

CONSTRUYENDO UNA RED GLOBAL DE INTERNET DE LAS COSAS ENTRE TOD@s

Juan Félix Mateos

Mayo 2019

The Things Network: Misión

Crear una red IoT descentralizada y tecnológicamente independiente, en la que los usuarios son a la vez los propietarios y los operadores del sistema



The Things Network: Principios

Tus datos son tus datos

Neutralidad de la red

Código abierto



Cómo empezó todo

Julio de 2015, Amsterdam

Wienke Giezeman
Johan Stokking





Long Range Wide Area Network

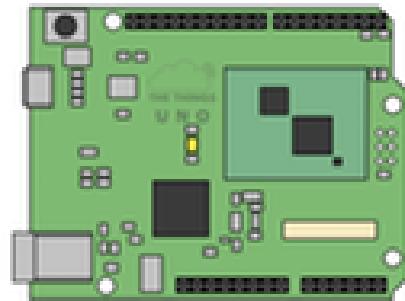
KICKSTARTER



TheThings
GATEWAY



TheThings UNO



Año 2015
**KICK
STARTER**

295.331 €

de la meta de 150.000 €

934

patrocinadores



TheThings NODE

AELORA

[www.aelora.nl](http://wwwaelora.nl)





BORBORA – CHILDREN AIR QUALITY

www.waag.org



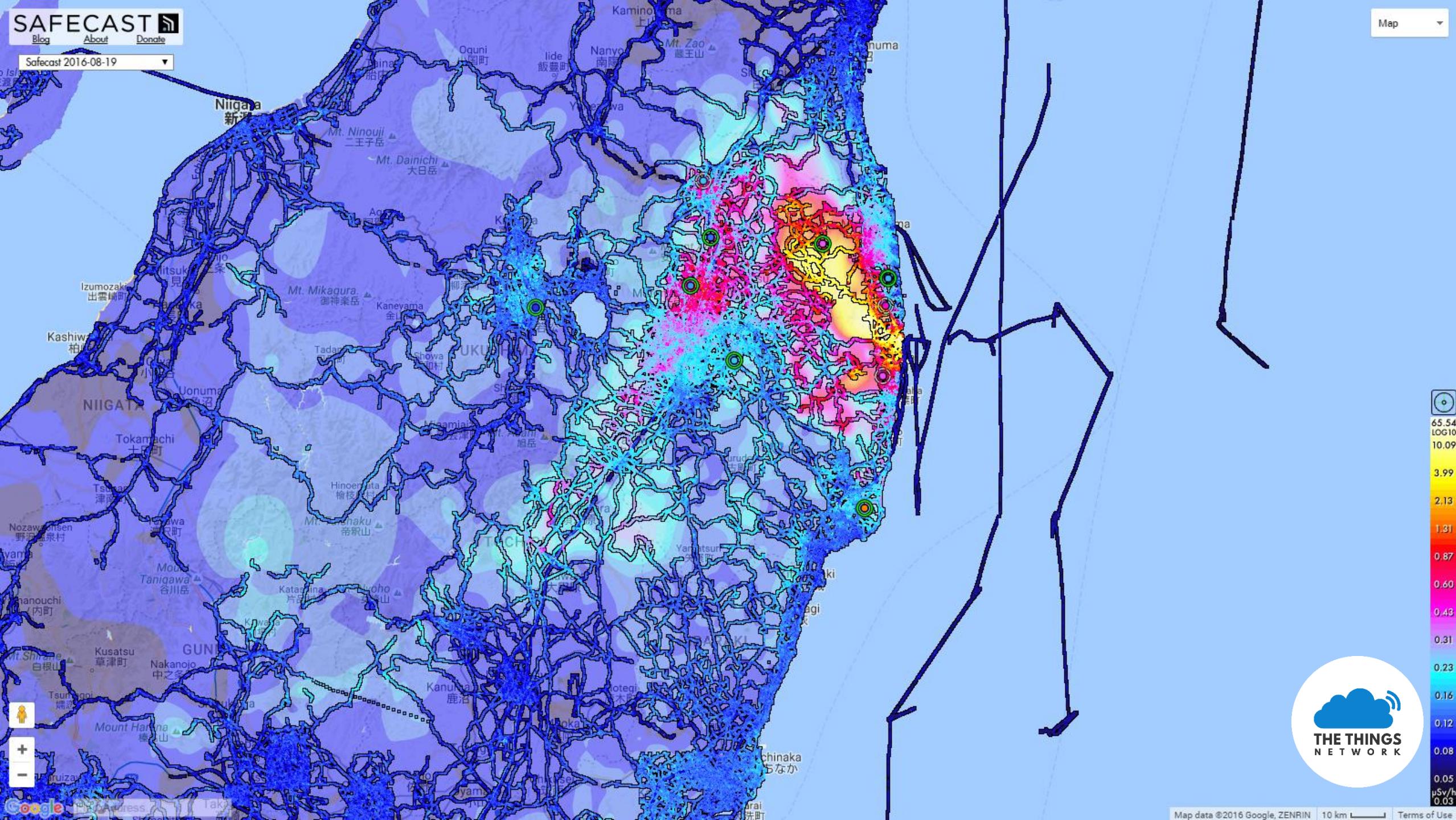


SAFECAST

www.blog.safecast.org/



Safecast 2016-08-19 ▾



HOOSJE BOOTJE





FLOOD.NETWORK

www.flood.network/



FLOOD.NETWORK



SMART MOUSE TRAP

www.xignal.com



LoRa vs LoRaWAN vs THE THINGS NETWORK

CONCEPTOS TÉCNICOS



Conexiones punto a punto

Largo alcance

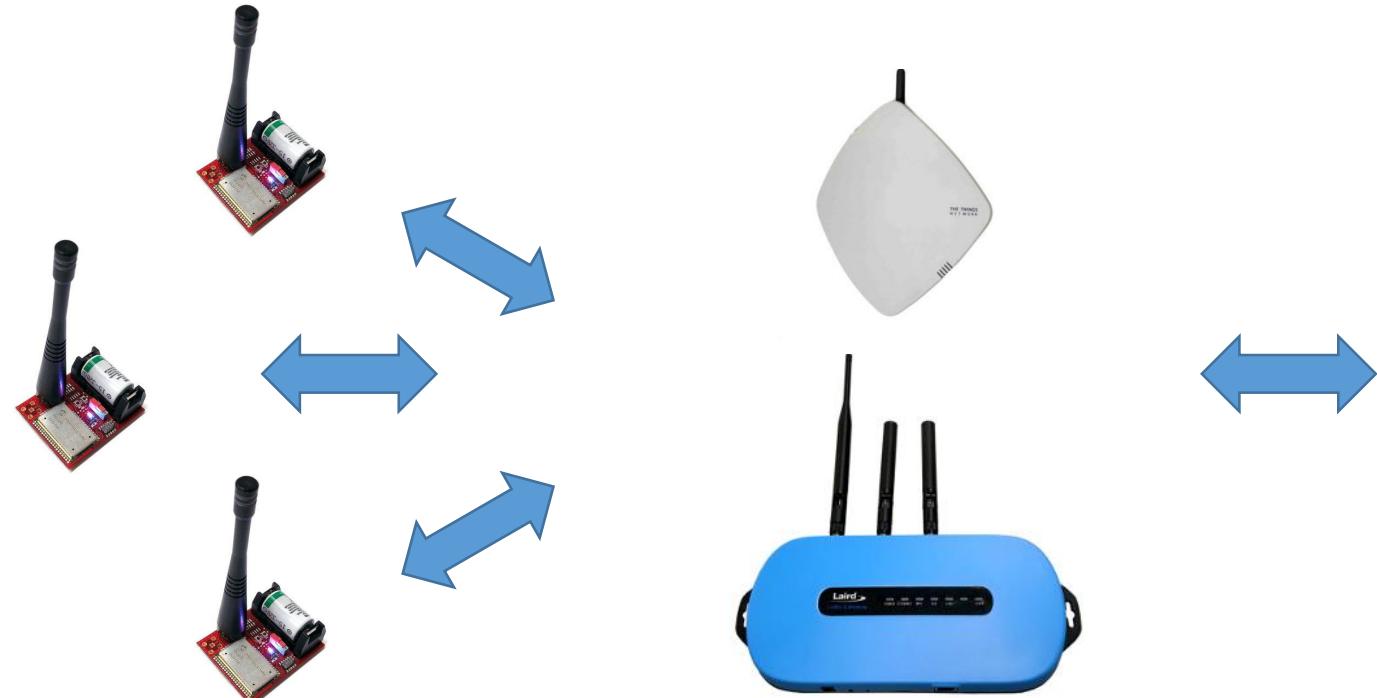
Bajo consumo de energía

Bajo ancho de banda



Nodo ↔ **Mis** gateways ↔ Internet

Solución local



Nodo ↔ **Cualquier** Gateway TTN ↔ The Things Network
Solución global

LoRa

COMPARISON – main LPWAN technologies



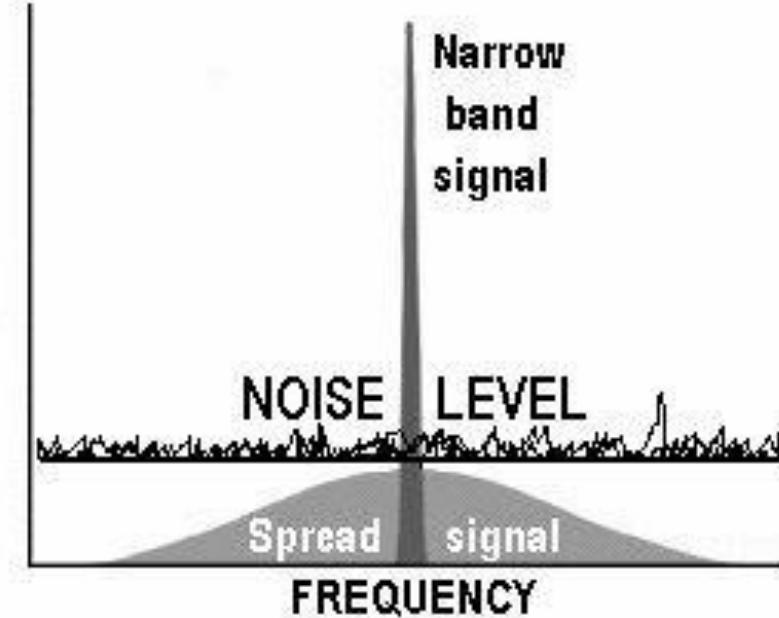
Feature	LORAWAN	SIGFOX	LTE Cat 1	LTE M	NB - LTE
Modulation	SS chip	UNB / GFSK / BPSK	OFDMA	OFDMA	OFDMA
Rx Bandwidth	500 – 125 KHz	100 Hz	20 MHz	20 – 1.4 MHz	200 KHz
Data Rate	290bps – 50Kbps	100 bit / sec 12 / 8 bytes Max	10 Mbit /sec	200 kbps – 1 Mbps	Average 20K bit / sec
Max. # Msgs/day	Unlimited	UL: 140 msgs / day	Unlimited	Unlimited	Unlimited
Max Output Power	20 dBm	20 dBm	23 – 46 dBm	23/30 dBm	20 dBm
Link Budget	154 dB	151 dB	130 dB+	146 dB	150 dB
Battery lifetime – 2000 mAh	105 months	90 months		18 months	
Power Efficiency	Very High	Very High	Low	Medium	Med high
Interference immunity	Very High	Low	Medium	Medium	Low
Coexistence	Yes	No	Yes	Yes	No
Security	Yes	No	Yes Oui	Yes	Yes
Mobility / localization	Yes	Limited mobility, No localization	Mobility	Mobility	Limited mobility, No localization

Source: LoRAWAN Alliance, 2015

www.vertical-m2m.com



LoRaWAN vs SigFox CSS (Chirp Spread Spectrum) vs UNB (Ultra Narrow Band)



Modulación LoRa

Chirp Spread Spectrum

Tecnología de los 40

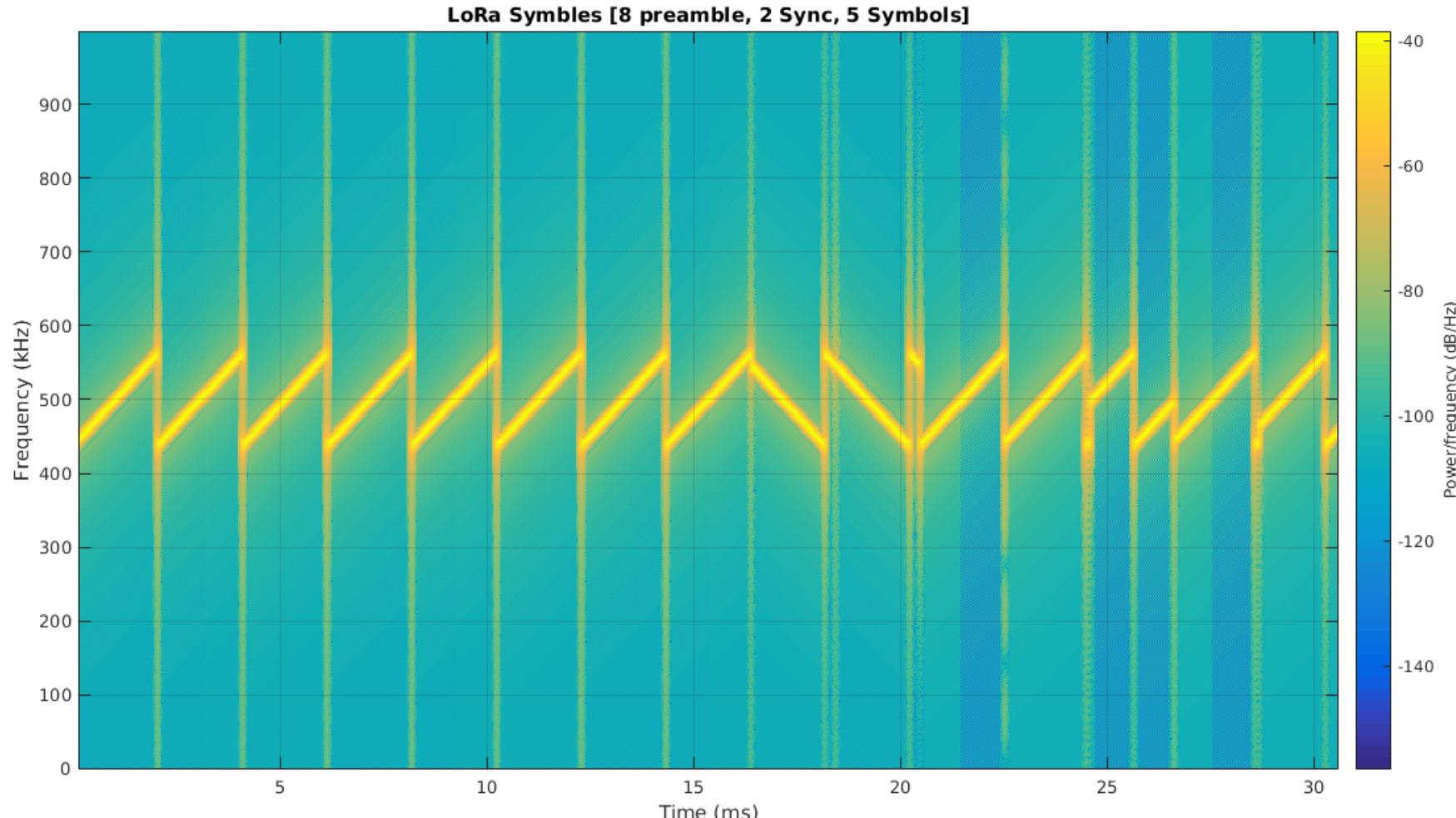
Utilizada en ámbitos militares → Rádar

Largo alcance y penetración

Difícil de detectar

Alta resistencia a interferencias

LoRa Frame

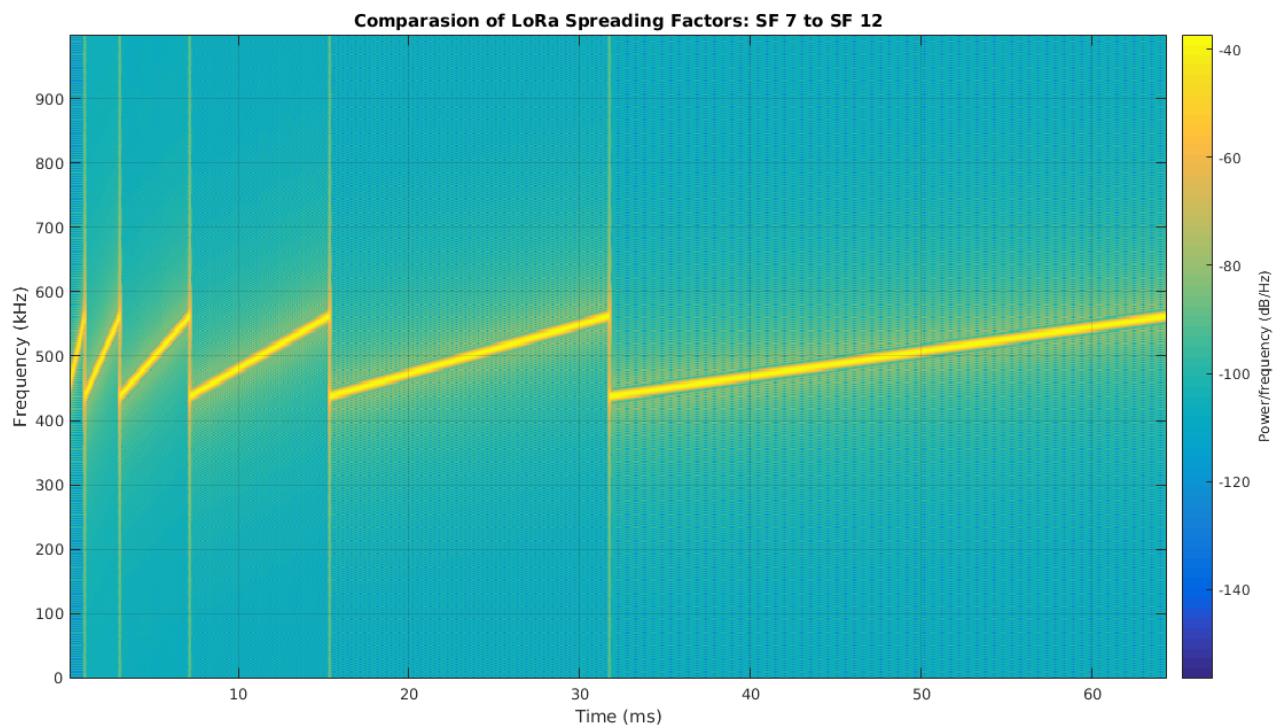


LoRa: Spread Factor

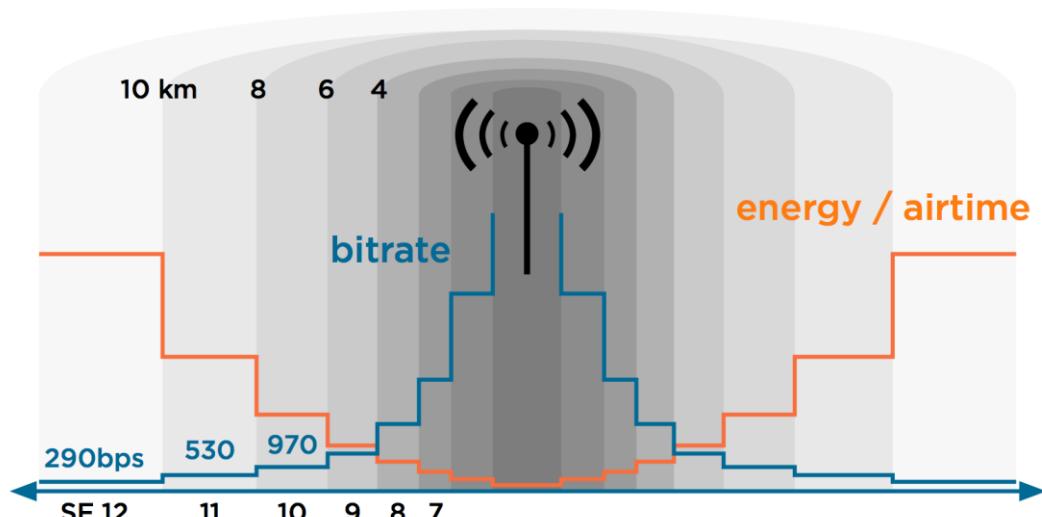
Velocidad vs Alcance vs
Consumo

A mayor velocidad, menor
alcance

A mayor velocidad, menor
consumo



LoRa: Spread Factor



<https://blog.surf.nl/en/lora-the-internet-of-things/>

LoRa Spreading Factors (125kHz bw)

Spreading Factor	Chips/symbol	SNR limit	Time-on-air (10 byte packet)	Bitrate
7	128	-7.5	56 ms	5469 bps
8	256	-10	103 ms	3125 bps
9	512	-12.5	205 ms	1758 bps
10	1024	-15	371 ms	977 bps
11	2048	-17.5	741 ms	537 bps
12	4096	-20	1483 ms	293 bps

<http://www.techplayon.com/lora-link-budget-sensitivity-calculations-example-explained/>

LoRa: Duty Cycle

36 segundos por hora

Entre 59 y 250 bytes por mensaje dependiendo del SF

Sección 7.2.3 de la norma ETSI EN300.220

- g0 (863.0 – 868.0 MHz): 1%
- g1 (868.0 – 868.6 MHz): 1%
- g2 (868.7 – 869.2 MHz): 0.1%
- g3 (869.4 – 869.65 MHz): 10%
- g4 (869.7 – 870.0 MHz): 1%

The Things Network: política de acceso justo

- La red es un procomún
 - Todo@s nos beneficiamos de un uso razonable
- **Uplink:** 30 segundos por día y nodo (aprox. 550 mensajes en SF7)
- **Downlink:** 10 mensajes por día y nodo

LORA

ALCANCE

Yes No

~1Km (urbano) / ~10Km (rural)

BAJO CONSUMO

Yes No

La baterías duran años

MILES DE DISPOSITIVOS

Yes No

Conectados a un mismo gateway

BANDA SIN LICENCIAS

Yes No

868MHz (EU) 915MHz (US)

ANCHO DE BANDA

Yes No

Max 50kb/s

THE THINGS NETWORK

LoRaWAN



The Things Network: Default Channels

This section applies to any region where the ISM radio spectrum use is defined by the ETSI [EN300.220] standard.

The network channels can be freely attributed by the network operator. However the three following 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	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%

Table 2: EU863-870 default channels

The Things Network: Data Rates

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..14	RFU	
15	Defined in LoRaWAN ¹	

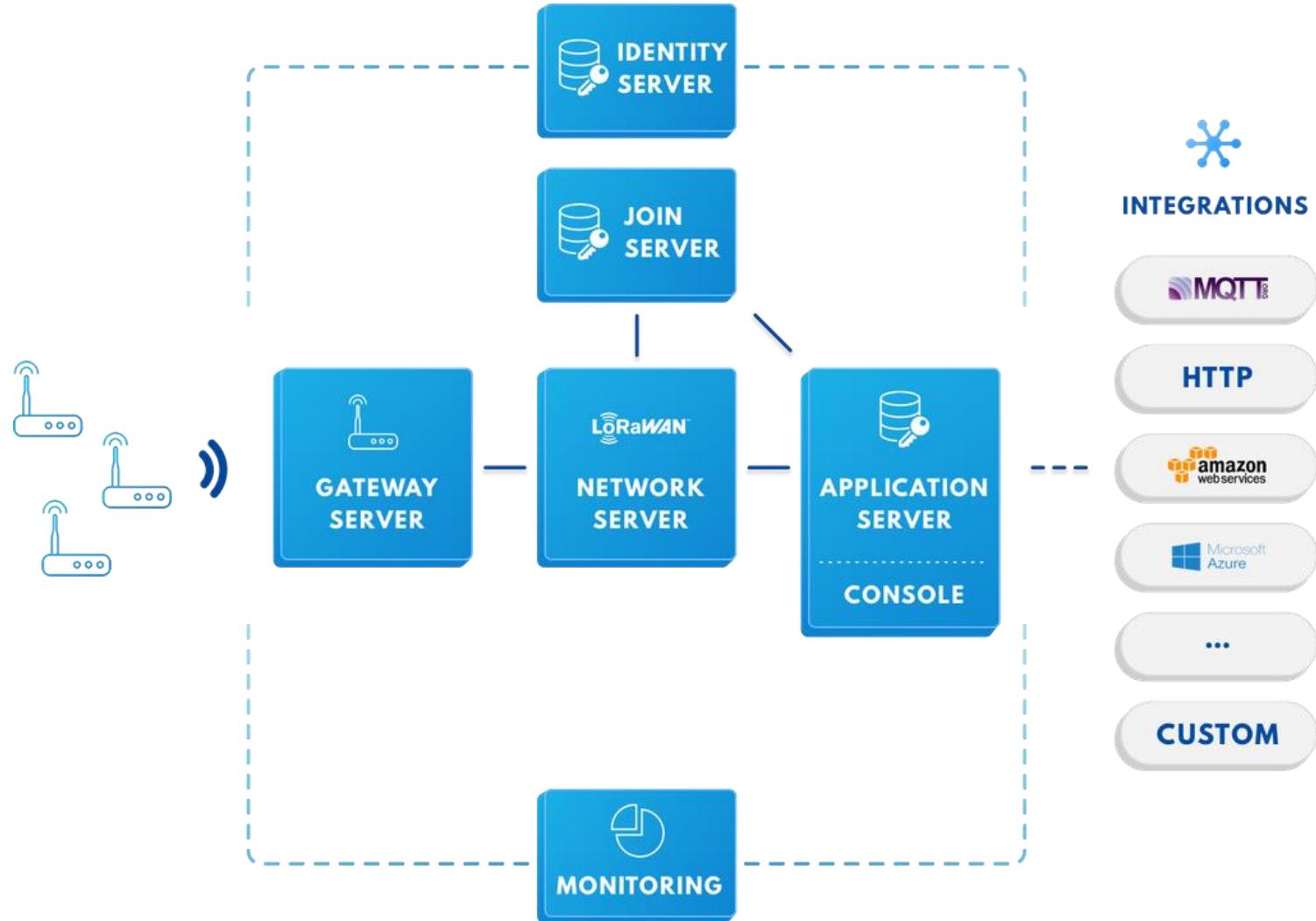
Table 4: TX Data rate table

The Things Network: Tamaño de la carga de pago

DataRate	M	N
0	59	51
1	59	51
2	59	51
3	123	115
4	250	242
5	250	242
6	250	242
7	250	242
8:15	Not defined	

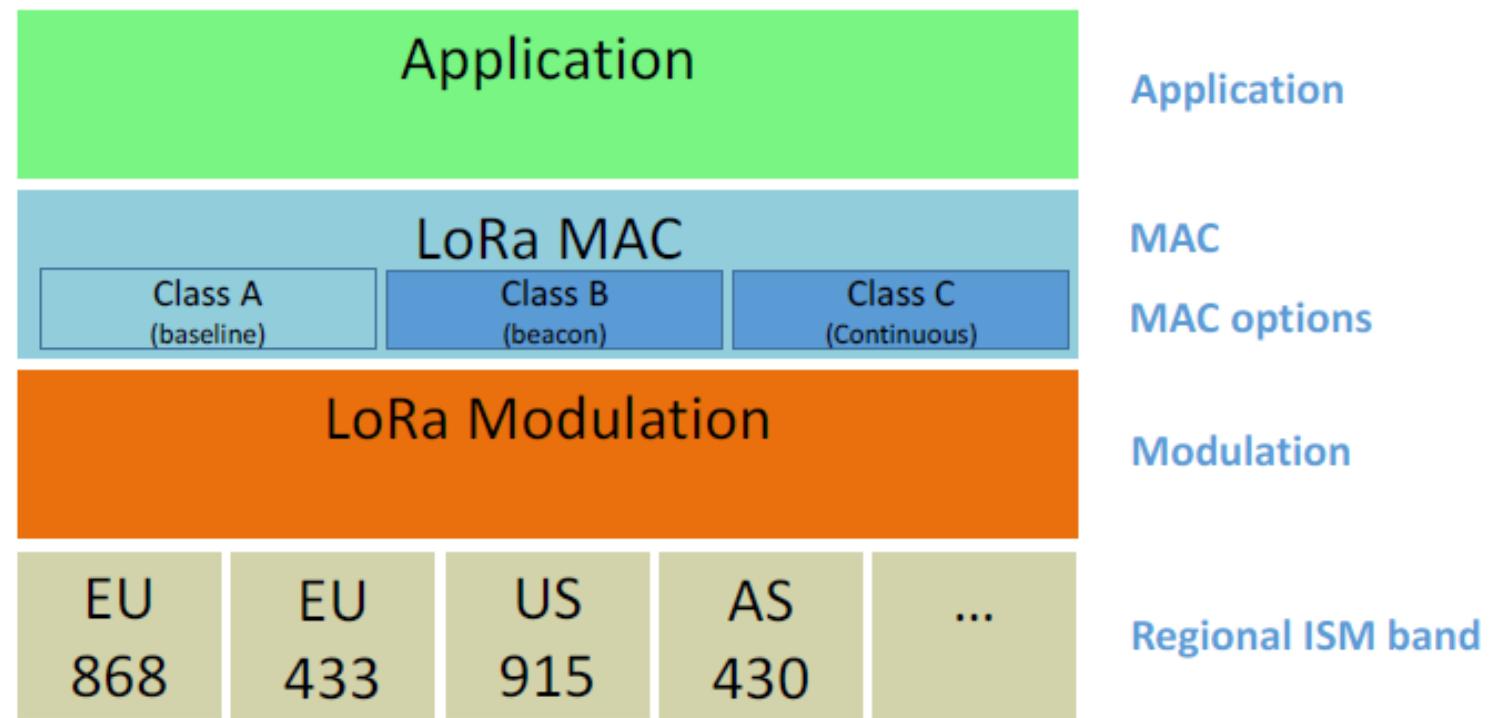
Table 8 : EU863-870 maximum payload size (not repeater compatible)

The Things Network: Stack v3 OTAA__ABP



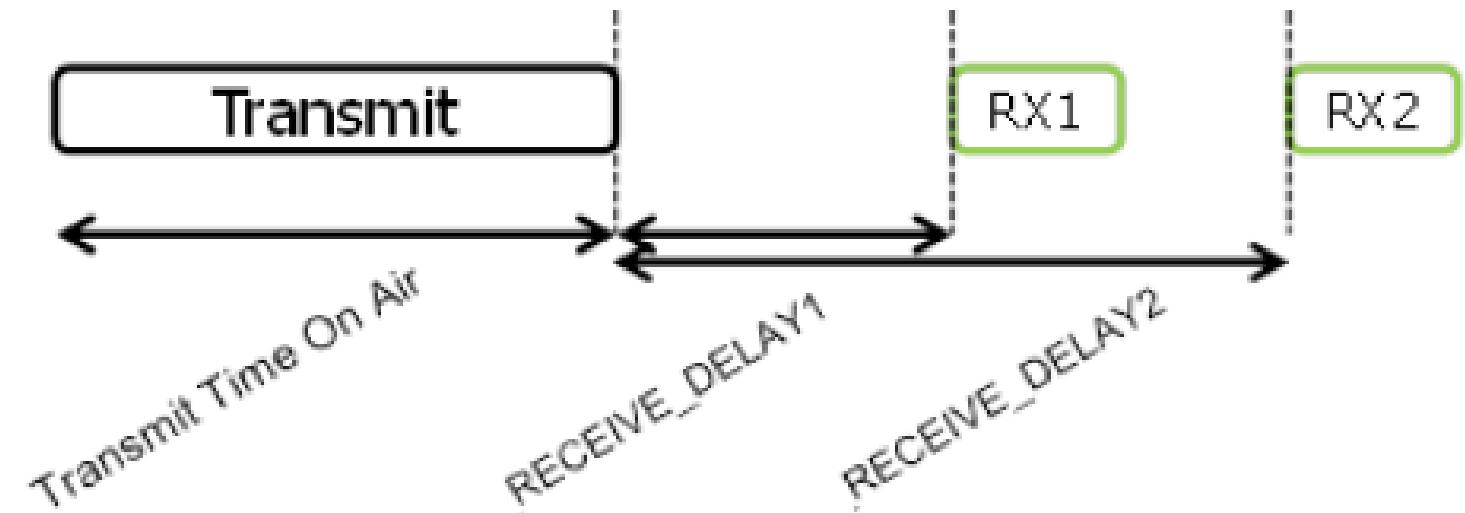
The Things Network: Clase A, B y C

- A: Default
- B: Beacon
- C: Continuos



The Things Network: Uplink y downlink en clase A

- Delay1 = 1s
- Delay2 = 2s



The Things Network: Downlink DR

- El datarate del downlink es:
 - RX1: Depende del DR del uplink y de un parámetro de desplazamiento (offset)
 - RX2: Está fijado en 869.525 MHz / DR0 (SF12, 125 kHz)

The Things Network: ADR, CAD y LBT

- ADR: Adaptive Data Rate
 - No habilitar hasta que el dispositivo esté estable (sin movimiento)
 - El sistema considera los últimos 20 mensajes para determinar el DR óptimo
- CAD: Channel Activity Detection
 - Se utiliza a nivel de hardware para detectar si hay downlink
- LBT: Listen Before Talk
 - No se usa; se ha optado por un duty cycle

The Things Network: Anatomía de un paquete LoRaWAN

Radio PHY layer:

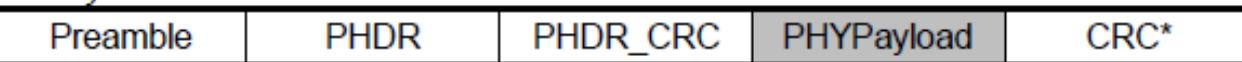
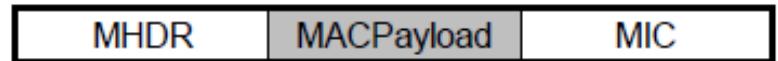
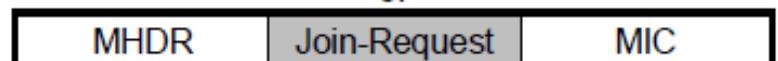


Figure 5: Radio PHY structure (CRC* is only available on uplink messages)

PHYPayload:



or



or

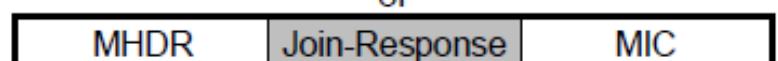


Figure 6: PHY payload structure

MACPayload:



Figure 7: MAC payload structure

FHDR:

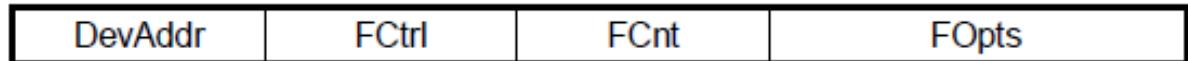


Figure 8: Frame header structure

- El tamaño máximo aplica al MACPayload
- Message Integrity Code
- ADR y ACK se codifican en FCtrl
- El FRMPayload va encriptado en AES-128

The Things Network: Paquetes uplink con confirmación

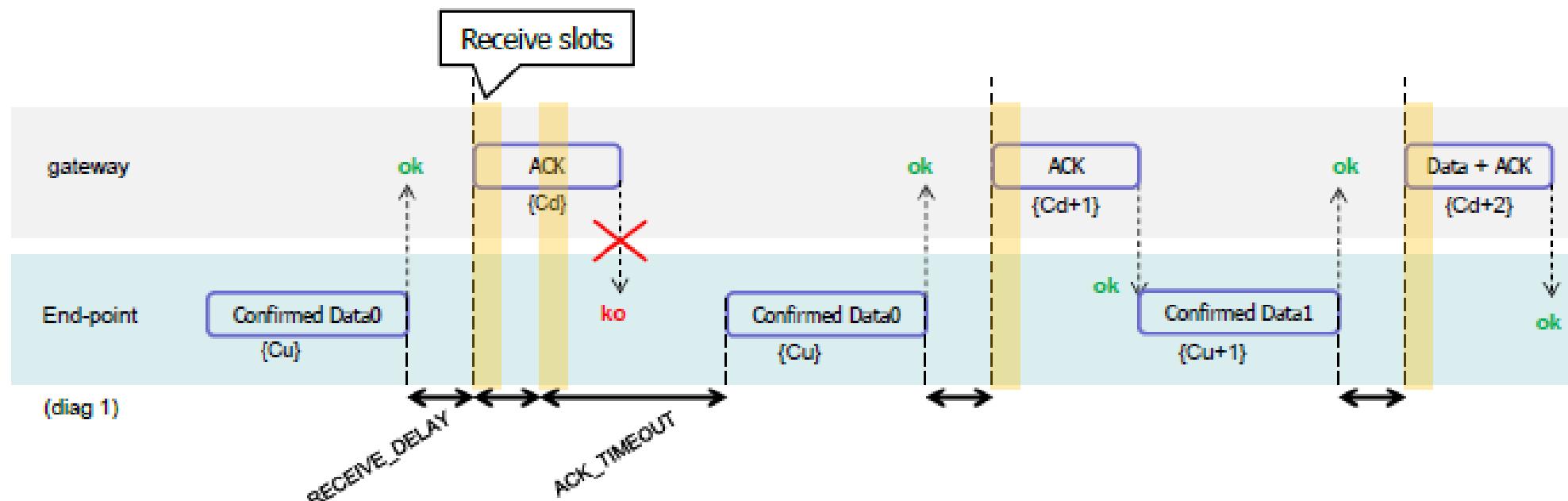


Figure 28: Uplink timing diagram for confirmed data messages

The Things Network: Paquetes downlink con confirmación

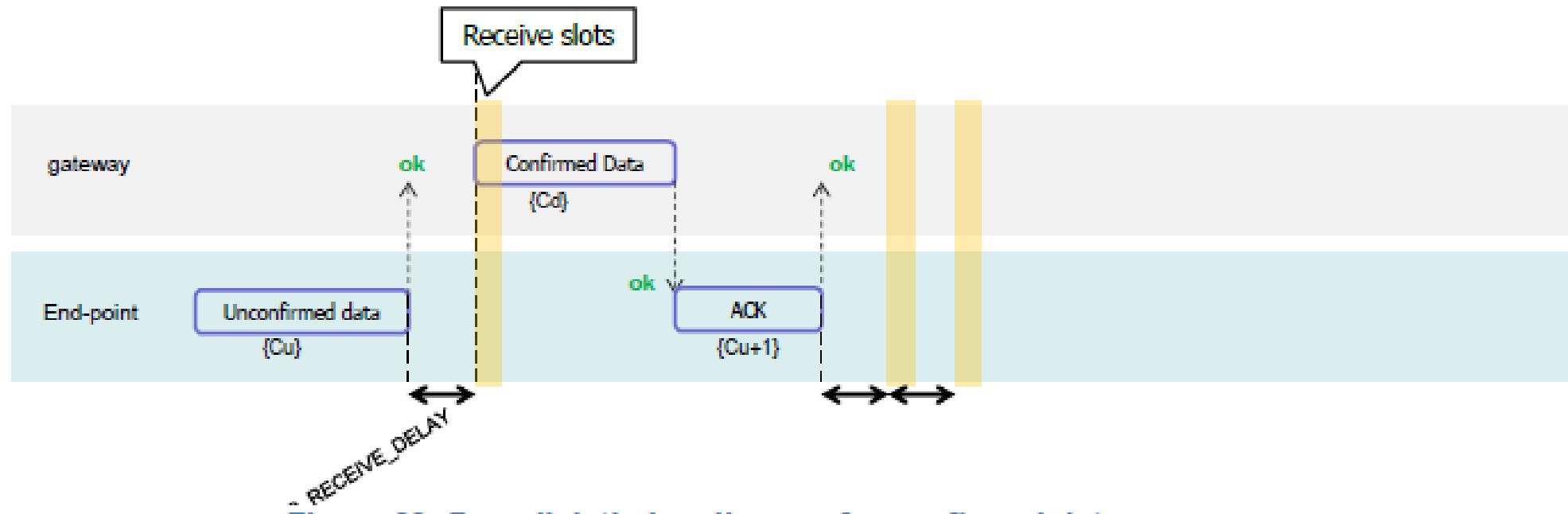


Figure 29: Downlink timing diagram for confirmed data messages

Activos

Gateway single channel y nodo puerta abierta

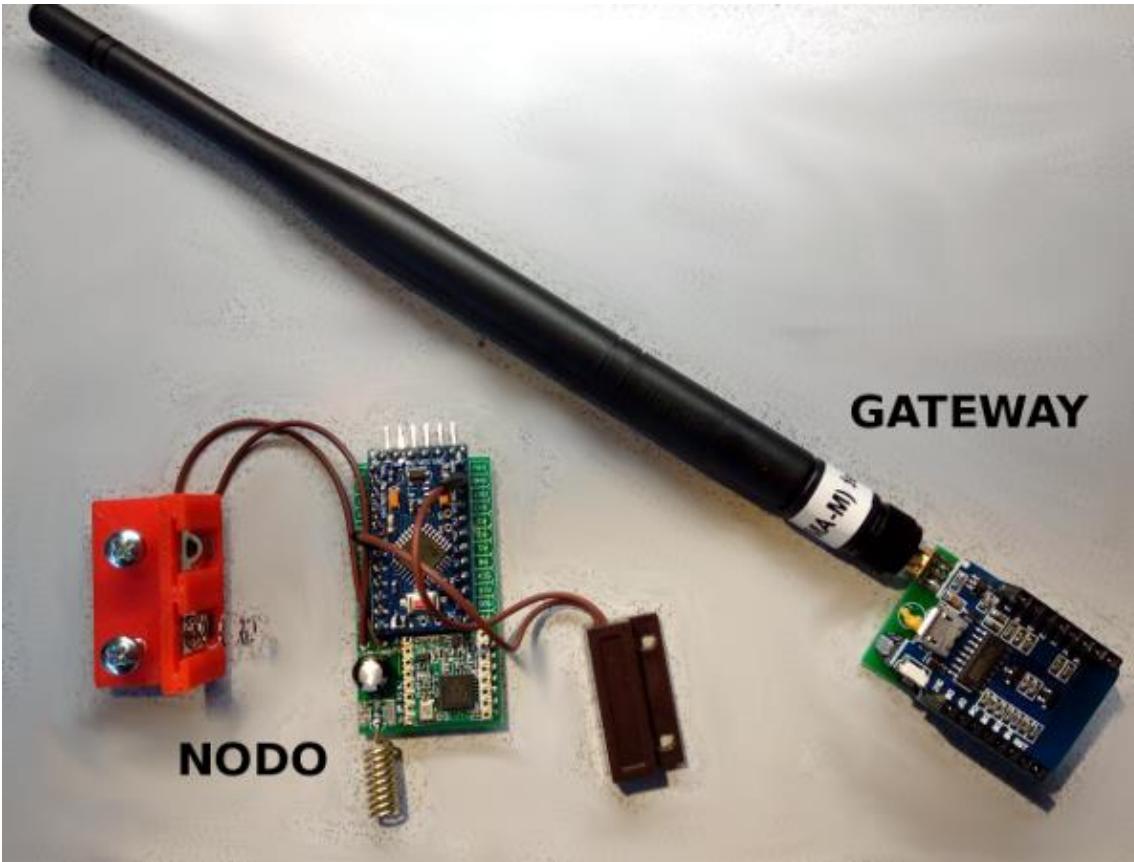
Nodo TTN_MAD v3.1

Nodo TTN_MAD v4

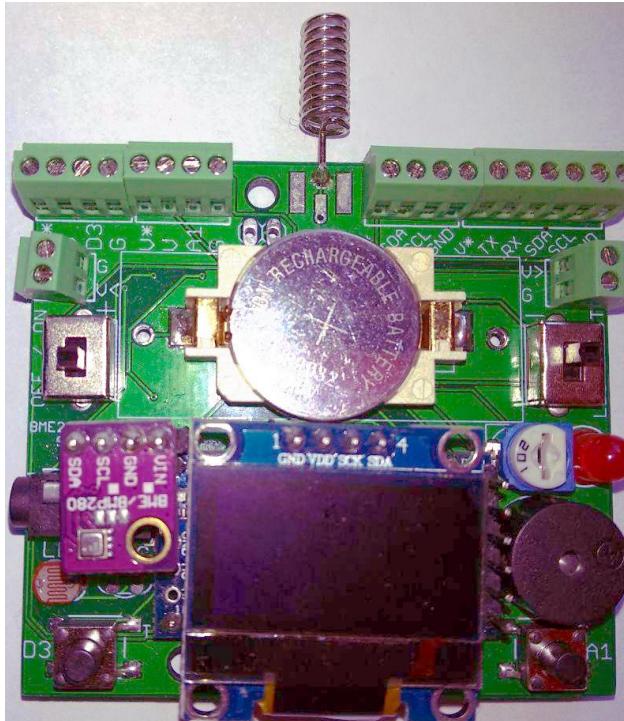
Nodo TTN_MAD v6

...

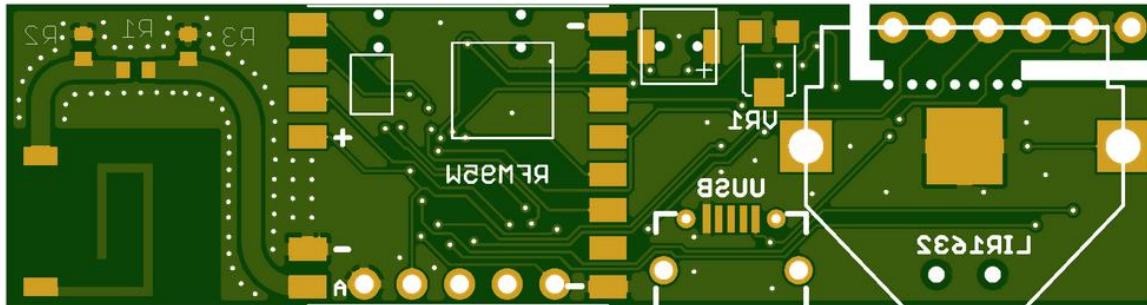
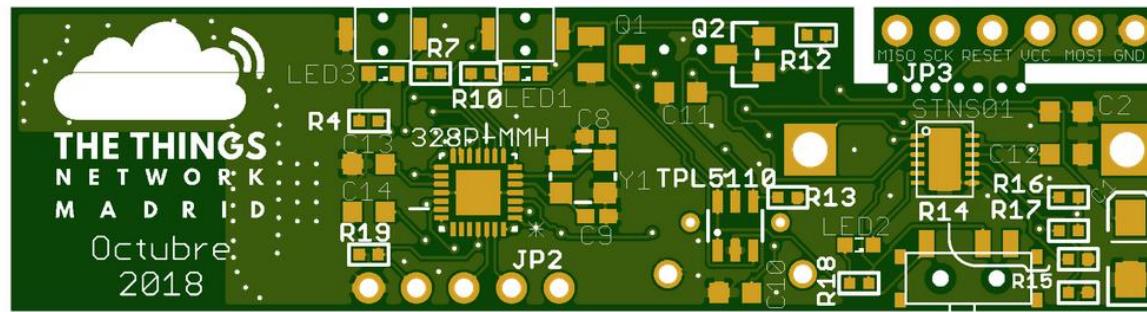
Gateway single channel y nodo puerta abierta



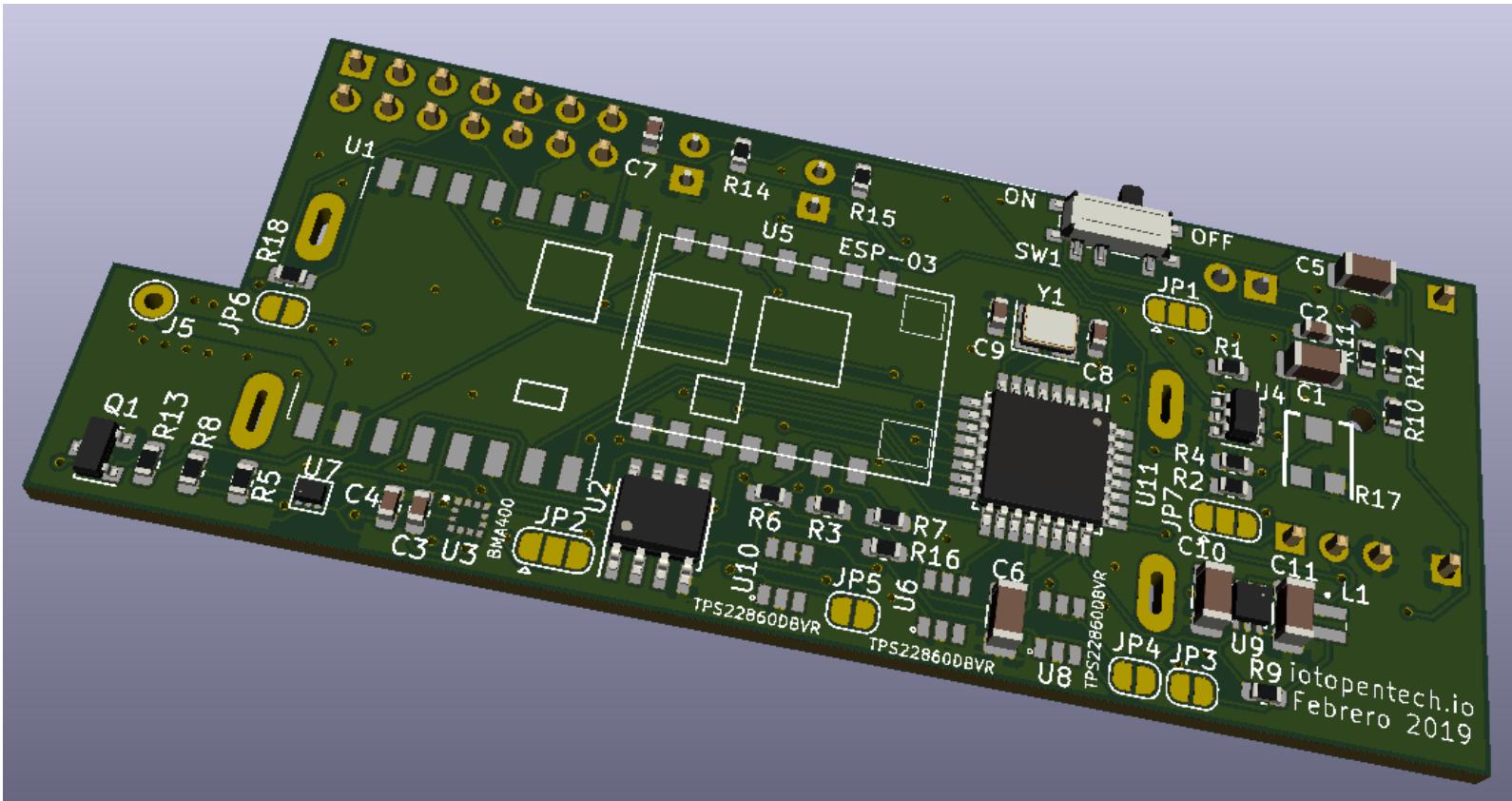
Nodo TTN_MAD v3.1



Nodo TTN_MAD v4



Nodo TTN_MAD v6



Nodo TTN_MAD v6

Modos de funcionamiento:

- Usualmente dormido
 - Despierta por interrupción o por polling
- Usualmente apagado (TPL5111)
 - Arranca a intervalos fijos (entre 100ms y 2 horas)

Nodo TTN_MAD v6

Alimentación

- 2 Baterías AAA
- Opcionalmente BOOST TPS61291
- Alimentación interrumpida para periféricos mediante TPS22860
 - VSWITCH
 - VESP03

Nodo TTN_MAD v6

Periféricos no excluyentes

- ESP03
- Acelerómetro BMA400
- Sensor T^a y H^a HDC2010
- Memoria FRAM FM24
- 2 LEDS
- Buzzer

Nodo TTN_MAD v6

Periféricos excluyentes

- Interrupción digital
 - Botón
 - Acelerómetro
 - Sensor de puerta abierta u otro
- Analogicos
 - Sensor de corriente
 - LDR/NTC/Inundación u otro

¿Qué son las integraciones?

- Tus datos son tus datos: Si no te encargas de ellos se pierden
 - ¿Cómo me encargo de ellos?
 - Con integraciones para:
 - Generar avisos
 - Almacenarlos
 - Modificar el estado de actuadores

¿Qué aspecto tienen los datos?

- Payload
 - RAW
 - Formateada
- Metadata

Applications > jfmateos_taller_integraciones > Data

Filters: uplink, downlink, activation, ack, error

time counter port

▲ 18:46:05 144 1 dev id: [jfmateos_nodo_v3](#) payload: 01 67 00 C8 02 73 03 A8 03 68 58 04 02 01 38 05 66 00 06 01 01

Uplink

Payload

01 67 00 C8 02 73 03 A8 03 68 58 04 02 01 38 05 66 00 06 01 01

Fields

```
{ "analog_in_4": 3.12, "barometric_pressure_2": 93.6, "digital_out_6": 1, "presence_5": 0, "relative_humidity_3": 44, "temperature_1": 20 }
```

Metadata

```
{ "time": "2018-12-13T17:46:05.459148513Z", "frequency": 868.1, "modulation": "LORA", "data_rate": "SF7BW125", "coding_rate": "4/5", "gateways": [ { "gtw_id": "eui-2c3ae0fffff225dif", "timestamp": 2342586533, "time": "", "channel": 0, "rssi": -51, "snr": 6, "latitude": 40.37384, "longitude": -3.7321 }, { "gtw_id": "eui-b827ebffffe8d9794", "timestamp": 1288370683, "time": "2018-12-13T17:46:05.440009Z", "channel": 0, "rssi": -60, "snr": 10, "rf_chain": 1, "latitude": 40.37384, "longitude": -3.7321 } ] }
```

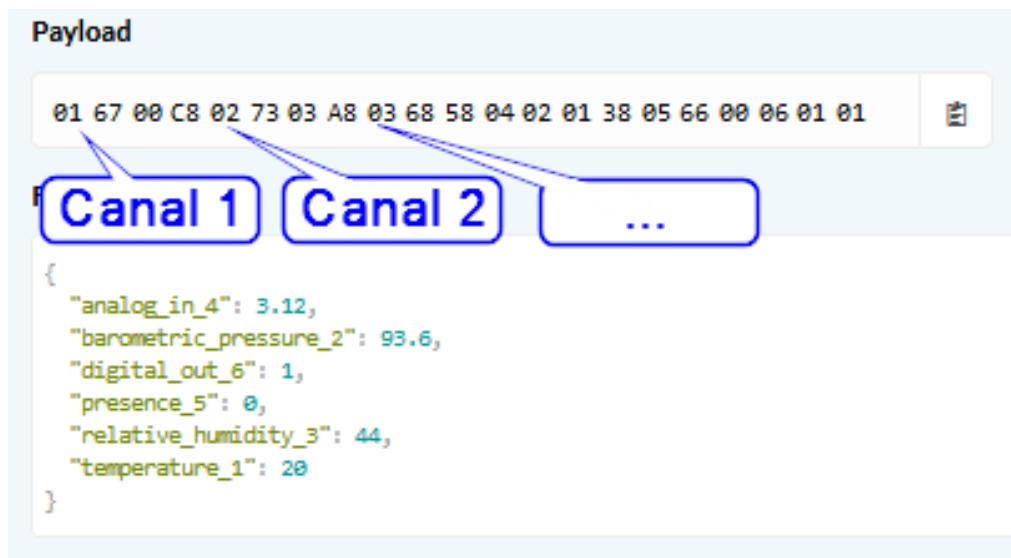


¿Cómo formateamos el Payload?

- Podemos usar nuestro propio esquema...
- ...pero Cayenne lpp (low power payload) es muy popular y logra cierto nivel de estandarización basado en:
 - IPSO Alliance Smart Objects Guidelines

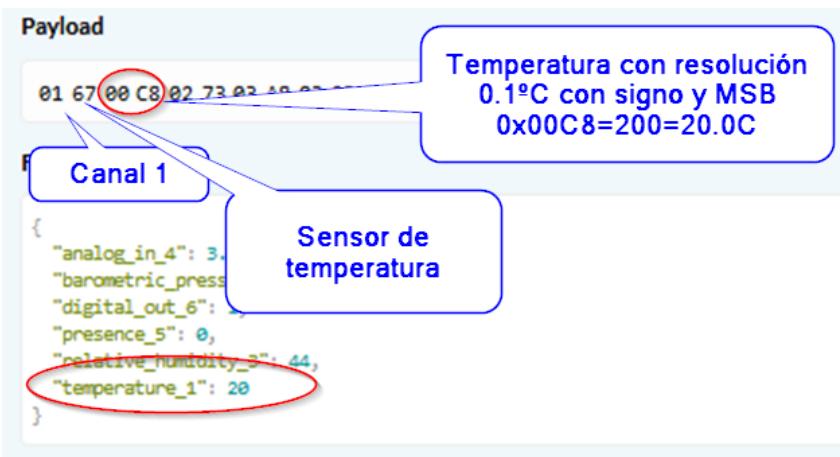
Cayenne LPP: Canal

- Cada sensor/actuador está identificado por un número de canal del 0 al 64



Cayenne LPP: Tipos de datos

- Cada sensor/actuador tiene asociado un tipo de dato



Type	IPSO	LPP	Hex	Data Size	Data Resolution per bit
Digital Input	3200	0	0	1	1
Digital Output	3201	1	1	1	1
Analog Input	3202	2	2	2	0.01 Signed
Analog Output	3203	3	3	2	0.01 Signed
Illuminance Sensor	3301	101	65	2	1 Lux Unsigned MSB
Presence Sensor	3302	102	66	1	1
Temperature Sensor	3303	103	67	2	0.1 °C Signed MSB
Humidity Sensor	3304	104	68	1	0.5 % Unsigned
Accelerometer	3313	113	71	6	0.001 G Signed MSB per axis
Barometer	3315	115	73	2	0.1 hPa Unsigned MSB
Gyrometer	3334	134	86	6	0.01 °/s Signed MSB per axis
GPS Location	3336	136	88	9	Latitude : 0.0001 ° Signed MSB Longitude : 0.0001 ° Signed MSB Altitude : 0.01 meter Signed MSB

Cayenne LPP: Biblioteca para Arduino

```
#include <CayenneLPP.h>

CayenneLPP lpp(uint8_t size);
    • Reserva el buffer para el payload
    • El tamaño máximo varía en función de la frecuencia y
        el spread factor (un valor seguro es 51 bytes)

lpp.reset();

lpp.addTemperature(1, 22.5);

lpp.addBarometricPressure(2, 1073.21);

lpp.addGPS(3, 52.37365, 4.88650, 2);

LMIC_setTxData2(1, lpp.getBuffer(), lpp.getSize(),
0);
```



```
uint8_t addDigitalInput(uint8_t channel, uint8_t value);
uint8_t addDigitalOutput(uint8_t channel, uint8_t value);

uint8_t addAnalogInput(uint8_t channel, float value);
uint8_t addAnalogOutput(uint8_t channel, float value);

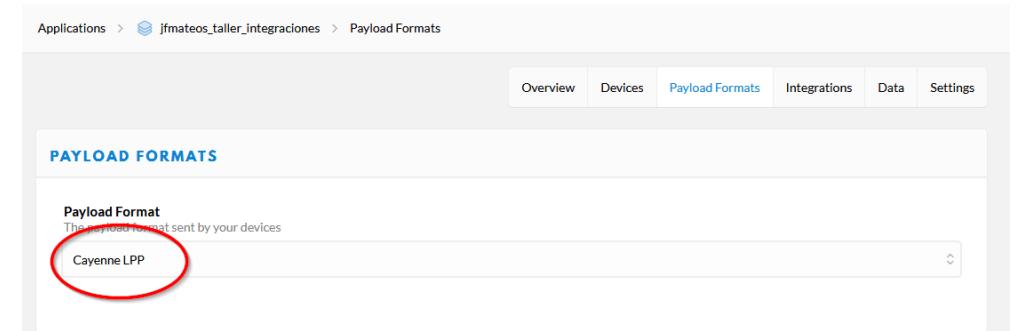
uint8_t addLuminosity(uint8_t channel, uint16_t lux);
uint8_t addPresence(uint8_t channel, uint8_t value);
uint8_t addTemperature(uint8_t channel, float celsius);
uint8_t addRelativeHumidity(uint8_t channel, float rh);
uint8_t addAccelerometer(uint8_t channel, float x, float y, float z);
uint8_t addBarometricPressure(uint8_t channel, float hpa);
uint8_t addGyrometer(uint8_t channel, float x, float y, float z);
uint8_t addGPS(uint8_t channel, float latitude, float longitude, float meters);
```

Cayenne LPP: Formato de payload

- Activamos el formato de payload Cayenne lpp para extraer los campos de la carga de pago
- De la carga de pago
 - 016700E1027329EC038807FDD800BEE10000C8
- Se extraen los campos

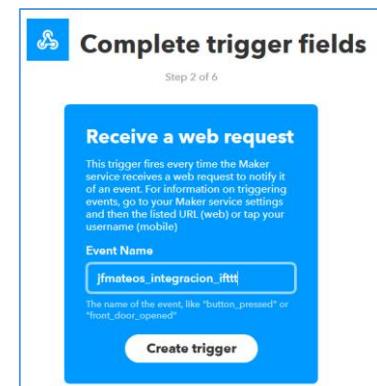
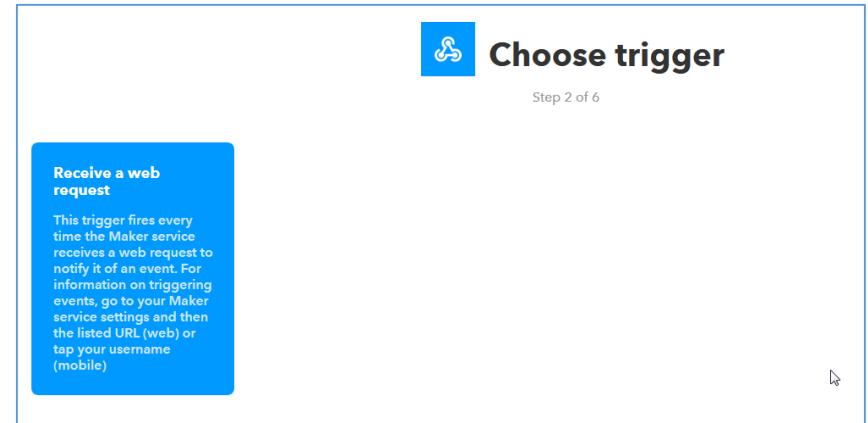
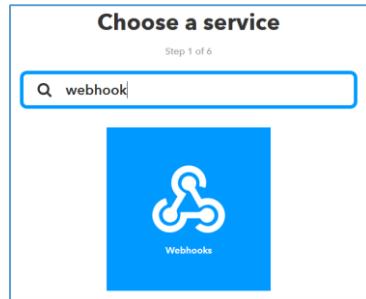
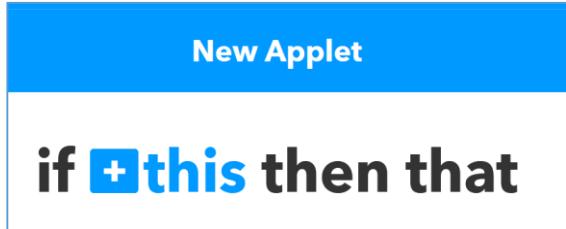
Fields

```
{  
    "barometric_pressure_2": 1073.2,  
    "gps_3": {  
        "altitude": 2,  
        "latitude": 52.3736,  
        "longitude": 4.8865  
    },  
    "temperature_1": 22.5  
}
```



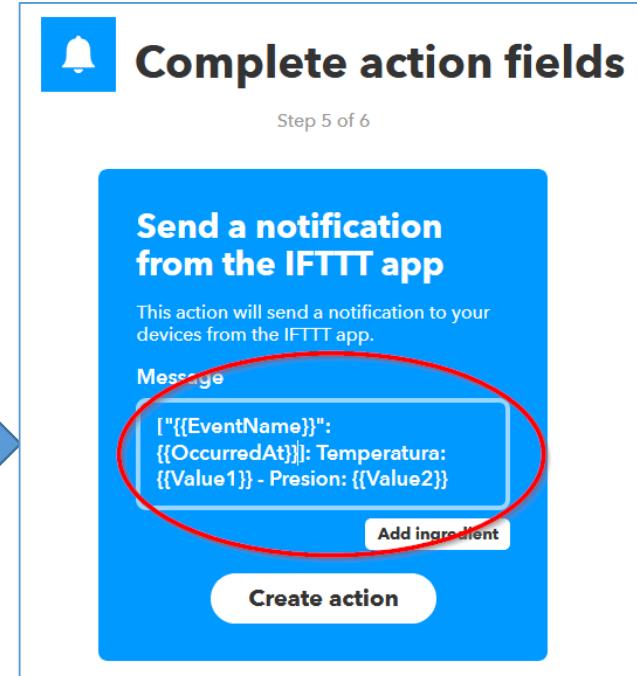
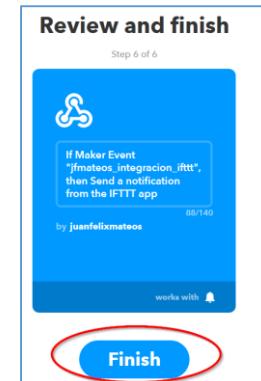
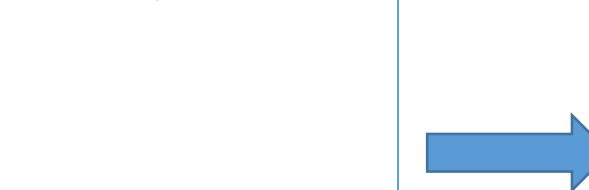
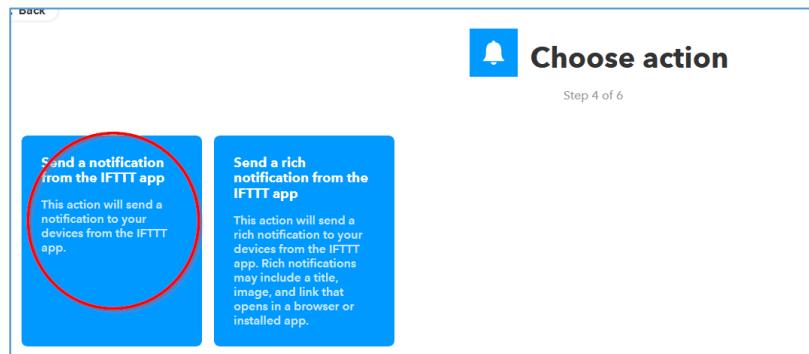
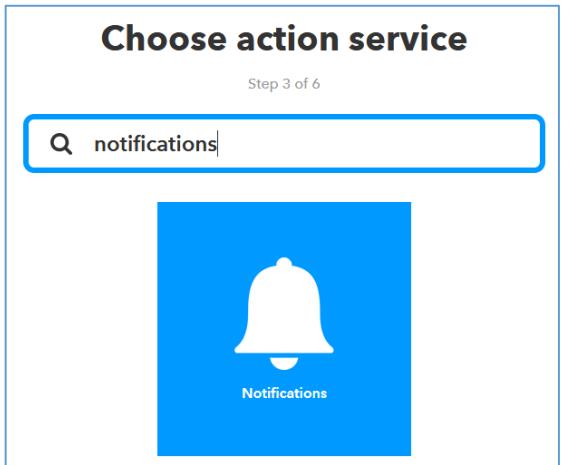
IFTTT: Crear un applet 1/3

- Definimos la sección **this** como un webhook



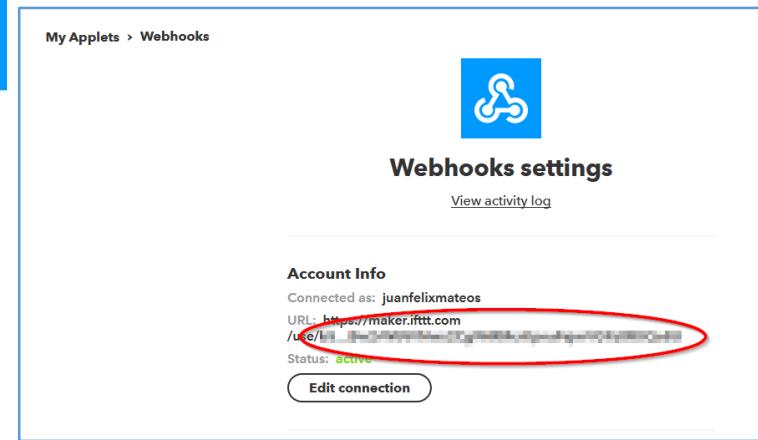
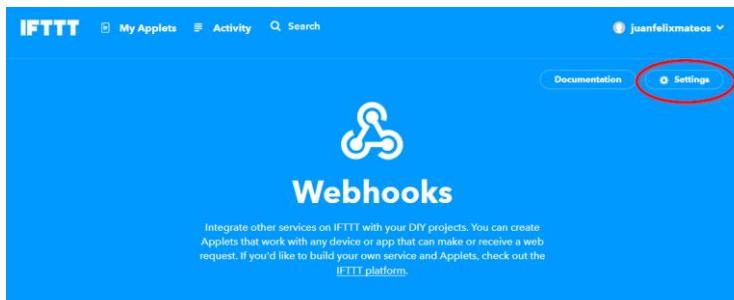
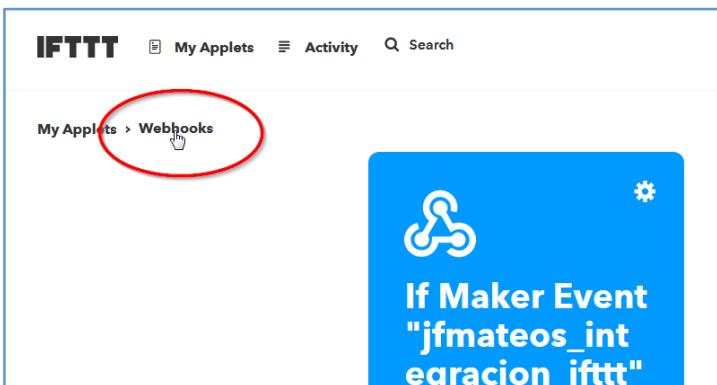
IFTTT: Crear un applet 2/3

- Definimos la sección **that** para que nos envíe una notificación



IFTTT: Crear un applet 3/3

- Obtener la clave/llave del webhook



IFTTT: Activar la integración en TTN

- Utilizar el nombre del evento y la clave de IFTTT

Applications > jfmateos_taller_integraciones > Integrations

Process ID

The unique identifier of the new integration process

✓

Event Name

The name of your IFTTT recipe

✗

Key

Your key

✗

Value 1

Payload field name to send as value 1

✗

Value 2

Payload field name to send as value 2

✗

Value 3

Payload field name to send as value 3

✓

[Cancel](#)

[Add integration](#)



CAYENNE

- Activamos la integración en TTN y tomamos el EUI del dispositivo

The screenshot shows the 'Integrations' tab selected in the Cayenne interface. It lists three available integrations: 'AllThingsTalk Maker v2.6.0 AllThingsTalk' (disabled), 'Cayenne v2.6.0 myDevices' (selected and highlighted with a red circle), and 'COLLOS collaborative location service v2.7.4 Semtech Corporation' (disabled).



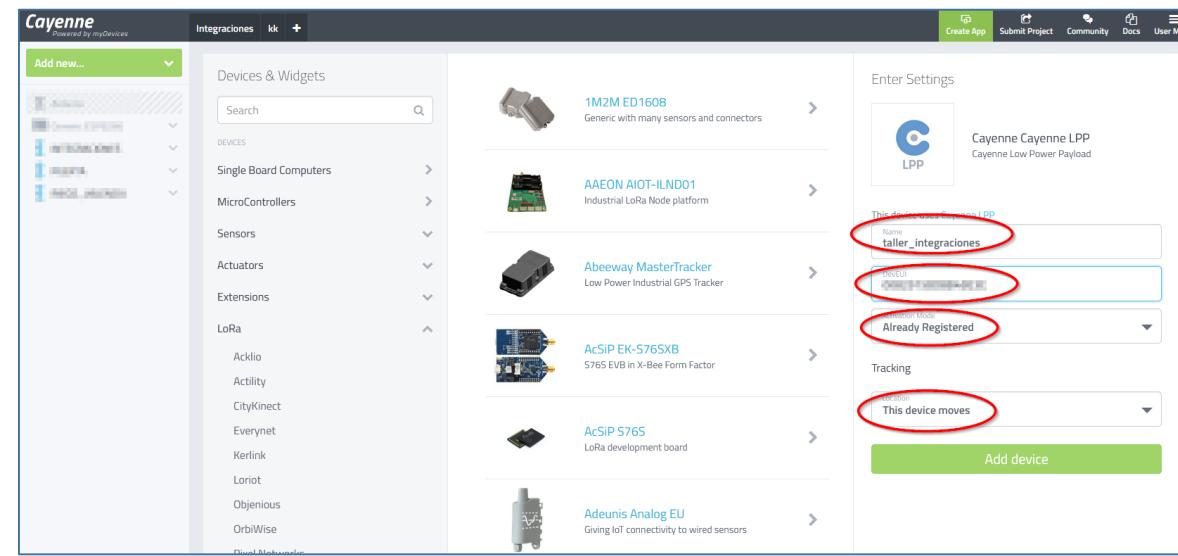
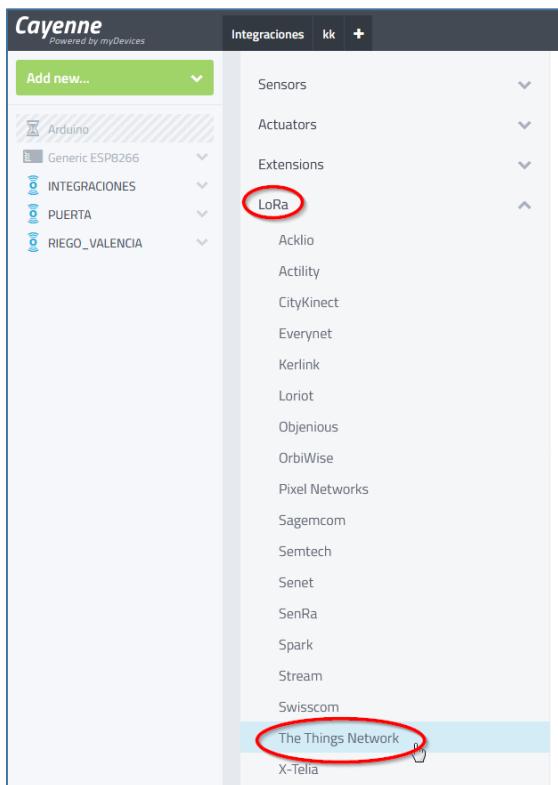
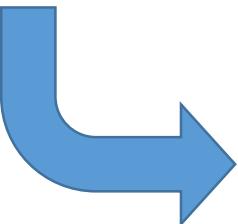
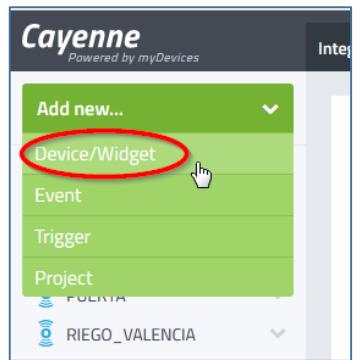
The screenshot shows the 'ADD INTEGRATION' dialog for the Cayenne integration. It requires a 'Process ID' (circled in red) and an 'Access Key' (circled in red). Both fields have 'default key' selected. At the bottom, there is a 'Cancel' button and a red-circled 'Add Integration' button.

The screenshot shows the 'DEVICE OVERVIEW' page for a device with Application ID 'jfmateos_taller_integraciones' and Device ID 'jfmateos_nodo_v1'. It displays various configuration parameters: Activation Method (ABP), Device EUI (circled in red), Application EUI, Device Address, Network Session Key, and App Session Key. A large blue arrow points upwards from the previous 'ADD INTEGRATION' dialog towards this screen.



CAYENNE

- Registramos el device en Cayenne



THE THINGS
NETWORK

CAYENNE

Cayenne
Powered by myDevices

Add new... ▾

Integraciones kk +

Create App Submit Project Community Docs User Menu

Overview Data taller_integraciones Network: The Things Network

Temperature (1) Barometer (2) RSSI SNR

22.50 1073.20 -75.00 9.80

Celsius Hectopascal dBm Decibels

GPS (3)

Mapa Satélite

Dec 20

Electric Ladyland Anne Frank Huis Westerkerk Homomonument De Nieuwe Kerk Koninklijk Paleis Amsterdam BODY WORLDS Amsterdam Sherlock Escape Rooms De Oude Kerk Red Light Secrets Hash Marihuana & Museum Amsterdam Museo de cera Madame Tussauds Amsterdam

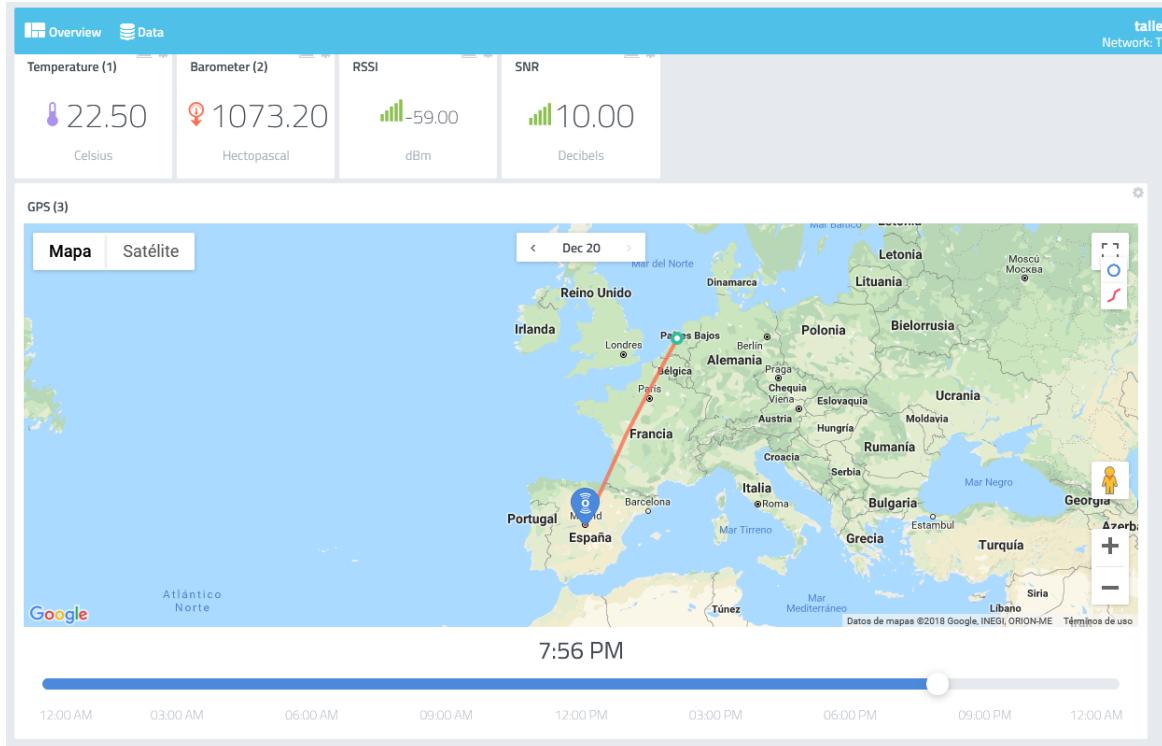
7:49 PM

00:00 AM

The screenshot shows the Cayenne web interface. On the left, there's a sidebar with a 'taller_integraciones' project selected. The main area has four data cards: Temperature (22.50 Celsius), Barometer (1073.20 hPa), RSSI (-75.00 dBm), and SNR (9.80 Decibels). Below these is a map of Amsterdam with various locations marked, including the Anne Frank House, Homomonument, and Koninklijk Paleis. A timeline at the bottom indicates it's 7:49 PM.

CAYENNE

- Simular un uplink con esta carga de pago para cambiar de Amsterdam a Madrid
 - 016700E1027329EC0388062A88FF6FB80000C8



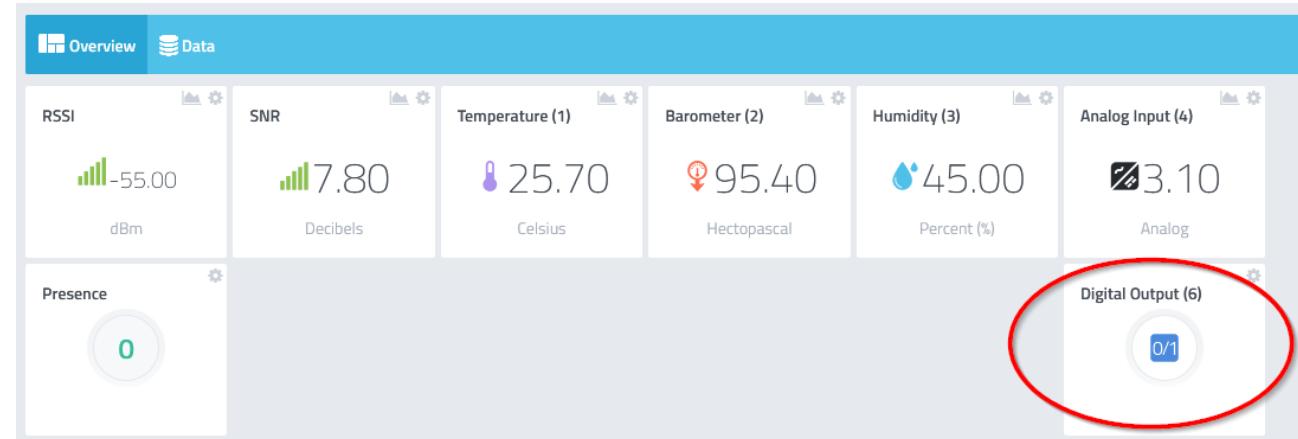
CAYENNE: Downlink

- Con los método addDigitalOutput() y addAnalogOutput() podemos generar downlinks desde Cayenne
 - Los downlink de Cayenne se envían con solicitud de ACK

```
lpp.addDigitalOutput(6, 1); // channel 6, set digital output high
```

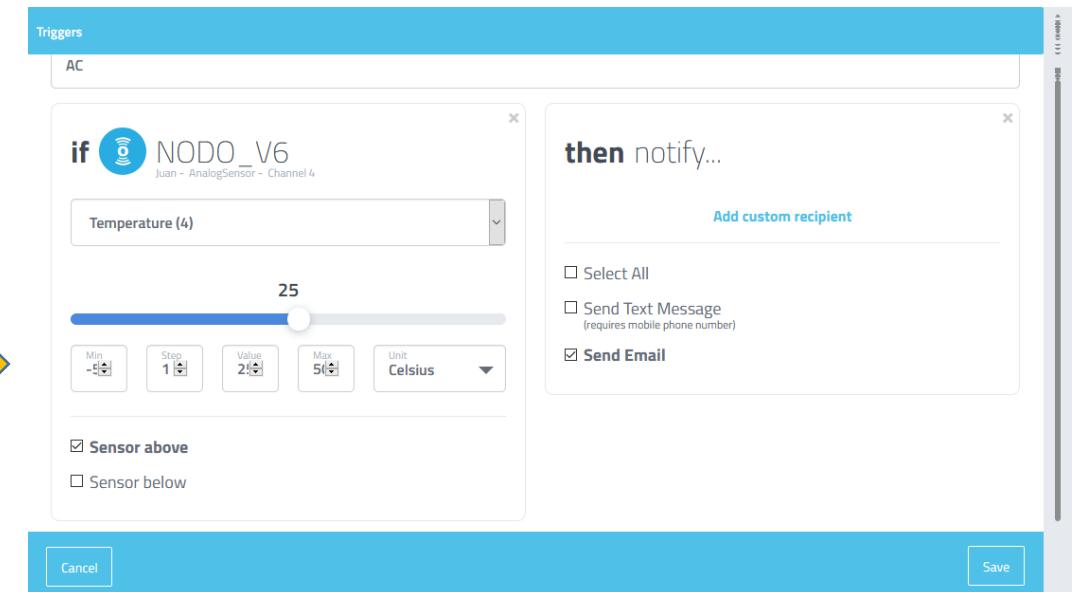
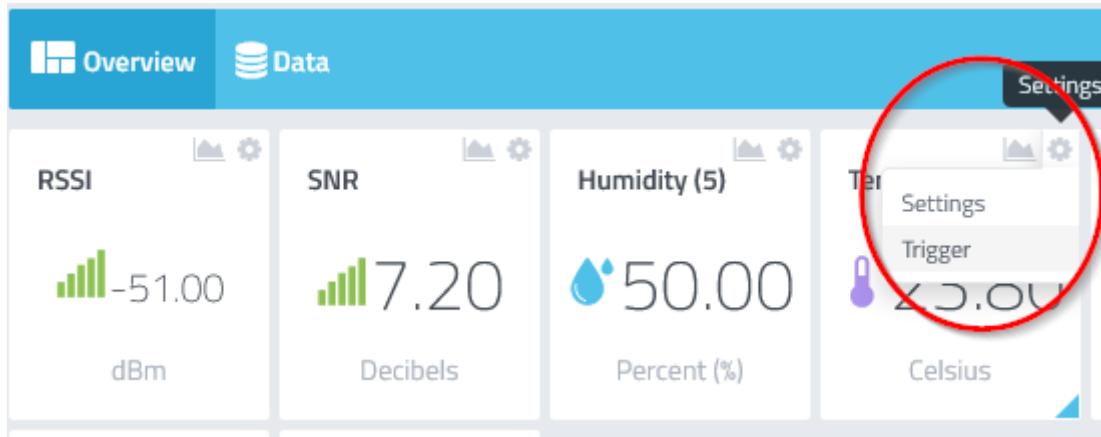
```
case EV_TXCOMPLETE:  
    Serial.println(F("EV_TXCOMPLETE (includes waiting for RX windows)"));  
    if (LMIC.txrxFlags & TXRX_ACK)  
        Serial.println(F("Received ack"));  
  
    if (LMIC.dataLen) {  
        Serial.println(F("Received "));  
        Serial.println(LMIC.dataLen);  
        Serial.println(F(" bytes of payload"));  
        for (int i = 0; i < LMIC.dataLen; i++) {  
            Serial.println(LMIC.frame[LMIC.dataBeg + i]);  
        }  
        if (LMIC.frame[LMIC.dataBeg + 2] == 100) {  
            digitalWrite(6, HIGH);  
        } else {  
            digitalWrite(6, LOW);  
        }  
    }  
}
```

digitalOutput
devuelve 0 o 100



CAYENNE: Triggers

- Podemos establecer un umbral y enviar una notificación o webhook



Data Storage

- La integración Data Storage almacena nuestros datos de la última semana



Applications > jfmateos_taller_integraciones > Integrations > main

Overview Devices Payload Formats Integrations Data Settings

INTEGRATION OVERVIEW

Status • Running

Integration info [go to platform](#) (This link is circled in red)

Platform Data Storage (v2.0.1)

Author The Things Industries B.V.

Description Stores data and makes it available through an API. Your data is stored for seven days.

Data Storage

- Usamos la Access Key para acreditarnos en la REST API de Swagger

This screenshot shows the 'Applications' section of the The Things Network console. It includes four main sections: 'APPLICATION EUIS' (with a copy button), 'DEVICES' (showing 3 registered devices), 'COLLABORATORS' (listing 'jfmateos'), and 'ACCESS KEYS' (listing a 'default key' with a copy button). A red circle highlights the 'copy' icon in the ACCESS KEYS section.

This screenshot shows the 'The Things Network Data Storage' API documentation via Swagger. It features a 'GET /api/v2/devices' operation and a 'query' section. A large yellow arrow points from the 'ACCESS KEYS' section of the previous screenshot to the 'Key:' input field in this screenshot. The 'Key:' field is highlighted with a red circle. The 'Authorize' button is also circled in red.



Data Storage

- Probamos el query de todos los datos

query

GET /api/v2/query

Show/Hide | List Operations | Expand Operations

Implementation Notes
Query the data for all devices

Response Class (Status 200)
An array of data

Model Example Value

```
[  
  {  
    "device_id": "string",  
    "raw": "string",  
    "time": "string",  
    "field1": "string",  
    "field2": "string"  
  }  
]
```

Response Content Type application/json ▾

Parameters

Parameter	Value	Description	Parameter Type	Data Type
last	<input type="text"/>	Duration on which we want to get the data (default 1h). Pass 30s for the last 30 seconds, 1h for the last hour, 2d for the last 48 hours, etc	query	string

[Try it out!](#) [Hide Response](#)

Curl

```
curl -X GET --header 'Accept: application/json' --header 'Authorization: ...'
```

Request URL
https://jfmateos_taller_integraciones.data.thethingsnetwork.org/api/v2/query

Response Body

```
"presence_5": 0,  
"raw": "AWcA8gJzA7oDaGUEAgE4BWYABgEBBwMu4A==",  
"relative_humidity_3": 50.5,  
"temperature_1": 24.2,  
"time": "2018-12-20T20:33:55.561273224Z",  
,  
{  
  "analog_in_4": null,  
  "analog_out_7": null,  
  "barometric_pressure_2": 1073.2,  
  "device_id": "jfmateos_nodo_v1",  
  "digital_out_6": null,  
  "gps_3": "map[latitude:52.3736 longitude:4.8865 altitude:2]",  
  "presence_5": null,  
  "raw": "AWcA4QJzKew0iAf92AC+4QAAyA==",  
  "relative_humidity_3": null,  
  "temperature_1": 22.5,  
  "time": "2018-12-20T20:34:40.972988337Z",  
,  
{
```

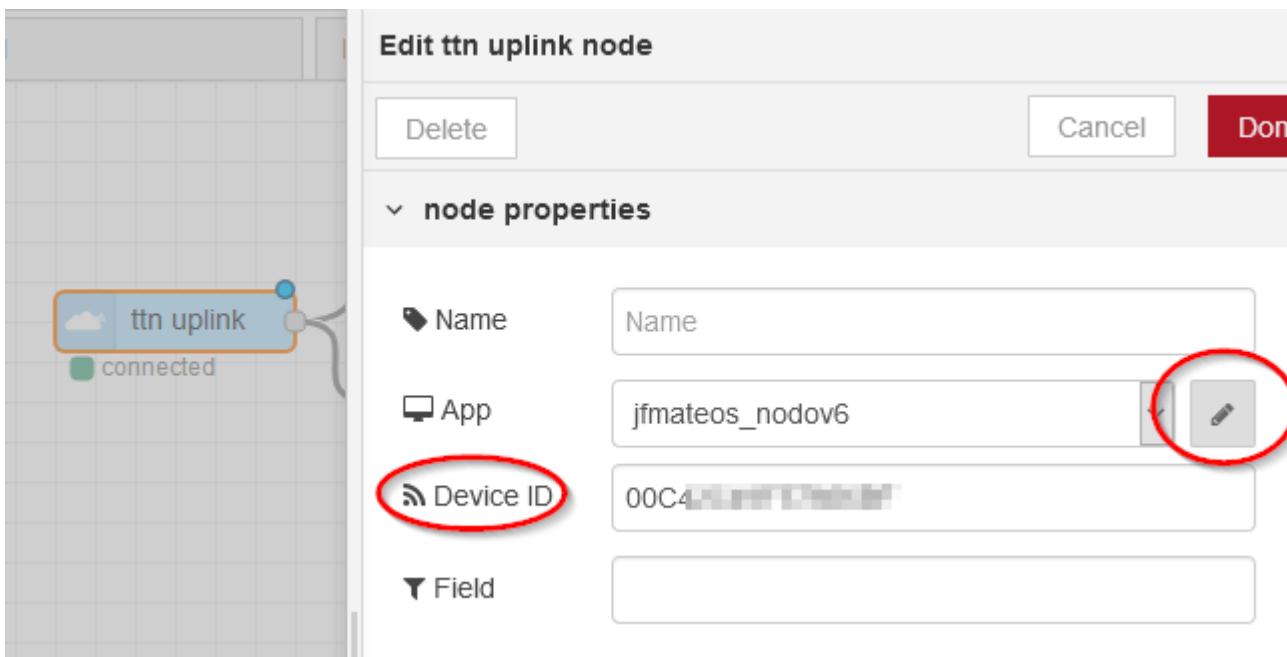
Response Code
200

Response Headers

```
{"connection": "keep-alive",  
 "content-type": "application/json",  
 "date": "Thu, 20 Dec 2018 21:21:52 GMT",  
 "server": "nginx/1.13.7",  
 "transfer-encoding": "chunked"}
```

Node-RED: uplink

- Identificamos la aplicación
- Opcionalmente podemos filtrar un device en particular



Edit ttn uplink node > **Edit ttn app node**

Delete Cancel Update

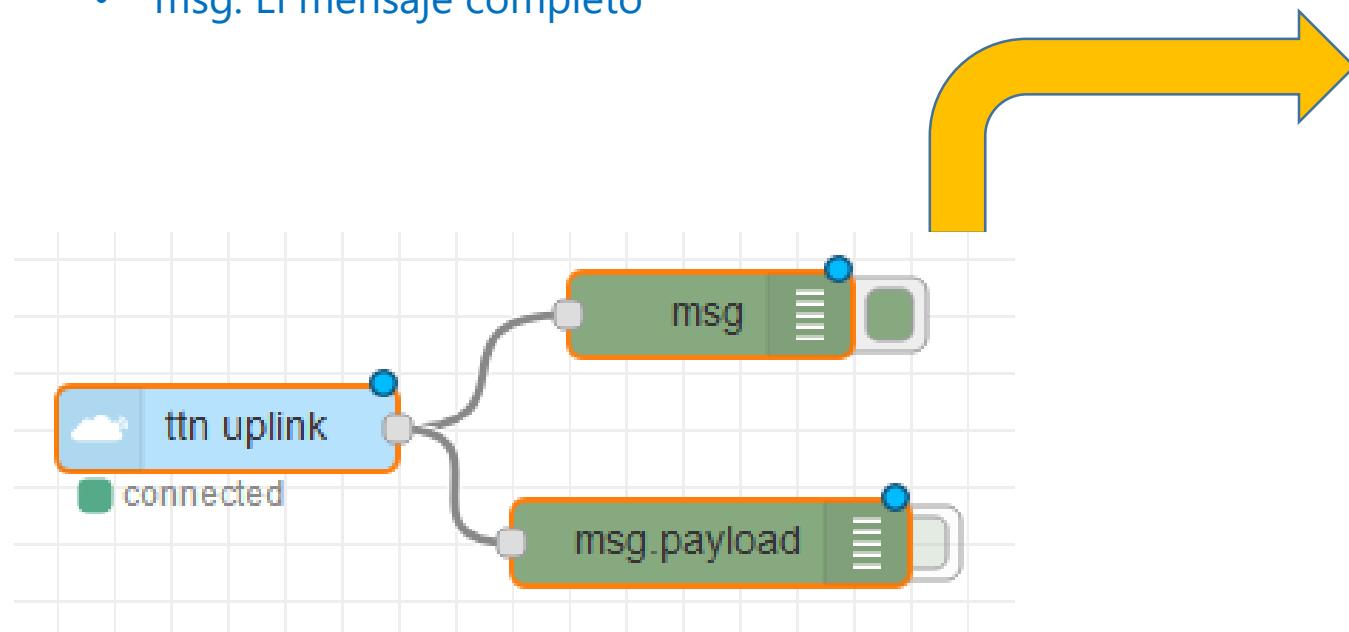
App ID: jfmateos_nodov6

Access Key: 

Discovery address: every.thethingsnetwork.org:1900

Node-RED: debug

- Con el nodo Debug podemos mostrar:
 - msg.payload: La carga de pago (valor por defecto)
 - msg: El mensaje completo



```
18/5/2019 8:43:00 node: 2cb17c9c.13f76c
msg.payload : Object
  ▼ object
    barometric_pressure_2: 1073.2
  ▼ gps_3: object
    altitude: 2
    latitude: 40.4104
    longitude: -3.6936
    temperature_1: 22.5
```



YOU ARE THE NETWORK
LET'S BUILD THIS THING TOGETHER!

Juan Félix Mateos

juanfeixmateos@gmail.com

www.thethingsnetwork.org