Long range, low power: LoRaWAN and The Things Network

Rob Bricheno - rwhb2@cam.ac.uk - @rwhb2 - 2019

We will cover

- Why is this interesting?
- How does it work?
- What are the problems?
- What’s out there?

But first!

- Raise your hand if...

But first!

- Raise your hand if…
  - You know what a microcontroller is

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  - You know how the internet works

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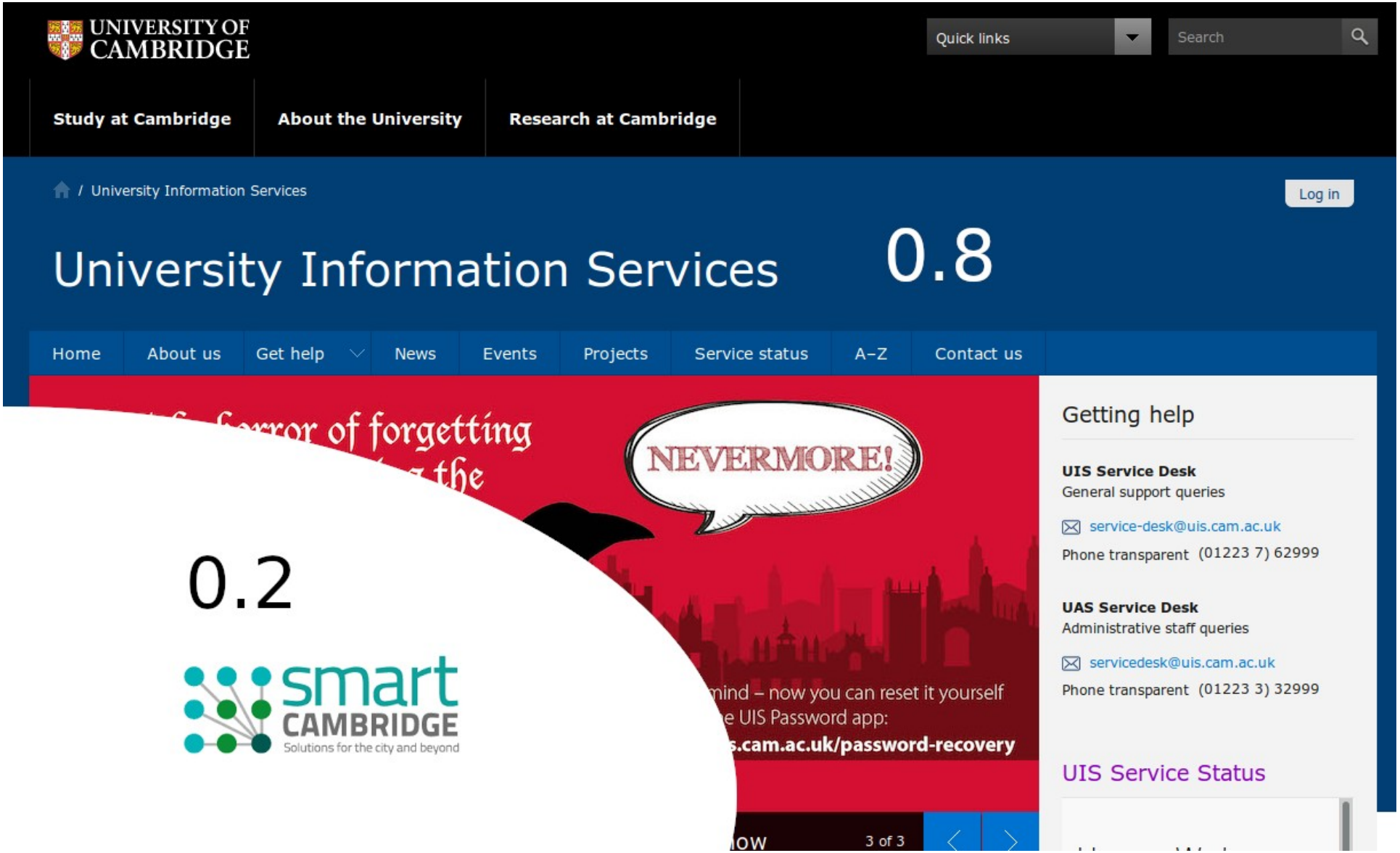
But first!

- Raise your hand if…
  - You know what a microcontroller is
  - You know how the internet works
  - You know what “cloud computing” means
  - You know how WiFi works

Why is this interesting?

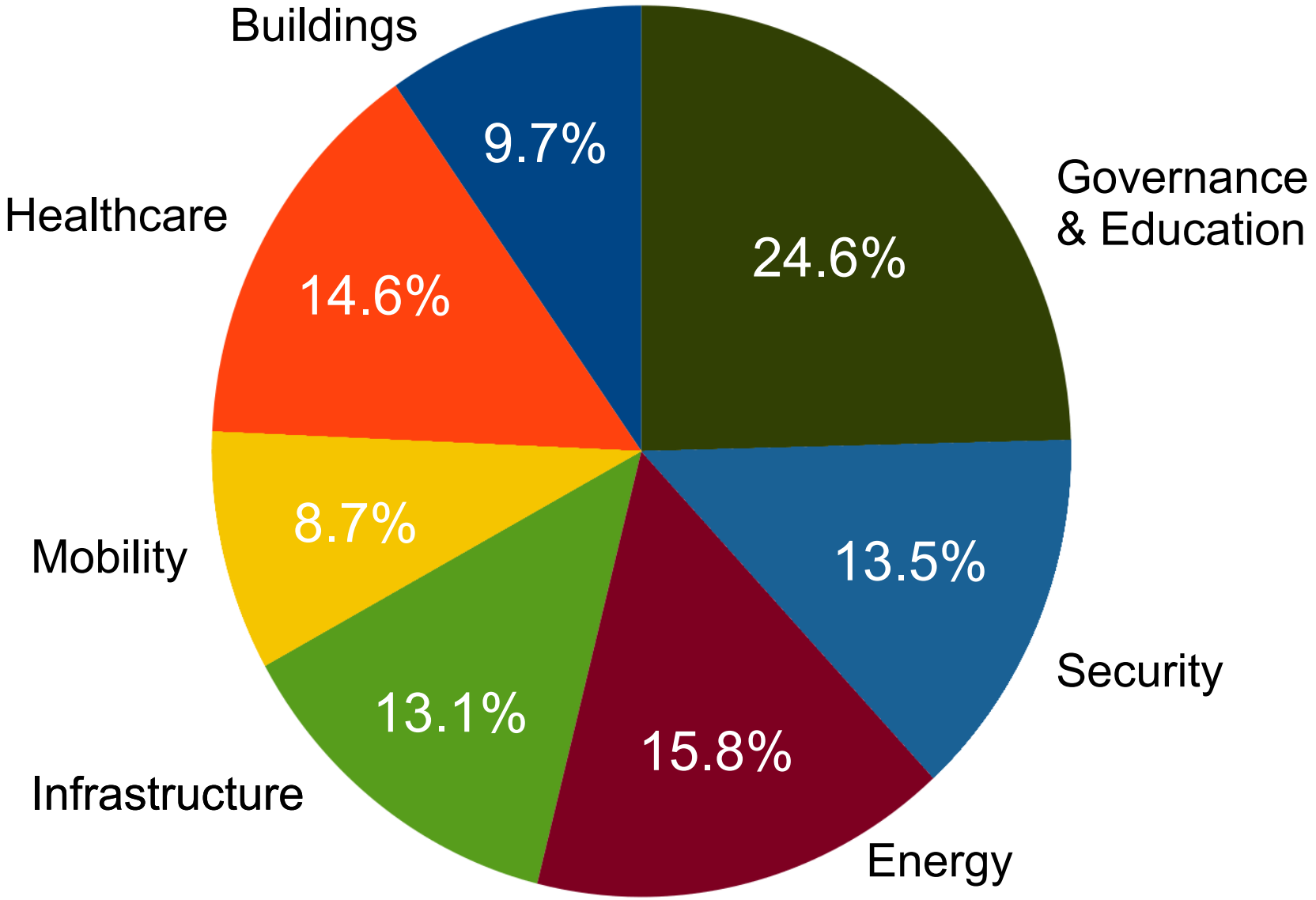
Rob Bricheno



How it happened

CATAPULT Digital

Cambridge – a smart city?



Internet of Nearby Things

- Ultra short range:
  - Near Field Communication (NFC)
- Wireless Personal Area Network (WPAN) ~2.5mW, ~10m
  - Bluetooth
  - Bluetooth Low Energy
  - Zigbee
  - Z-Wave
- Wireless Local Area Network (WLAN) ~80mW, 50m
  - WiFi

Internet of Far Away Things

- Cellular ~5000mW, 5km
  - GSM/GPRS
  - LTE
- Low Power Wide Area Network (LPWAN) ~20mW, …?
  - Sigfox
  - NB-IOT
  - LoRaWAN!

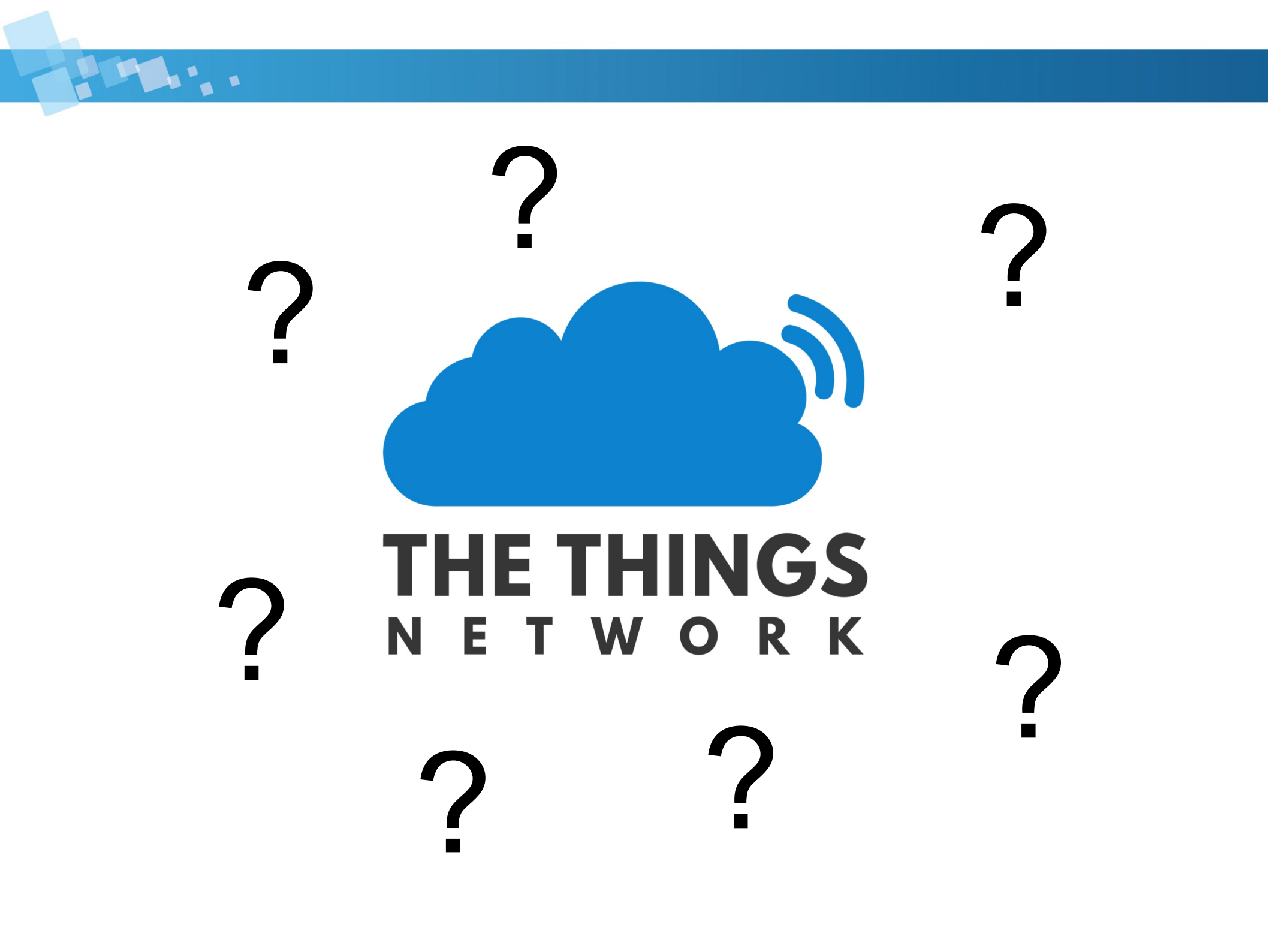
- 15 kilometre range
- 20,000 devices per gateway
- 10 year battery life

LoRaWAN?

- Long Range Wide Area Network
  - An LPWAN using LoRa (**Lo**ng **Ra**nge) as the physical layer
- Cycleo founded 2009, patented LoRa
- Bought by Semtech 2012
- LoRa alliance founded 2015
  - IBM, MicroChip, Orange, Cisco, KPN, Swisscom, Semtech, Bouygues Telecom, Singtel and Proximus, etc…
- A network stack build on top of LoRa

Some LoRaWAN use cases

- Utility metering for smart buildings
- Autonomous irrigation and soil health monitoring
- Smart parking
- Cattle tracking
- Cold chain assurance
- Natural disaster prediction


?
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THE THINGS
NETWORK

The Things Network

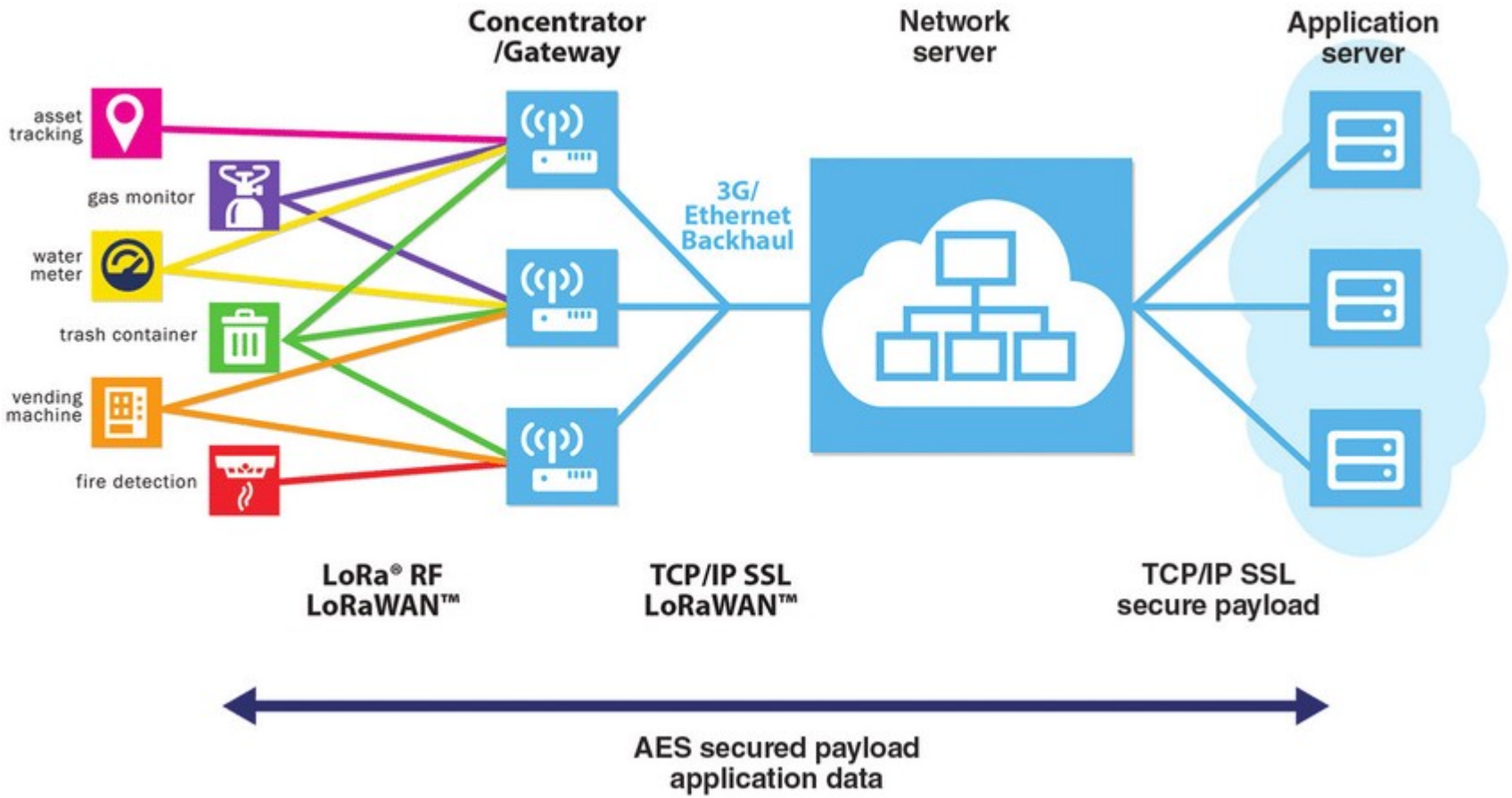
- LoRaWAN implementation
- A running instance of that implementation
- A community of people using that instance
- Adopted by Smart Cambridge in 2019

How does it work?

How does it work?

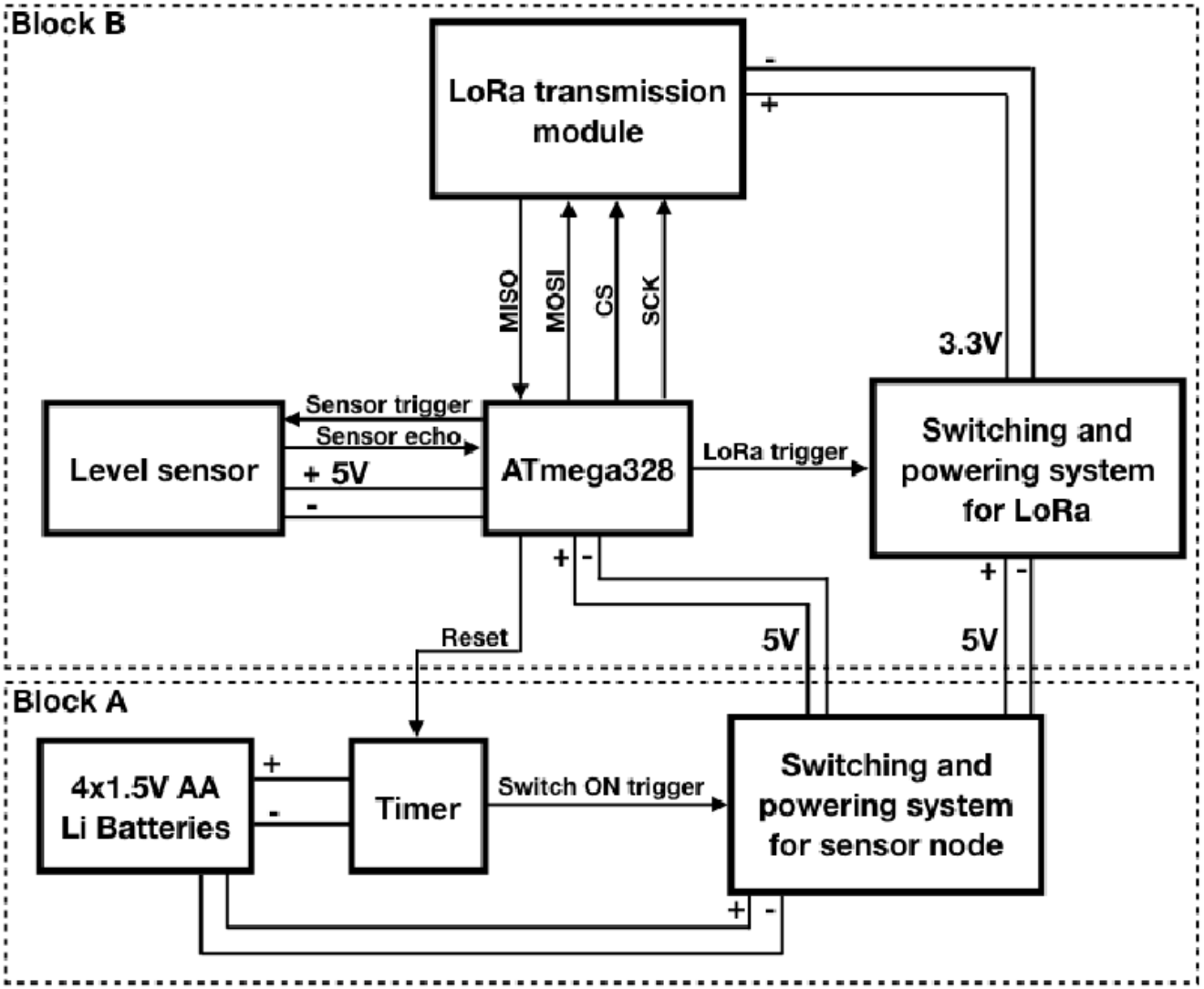
- The whole thing
- The sensor
- LoRa RF
- The LoRaWAN standard
- TTN network stack

The Whole Thing

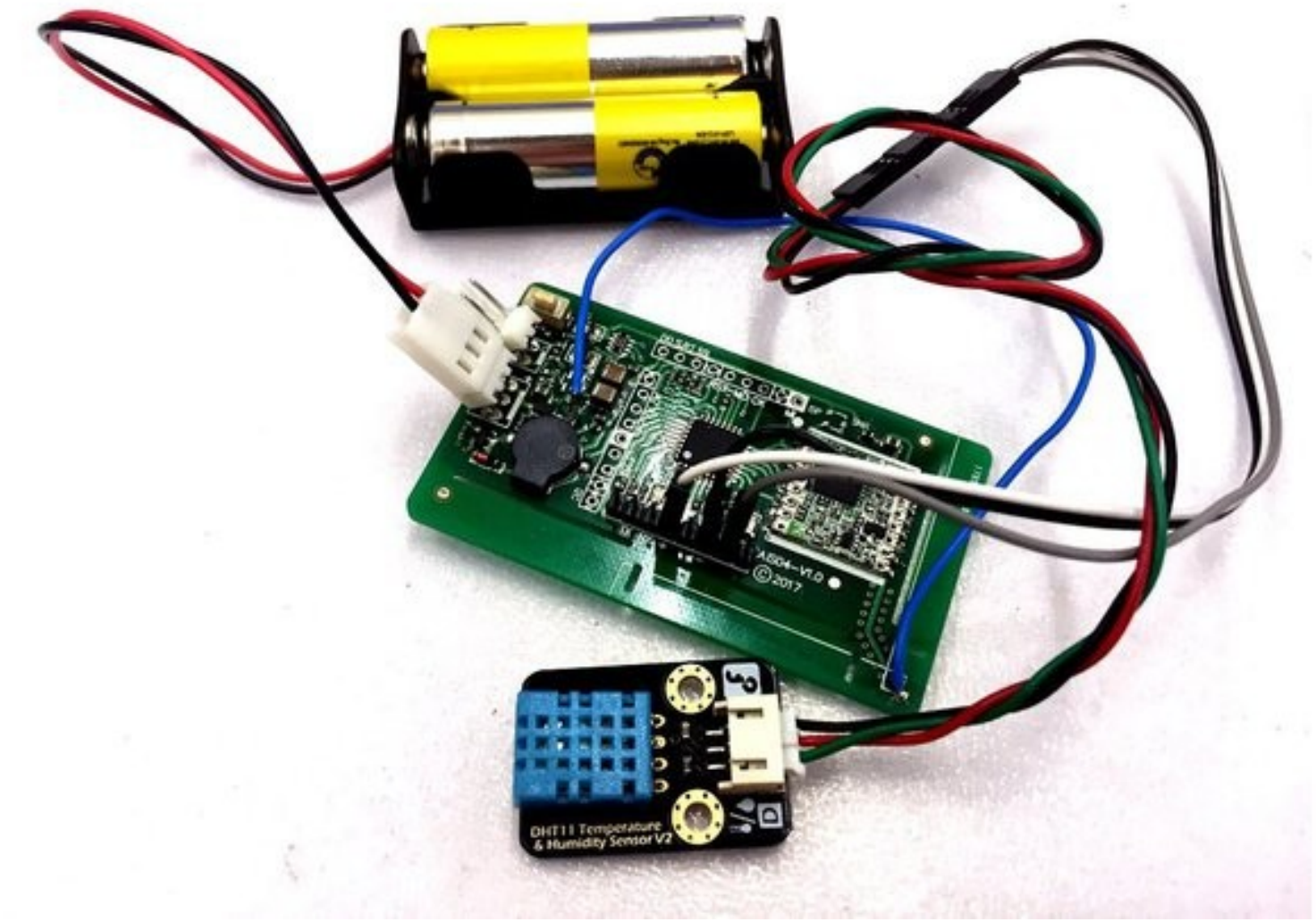


22.4°C

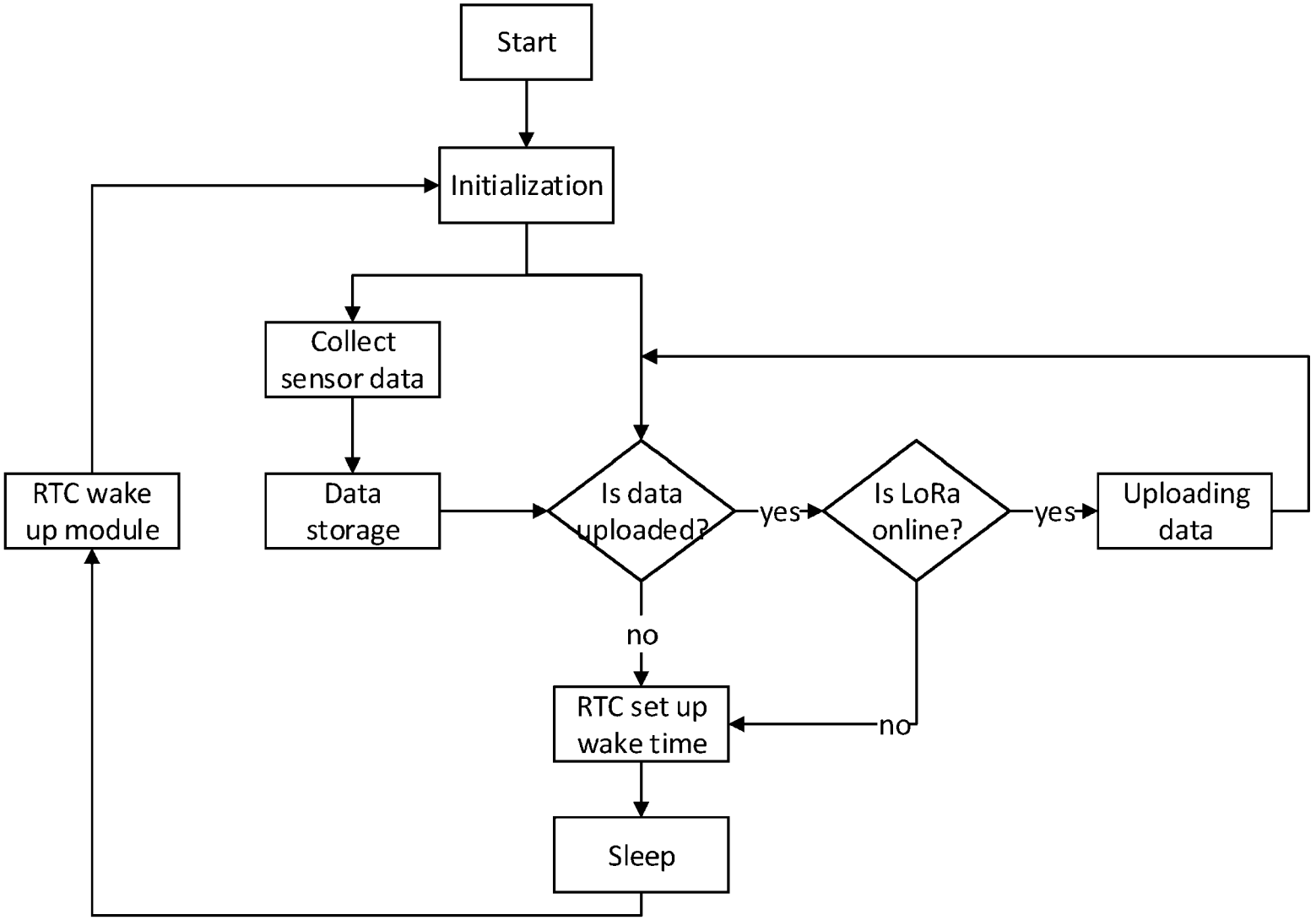
Example block diagram (level sensor)



How it might look (temperature sensor)



Desired workflow (sensor)



LoRa module

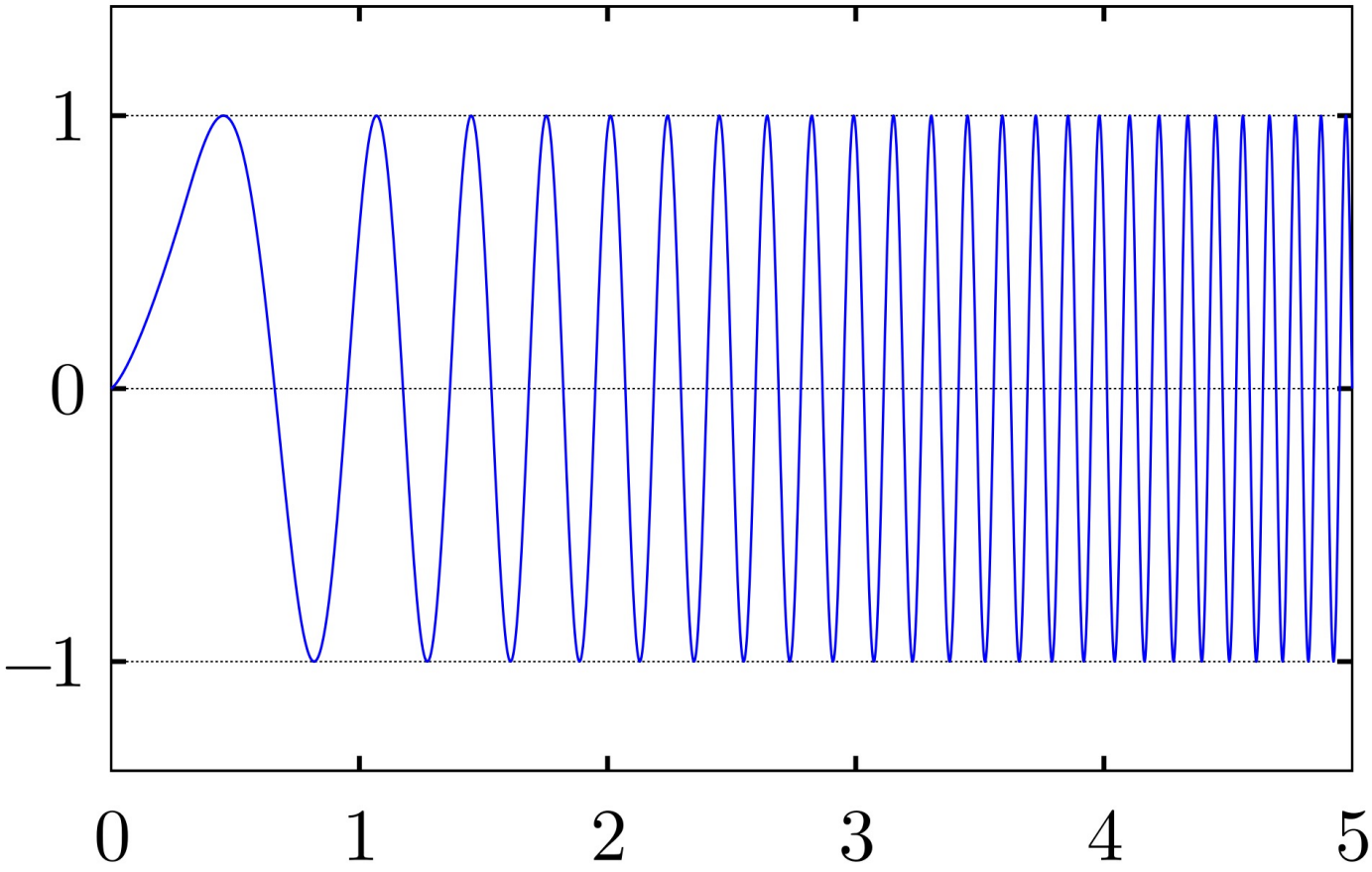
- Easy to use
- Certified
- May even have LoRaWAN stack (more later)

Spread Spectrum magic

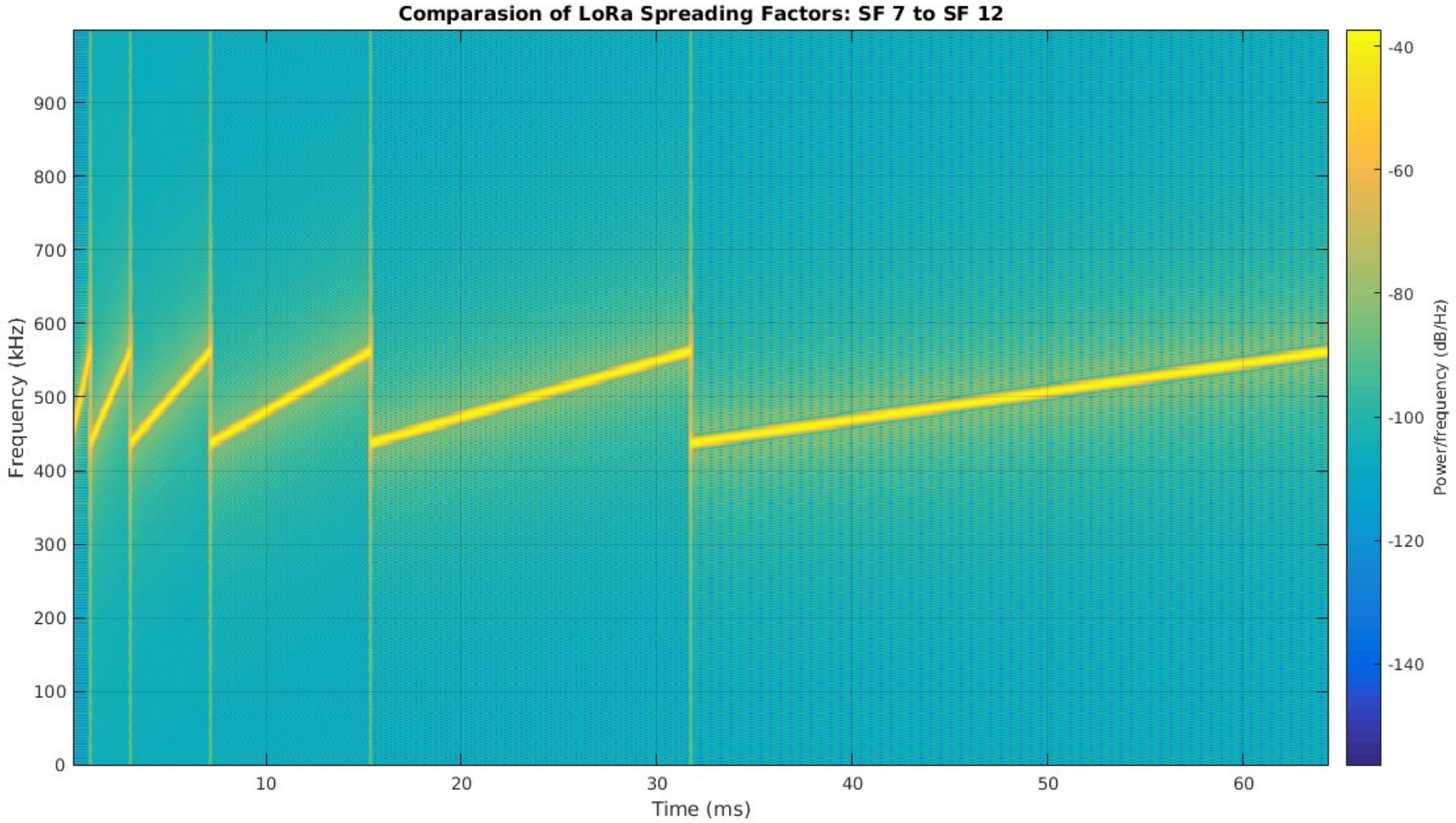
Link budget
151 dB!

LoRa - a Chirp Spread Spectrum technology

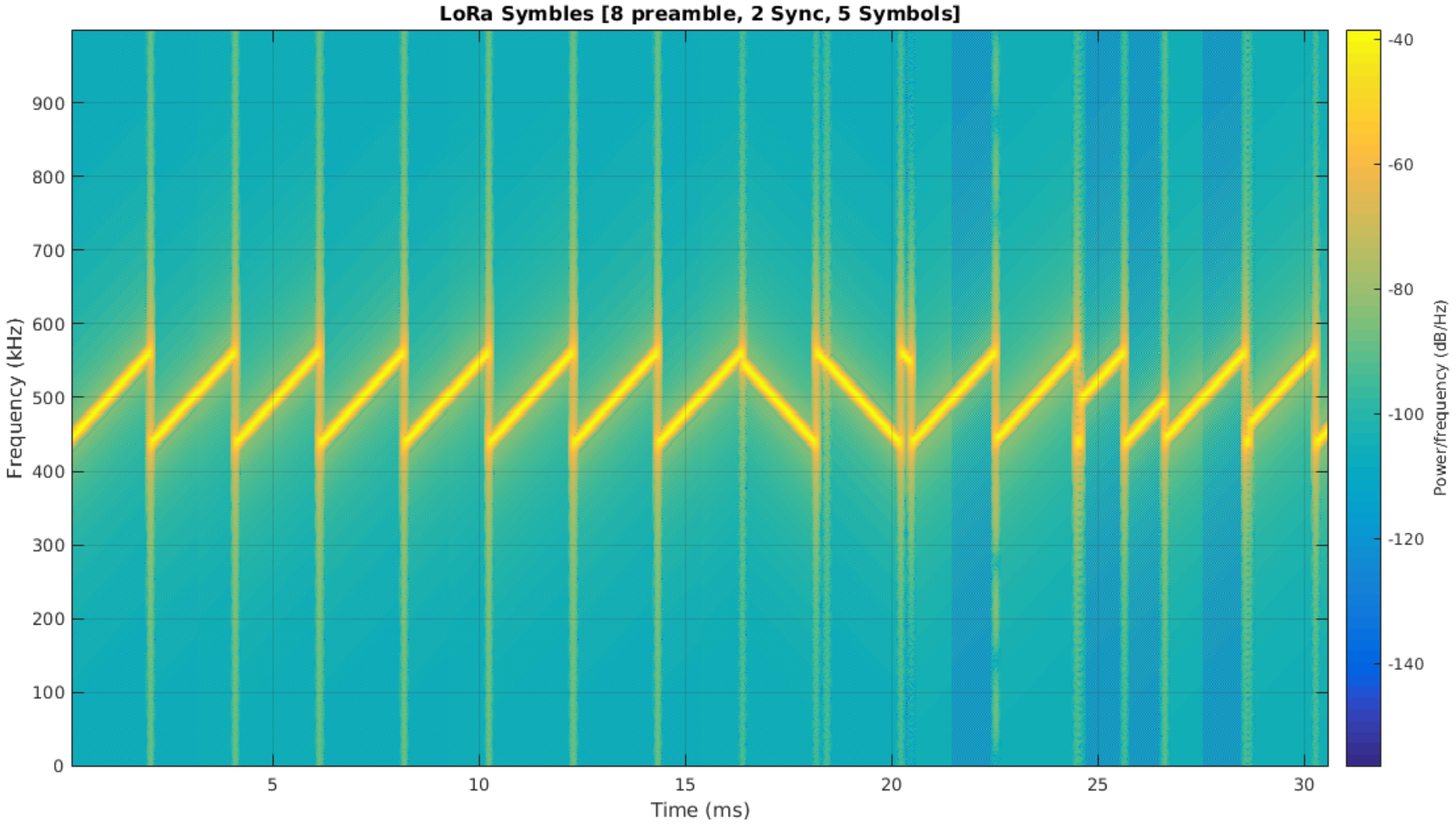
- A linear, frequency modulated upchirp in the time domain:



Spreading factors



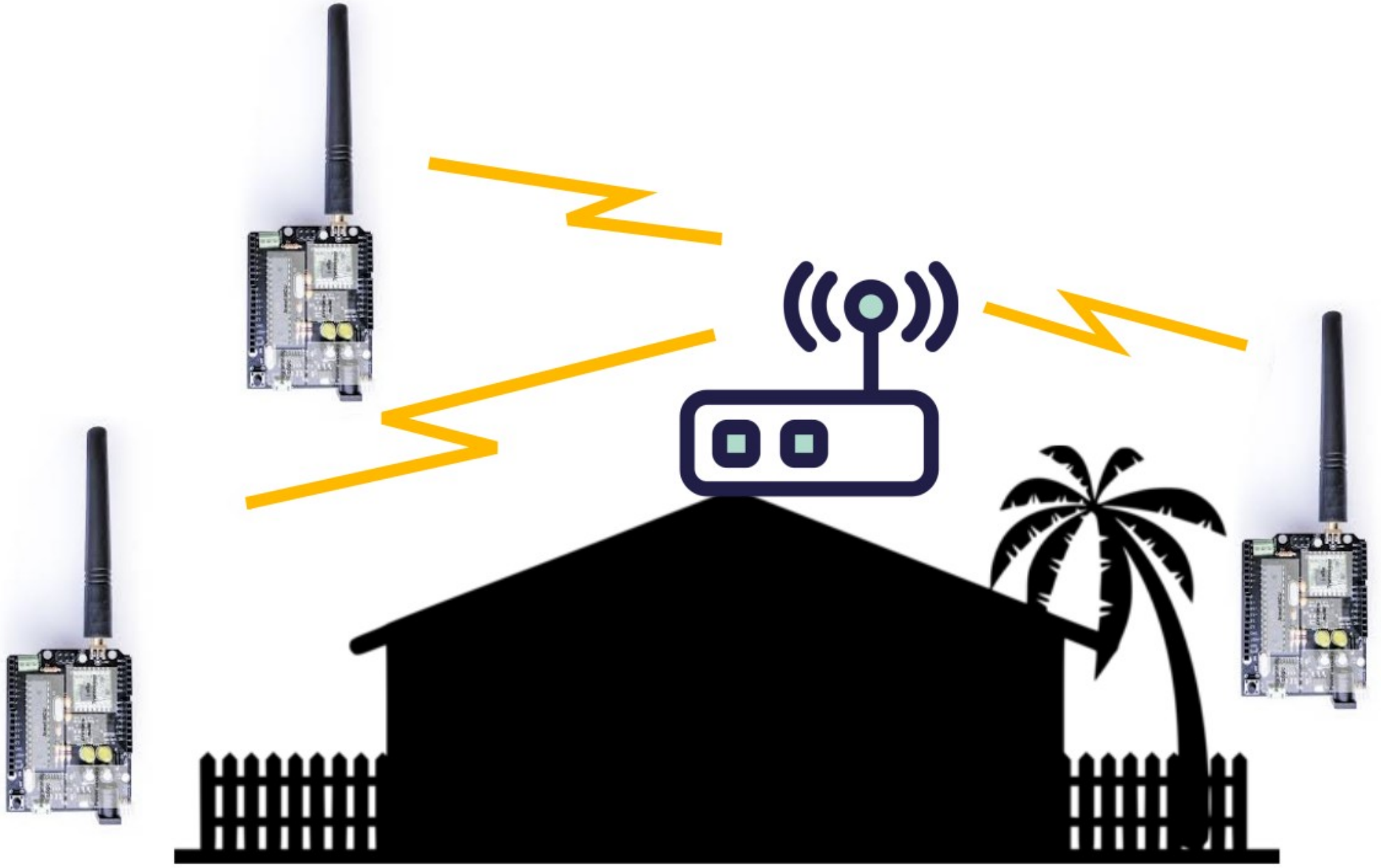
Example transmission



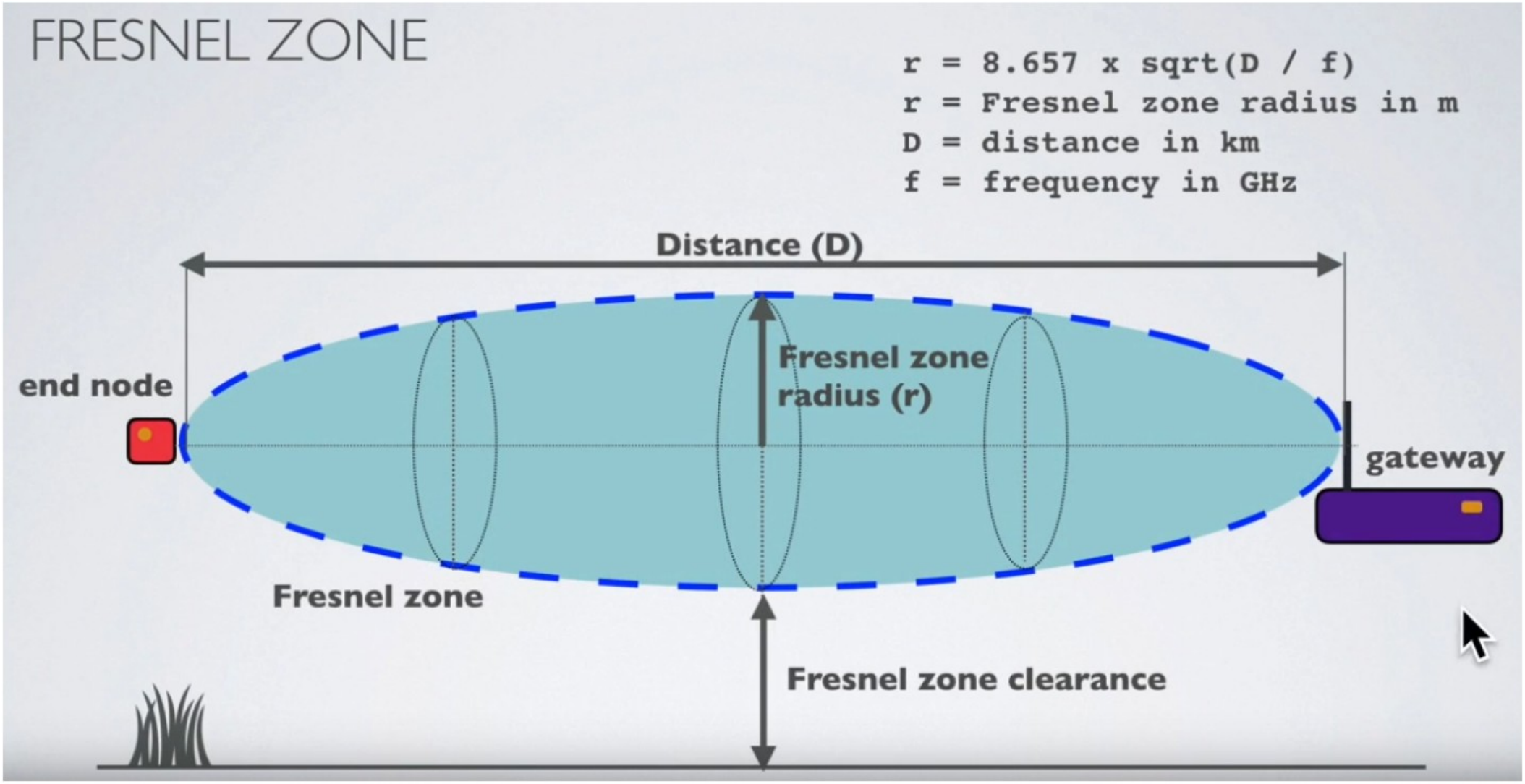
Variables

- Spreading factor (7-12)
- Bandwidth (125kHz, 250kHz & 500kHz)
- Channels (frequency)
  - Regional
  - 8ish
  - UK & EU 867.1MHz → 868.5MHz in .2MHz increments
  - Offcom adopts 2013/752/EU - 25mW - 1% duty cycle

LoRaWAN: many nodes talk to a gateway

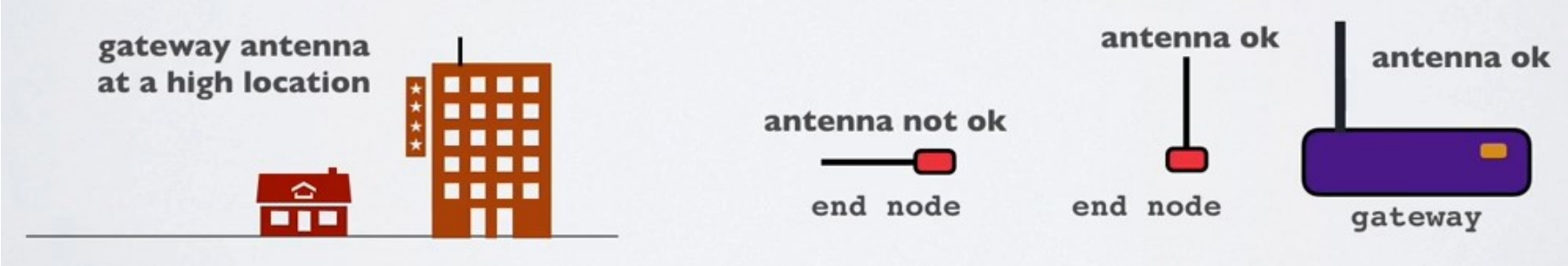


RF considerations

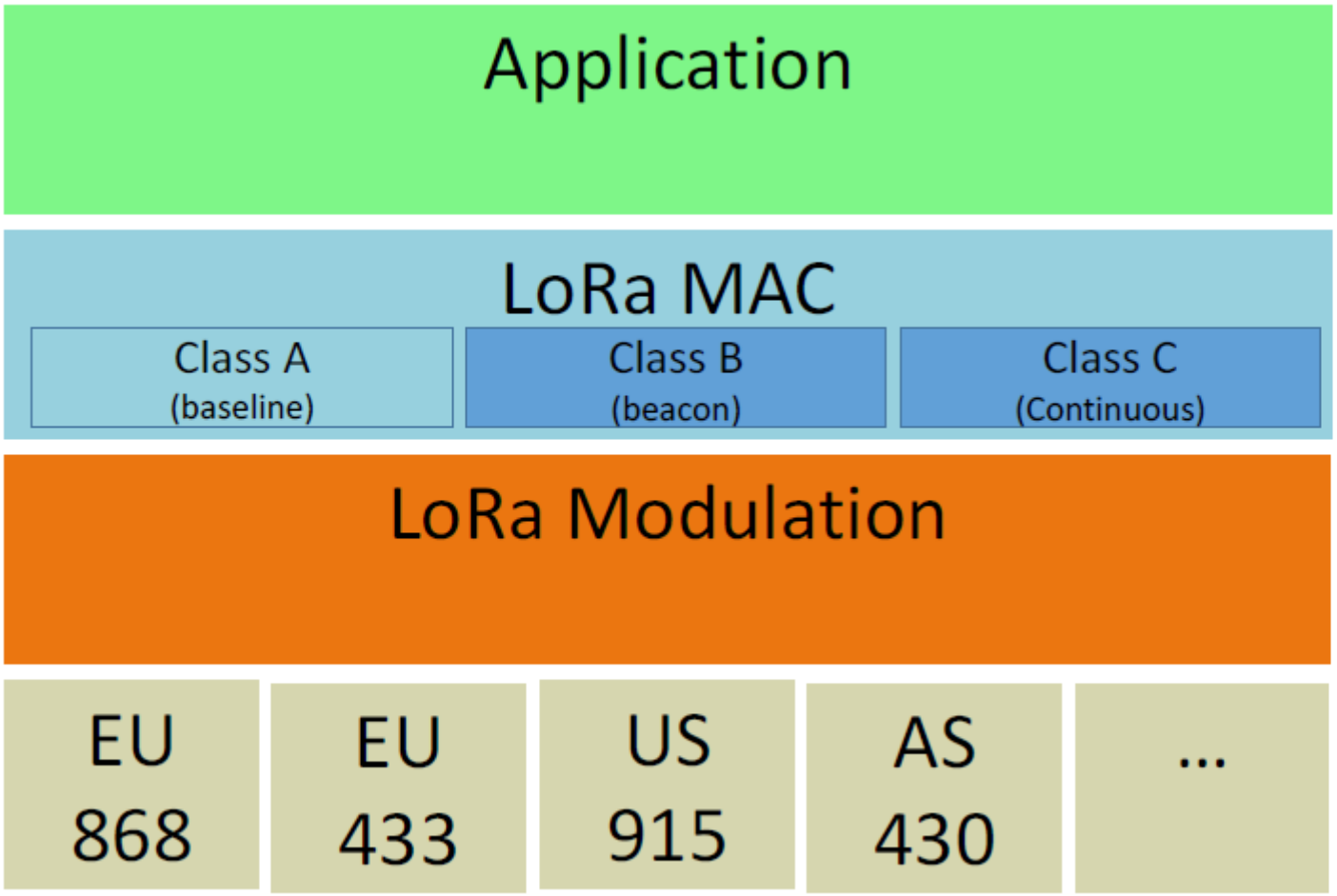


RF considerations

- Avoid objects within the Fresnel zone
  - including the ground!
  - Place antenna as high as possible
- Keep the antenna polarisation vertical for both gateway and end nodes and use an omnidirectional antenna.



LoRaWAN classes



Application

MAC

MAC options

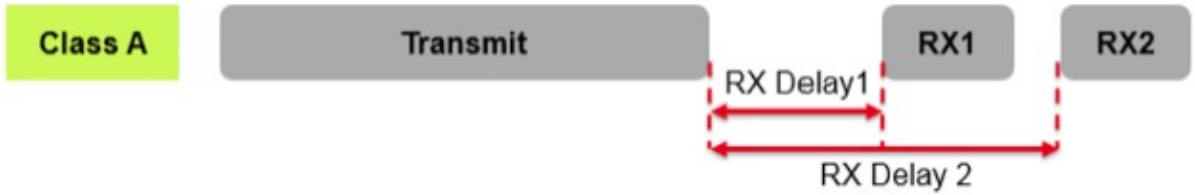
Modulation

Regional ISM band

Uplink and downlink methodolgy

CLASS A

End node always in sleep

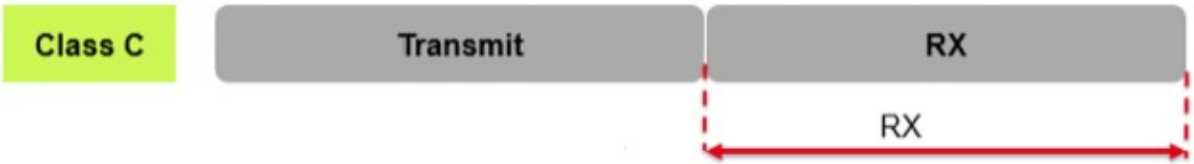


CLASS B

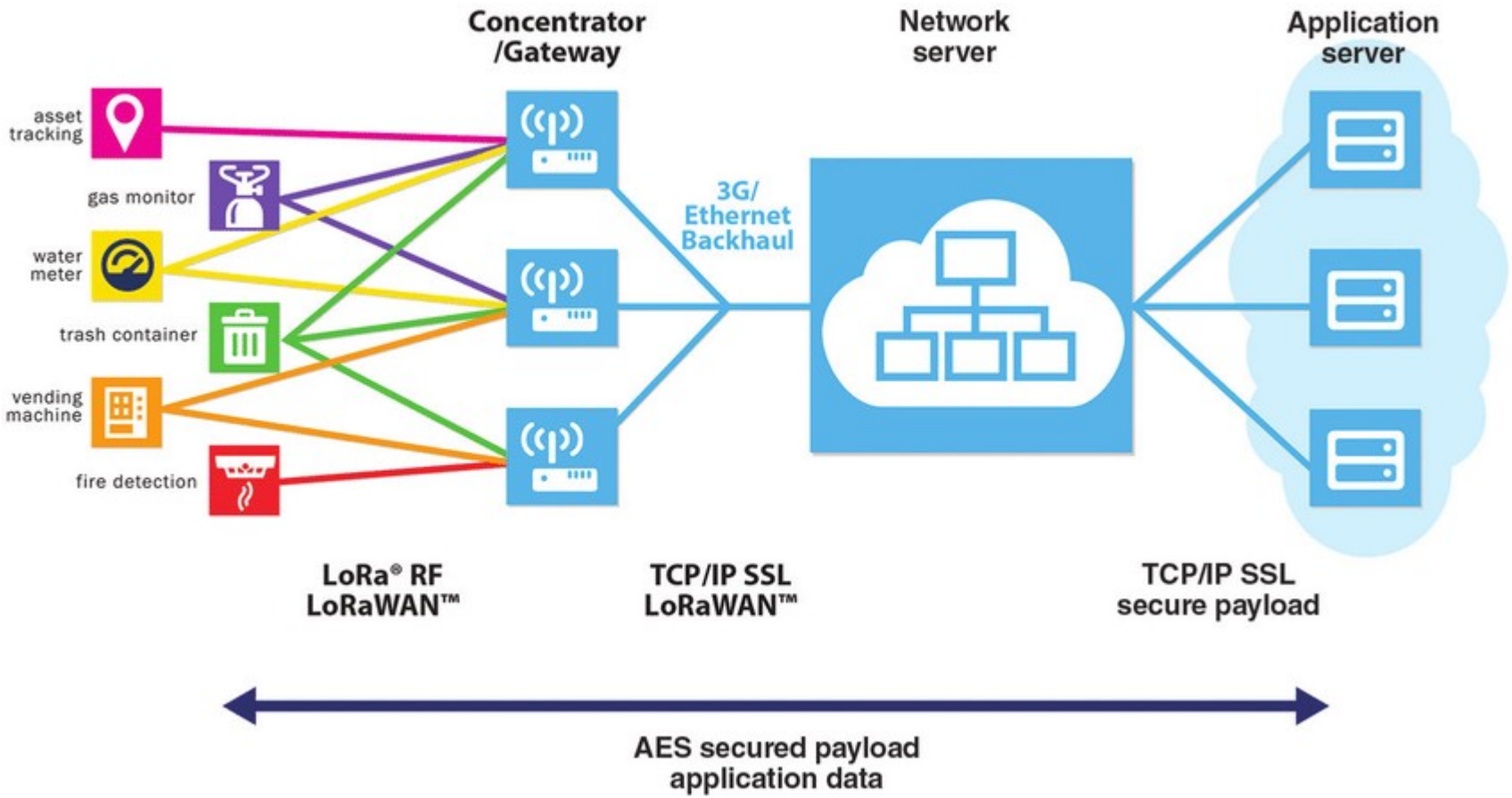
Periodic RX windows

CLASS C

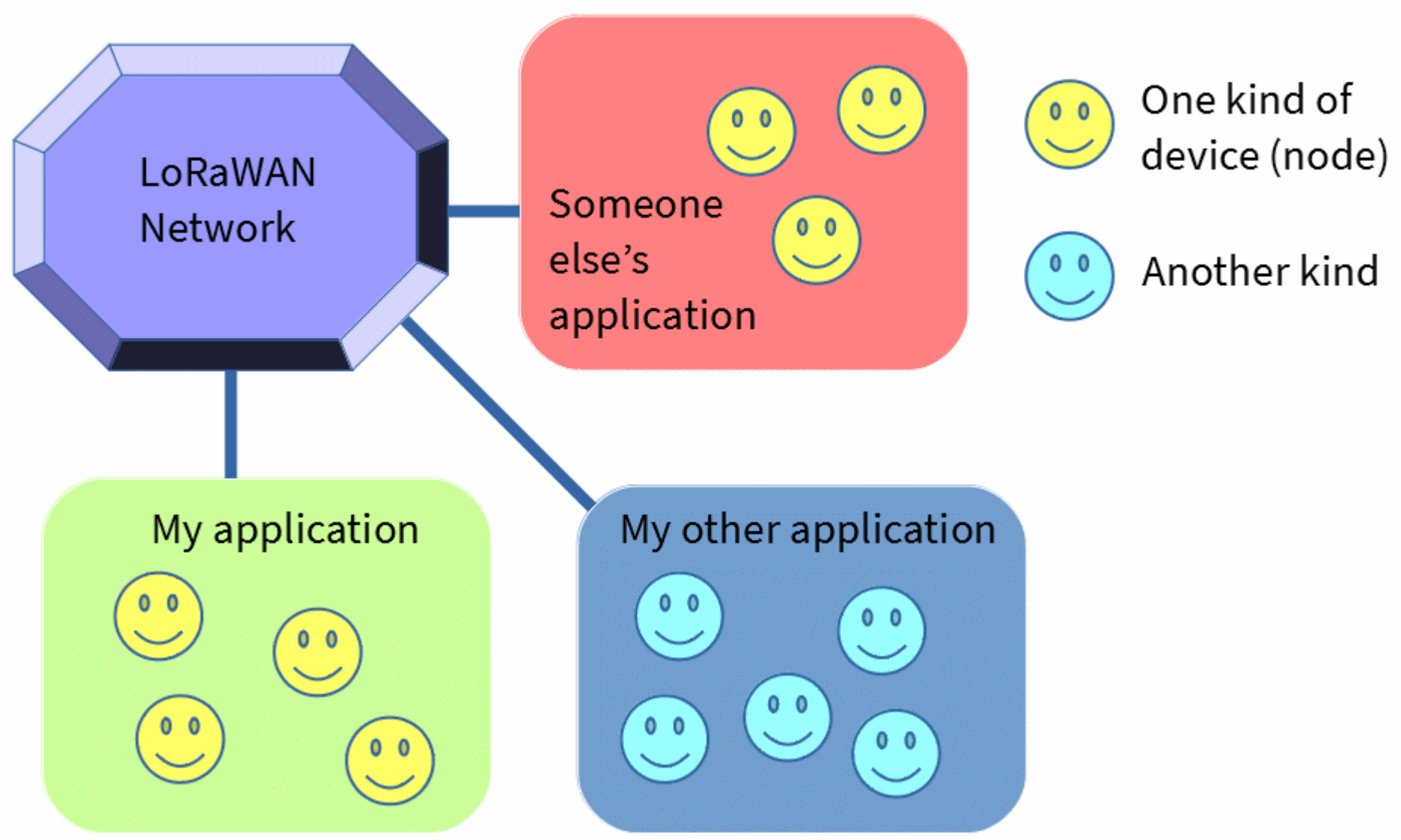
Continuously listening Asynchronous downlink



The network server



Applications and Devices



Personalization and Activation

- Over The Air Activation (OTAA)
  - Do a bit of personalization of the node, then “activate” it “over the air”
  - More secure
  - Allows network to assign channels
- Activiation By Personalization (ABP)
  - Configure everything on the node
  - Ties a device to a specific network
  - Frame counter issue (more later)

Required personalization for OTAA

- AppEUI
  - a global application ID
  - EUI64 - Extended Unique Identifier, 64 bits
- DevEUI
  - a global end-device ID, EUI64
- AppKey
  - an AES-128 root key specific to the **end-device**

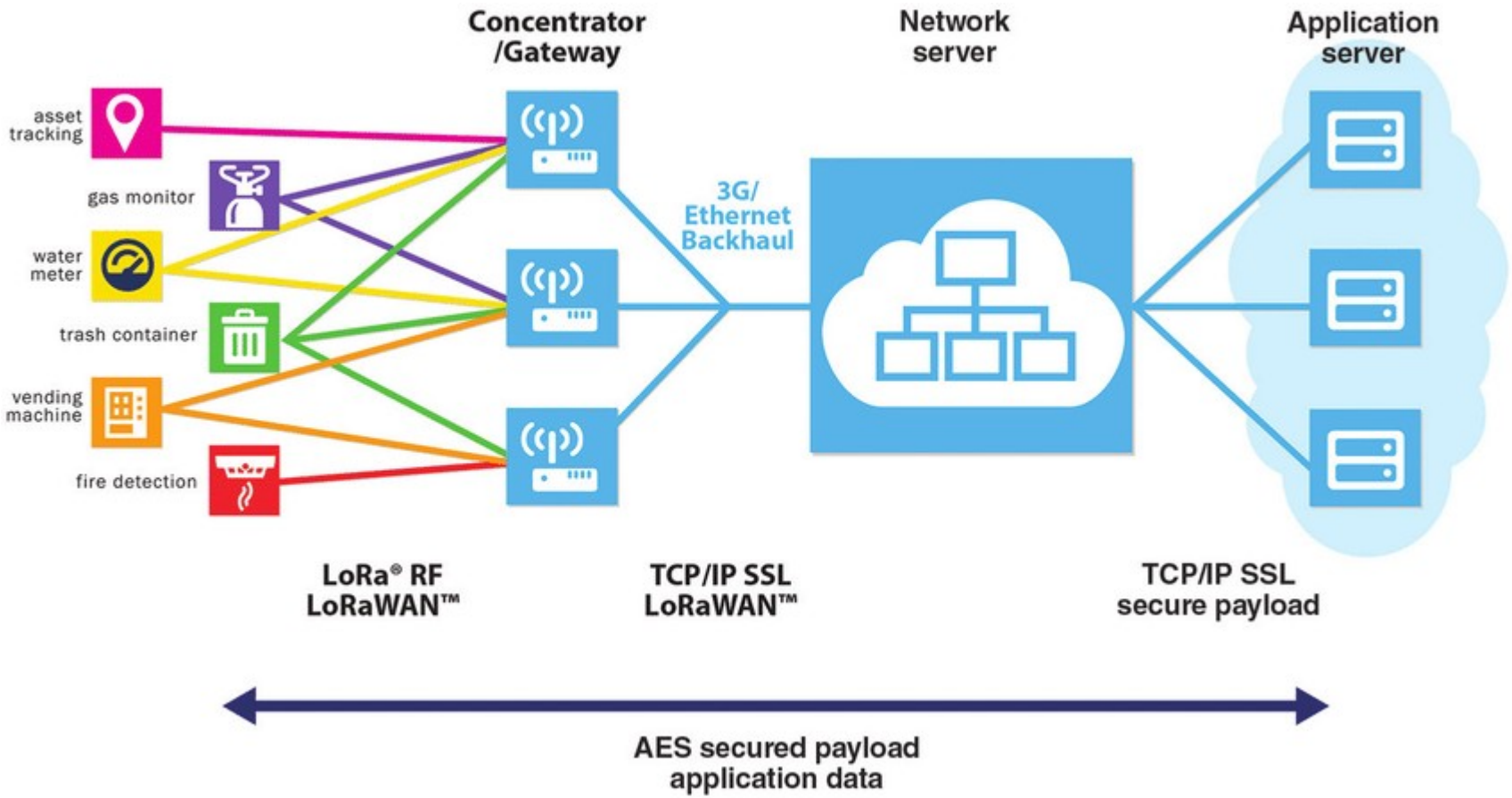
Activation – Session Keys

- Two unique AES128 session keys derived and stored during “join” process
- NwkSKey
  - used by the network to check the validity of messages
- AppSKey
  - used for encryption and decryption of the payload
- In Activation By Personalization, these session keys are programmed in to the node **instead** of the AppEUI, DevEUI and AppKey

A note on security

- Frame counters prevent replay attacks
- AES is symmetric encryption
- The network operator can (in theory) look at all of your data

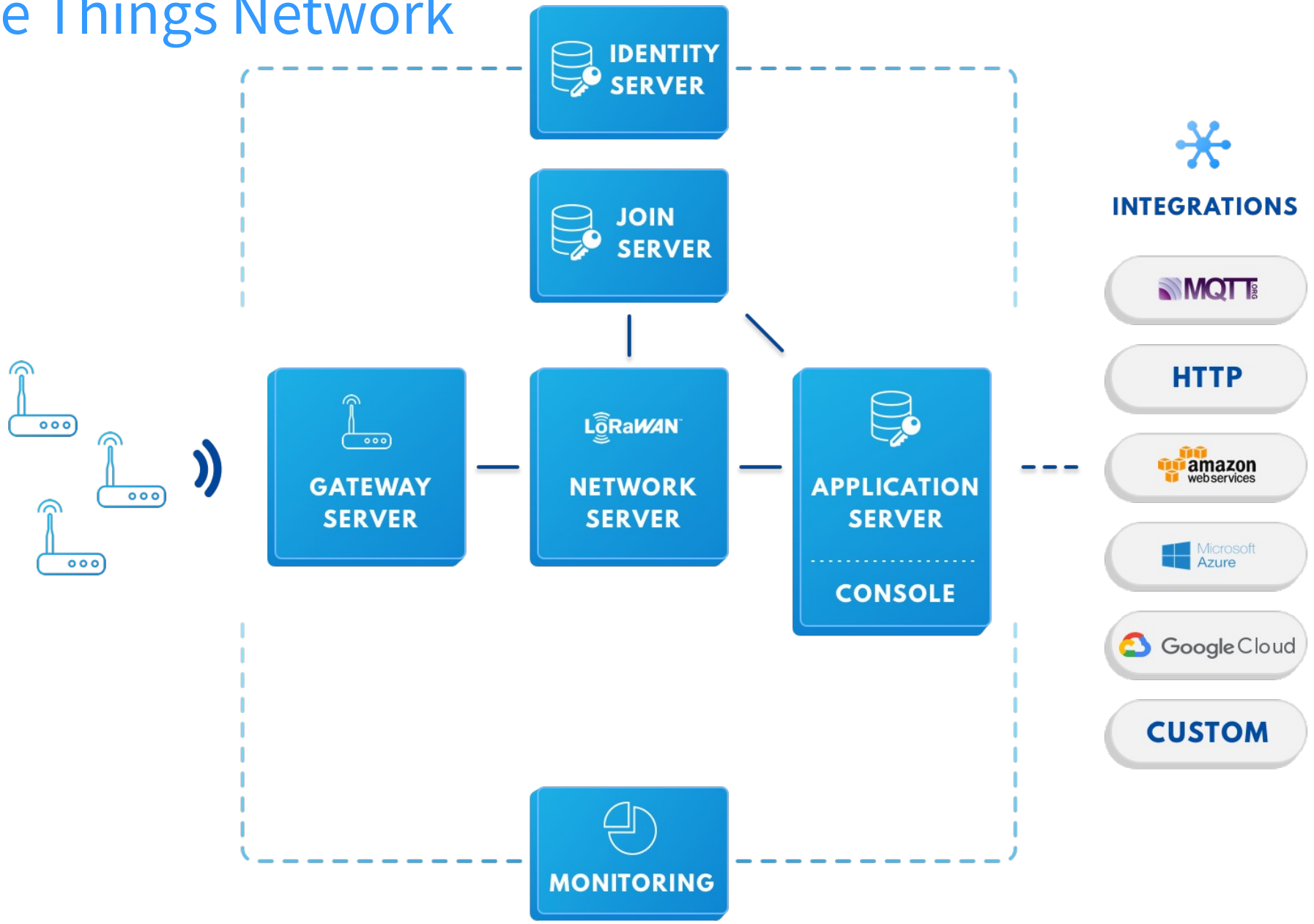
To the Internet and beyond!



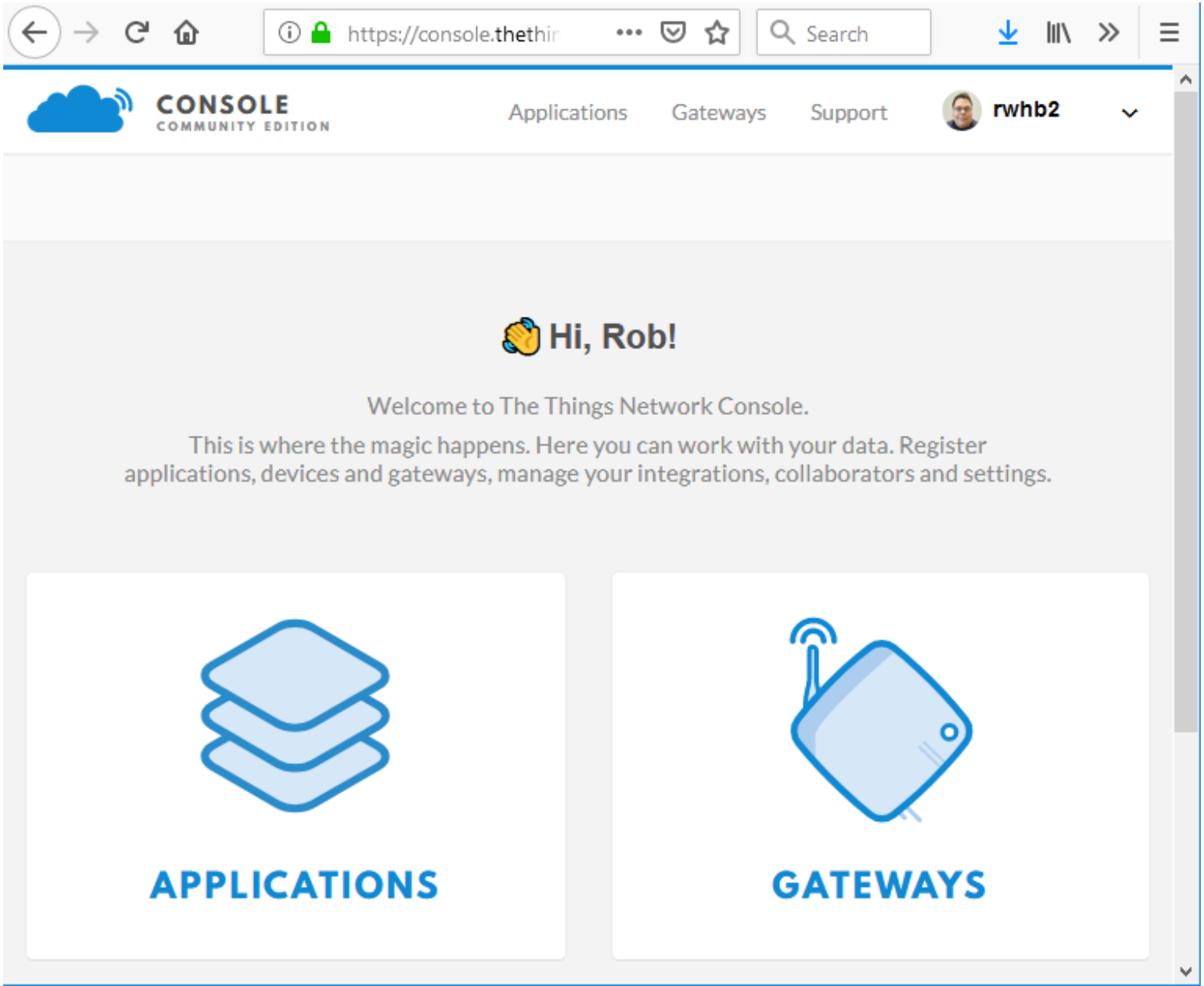
Popular integrations

- MQTT
  - Message Queuing Telemetry Transport
  - Publish/Subscribe model relying on a broker
- HTTP
  - Post to your API
- Node-RED
  - Free, self-host-able
- AWS IOT (or similar) data platform

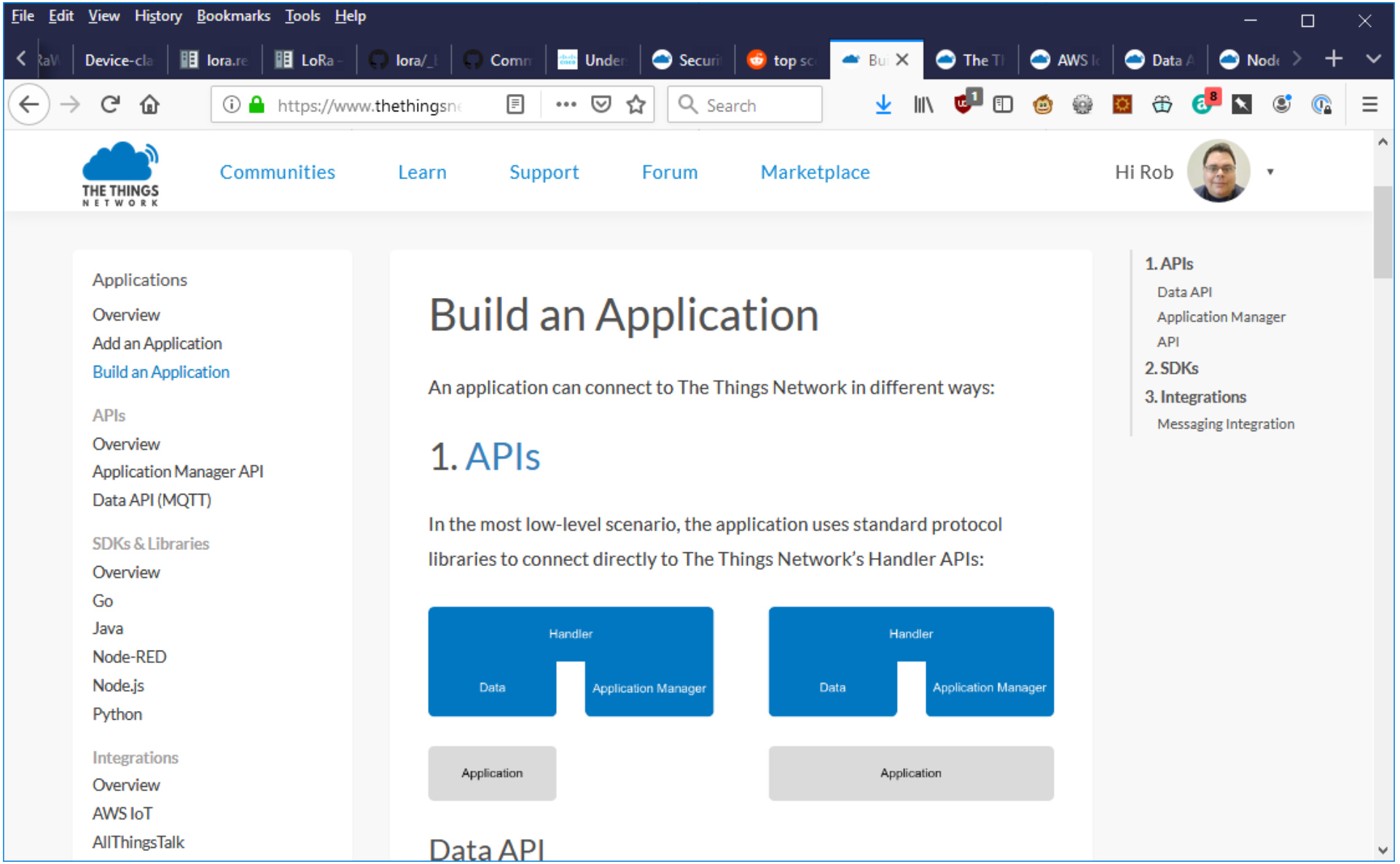
The Things Network



Console

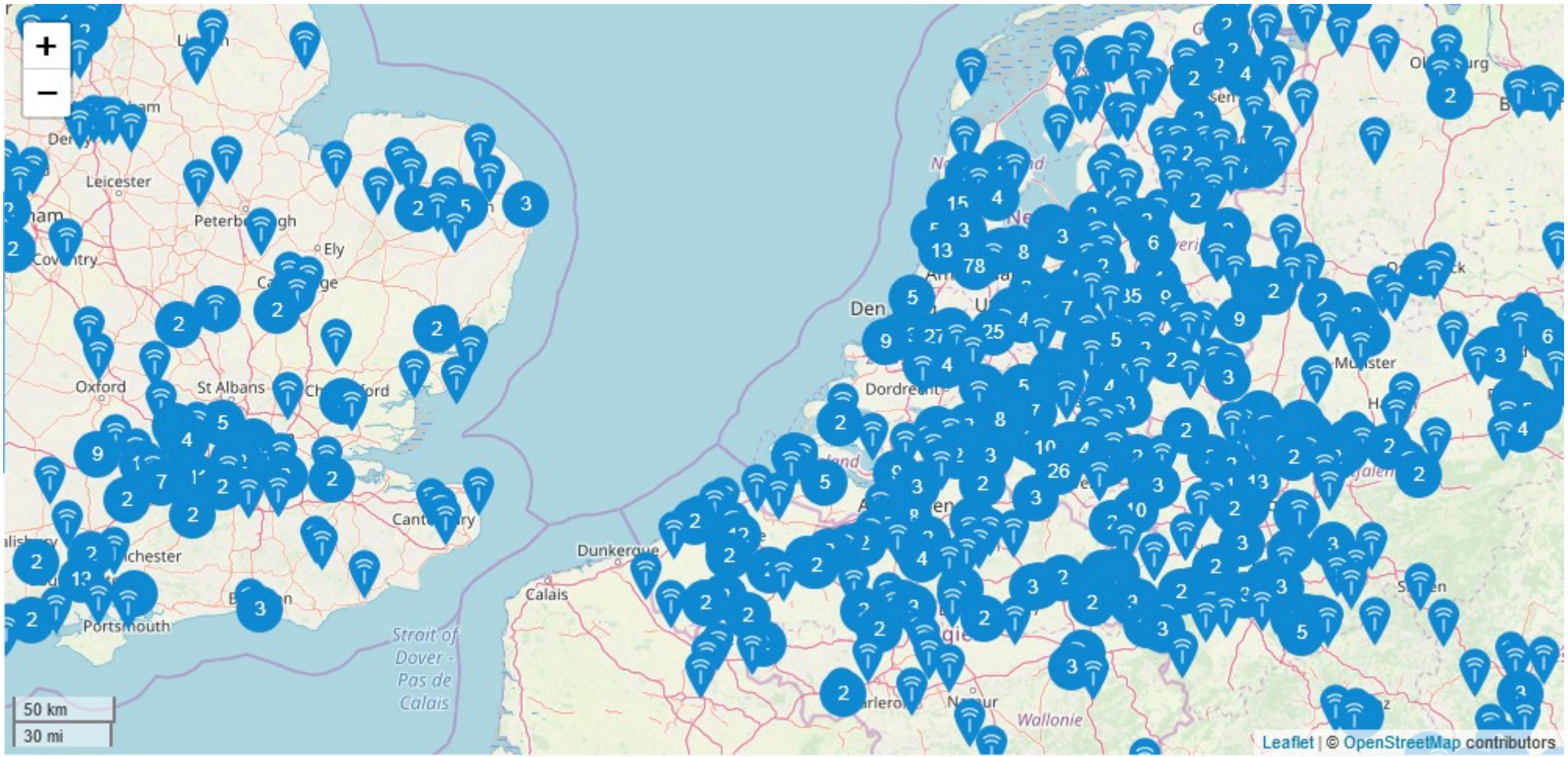

https://console.thethir
Search
CONSOLE
COMMUNITY EDITION
Applications
Gateways
Support
rwhb2
Hi, Rob!
Welcome to The Things Network Console.
This is where the magic happens. Here you can work with your data. Register applications, devices and gateways, manage your integrations, collaborators and settings.
APPLICATIONS
GATEWAYS

Excellent documentation

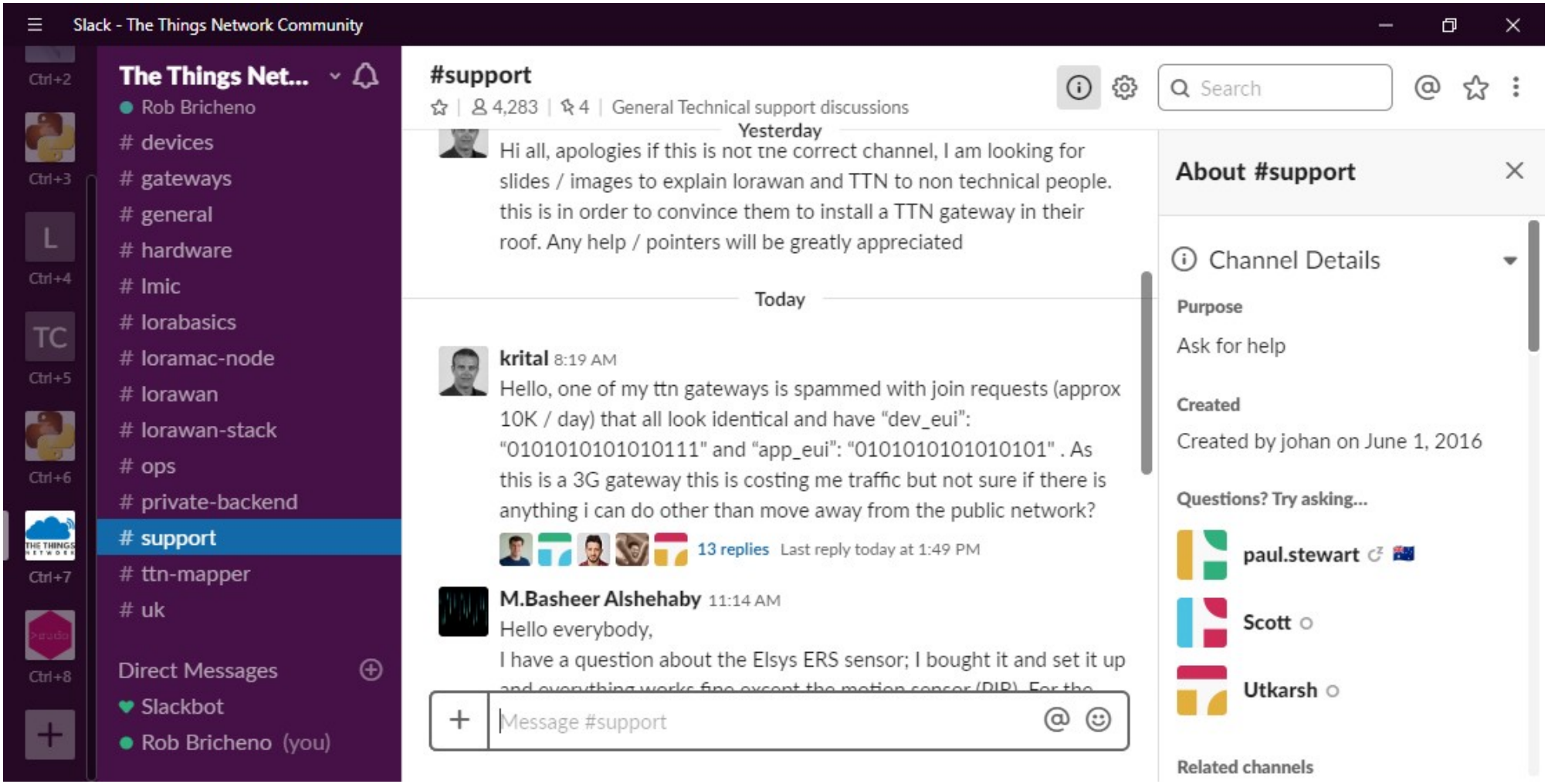


There are 7853 gateways up and running

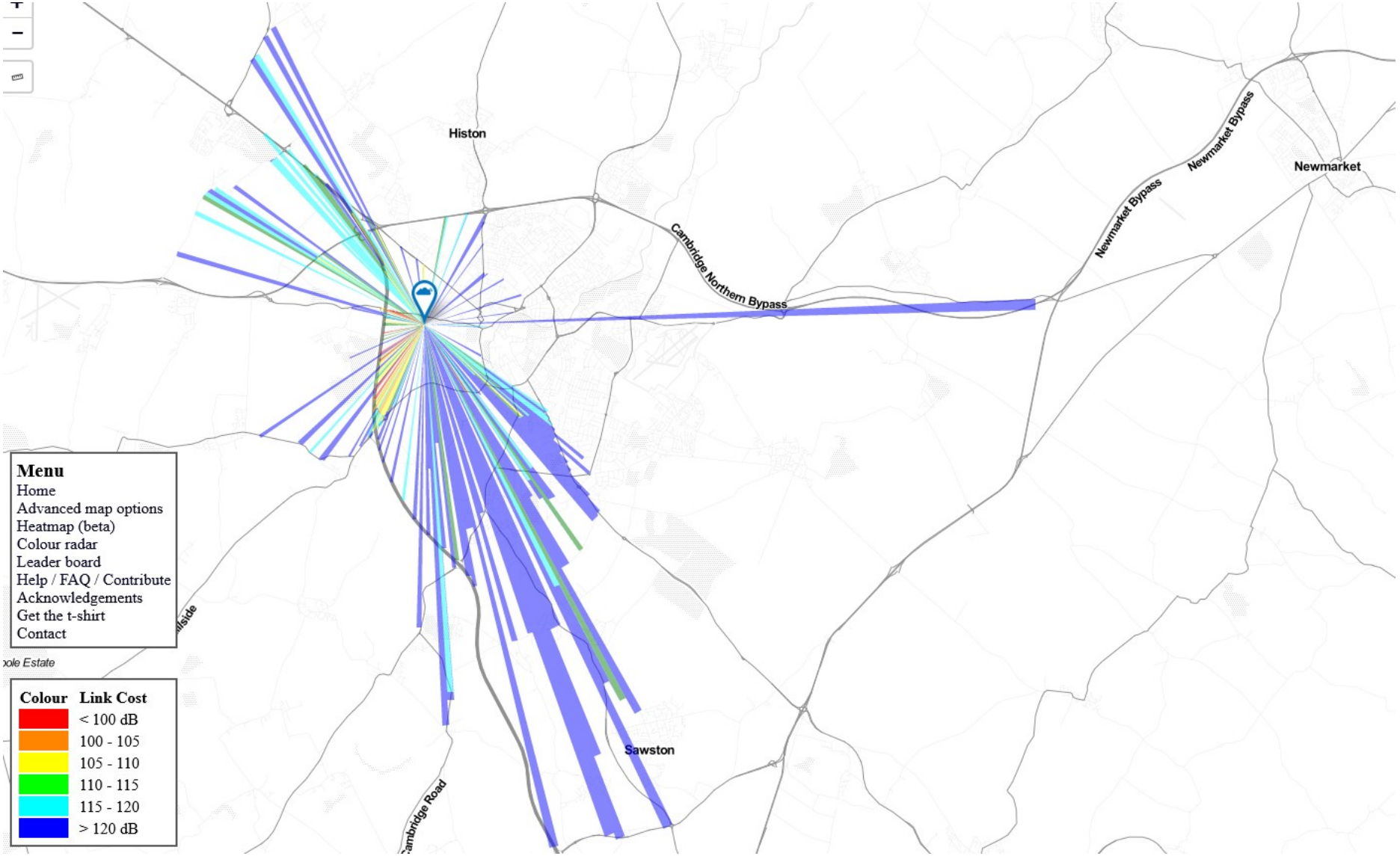
(We’re playing catch-up)



Strong community



ttnmapper.org



What are the problems?

Extremely low data rate

Data Rate	Configuration	bits/s	Max payload (bytes)
DR0	SF12/125kHz	250	59
DR1	SF11/125kHz	440	59
DR2	SF10/125kHz	980	59
DR3	SF9/125kHz	1760	123
DR4	SF8/125kHz	3125	230
DR5	SF7/125kHz	5470	230

Further limitations

- Duty cycle etc (ISM bad regulations)
  - For uplink, the maximum transmission power is limited to 25mW (14 dBm).
  - For downlink (for 869.525MHz), the maximum transmission power is limited to 0.5W (27 dBm)
  - There is an 0.1% and 1.0% duty cycle per day depending on the channel.
  - Maximum allowed antenna gain +2.15 dBi.
- The Things Network fair use policy
  - The uplink airtime is limited to 30 seconds per day (24 hours) per node.
  - The downlink messages are limited to 10 messages per day (24 hours) per node.

Fighting operators

- Other LoRaWAN operators
- Other 868MHz technologies
- Packet broker?

Not “real time”

- Messages may be enqueued on the node indefinitely if it is not in range
- Messages might go missing altogether (up to you)

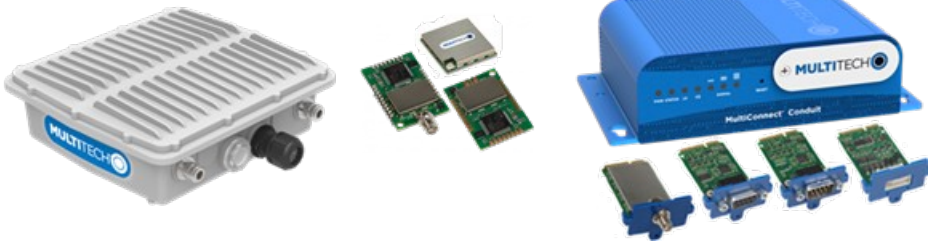
Regulatory issues...?

- FCC & CE certification

What’s out there?

Professional kit

(c) Elsys



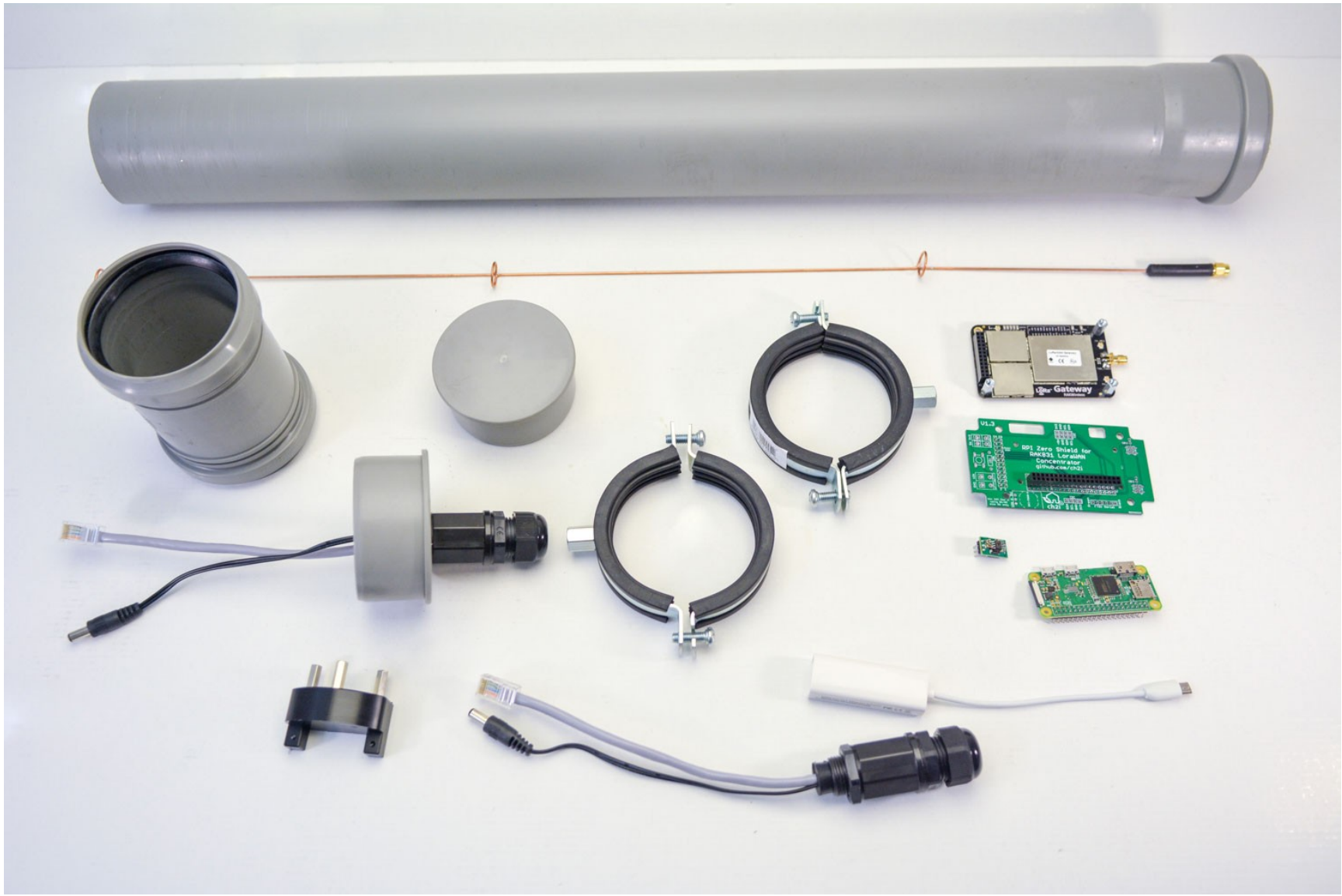
(c) Multitech

(c) Talkpool

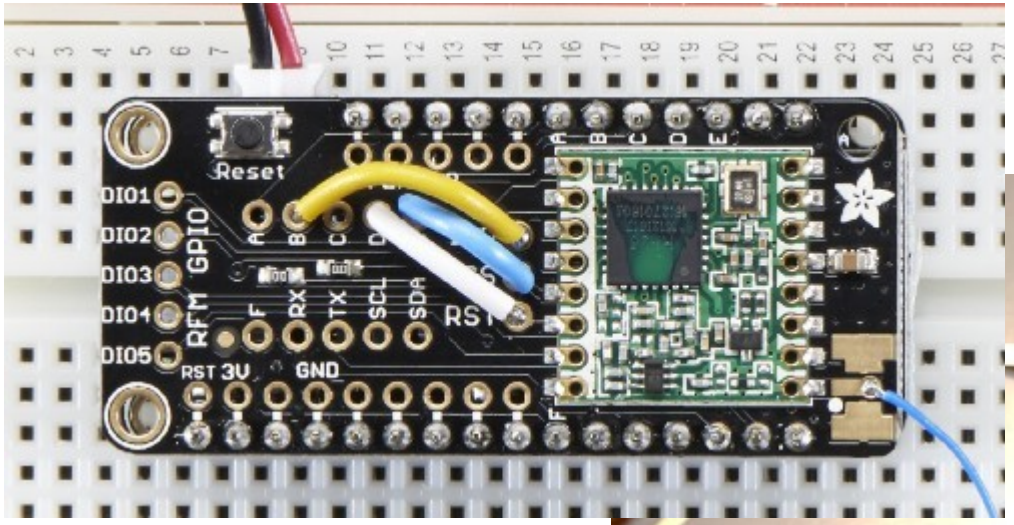
LoRaWAN CERTIFIED™

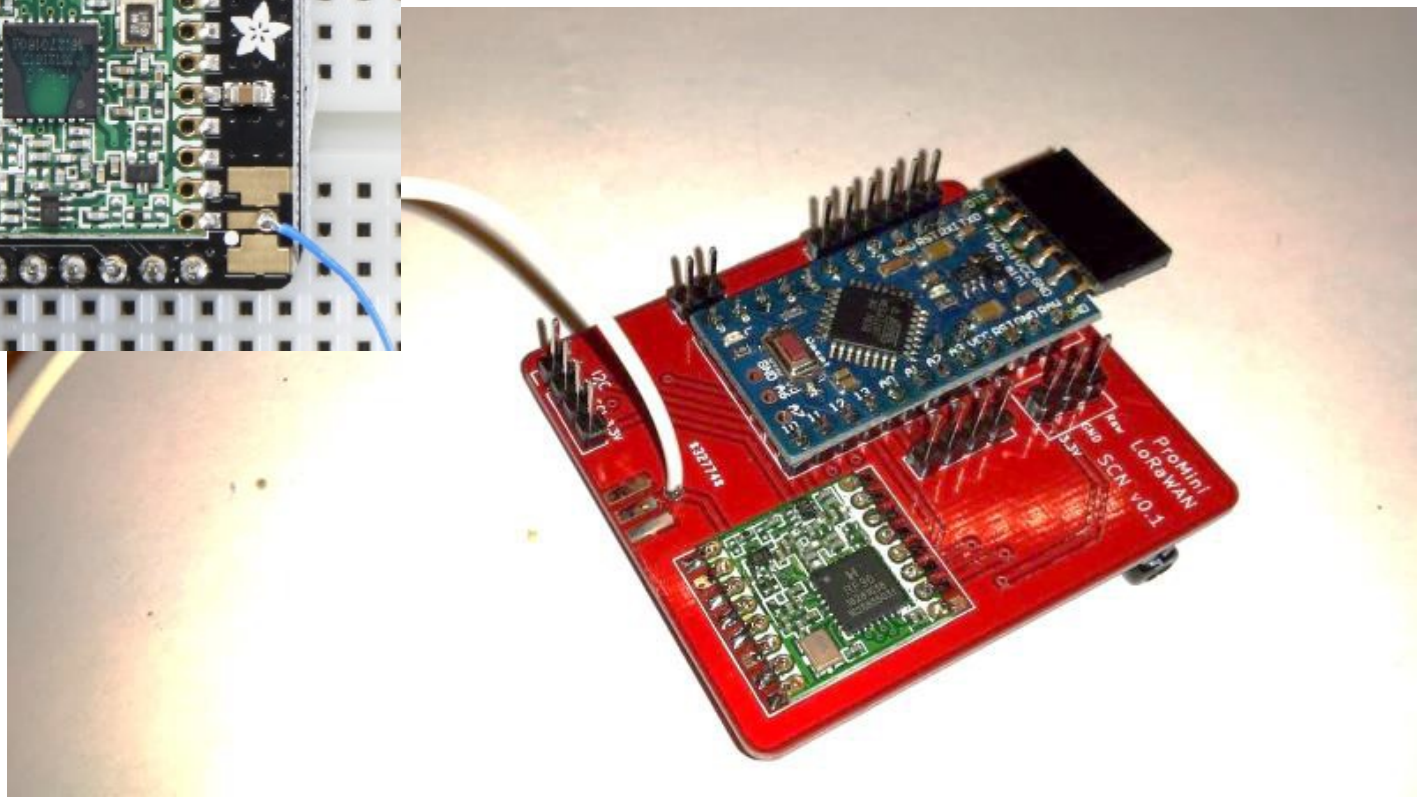
LoRa Alliance®

DIY


Gateway
RPi Zero Shield for
RAK831 LoraWAN
Concentrator
github.com/ch2i

DIY node


Reset
DIO1
DIO2
DIO3
DIO4
DIO5
RFM GPIO
RST 3V
GND
RX
TX
SCL
SDA
RST


ProMini
LoRaWAN
SCN v0.1

Special mention – pi-supply.com

Free Platforms

- io.adafruit.com
- IBM Watson IOT
- Wolkabout
- AWS, Google, Azure
- Node-RED on heroku or your Pi
- Smart Cambridge
- Roll your own!

What next?

- Sign up to The Things Network
- Get on Slack
- Make a node
- Test some data platforms
- Set up a gateway
- Do some mapping
- Learn certification?
- Think up experiments!

Thank you!

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Credits

- Internet of Things by https://www.flickr.com/photos/wilgengebroed/ CC BY-SA 3.0
- The Whole Thing from Jamali-Rad, Hadi & Campman, Xander & MacKay, Ian & Walk, Wim & Beker, Mark & van den Brand, Johannes & Jan Bulten, Henk & van Beveren, Vincent. (2018). IoT-based wireless seismic quality control. The Leading Edge. 37. 214-221. 10.1190/tle37030214.1.
- Example block diagram from Jamali-Rad, Hadi & Campman, Xander & MacKay, Ian & Walk, Wim & Beker, Mark & van den Brand, Johannes & Jan Bulten, Henk & van Beveren, Vincent. (2018). IoT-based wireless seismic quality control. The Leading Edge. 37. 214-221. 10.1190/tle37030214.1.
- Photograph of node by AVRcircuit on Tindie https://www.tindie.com/products/avrcircuit/loraland-battery-powered-lora-arduino-module/
- Workflow from Ma, Yushuang; Zhao, Long; Yang, Rongjin; Li, Xiuhong; Song, Qiao; Song, Zhenwei; Zhang, Yi. 2018. "Development and Application of an Atmospheric Pollutant Monitoring System Based on LoRa—Part I: Design and Reliability Tests." Sensors 18, no. 11: 3891.
- Wizard Oil photo by clotho98 CC BY-NC 2.0 https://www.flickr.com/photos/clotho98/5727265431/
- Upchirp by https://commons.wikimedia.org/wiki/User:Georg-Johann CC BY-SA 3.0
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- Node image from “Sensors” https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6387282/ CC BY 4.0
- LoRaWAN classes from the LoRaWAN specification 1.0.3 Copyright © 2019 LoRa Alliance™ https://lora-alliance.org/resource-hub/lorawanr-specification-v103
- Uplink and downlink methodology for LoRaWAN classes from Polonelli T, Brunelli D, Marzocchi A, Benini L. Slotted ALOHA on LoRaWAN-Design, Analysis, and Deployment. Sensors (Basel). 2019;19(4):838. Published 2019 Feb 18. doi:10.3390/s19040838
- Fresnel zone and antenna guidance (c) mobilefish.com https://www.mobilefish.com/developer/lorawan/lorawan_quickguide_tutorial.html https://lora.readthedocs.io/en/latest/
- TTN logo and architecture (c) The Things Network https://www.thethingsnetwork.org/
- IRNAS outdoor gateway from https://www.irnas.eu/irnas-outdoor-lorawan-gateway/ CC BY-SA 4.0
- Pro Mini node image from Building a LoRa node and connecting it to The Things Network (TTN) Version 1.0 Frank Beks March, Robin Harris and Rob Miles https://usermanual.wiki/Document/BuildInstructions.554518190.pdf CC BY-NC 4.0
- Radio Featherwing Wiring image (c) Adafruit CC BY-SA 3.0