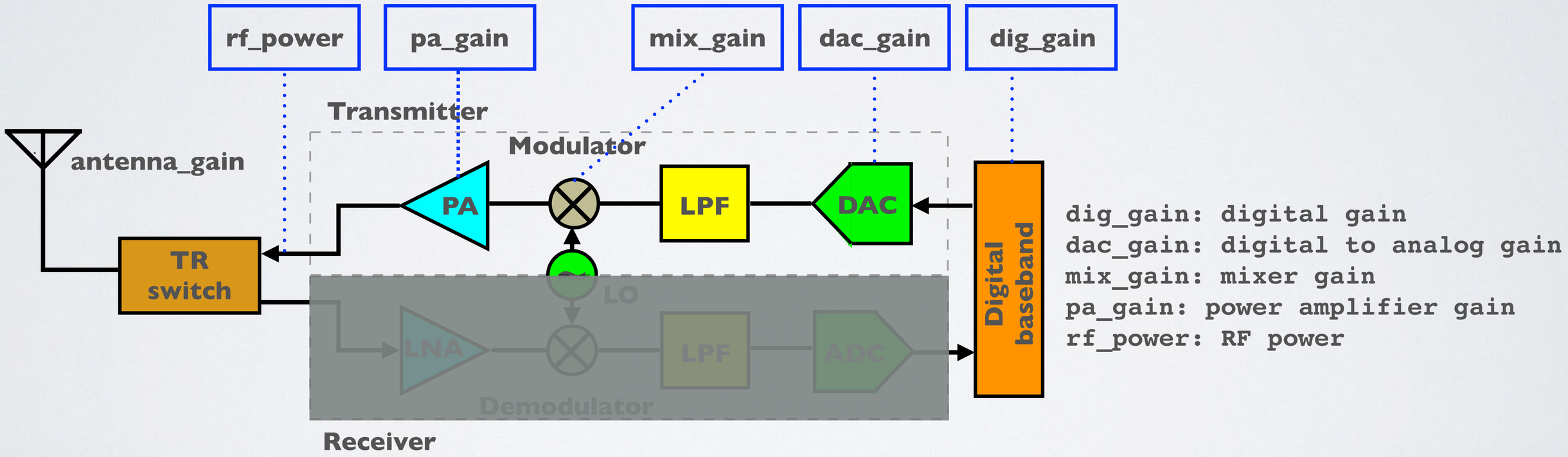
DIGITAL RADIO TRANSCEIVER

1. The digital data that contains the information that needs to be transmitted.
2. The Digital-to-Analog Converter (DAC) converts the digital data to an analog signal.
3. The Low Pass Filter (LPF) filters out the noise, etc from the analog signal.
4. A Local Oscillator (LO) generates a carrier signal and modulates the carrier signal onto the analog signal thus creating an RF signal.
5. The power amplifier boost the RF signal.
6. The Transmit/Receive (TR) switch sends the amplified RF signal to the transmitting antenna.

DIGITAL RADIO TRANSCEIVER

- The receiver works the same as the transmitter but in reverse order.
  By the way LNA stands for Low Noise Amplifier.

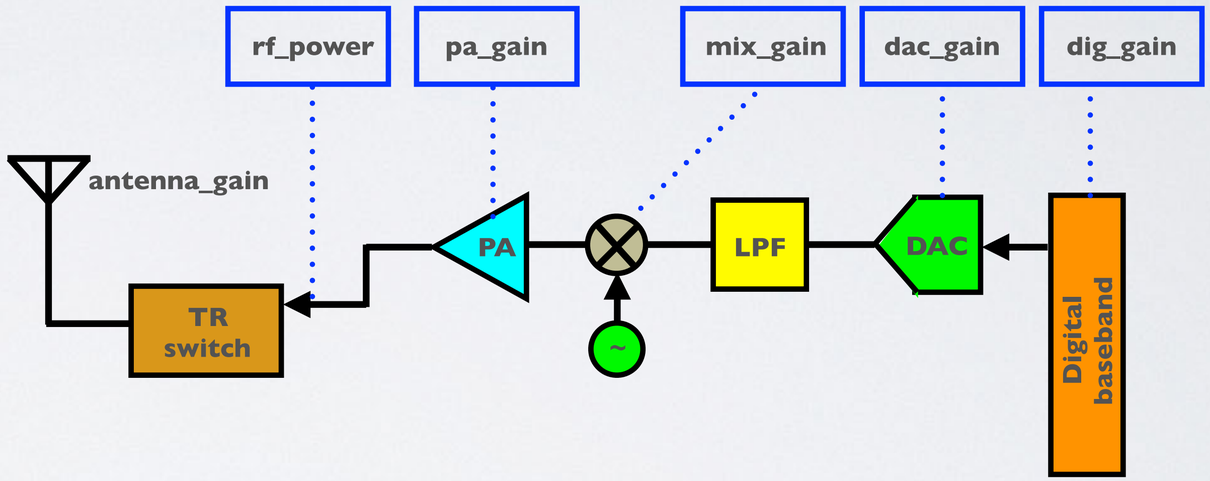
- Now lets only focus on the transmitter.



LUT PARAMETERS EXPLAINED

- The parameters dig_gain, dac_gain, mix_gain, pa_gain and rf_power can be found in the global_conf.json file, for example:

```
"tx_lut_9": {
   /* TX gain table, index 9 */
   "pa_gain": 2,
   "mix_gain": 10,
   "rf_power": 14,
   "dig_gain": 0
},
```



dac_gain is always 3 and is therefore not found in the configuration file.

- If a specific rf_power is needed the corresponding power settings (pa_gain, mix_gain, and dig_gain) can be found in the global_config.json LookUp Table (LUT).

GLOBAL_CONF.JSON: SX1301_CONF.TX_LUT_N

Name	Required	Type	Function
SX1301_conf.tx_lut_N (N=0-15). Configure the concentrator TX gain Look Up Table (LUT). These parameters are board dependant. TX gain LUT must have at least one entry.			
pa_gain	No	unsigned integer	Controls the external PA gain (SX1301 I/O). Allowed values: 0-3 Default value: 0.
dac_gain	No	unsigned integer	Controls the radio DAC gain. ONLY supported value dac_gain = 3. Default value: 3.
dig_gain	No	unsigned integer	Controls the SX1301 digital gain. Allowed values: 0 and 3. Default value: 0.
mix_gain	No	unsigned integer	Control the radio mixer gain. Allowed values: 8-14 Default value: 3 (will cause an error!).
rf_power	No	signed integer	Measured TX power at the board connector, in dBm. Default value: 0.

LUT PARAMETERS EXPLAINED

- A maximum of 16 power settings can be configured (tx_lut_0 … tx_lut_15).
  These settings are board specific and have been selected during calibration for each concentrator.

- I have noticed that concentrators based on the Semtech SX1301 reference designs uses the same LUT power settings, see:
  https://github.com/Lora-net/packet_forwarder/tree/master/lora_pkt_fwd/cfg

- Semtech created two SX1301 reference designs (see: https://github.com/Lora-net/packet_forwarder):
  - The Semtech reference design board SX1301AP1 (PCB_E286) which uses no FPGA.
  - The Semtech reference design board SX1301AP2 (PCB_E336) which uses an FPGA.

LUT PARAMETERS EXPLAINED

- LUT power settings for Semtech reference design board **SX1301 no FPGA**, see: https://github.com/Lora-net/packet_forwarder/blob/master/lora_pkt_fwd/cfg/global_conf.json.PCB_E286.EU868.basic

- LUT power settings for Semtech reference design board **SX1301 with FPGA**, see: https://github.com/Lora-net/packet_forwarder/blob/master/lora_pkt_fwd/cfg/global_conf.json.PCB_E336.EU868.basic

LUT power settings SX1301 no FPGA

	0	1	2	3	4	5	6	7	8	9	10	11
pa_gain	0	0	0	1	1	1	1	2	1	2	2	3
mix_gain	8	10	12	8	10	12	13	9	15	10	11	9
rf_power	**-6**	**-3**	**0**	**3**	**6**	**10**	**11**	**12**	**13**	**14**	**16**	**20**
dig_gain	0	0	0	0	0	0	0	0	0	0	0	0

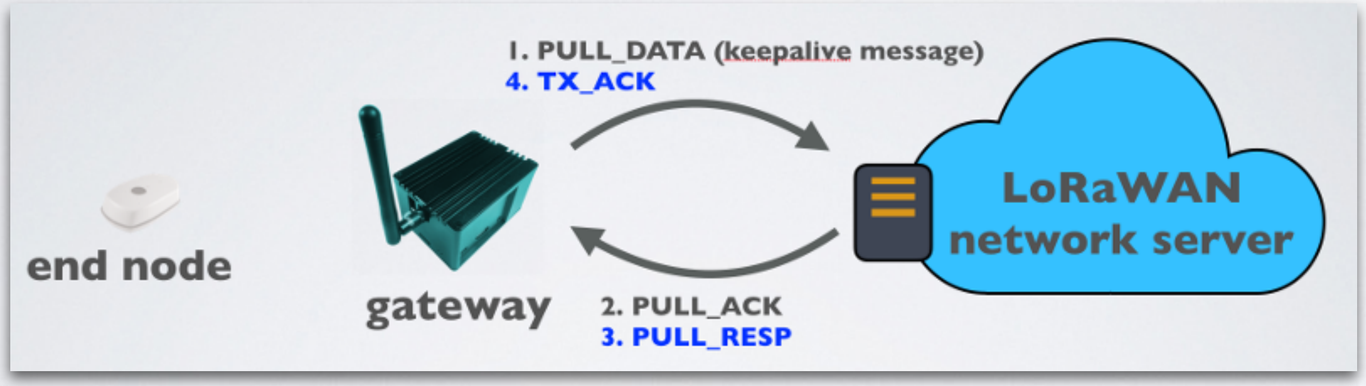
LUT power settings SX1301 with FPGA

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
pa_gain	0	0	0	0	1	1	1	1	1	1	2	2	2	2	3	3
mix_gain	8	10	10	14	10	12	12	12	14	13	9	11	13	15	10	10
rf_power	**-6**	**-3**	**0**	**3**	**6**	**10**	**11**	**12**	**13**	**14**	**16**	**20**	**23**	**25**	**26**	**27**
dig_gain	3	3	1	2	3	2	1	0	2	0	2	1	1	2	2	1

LUT PARAMETERS EXPLAINED

- Always check the concentrators manuals which LUT power settings to use.
  Do not copy the previous LUT settings.
  But what is the purpose of these LUT power settings?

- When a downlink message is created a PULL_RESP message is send from the LoRaWAN network server to the gateway (see Tutorial 29). The txpk JSON object has the parameter "**powe**" which is the ***proposed* RF power** in dBm.
  See: https://www.mobilefish.com/download/lora/tcpdump_output_with_notes.txt



LUT PARAMETERS EXPLAINED

- This means the network server is in charge of requesting transmit powers.

- The gateway extracts the proposed RF power (powe) from the txpk JSON object. **The proposed RF powers are in fact ERP values.**

- Lets assume powe=9 dBm, antenna_gain=2 **dBd** and the gateway concentrator uses the following LUT power settings:

LUT power settings SX1301 no FPGA

	0	1	2	3	4	5	6	7	8	9	10	11
pa_gain	0	0	0	1	1	1	1	2	1	2	2	3
mix_gain	8	10	12	8	10	12	13	9	15	10	11	9
rf_power	**-6**	**-3**	**0**	**3**	**6**	**10**	**11**	**12**	**13**	**14**	**16**	**20**
dig_gain	0	0	0	0	0	0	0	0	0	0	0	0

I am using dBd and NOT dBi, because the proposed RF powers are in fact ERP values.

In this tutorial the assumption is made that the network server sends ERP values and not EIRP values.

LUT PARAMETERS EXPLAINED

- The antenna_gain is subtracted from the proposed RF power (powe) to stay within the legal limits:

  `rf_power (dBm) = powe (dBm) - antenna_gain (dBd)`

- powe=8 dBm and antenna_gain=2 dBd **(This includes cable losses etc.)**
  rf_power = 8 - 2 = 6 dBm

- The gateway searches the LUT for rf_power=6 dBm (see tx_lut_N in global_conf.json file).

- I will remind you again, these power settings are board specific and have been selected during calibration for each concentrator. As a gateway user you should not mess around with these settings.

LUT PARAMETERS EXPLAINED

- The gateway finds the entry rf_power=6 dBm in the LUT.

LUT power settings SX1301 no FPGA

	0	1	2	3	4	5	6	7	8	9	10	11
pa_gain	0	0	0	1	1	1	1	2	1	2	2	3
mix_gain	8	10	12	8	10	12	13	9	15	10	11	9
rf_power	**-6**	**-3**	**0**	**3**	**6**	**10**	**11**	**12**	**13**	**14**	**16**	**20**
dig_gain	0	0	0	0	0	0	0	0	0	0	0	0

- The gateway now knows how to adjust the power amplifier gain (pa_gain=1), the mixer gain (mix_gain=10) and the digital gain (dig_gain=0) to obtain a 6 dBm TX output.

LUT PARAMETERS EXPLAINED

- If the rf_power is not found in the LUT than an error will be logged, the downlink packet will be rejected and de facto the packet is lost.

- The following logs are created with Semtech LoRa library (V5.0.1) and Semtech UDP Packet Forwarder (V4.0.1), by changing rf_power=14 to -14.

```
Mar 12 12:22:50 ttn-gateway ttn-gateway[599]: JSON down: {“txpk":{"imme":false,"tmst":
749257172,”freq":868.5,"rfch":0,"powe"14,"modu":"LORA","datr":"SF8BW125","codr":"4/5",
"ipol":true,"size":14,"ncrc":true,"data":"YJEvASYAAQABT61h2m4="}}
Mar 12 12:22:50 ttn-gateway ttn-gateway[599]:
ERROR: Packet REJECTED, unsupported RF power for TX - 14
```

/var/log/syslog

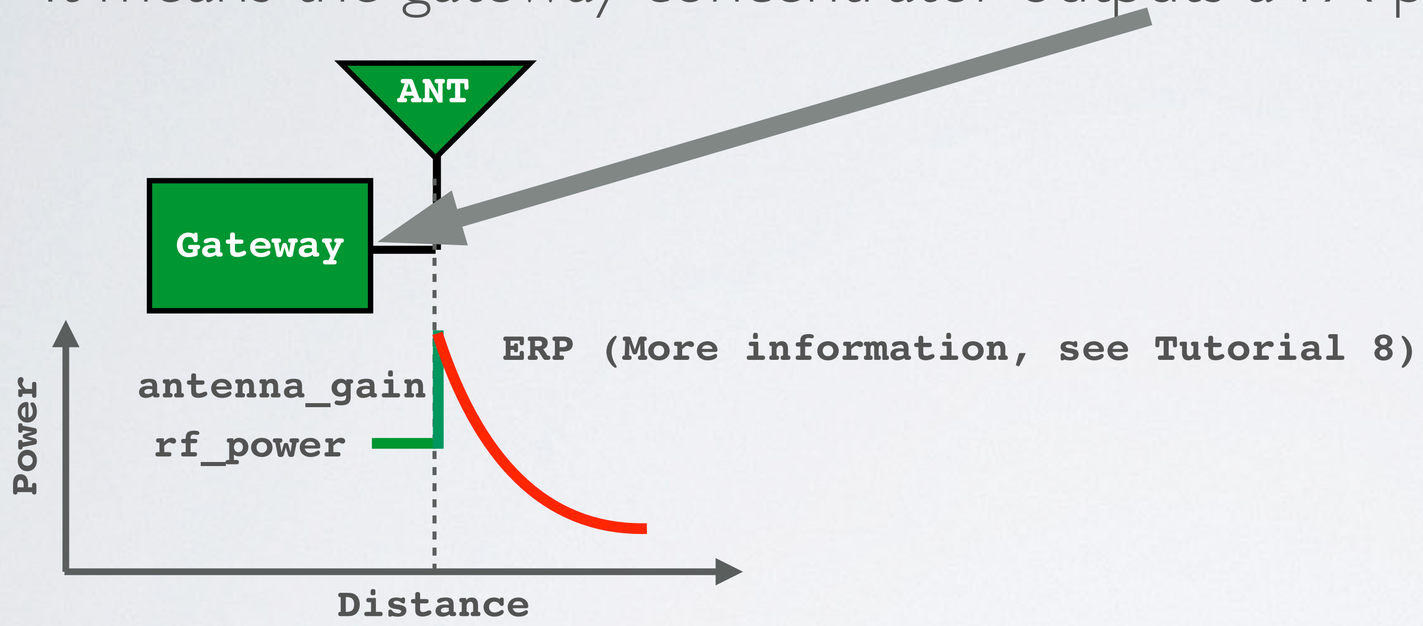
```
{“txpk”:{“imme":false,"tmst":749257172,"freq":868.5,"rfch"0,"powe"14,"modu":"LORA",
“datr":"SF8BW125","codr":"4/5","ipol":true,"size":14,"ncrc":true,
"data":"YJEvASYAAQABT61h2m4="}}

{“txpk_ack":{"error":"TX_POWER"}}
```

sudo tcpdump -XUq port 1700 | tee tcpdump_output.txt

LUT PARAMETERS EXPLAINED

- What does it mean an rf_power = 6 dBm?
  It means the gateway concentrator outputs a TX power of 6 dBm.



- ERP = rf_power + antenna_gain (+ cable losses)

LUT PARAMETERS EXPLAINED

- ERP= rf_power + antenna_gain (+ cable losses)

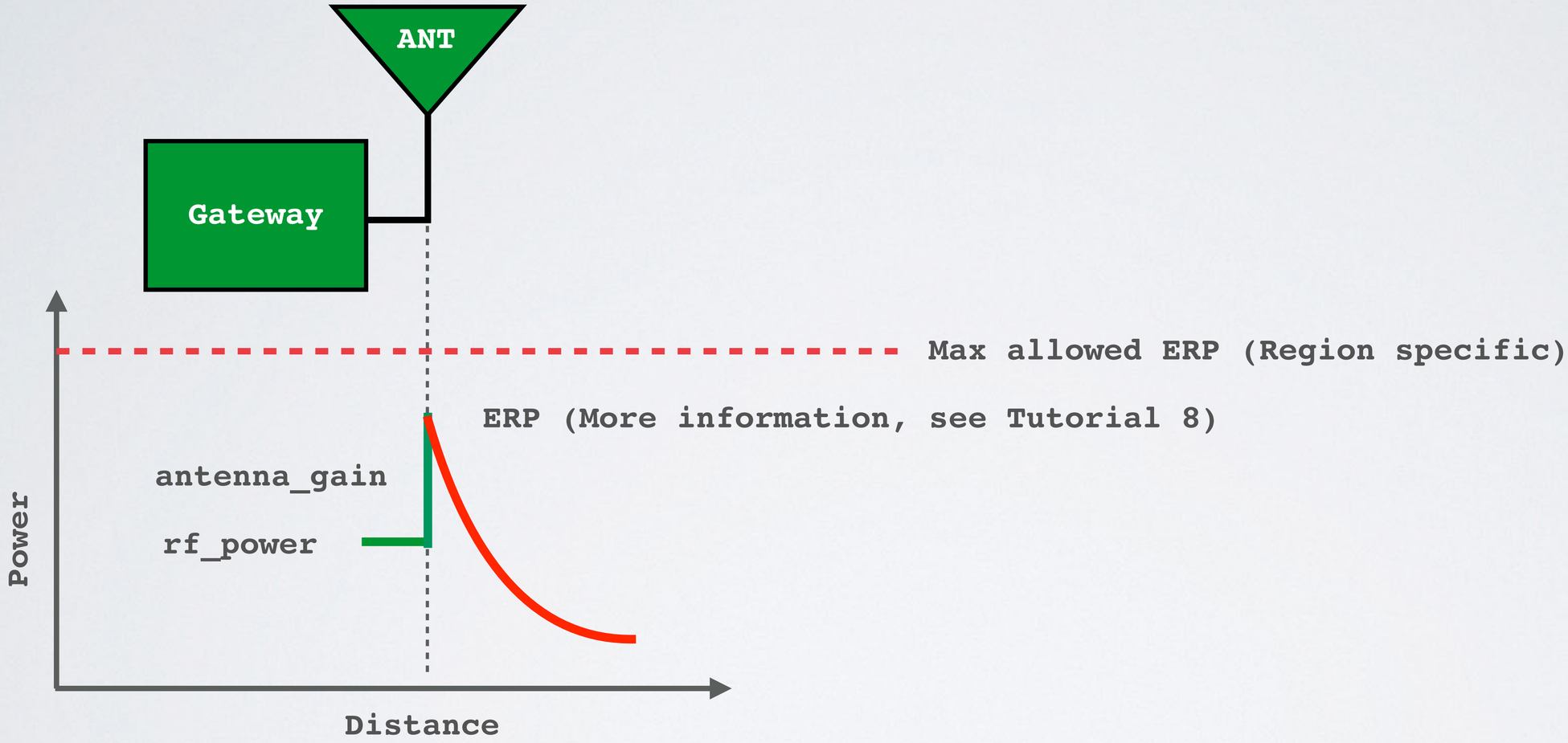
- It is important to specify the antenna_gain in the global_conf.json file, otherwise the ERP does not comply with the regulations.

- For example in the EU863-870 region,
  for frequency range 860.00-868.60 MHz and 868.70-869.20 MHz,
  the maximum allowed ERP = 25 mW ≈ 14 dBm

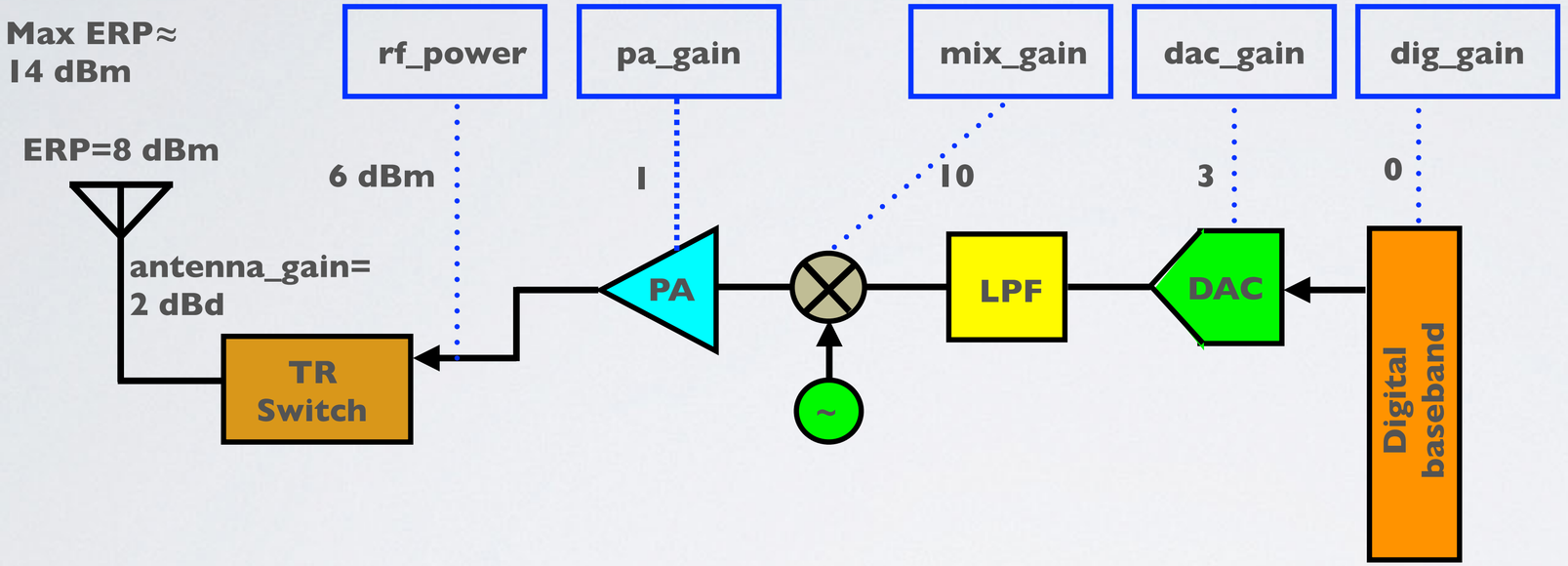
- Convert antenna_gain in dBi to dBd:
  dBd = dBi - 2.15

- After ERP is calculated make sure:
  ERP <= Max allowed ERP

LUT PARAMETERS EXPLAINED



LUT PARAMETERS EXPLAINED



- In this example, the ERP is 8 dBm (=rf_power + antenna_gain + cable losses) for the downlink.

- If the max allowed ERP ≈ 14 dBm than this power complies with the EU863-870 regulations.

LUT PARAMETERS EXPLAINED