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

The Things Network: Principios

Tus datos son tus datos

Neutralidad de la red

Código abierto

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Cómo empezó todo

Julio de 2015, Amsterdam

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Wienke Giezeman

Johan Stokking

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Long Range Wide Area Network

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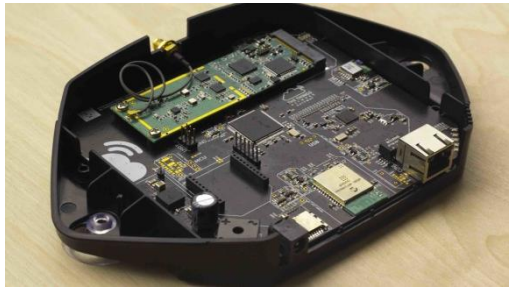
KICKSTARTER



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GATEWAY

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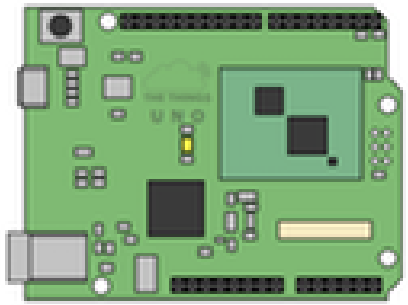

Año 2015
KICK STARTER

295.331 €
de la meta de 150.000 €

934
patrocinadores

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AELORA

www.aelora.nl

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BORBORA – CHILDREN AIR QUALITY

www.waag.org


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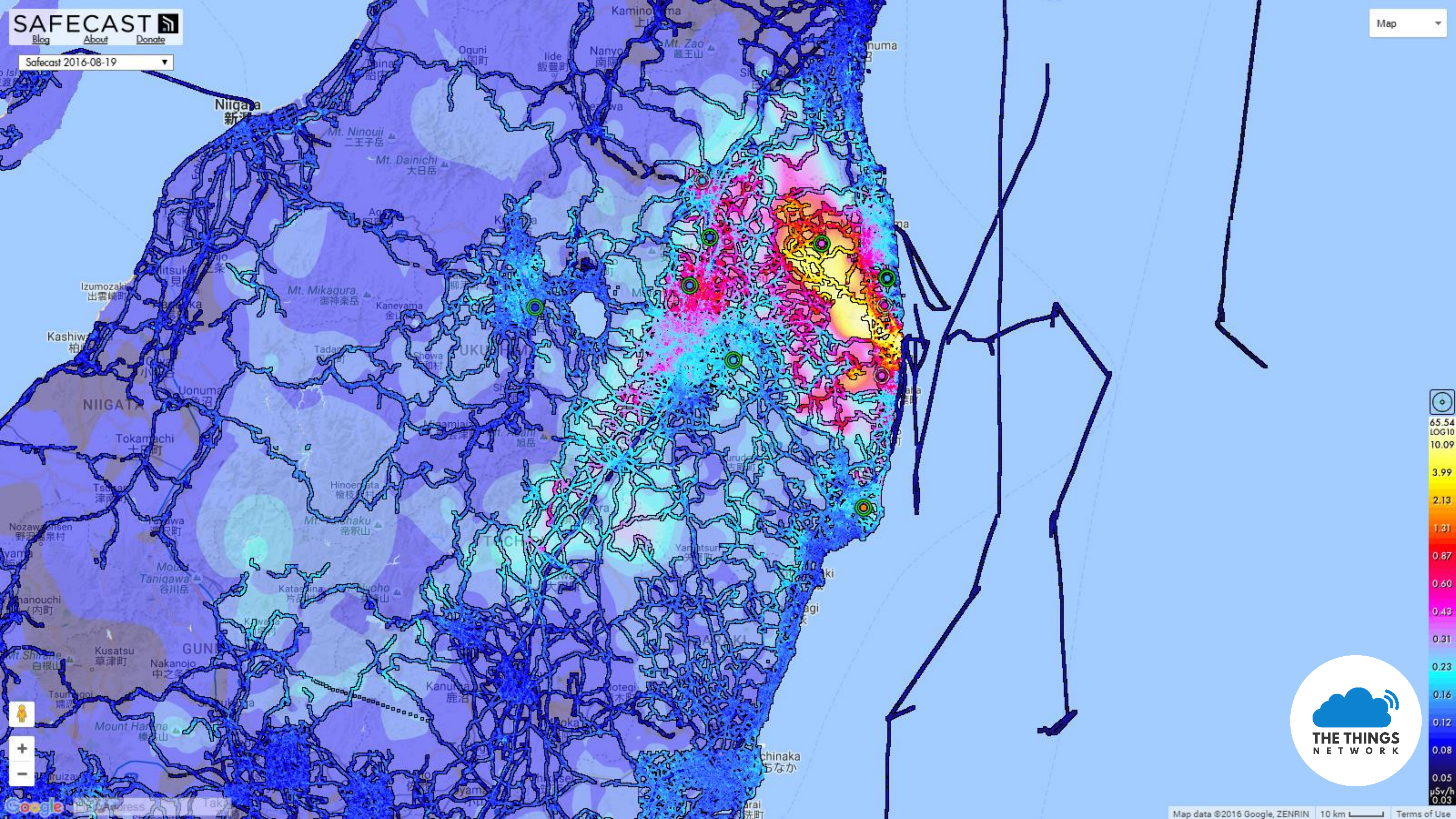

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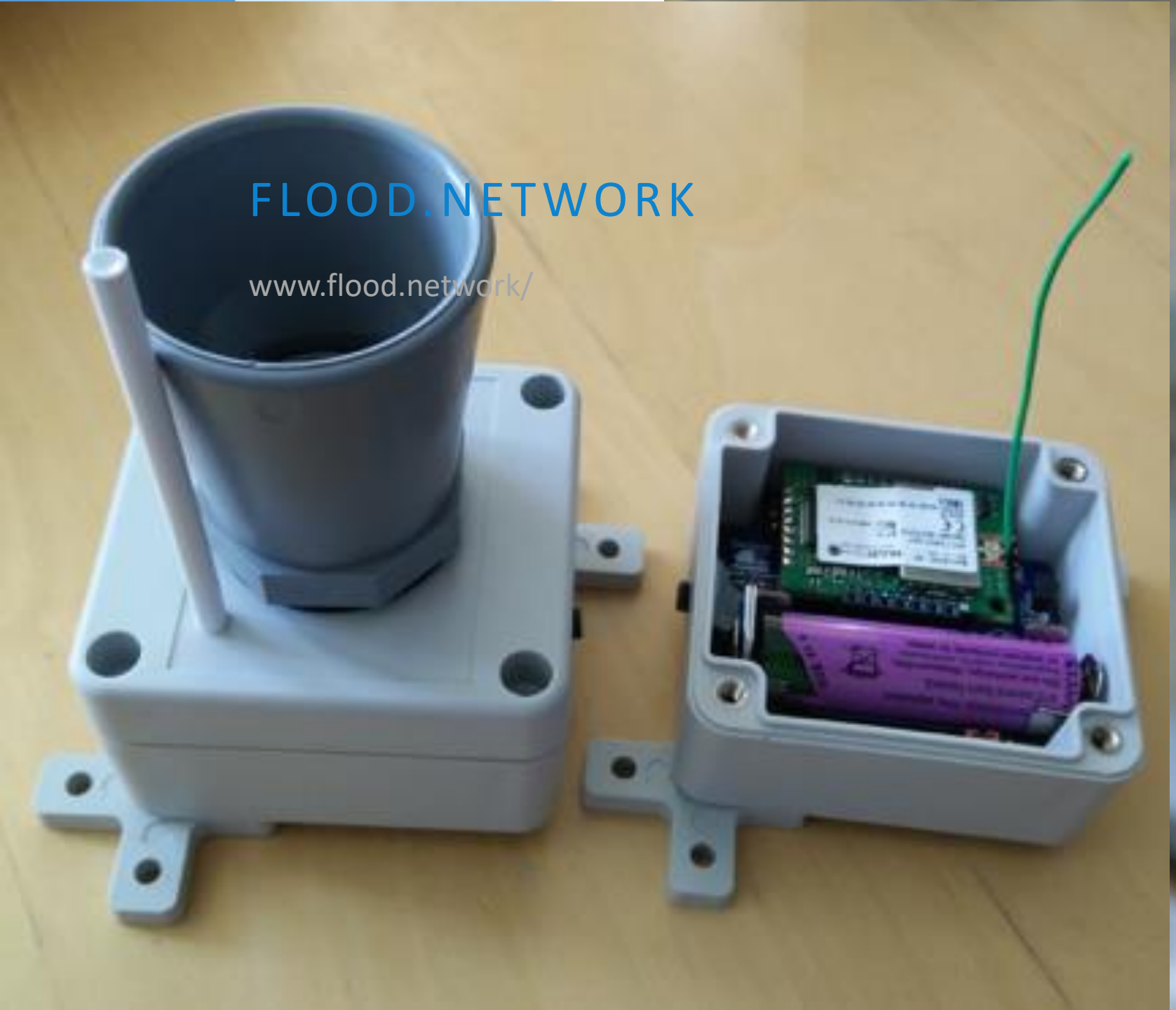
FLOOD.NETWORK

www.flood.network/



FLOOD.NETWORK

SMART MOUSE TRAP

www.xignal.com

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LoRa vs LoRaWAN vs THE THINGS NETWORK

CONCEPTOS TÉCNICOS

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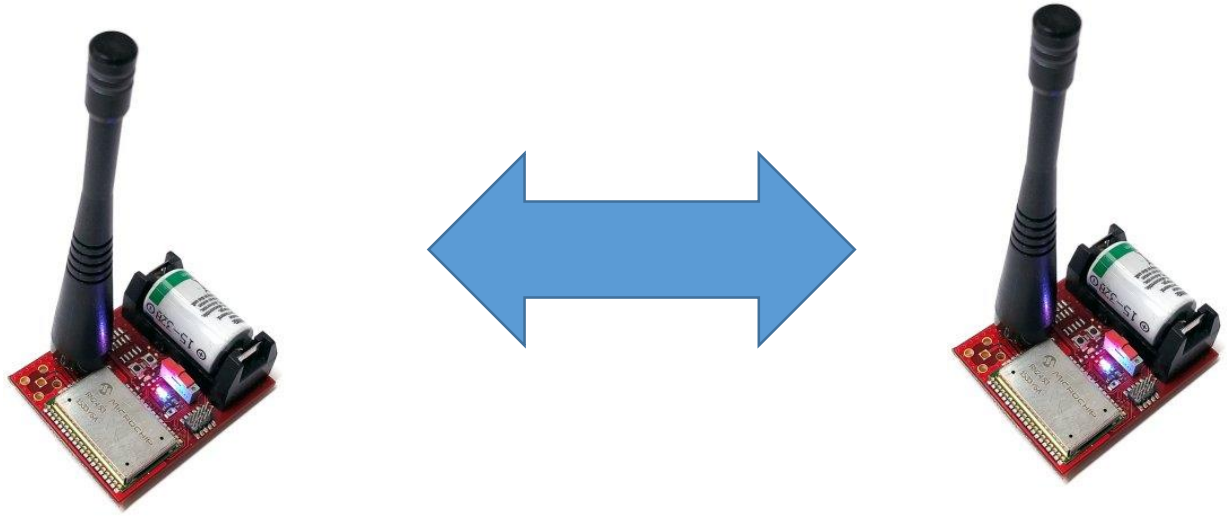
LoRa™



Conexiones punto a punto

Largo alcance

Bajo consumo de energía

Bajo ancho de banda

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LoRaWAN™

Nodo ↔ **Mis** gateways ↔ Internet

Solución local

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

Solución global

LoRa

COMPARISON – main LPWAN technologies

Vertical M2M

Feature	LORAWAN	SIGFOX	LTE Cat 1	LTE M	NB - LTE
Modulation	SS chip	UNB / GFSK / BPSK	OFDMA	OFDMA	OFDMA
Rx Bandwith	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 Outpu 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

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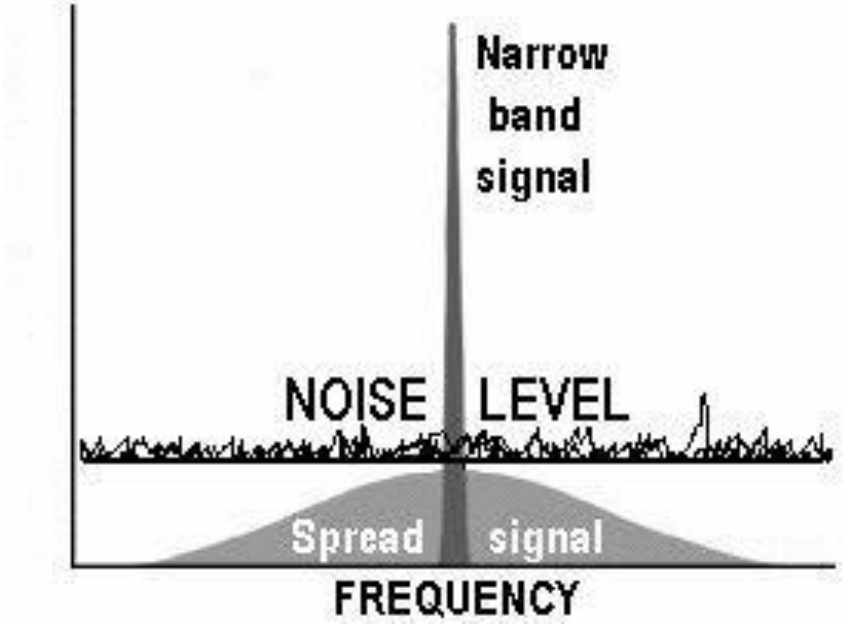
LoRaWAN vs SigFox
CSS (Chirp Spread Spectrum) vs UNB (Ultra Narrow Band)



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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

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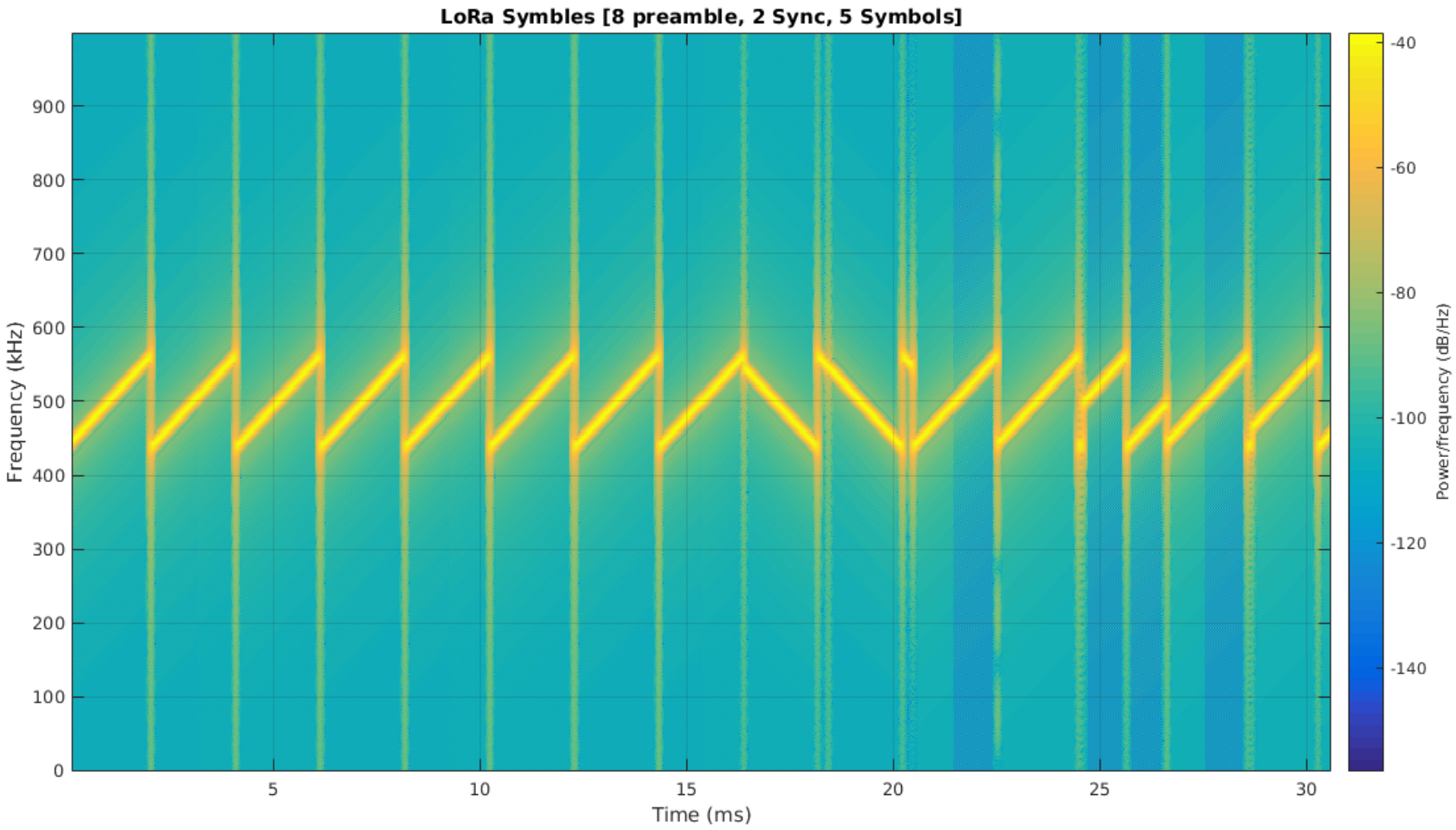
LoRa Frame



http://www.sghoslya.com/p/lora-is-chirp-spread-spectrum.html

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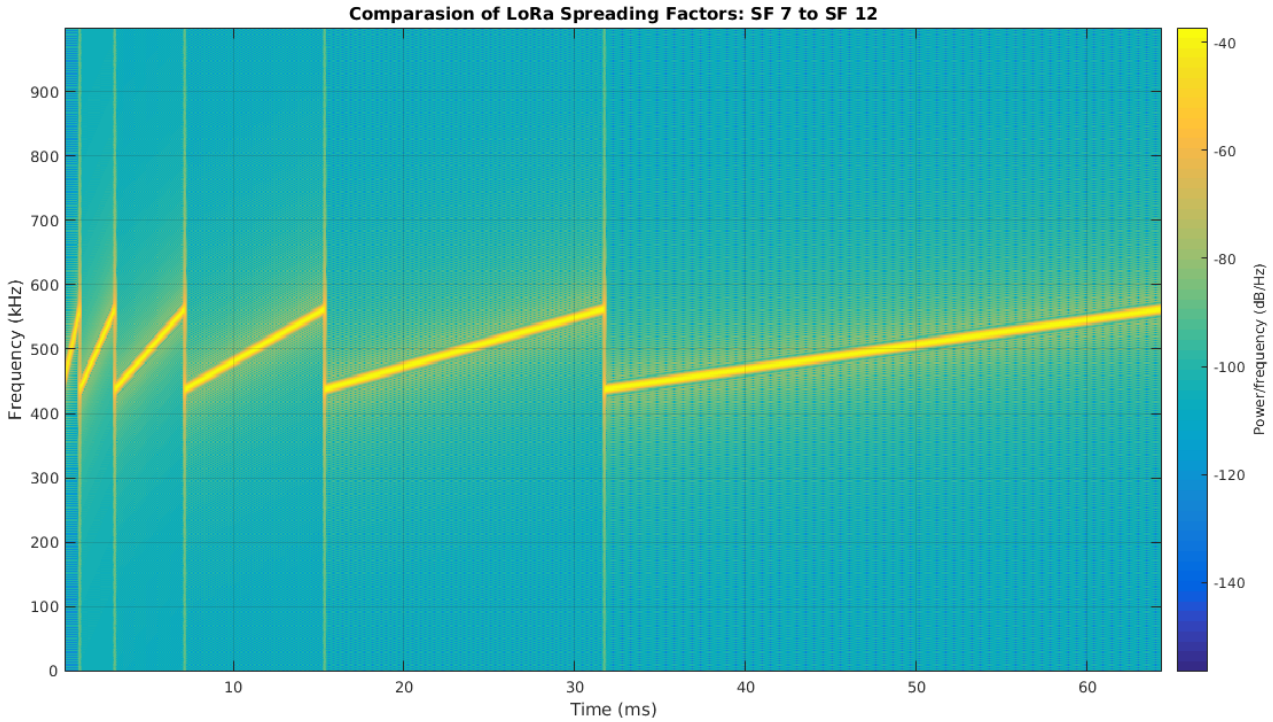
LoRa: Spread Factor

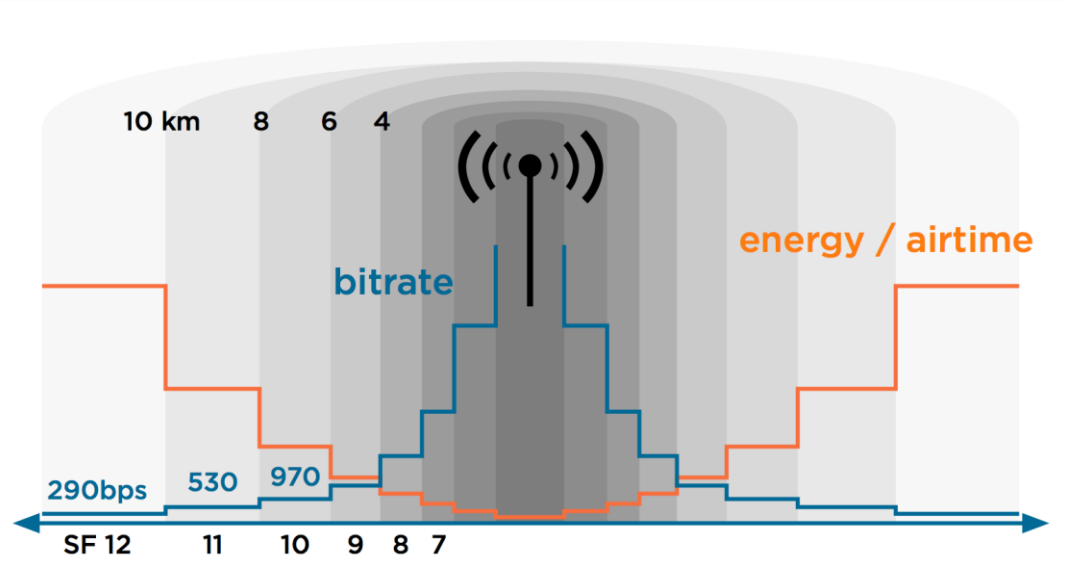
Velocidad vs Alcance vs Consumo

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/

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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%

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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

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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

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THE THINGS NETWORK

LoRaWAN

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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

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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

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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)

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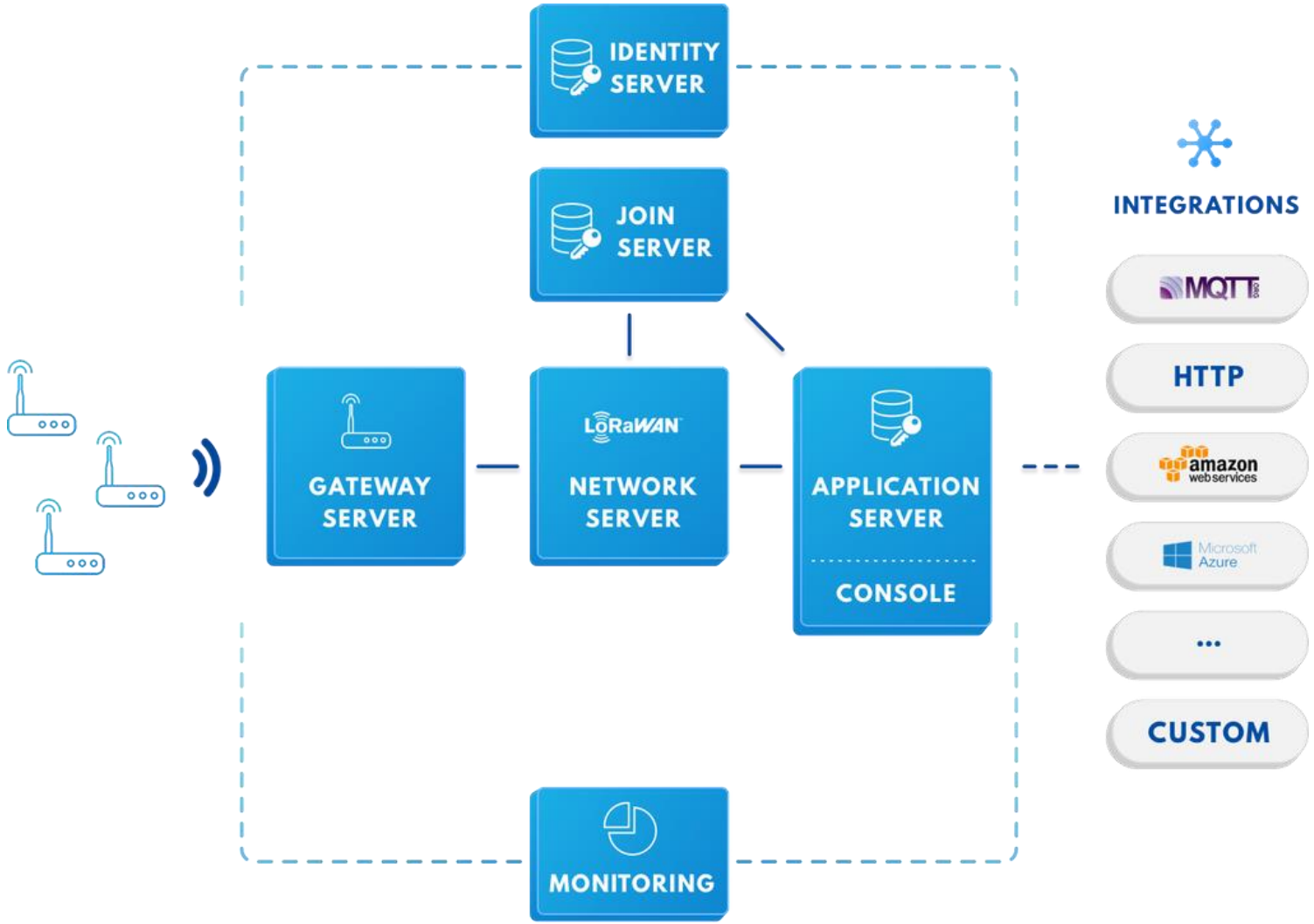
The Things Network: Stack v3 OTAA__ABP



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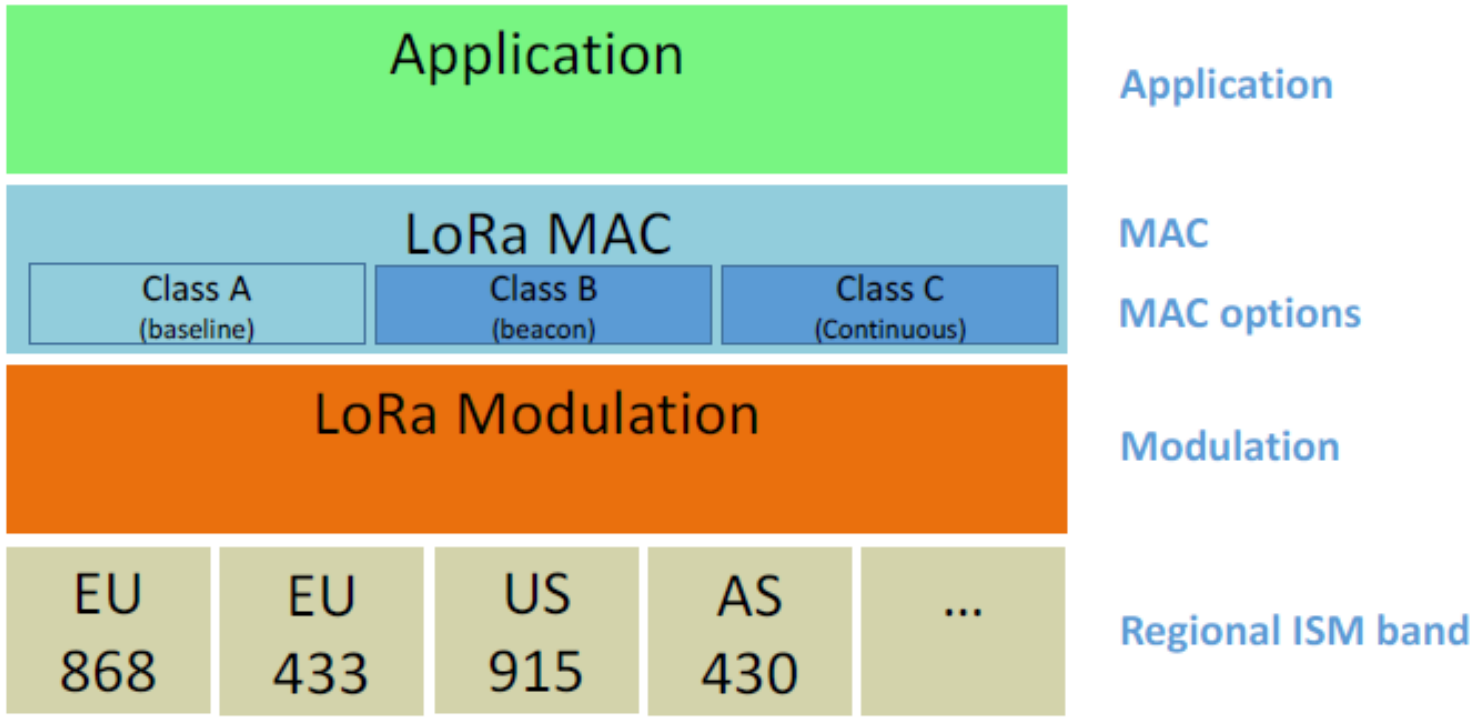
The Things Network: Clase A, B y C

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



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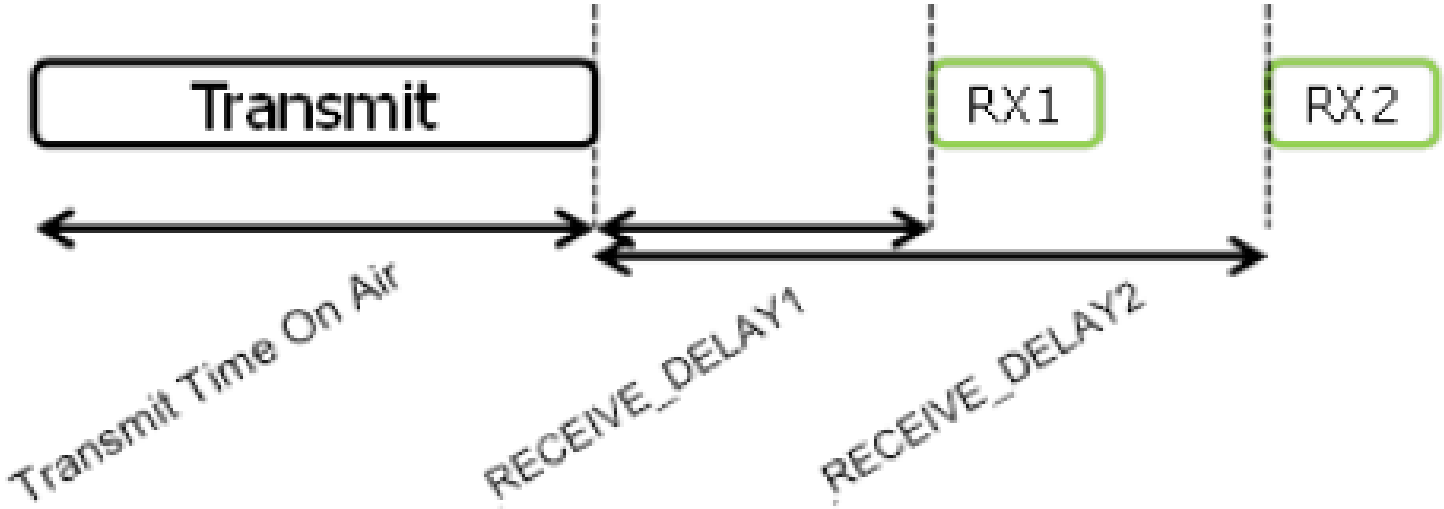
The Things Network: Uplink y downlink en clase A

- Delay1 = 1s
- Delaty2 = 2s



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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)

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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

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The Things Network: Anatomía de un paquete LoRaWAN

Radio PHY layer:

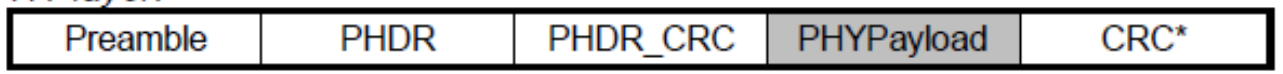

Figure 5: Radio PHY structure (CRC* is only available on uplink messages)

PHYPayload:

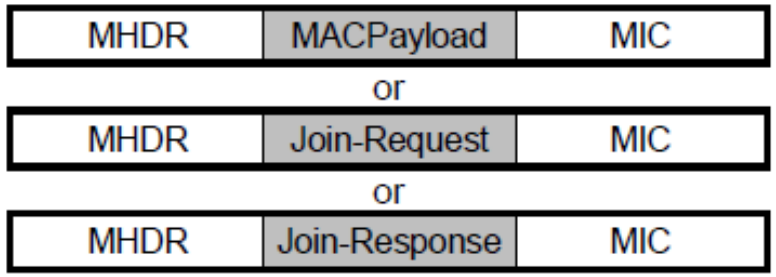

Figure 6: PHY payload structure

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

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The Things Network: Paquetes uplink con confirmación

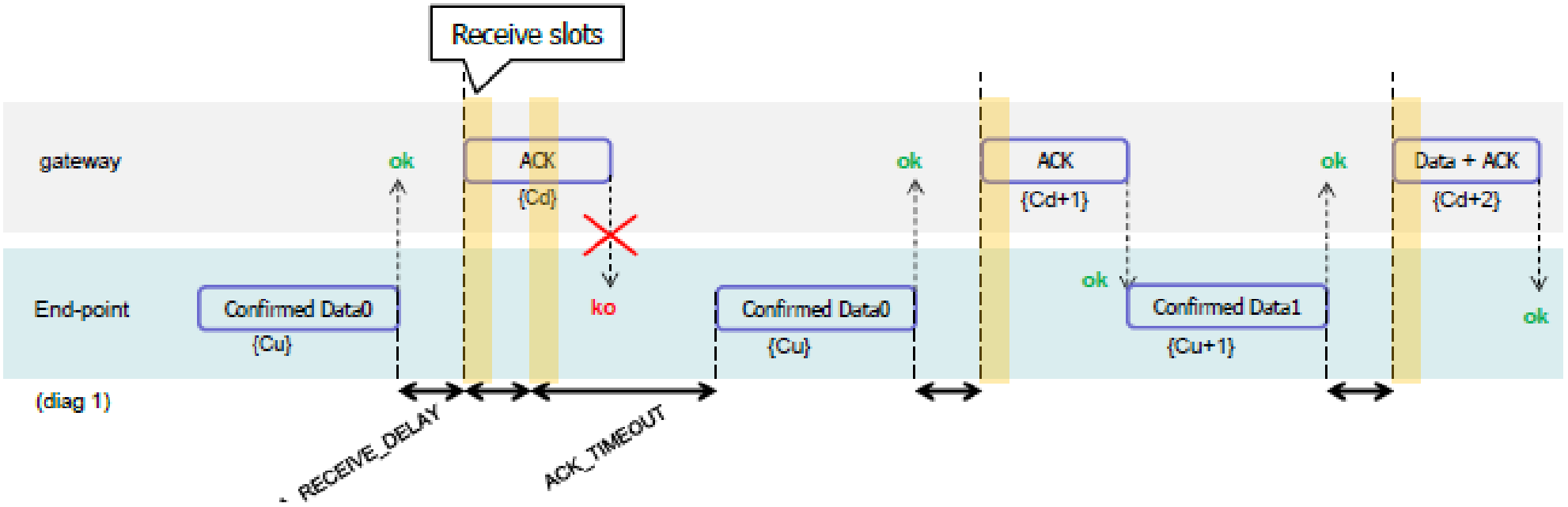

Figure 28: Uplink timing diagram for confirmed data messages

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The Things Network: Paquetes downlink con confirmación

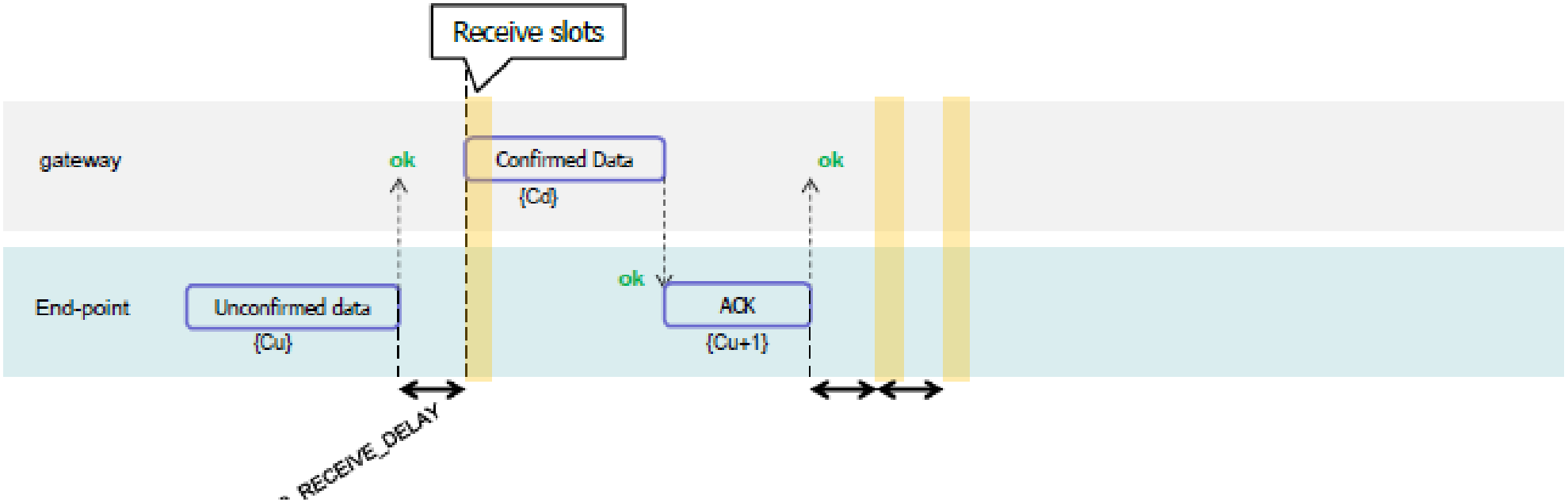

Figure 29: Downlink timing diagram for confirmed data messages

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Activos

Gateway single channel y nodo puerta abierta

Nodo TTN_MAD v3.1

Nodo TTN_MAD v4

Nodo TTN_MAD v6

...

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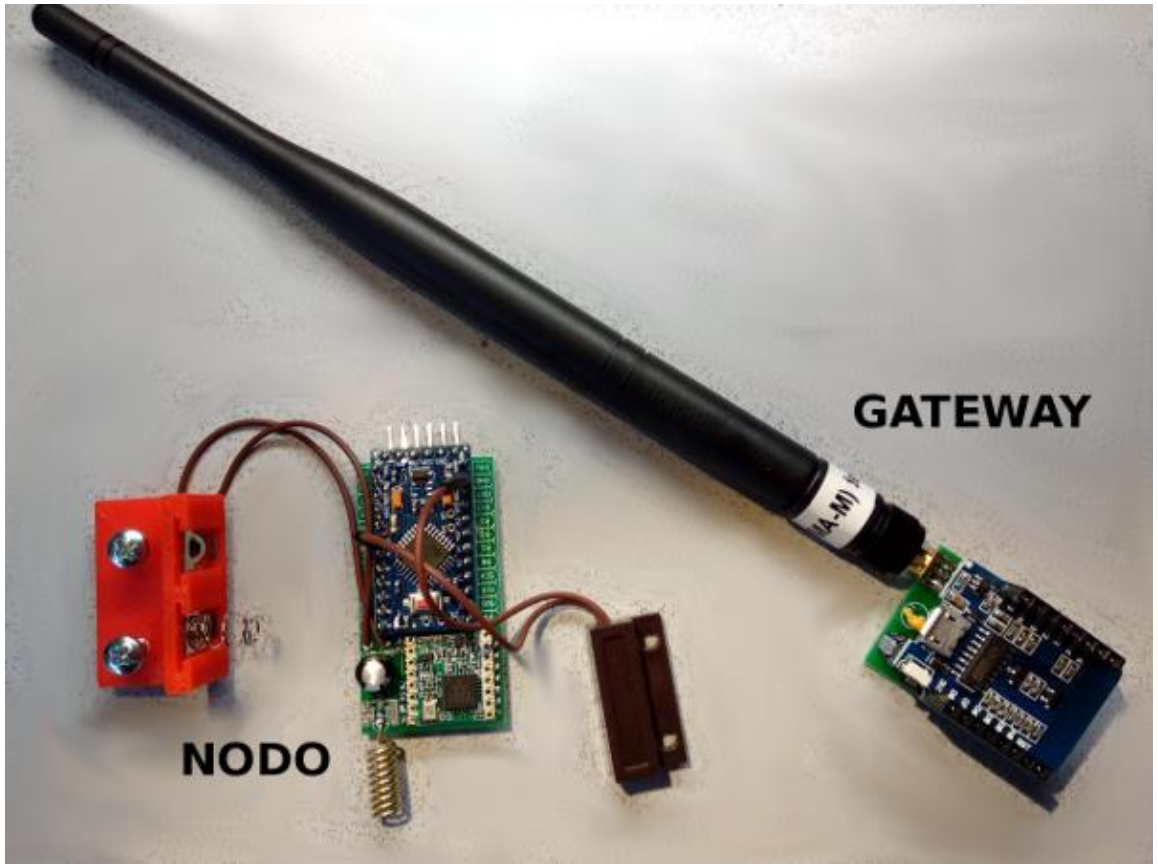
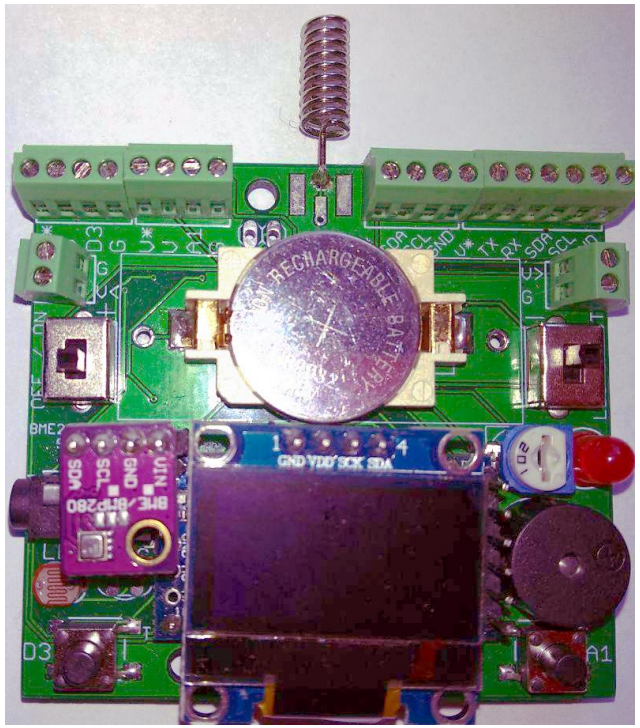
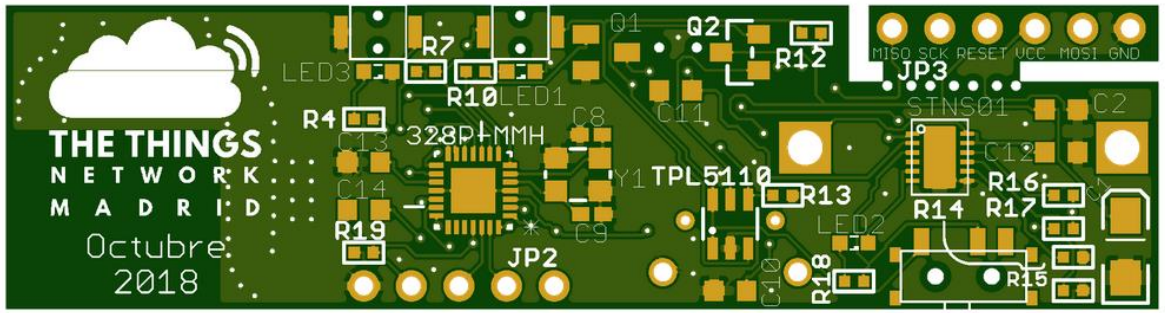
Gateway single channel y nodo puerta abierta

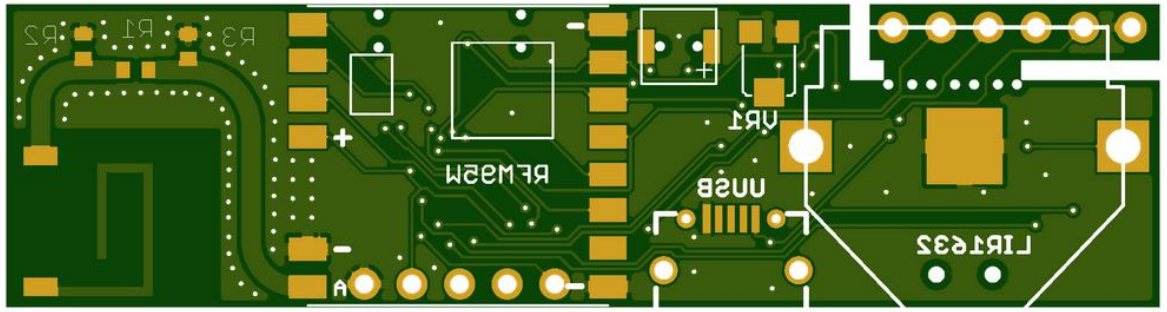


Nodo TTN_MAD v3.1



Nodo TTN_MAD v4





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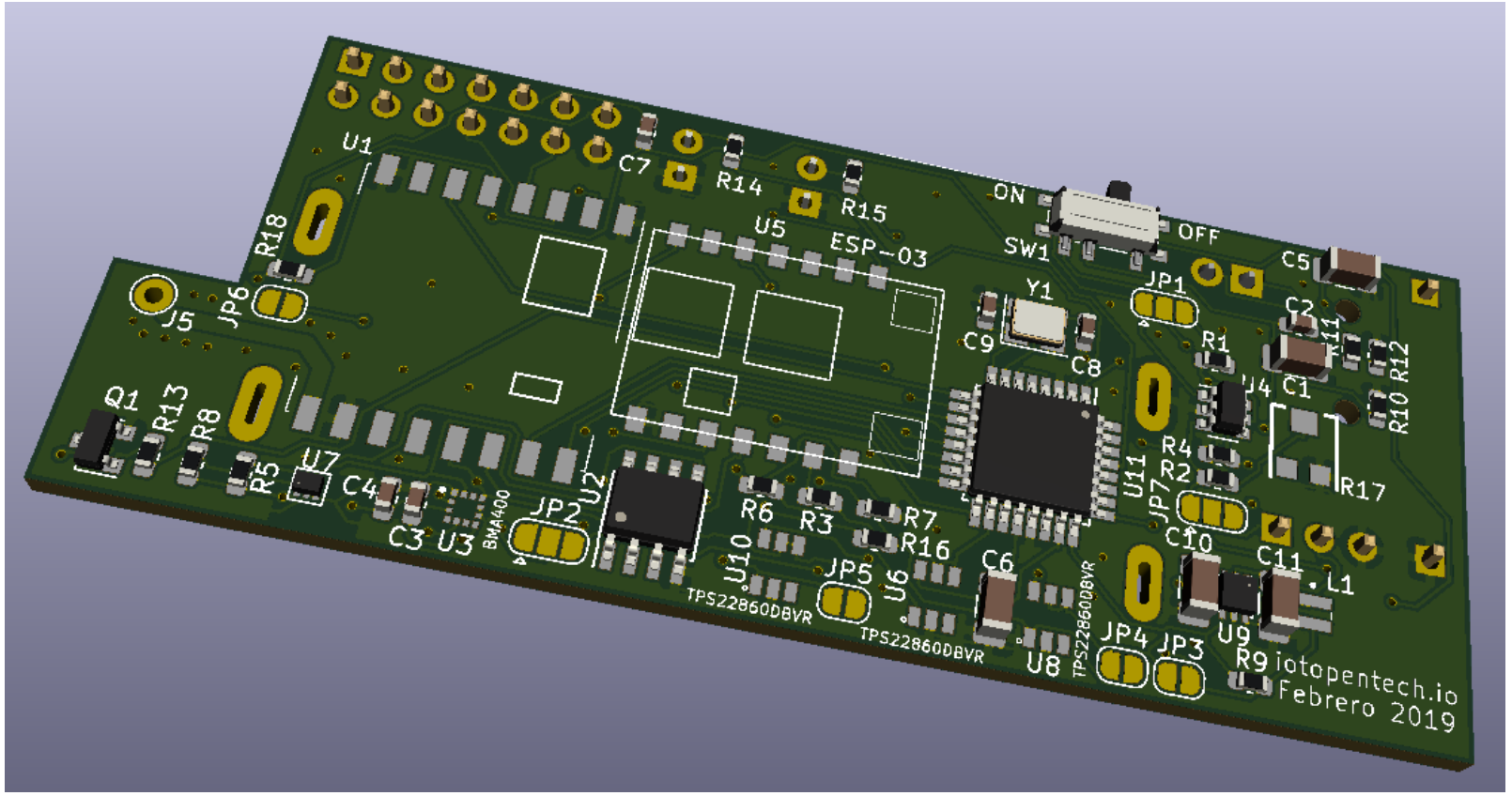
Nodo TTN_MAD v6



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)

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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 Tª y Hª 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

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¿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

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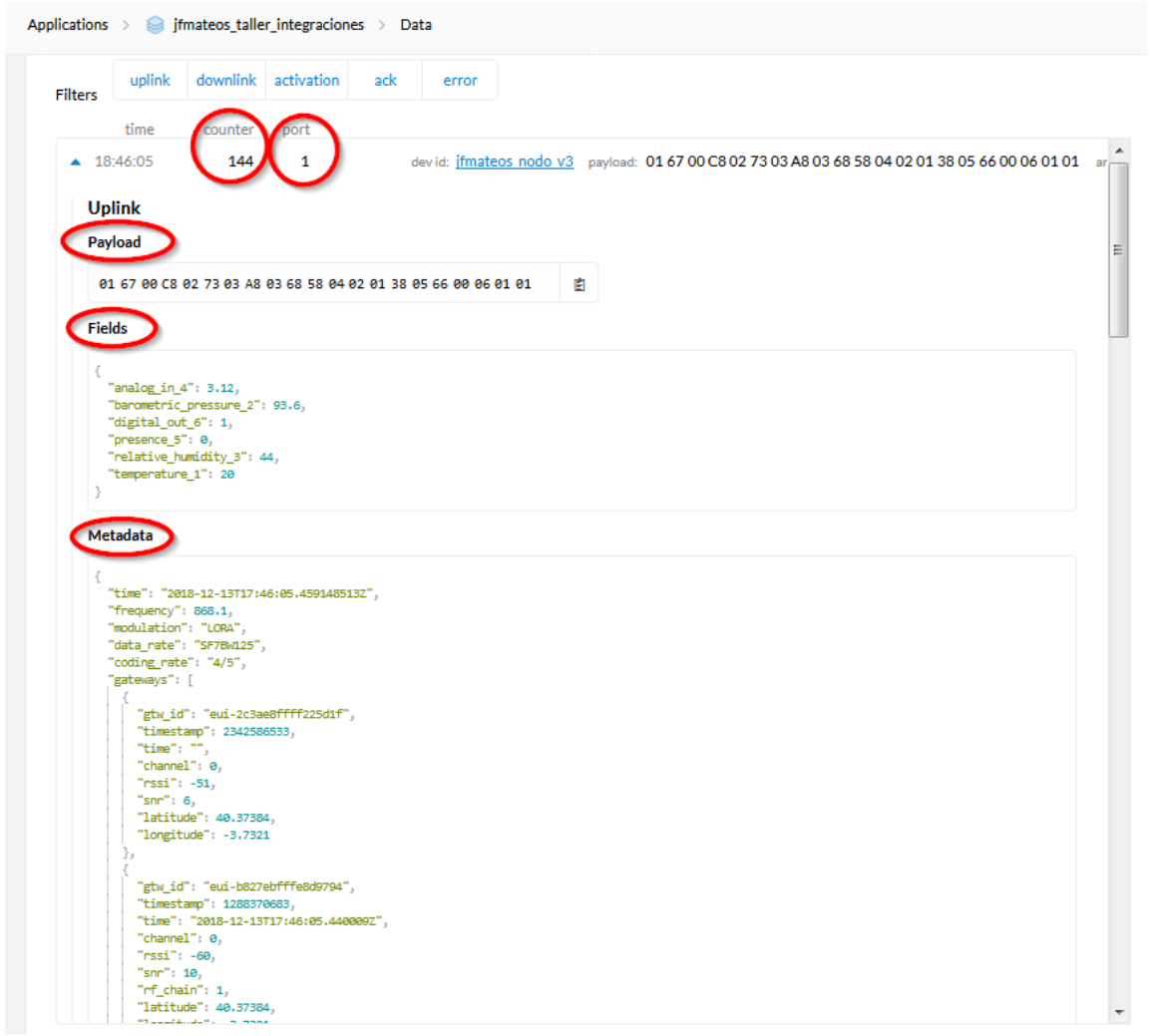
¿Qué aspecto tienen los datos?

- Payload
  - RAW
  - Formateada
- Metadata



¿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

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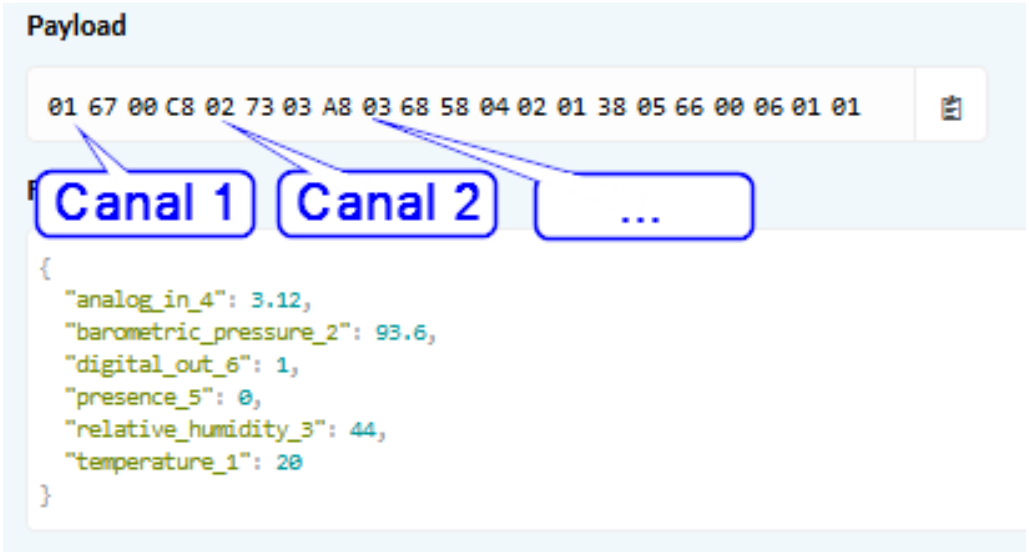
Cayenne LPP: Canal

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



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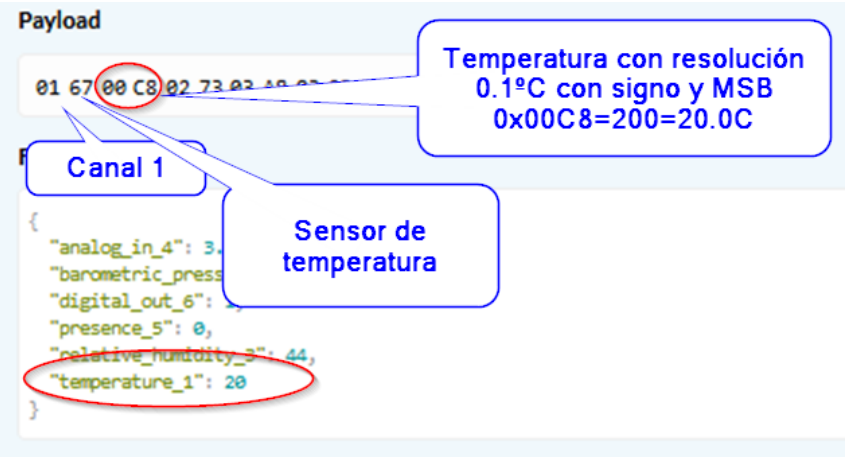
Cayenne LPP: Tipos de datos

- 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

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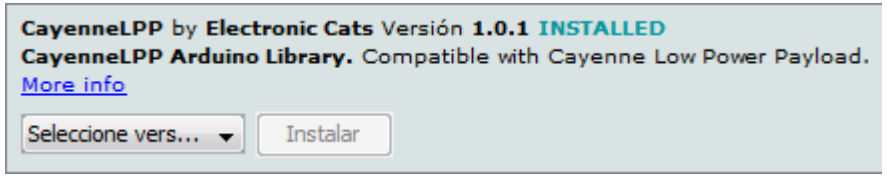
Cayenne LPP: Biblioteca para Arduino

```
#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);
```

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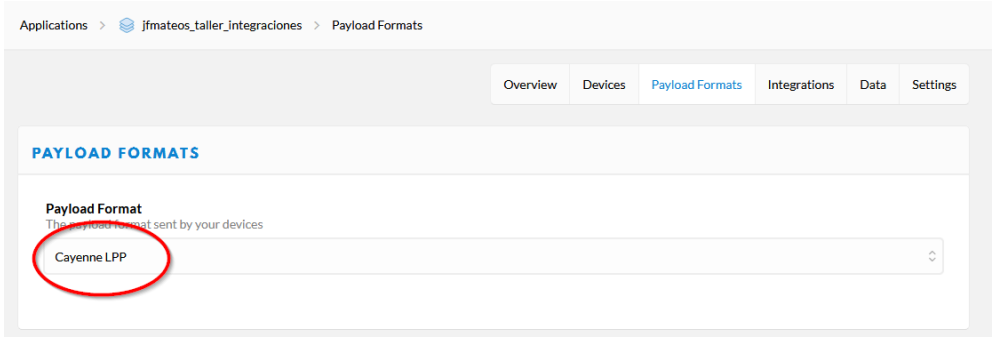
Cayenne LPP: Formato de payload

- 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
}
```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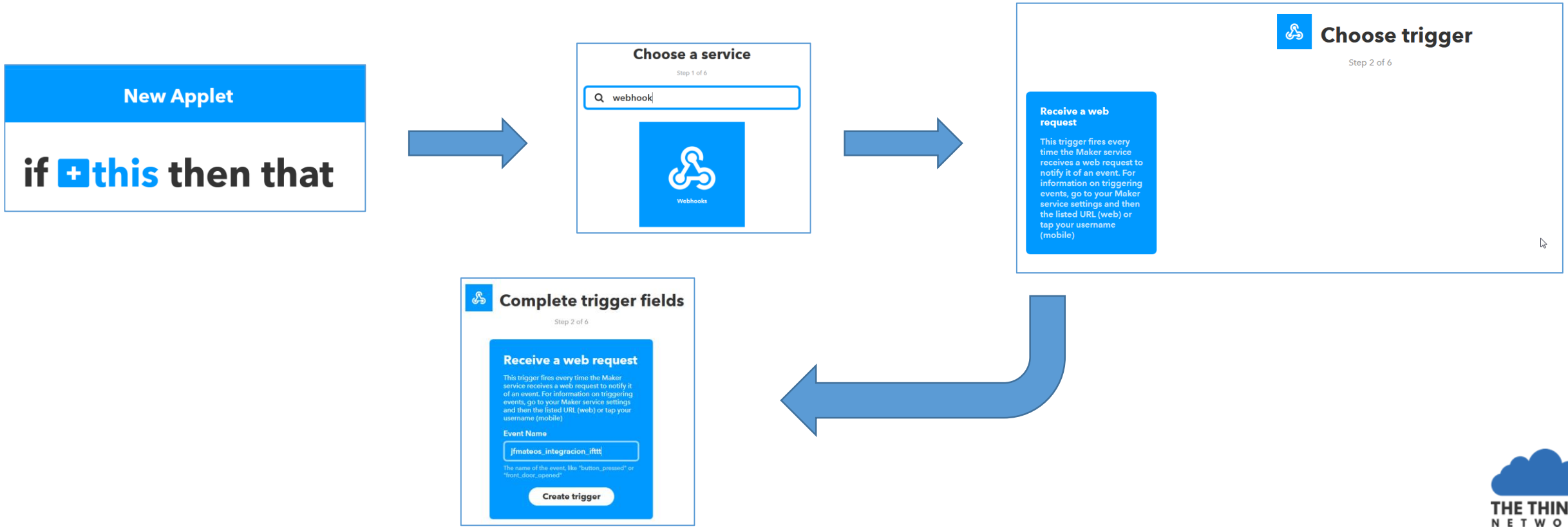
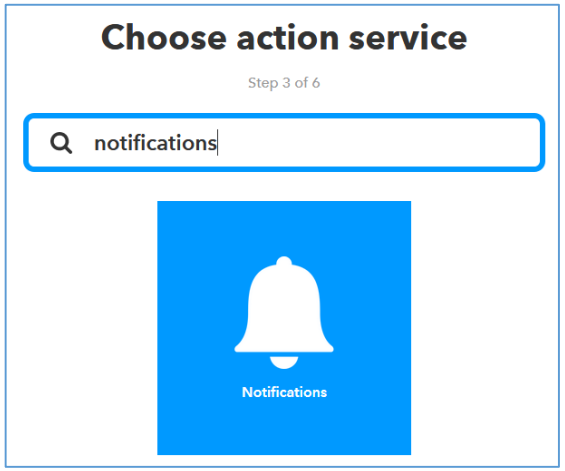
IFTTT: Crear un applet 1/3

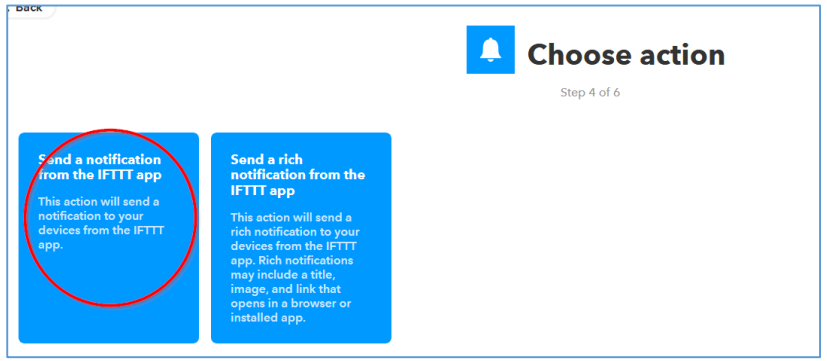
- Definimos la sección **this** como un webhook

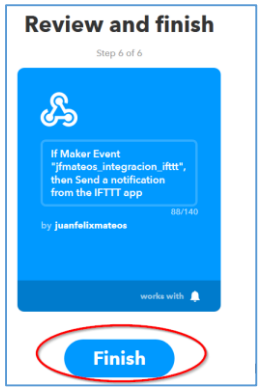


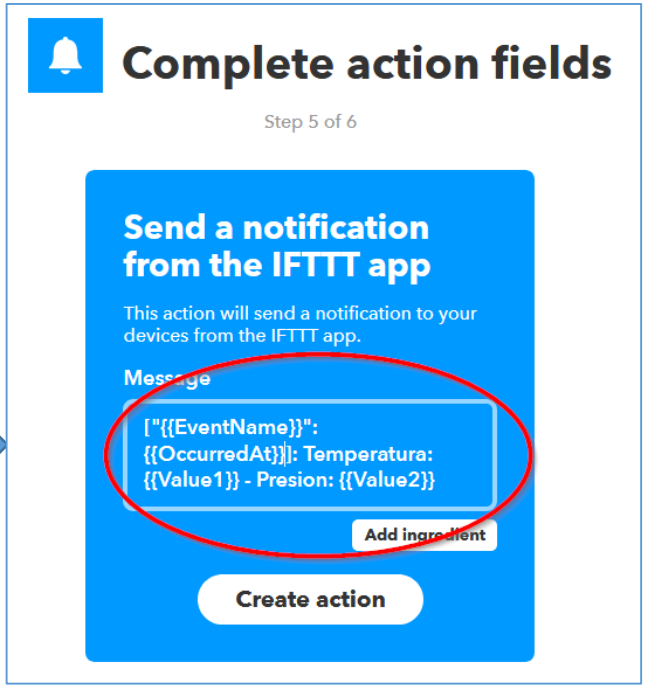
IFTTT: Crear un applet 2/3

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



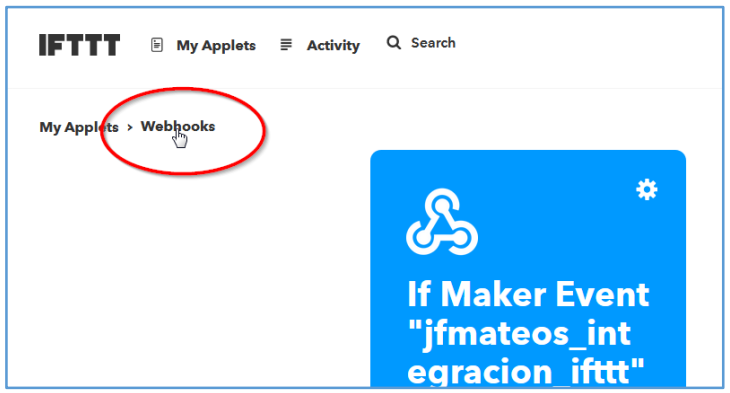


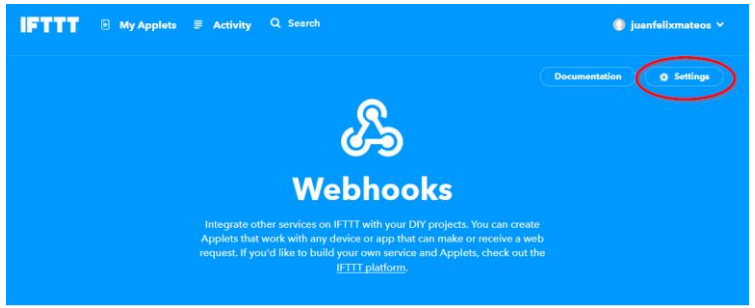


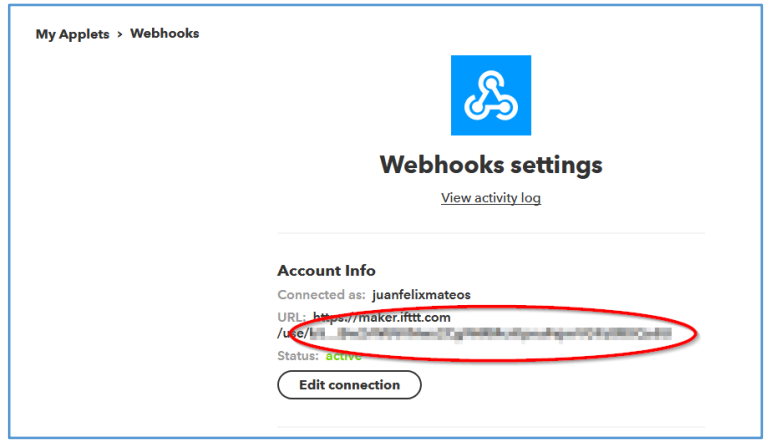


IFTTT: Crear un applet 3/3

- Obtener la clave/llave del webhook

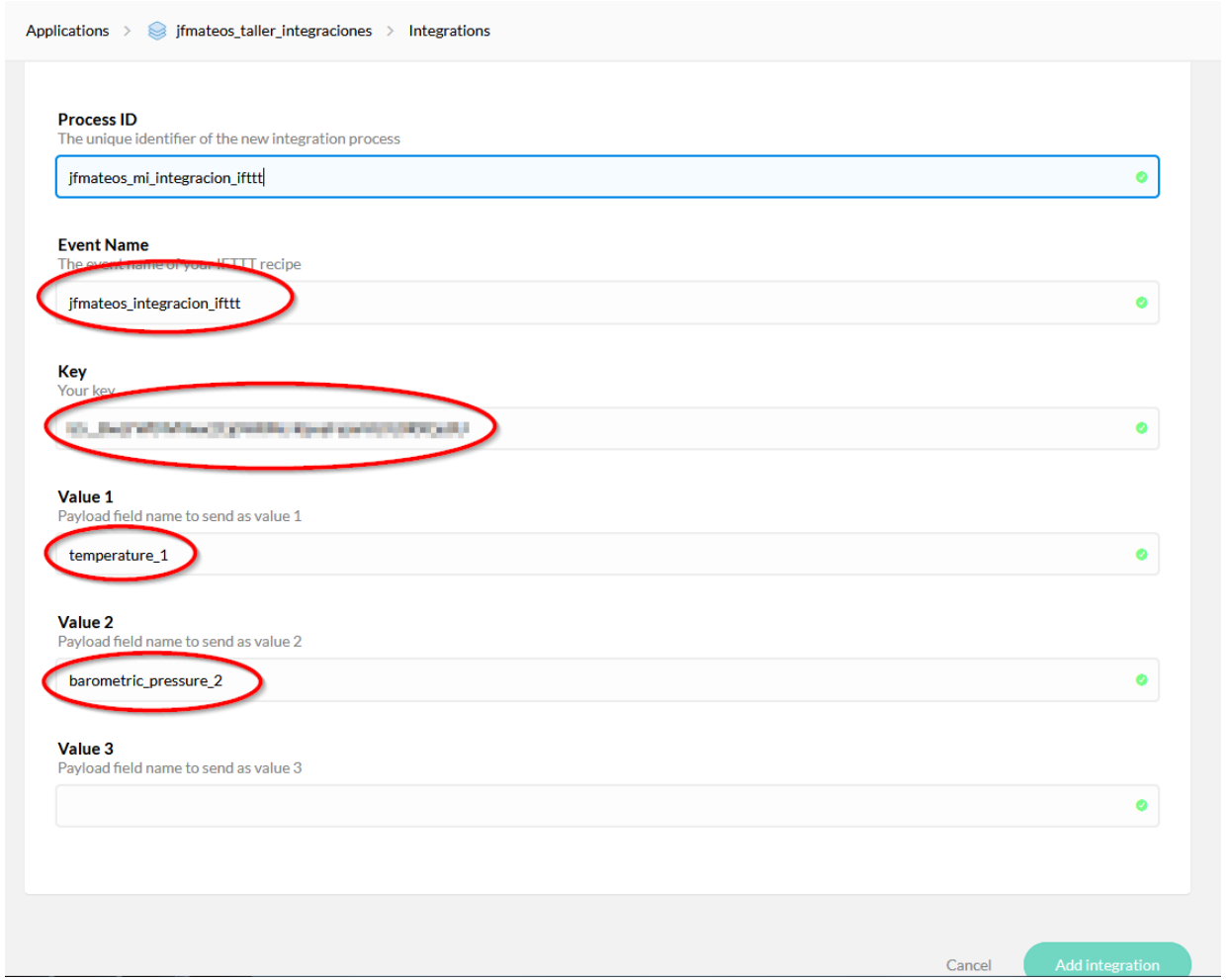






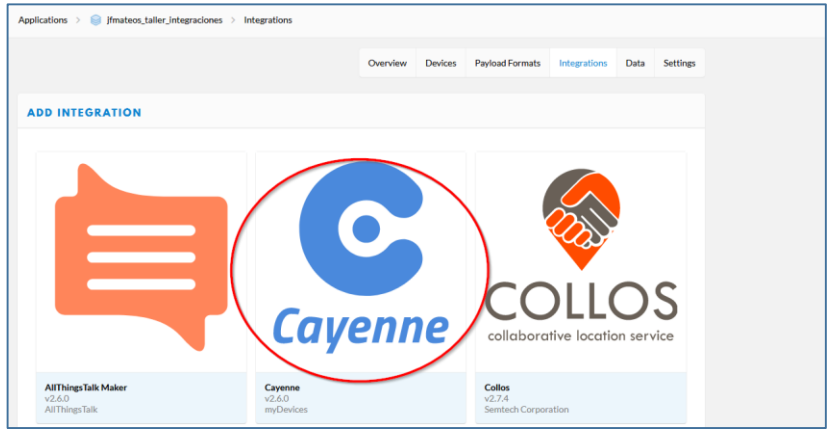
IFTTT: Activar la integración en TTN

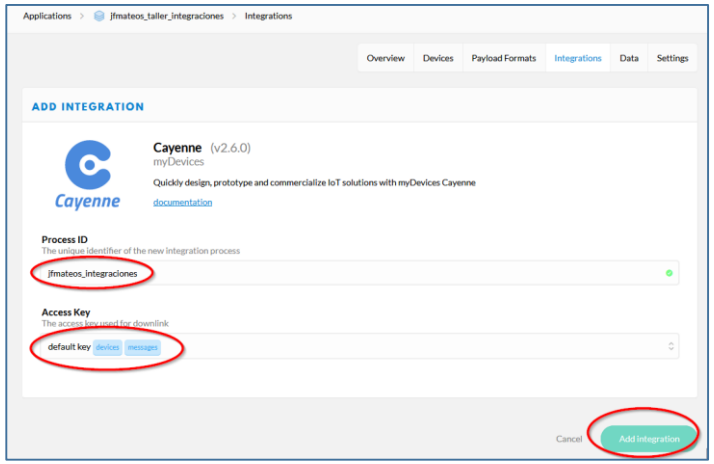
- Utilizar el nombre del evento y la clave de IFTTT

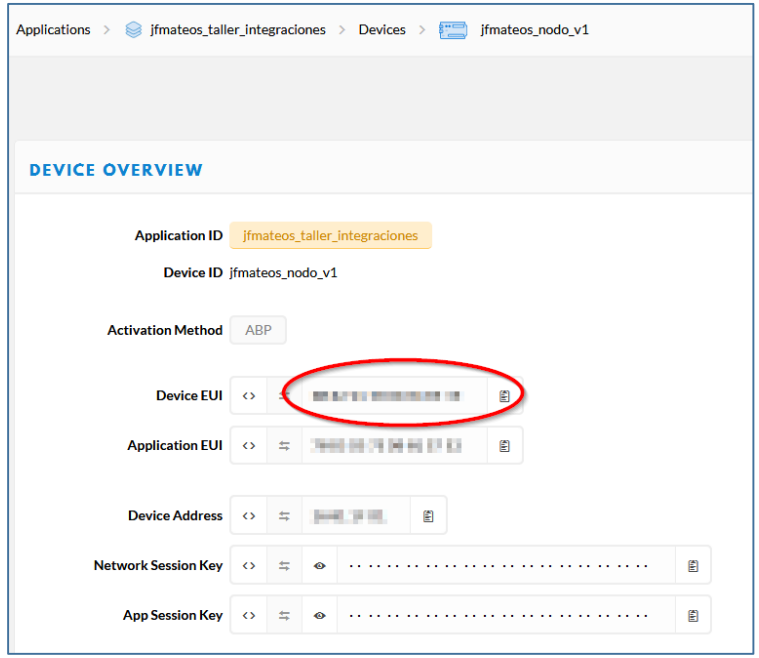


CAYENNE

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

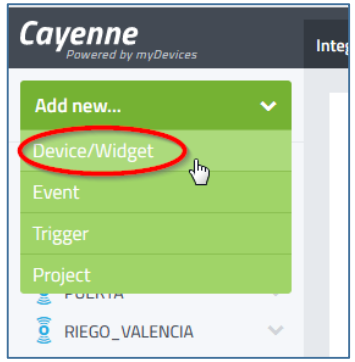


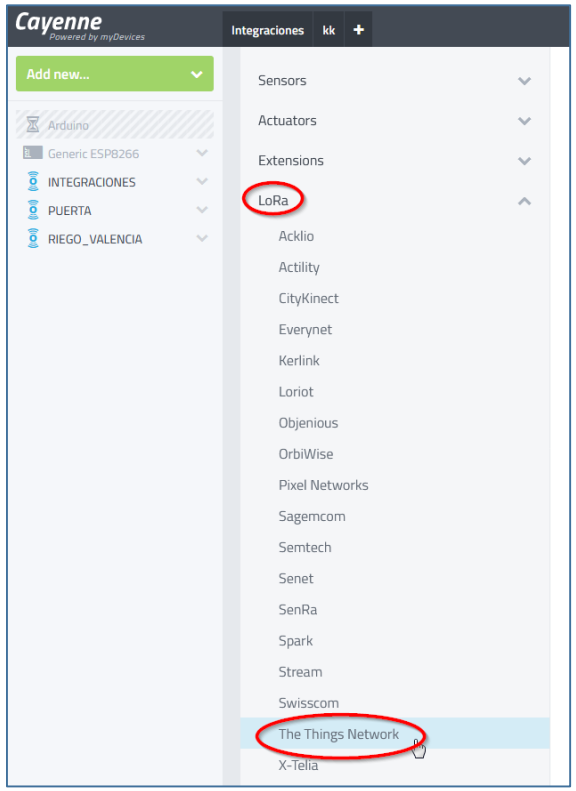


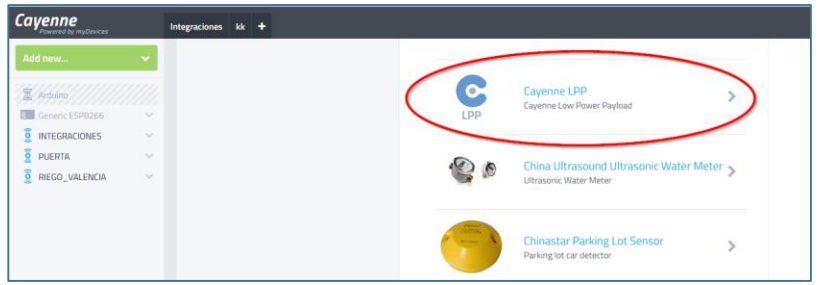


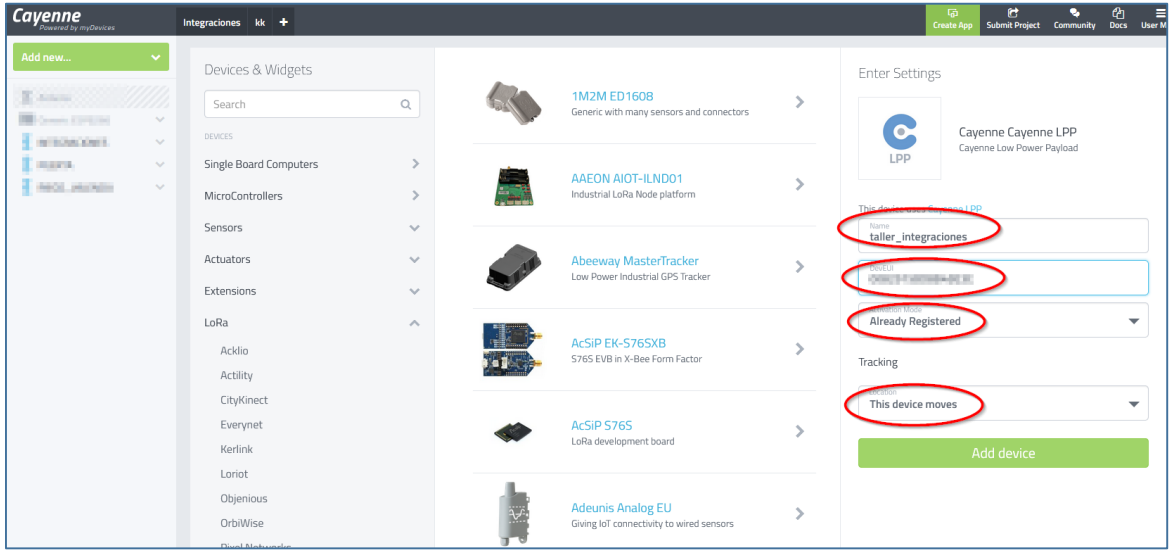
CAYENNE

- Registramos el device en Cayenne



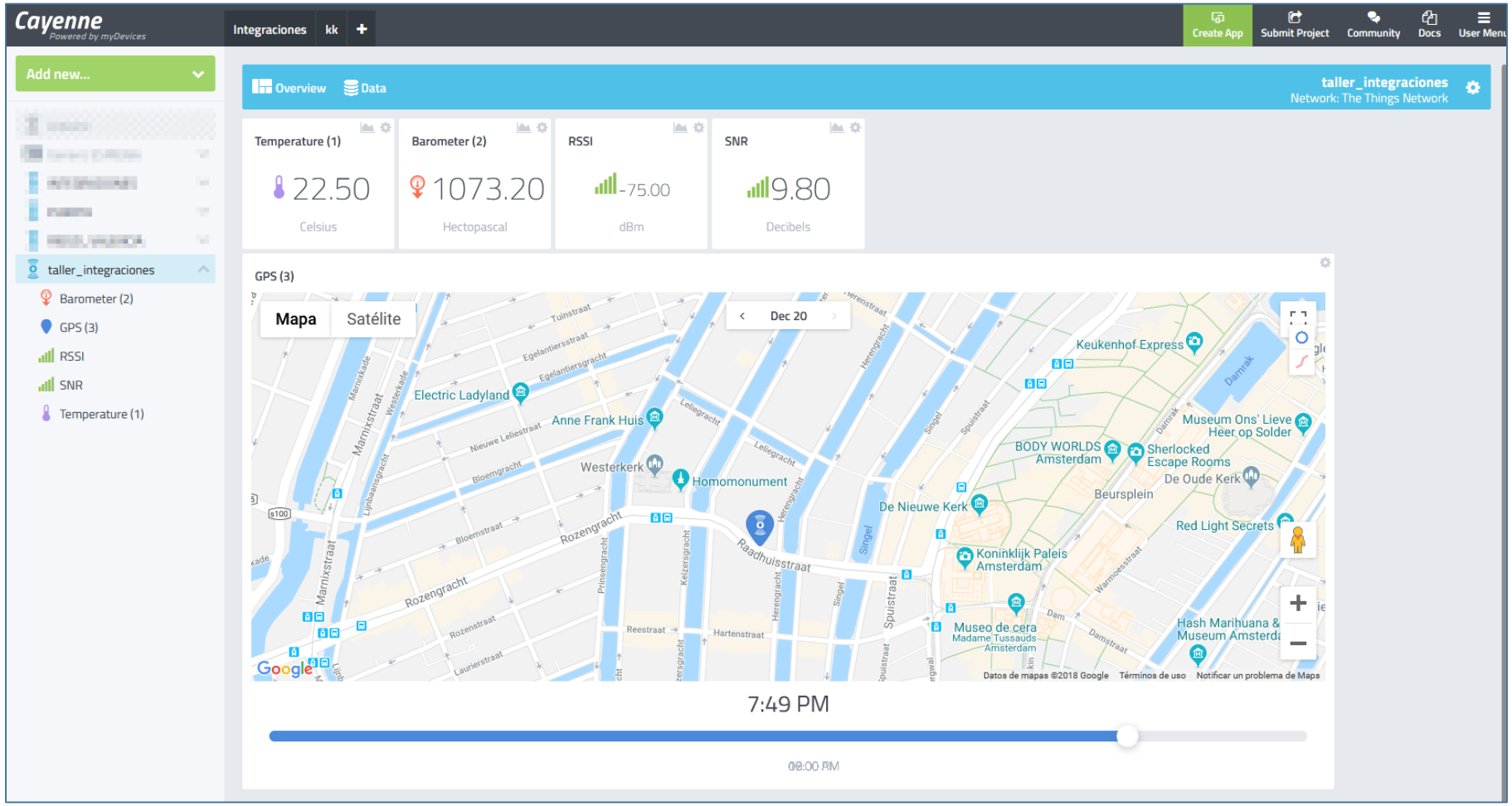






THE THINGS NETWORK

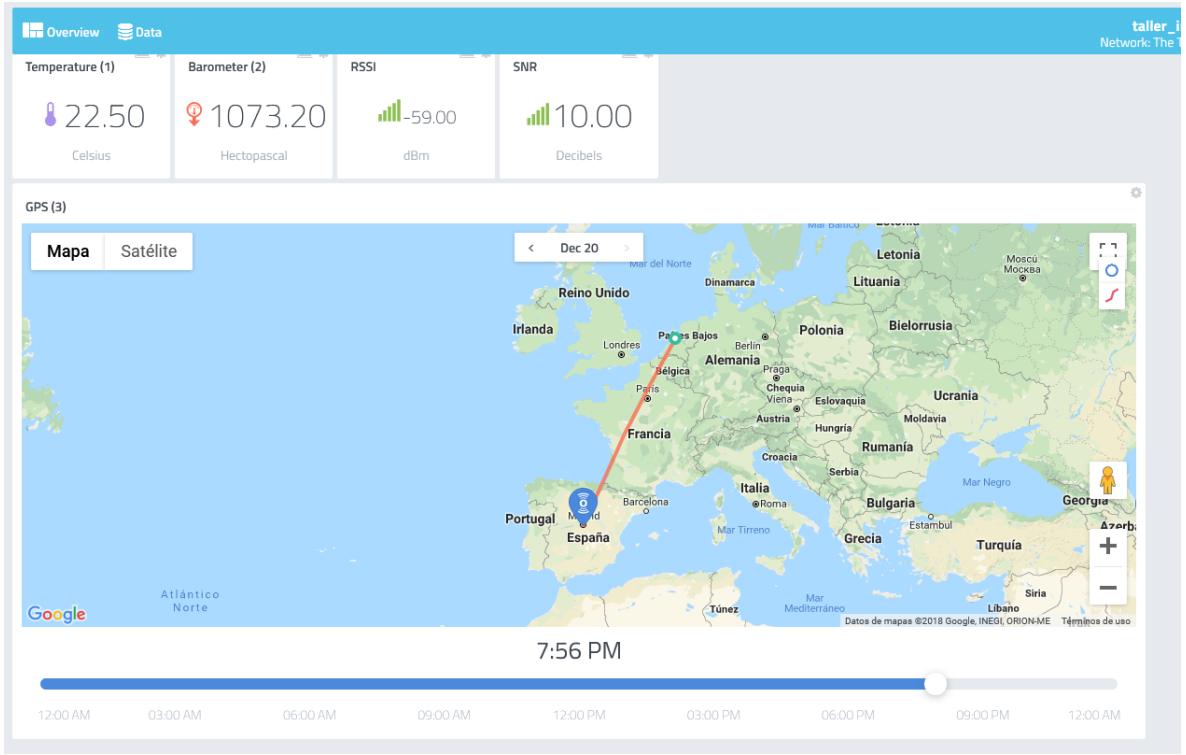
CAYENNE



THE THINGS NETWORK

CAYENNE

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



CAYENNE: Downlink

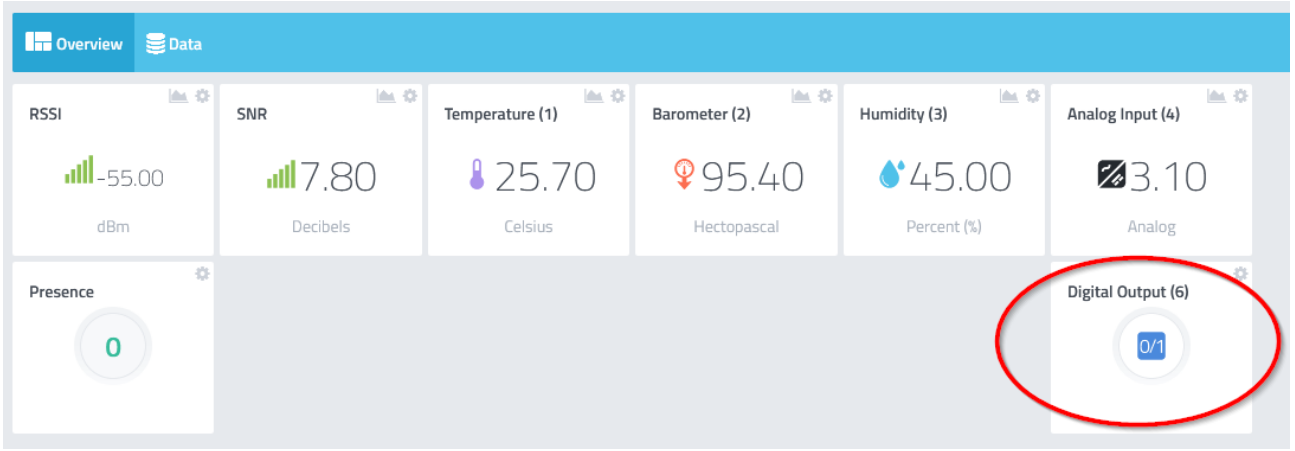
- Con los método addDigitalOutput() y addAnalogOutput() podemos generar downlinks desde Cayenne
  - Los downlink de Cayenne se envían con solicitud de ACK

```
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);
    }
  }
```

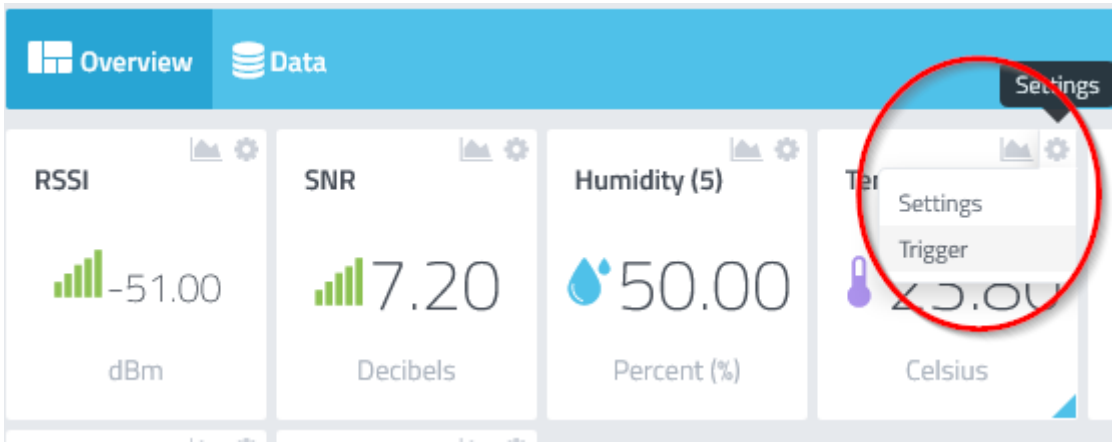
digitalOutput devuelve 0 o 100

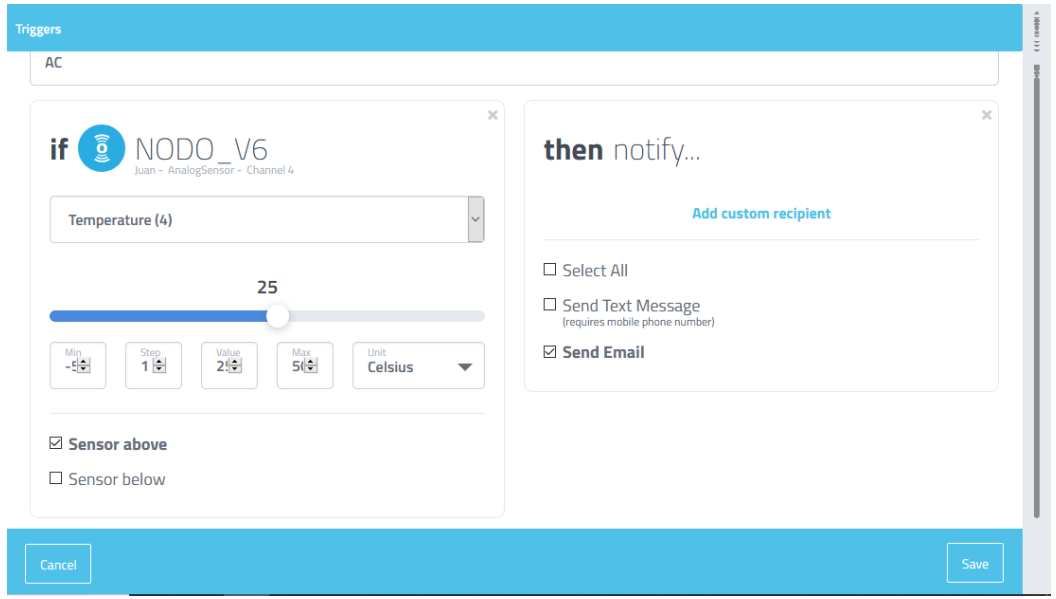


THE THINGS NETWORK

CAYENNE: Triggers

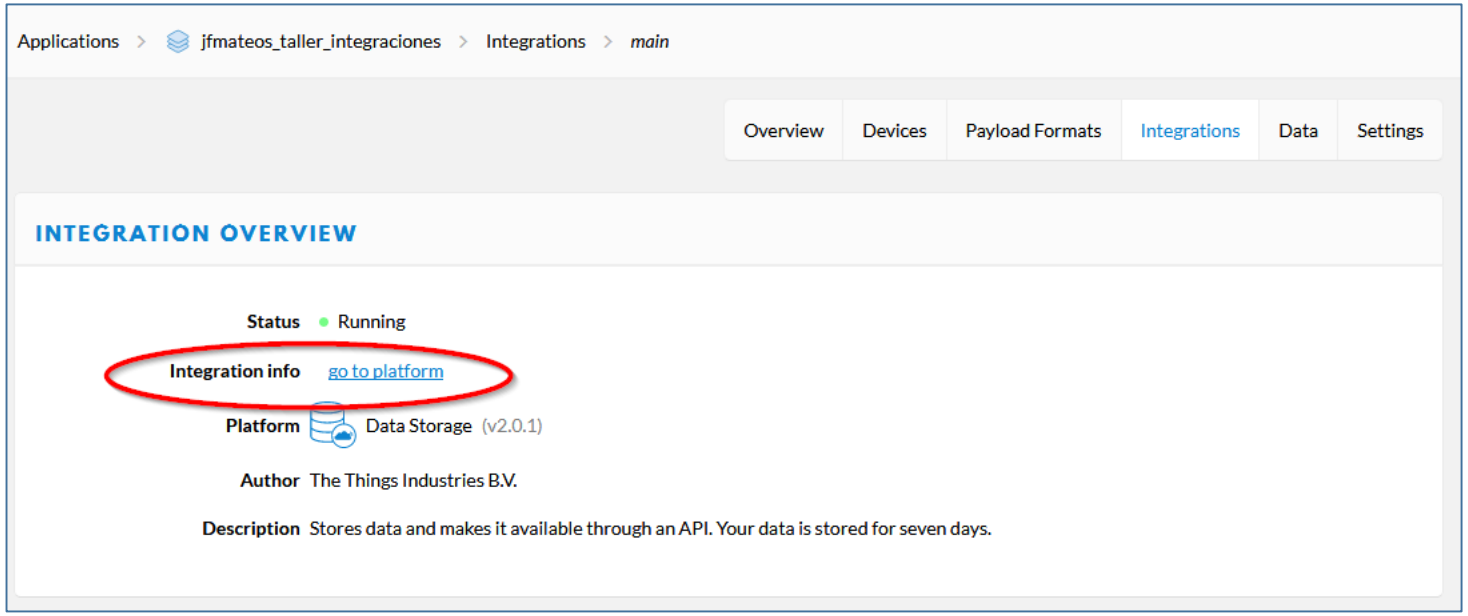
- Podemos establecer un umbral y enviar una notificación o webhook





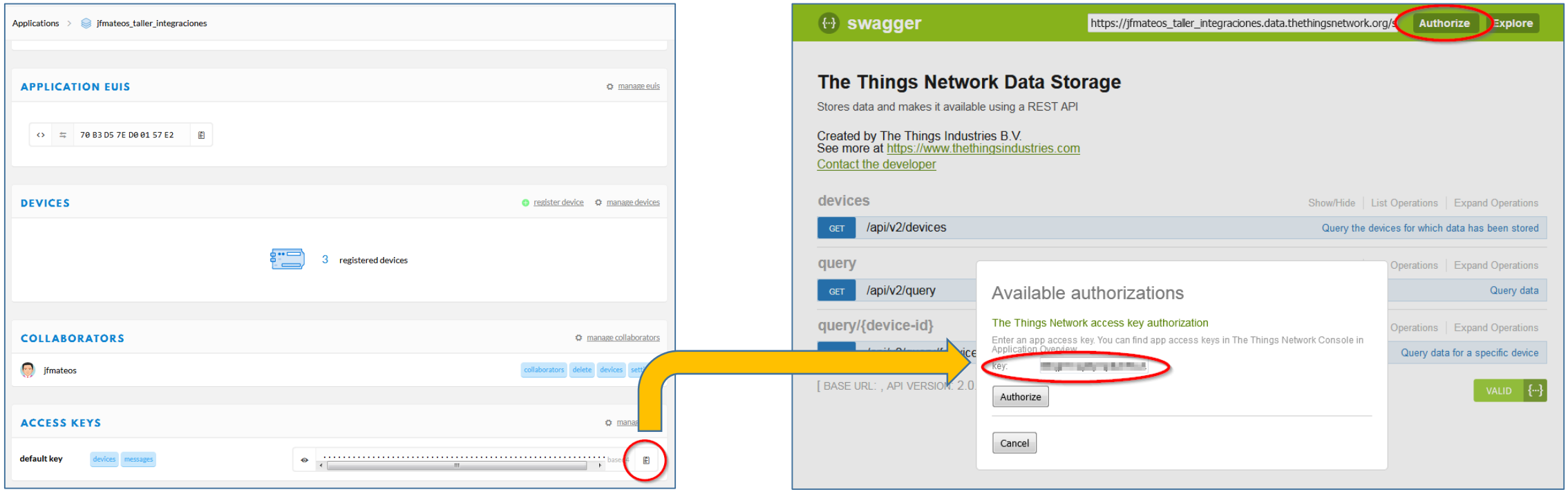
Data Storage

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



Data Storage

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



Data Storage

- Probamos el query de todos los datos

query

Show/Hide | List Operations | Expand Operations

GET /api/v2/query — Query data

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		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": "AWcA4QJzKewDiAf92AC+4QAAyA==",
    "relative_humidity_3": null,
    "temperature_1": 22.5,
    "time": "2018-12-20T20:34:40.972988337Z"
  },
  {
```


Response Code

```
200
```

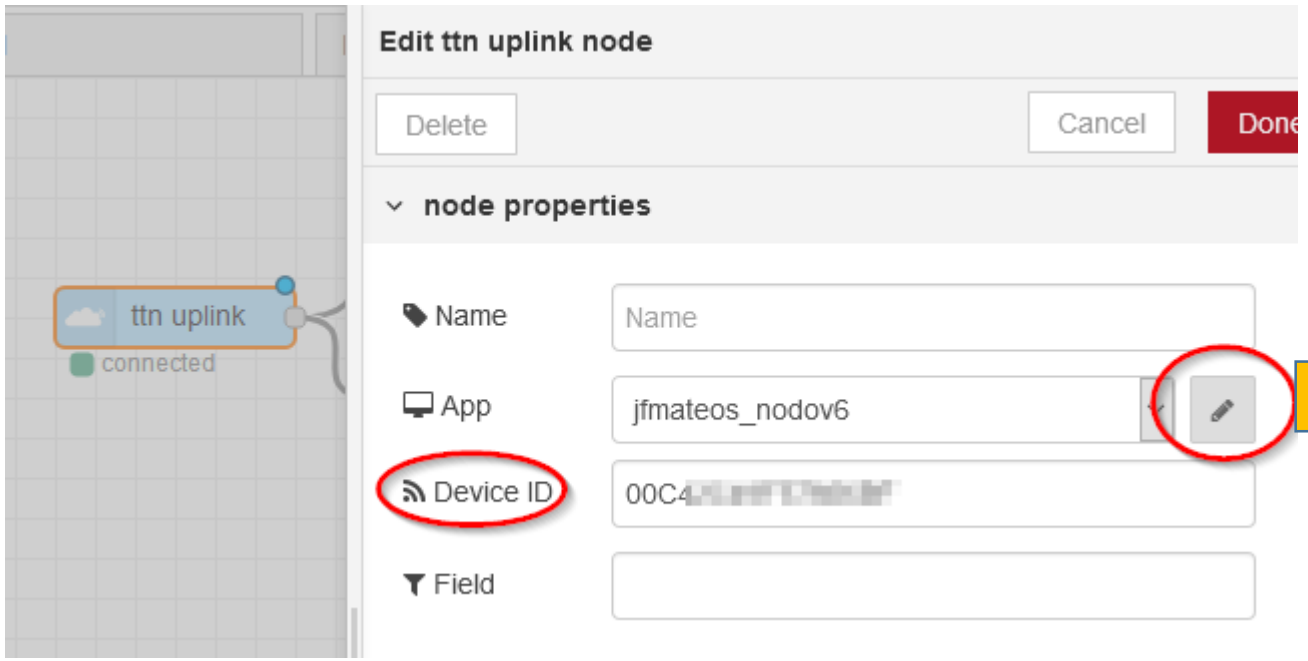
Response Headers

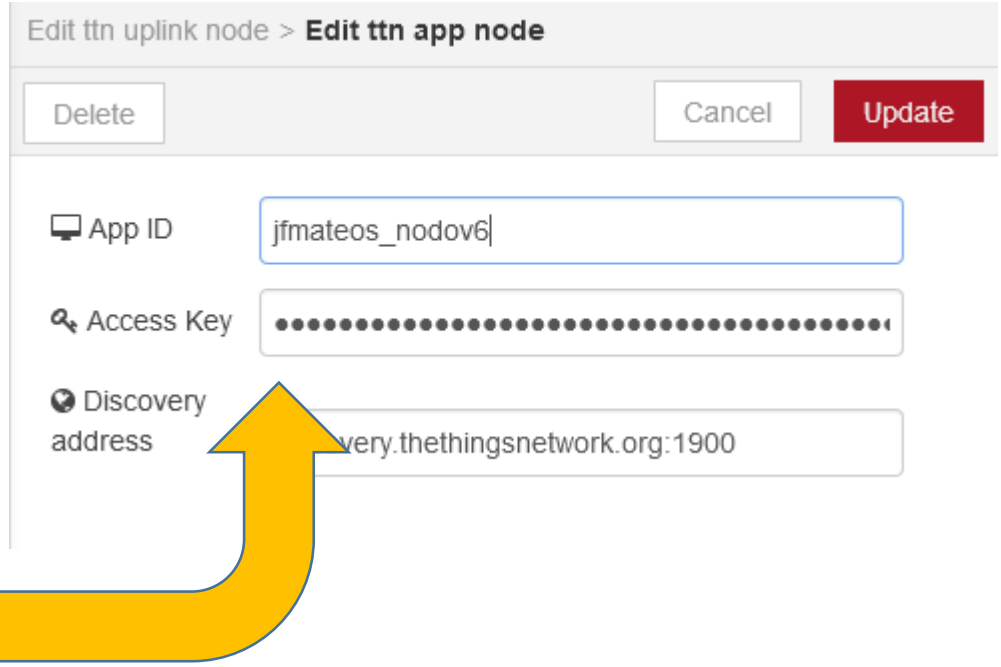

```
{
  "connection": "keep-alive",
  "content-type": "application/json",
  "date": "Thu, 20 Dec 2018 21:21:52 GMT",
  "server": "nginx/1.13.7",
  "transfer-encoding": "chunked"
}
```


THE THINGS NETWORK

Node-RED: uplink

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

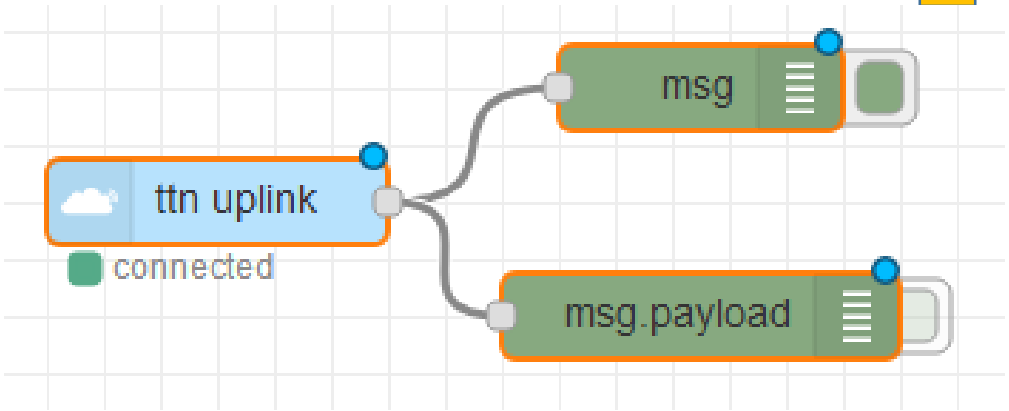


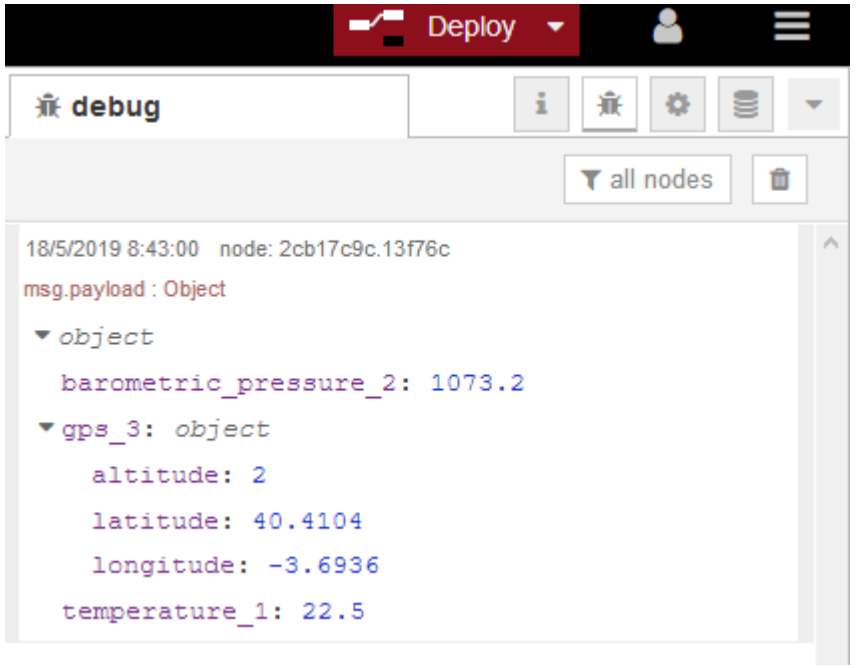


THE THINGS NETWORK

Node-RED: debug

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





THE THINGS NETWORK

YOU ARE THE NETWORK

LET'S BUILD THIS THING TOGETHER!

Juan Félix Mateos

juanfelixmateos@gmail.com

www.thethingsnetwork.org