IoT Engineering
8: Long Range Connectivity with LoRaWAN

Slides: tmb.gr/iot-8

Overview

These slides introduce *LoRaWAN connectivity*.

How the network is built from nodes and gateways.

Sending small amounts of data over a long distance.

Getting the data to an application from the backend.

Prerequisites

Set up the Feather nRF52840 Express for Arduino.

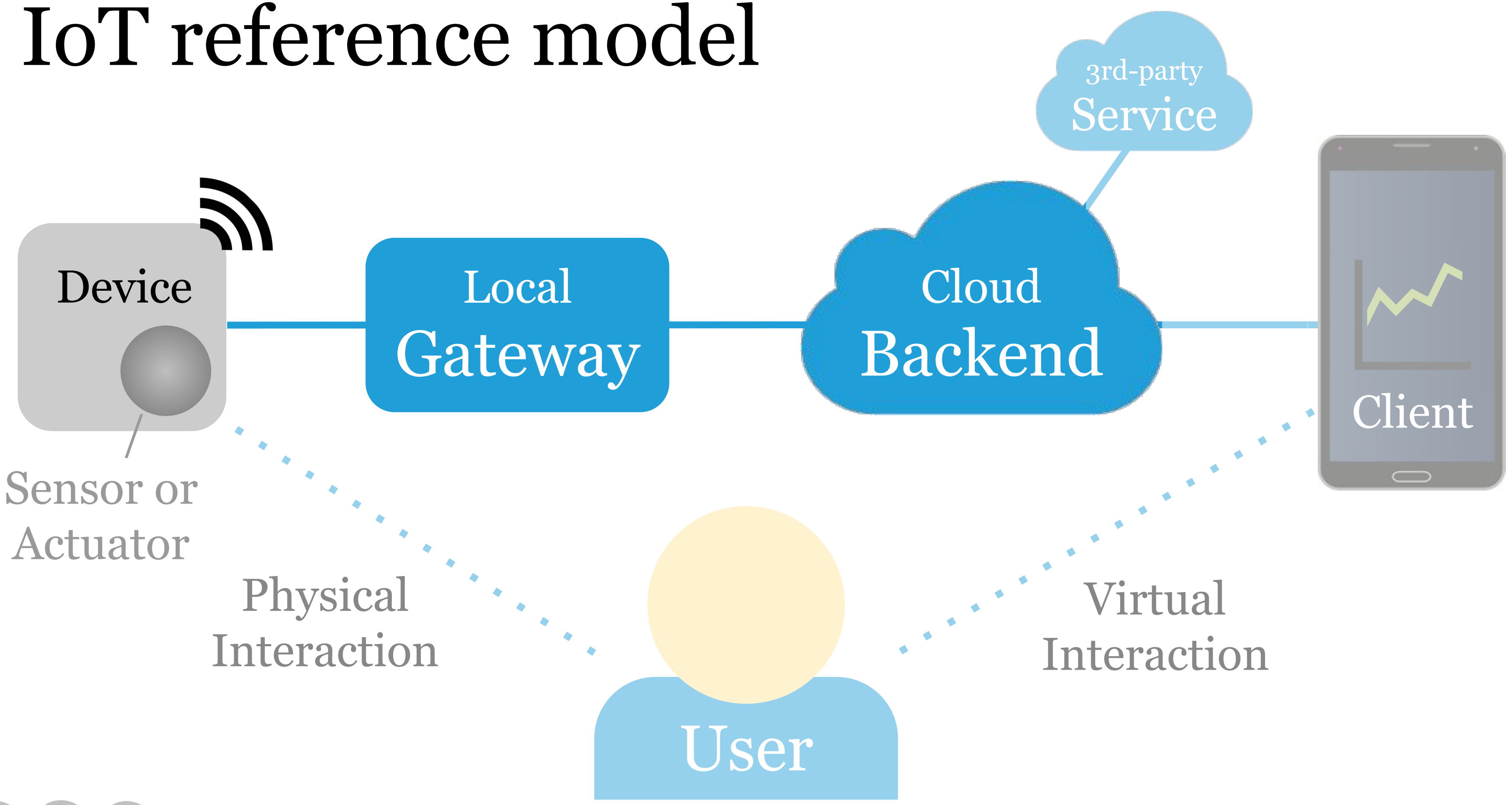
Or set up the Feather Huzzah ESP8266, both work.

A LoRaWAN gateway has to be in range for testing*.

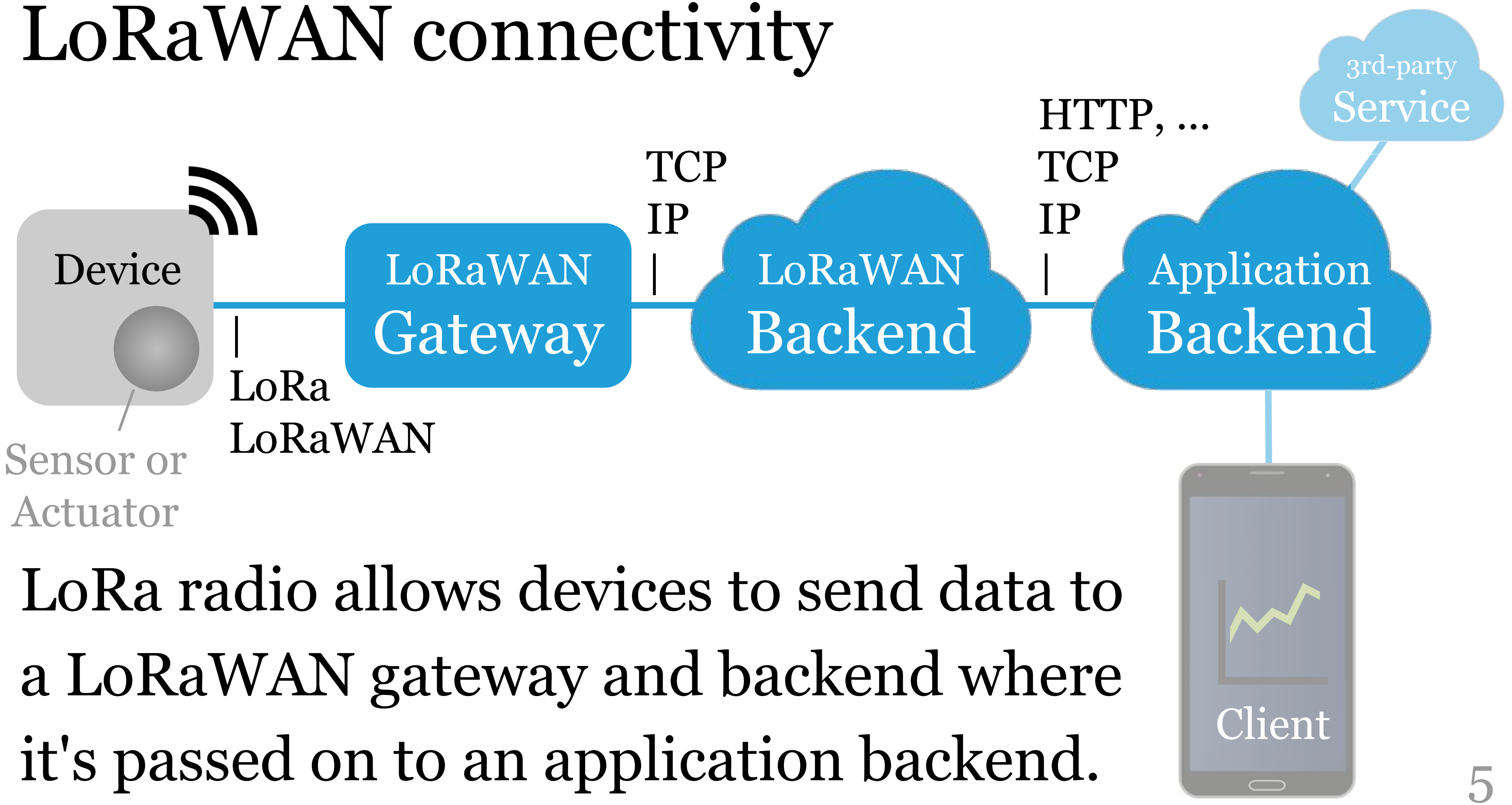
The Raspberry Pi with Node.js is our app backend.

*Here's a gateway map for thethingsnetwork.org.

IoT reference model



LoRaWAN connectivity



LoRa radio allows devices to send data to a LoRaWAN gateway and backend where it's passed on to an application backend.

LoRa

LoRa is a digital wireless communication technology.

The LoRa physical layer protocol is proprietary.

Semtech, the owner, sells LoRa transceivers.

LoRa radio is long range* and low power.

*Around 1 km in cities, 10+ km in open terrain.

LoRaWAN

LoRaWAN is a low power*, wide area networking protocol (LPWAN) based on the LoRa physical layer.

The LoRaWAN specification (v1.0.3) is developed by the LoRa Alliance, a non-profit industry consortium.

LoRaWAN defines link layer parameters, addressing, a transport protocol and the network architecture.

*E.g. LoRaWAN 10/30 mA vs. Wi-Fi 50/150 mA.

LoRaWAN terminology

The LoRaWAN community uses the following terms:

Node — device with sensors, LoRaWAN connectivity.

Gateway — LoRa (to Internet, i.e. TCP/IP) gateway.

Network server — LoRaWAN specific backend.

Application server — application backend.

LoRaWAN frequencies

LoRaWAN uses frequencies in license-free bands.

Frequencies depend on the geographic region.

EU 868 MHz, US 915 MHz, Asia 433 MHz, ...

There are frequency plans, per country*.

*Based on the regional parameters specification.

LoRaWAN network providers

There are various ways to get LoRaWAN coverage, e.g.

LoRaWAN network providers like Swisscom (Actility).

LoRaWAN backend/solution providers like Loriot.

Open infrastructure like The Things Network.

This course uses The Things Network.

The Things Network (TTN)

TTN is an open source project started in Amsterdam.

Everybody can put up a gateway to extend coverage.

Everybody can get an account and register devices.

The network is open, but your data stays private.

TTN has regional communities, e.g. TTN Zürich.

Mapping network coverage

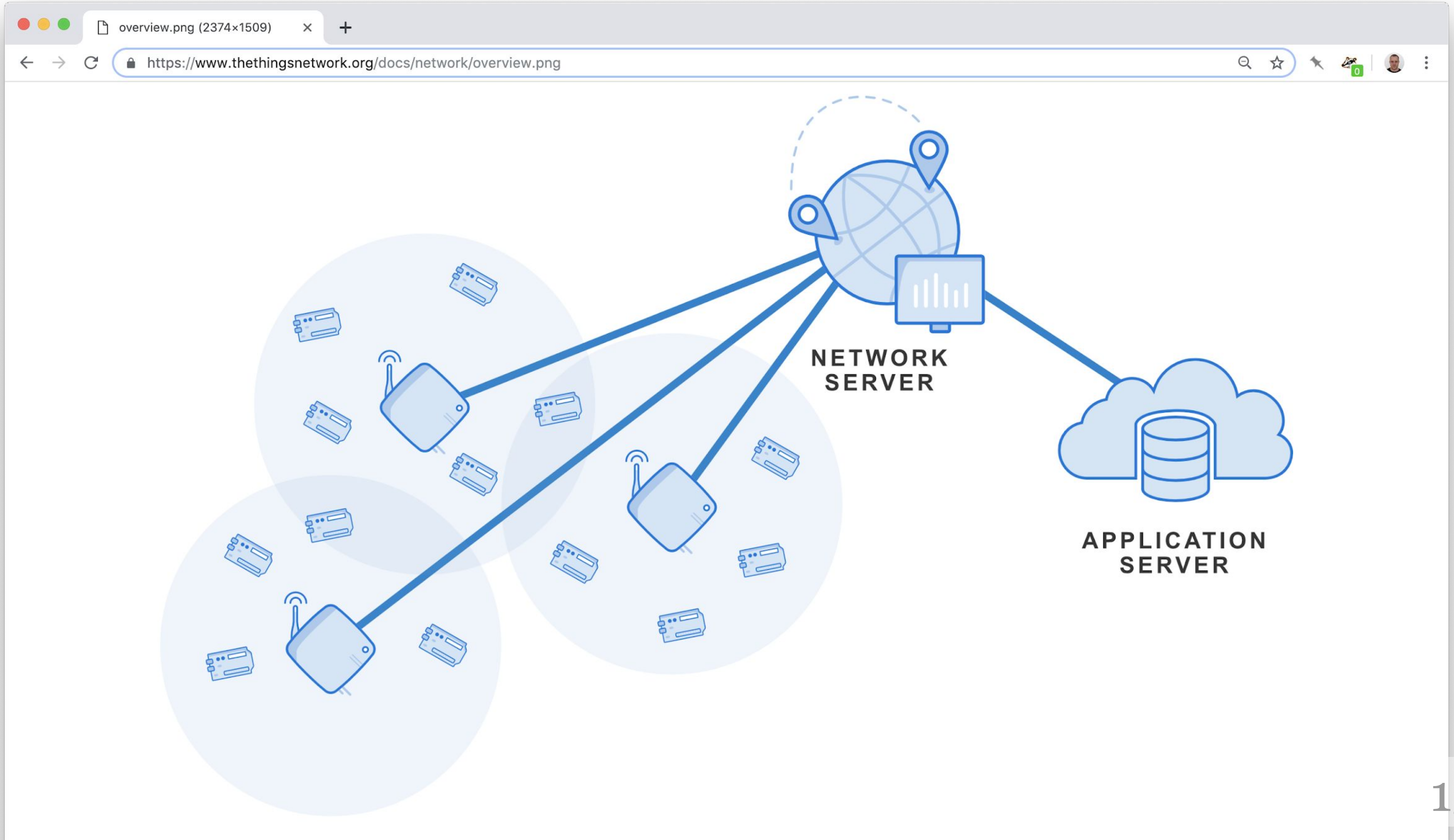
TTNMapper is a community effort to map coverage.

The iOS or Android app provides GPS location data.

The data is correlated with metadata from gateways.

Any LoRaWAN device sending* packets works fine.

*One packet can be received by multiple gateways.


overview.png (2374×1509)
https://www.thethingsnetwork.org/docs/network/overview.png
NETWORK SERVER
APPLICATION SERVER

LoRaWAN gateways

Gateways forward *uplink* data packets to the backend.

There, they are deduplicated & routed to applications.

Downlink packets are "broadcast" to nearby devices.

No license is required* to run a LoRaWAN gateway.

*If operating in a unlicensed radio frequency band.

LoRaWAN security

LoRaWAN transport security is based on 128 bit keys:

Network Session Key — admits a device to a network.

Application Session Key — encrypts/decrypts payload.

These keys can be static or generated for each session.

Over The Air Activation (OTAA)

OTAA uses an app key to generate keys per session.

- Device has a *DevEUI*, *AppEUI* and *AppKey*
- Device sends a *Join Request*, uses *Join Response* and *AppKey* to derive an *AppSKey* and *NwkSKey*
- Device must be able to store the generated keys
- Join decision can be delegated to a *Join Server*

See spec or TTN docs on end-device activation.

Activation by Personalization (ABP)

ABP uses static app session and network session keys.

- Device has a *Device Address*, *AppSKey* & *NwkSKey*
- No *DevEUI*, *AppEUI* or *AppKey* is needed here
- There is no *Join*, the device just sends data
- Overall ABP is simpler, but less flexible
- Changing the provider is not possible

See also TTN docs on ABP vs. OTAA.

Registering an application on TTN

An *application* is required to add *devices* later on, grouping devices with the same payload format.

- Open the TTN console for Europe (eu1)
- Go to *Applications* > *Add application*
- Enter an *Application ID*, e.g. `fhnw-iot`
- Click *Create application*

Similar steps work for other LoRaWAN providers.

Registering a device on TTN

- Open the TTN console for Europe (eu1)
- Go to *Applications* > click, e.g. `fhnw-iot`
- Click *Add end device* > *Manually*
- Set freq. *EU recommended*, version *MAC V1.0.3*
- Click *Show advanced activation*
- Choose either *OTAA* or *ABP**
- Do *not yet* click register

*See next two pages to continue with OTAA or ABP.

Getting OTAA keys on TTN

If you're in the process of registering a OTAA device:

- Click *Generate* on *DevEUI*, *AppEUI* and *AppKey**
- Set an *End device ID*, e.g. `fhnw-iot-device-0`
- Click *Register end device*

*You'll add these keys to the device code later on.

Getting ABP keys on TTN

If you're in the process of registering an ABP device:

- Click *Generate* on *DevEUI*, *AppSKey* and *NwkSKey*
- Click the refresh icon to generate a *Device address*
- Set an *End device ID*, e.g. `fhnw-iot-device-0`
- Click *Register end device*, then for the same device
- Go to *General settings > Network layer > Advanced MAC settings > Reset frame counters [x]*

LoRaWAN hardware modules

Some LoRaWAN modules, based on Semtech SX127*x*:

RN2483 — via UART/AT commands (or stand-alone).

RFM95W — via SPI, stack runs on separate controller.

Murata — SoC including an ARM STM32 Cortex M0.

Make sure the frequency is allowed in your region.

FeatherWing RFM95W

RFM95W is a popular 868 MHz LoRa radio module.

The RFM95W FeatherWing needs a microcontroller.

Both MCU boards work, nRF52840 and ESP8266.

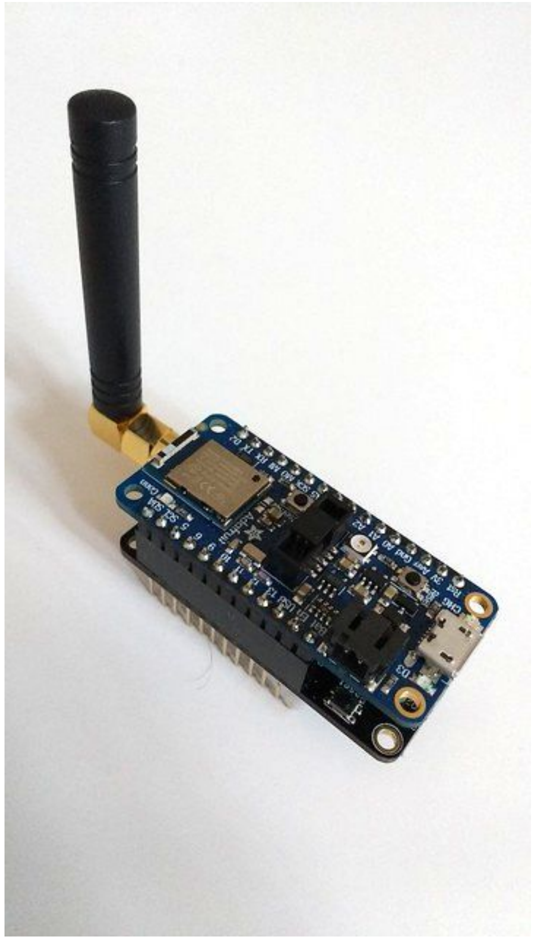
The pin mapping has to be adapted in the code.

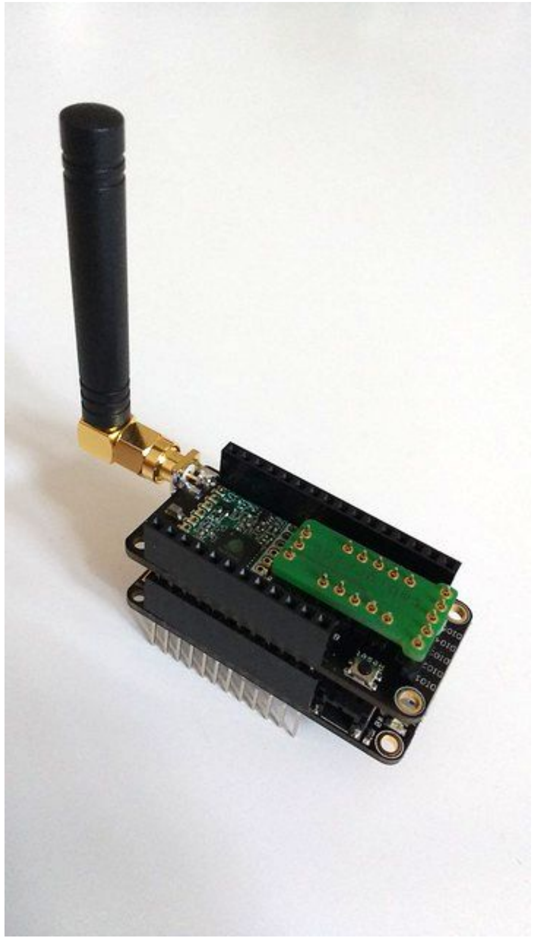
Setup RFM95W

First, make sure an antenna is present.

Then, nRF52840 goes on top of the LoRaWAN module.

Or, ESP8266 goes below the module.





Arduino LoRaWAN with LMIC library

These examples work on nRF52840 and ESP8266.

They run LMIC to use the RFM95W LoRa module.

Install the MCCI LMIC library in the Arduino IDE.

Edit *Arduino/libraries/MCCI_LoRaWAN_LMIC_library/project_config/lmic_project_config.h*

```
#define CFG_eu868 1 //#define CFG_us915 1
```

Arduino LoRaWAN ABP .ino^ESP, .ino^nRF

Set the *NwkSKey*, *AppSKey* and *Device Address*:

```
const u1_t PROGMEM NWKSKEY[16] = { … } // msb
const u1_t PROGMEM APPSKEY[16] = { … } // msb
const u4_t DEVADDR = 0x01234567; // msb
```

Double check to use the pin mapping for your board:

```
const lmic_pinmap lmic_pins = {...} // nRF52…
```

Set a custom message:

```
static uint8_t mydata[] = "Hello, world!";
```

Arduino LoRaWAN OTAA .ino^{ESP}, .ino^{nRF}

Set the *AppEUI*, *DevEUI* and *AppKey*:

```
const u1_t PROGMEM APPEUI[8]= { … } // lsb (!)
const u1_t PROGMEM DEVEUI[8]= { … } // lsb (!)
const u1_t PROGMEM APPKEY[16] = { … } // msb
```

Double check to use the pin mapping for your board:

```
const lmic_pinmap lmic_pins = {...} // nRF52…
```

Set a custom message:

```
static uint8_t mydata[] = "Hello, world!";
```

Hands-on, 15': Arduino LoRaWAN

Get an account at https://thethingsnetwork.org/

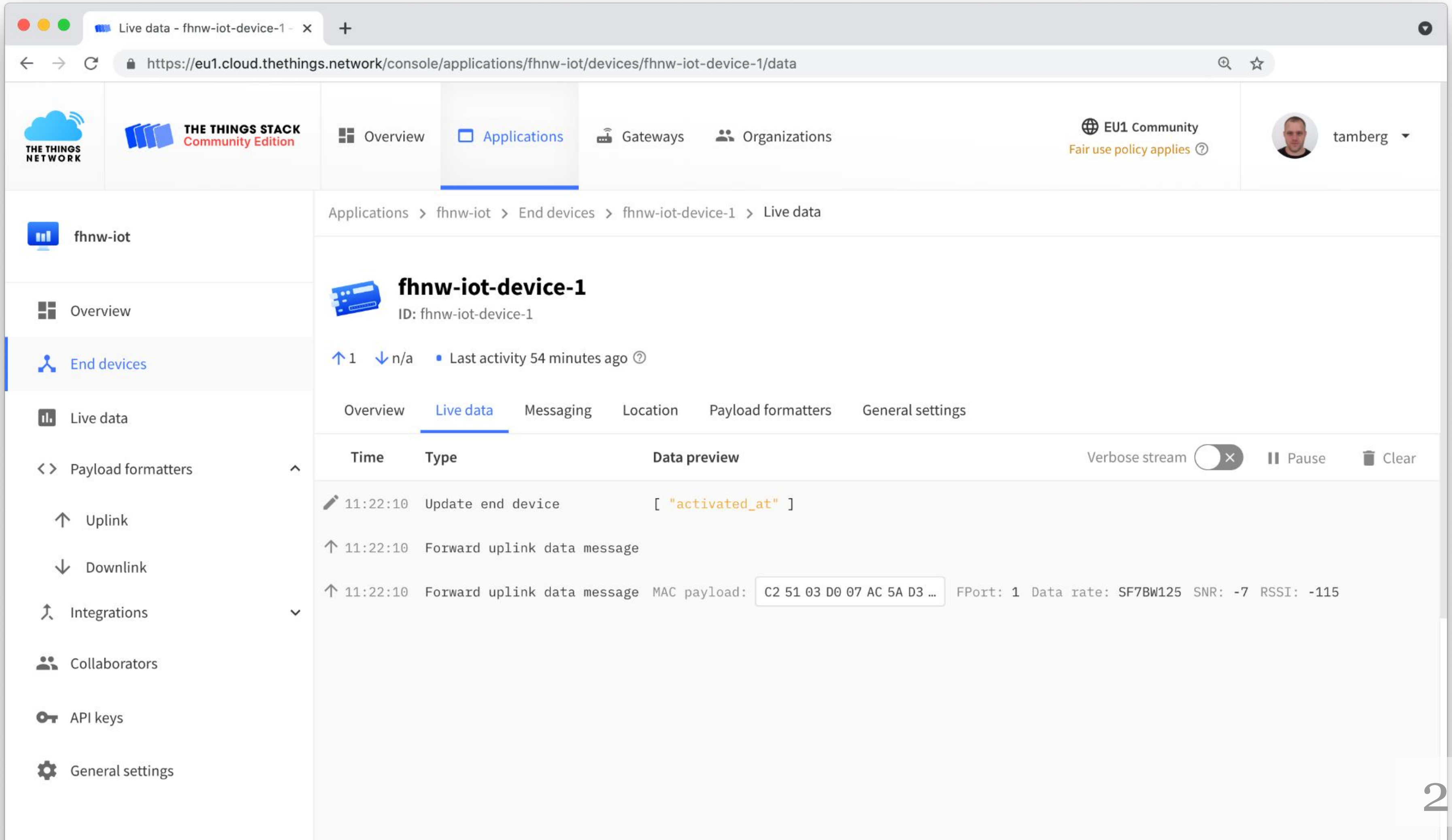
Register a TTN application, and register two devices.

Get ABP keys for one device, OTAA keys for another.

Set these keys in the LoRaWAN *.ino* code examples.

Make sure to use the right code for your hardware*.

*The pin mapping varies for ESP8266, nRF52840.



Time	Type	Data preview
11:22:10	Update end device	["activated_at"]
11:22:10	Forward uplink data message	
11:22:10	Forward uplink data message	MAC payload: C2 51 03 D0 07 AC 5A D3 … FPort: 1 Data rate: SF7BW125 SNR: -7 RSSI: -115

Uplink and downlink

Uplink — sending data from a device to the backend.

Downlink — sending from the backend to a device.

There's an *asymmetry* due to duty cycle limitations.

Gateways are *half-duplex*, they either send or listen.

LoRaWAN is better suited to send data *to* the cloud.

MQTT integration

The TTN backend offers an MQTT broker API.

To get uplink packets from a device:

```
$ mqtt sub -t "v3/<AppID>@ttn/devices/<DevID>/up"\
 -h "eu1.cloud.thethings.network" -u "<AppID>@ttn"\
 -P "<ApiKey>" # see TTN console > Integrations > MQTT
```

To send a packet downlink, to a device:

```
$ mqtt pub -t "v3/<AppID>@ttn/devices/<DevID>/down/push"\
 -m '{"downlinks":[{"f_port":1,"frm_payload":"<Base64>",\
 "priority": "NORMAL"}]}' -h … -u … -P … # as above
```

HTTP Webhook integration

The TTN backend provides a RESTful HTTP API.

A POST request allows to send packets downlink.

A *Webhook* URL can be set to receive uplink data.

The TTN backend calls this URL for each packet.

The backend also defines the JSON data format.

How to debug Webhook calls

To debug Webhook calls, set up a simple Web service:

```
$ wget https://raw.githubusercontent.com/\
tamberg/fhnw-iot/master/08/Nodejs/HttpLogger.js
$ node HttpLogger.js # runs on 127.0.0.1:8080
```

Make it accessible via Ngrok, PageKite or Yaler relay.

=> URL, e.g. `https://RELAY_DOMAIN.try.yaler.io/`

Set this URL as Webhook URL, watch the shell.

Product-specific integrations

LoRaWAN backends (here TTN) provide product specific integrations with 3rd-party services.

On The Things Network, to create a new integration:

- Open the TTN console for Europe (eu1)
- Go to *Applications* > click, e.g. `fhnw-iot`
- Go to *Integrations* > choose *AWS*, *Azure*, ...

Hands-on, 15': TTN integrations

Read the TTN MQTT and Webhooks API docs.

Use the Raspberry Pi as your application backend.

Use a MQTT SUB client to log incoming messages.

Set up an HTTP Logger to see TTN Webhook calls.

Data formats

Bandwidth is very limited, payload is ≤ 51 Byte.

JSON or plain ASCII formats use too much space:
`{"temperature":20.63}` vs. `20.63` vs. `0x080F`

TTN allows to use JS payload decoders & encoders.

A binary format suitable for LoRa is CayenneLPP.

Less Bytes per message => send more often.

Limitations

LoRaWAN has physical, legal & operator limitations:

Duty cycle limitations allow only 1% air time in EU*, apply to nodes *and* gateways, creating asymmetry.

The TTN Fair Use Policy limits uplink air time to 30s and downlink to 10 messages per 24h per node.

*See ETSI EN300.220 standard, 7.2.3.

Hands-on, 15': LoRaWAN use cases

Which applications become possible with LoRaWAN?

Does free wide area connectivity change anything?

Sketch the reference model for an application.

Find a case that clearly beats Wi-Fi, 3/4G.

Summary

LoRaWAN brings long range, low power connectivity.

We learned about gateways and network architecture.

We sent packets uplink, from a device, and downlink.

We understand how data arrives at the app backend.

Next: Dashboards and Apps for Sensor Data.

Feedback or questions?

Write me on Teams or email

thomas.amberg@fhnw.ch

Thanks for your time.