

IoT Engineering

8: Long Range Connectivity with LoRaWAN

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Today

⅓ slides,

⅔ hands-on.

Slides, code & hands-on: tmb.gr/iot-8



Prerequisites

Set up the [Feather nRF52840 Express](#) for Arduino.

Or set up the [Feather Huzzah ESP8266](#), both work.

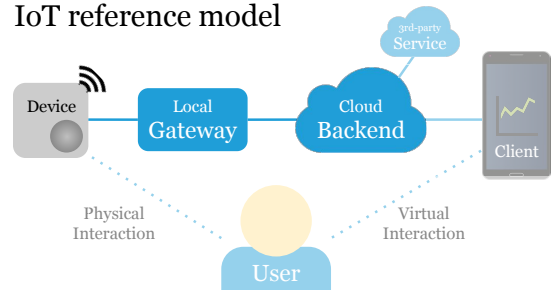
A LoRaWAN gateway has to be in range for testing*.

The [Raspberry Pi](#) with [Node.js](#) is our app backend.

*) See, e.g. thethingsnetwork.org gateway map.

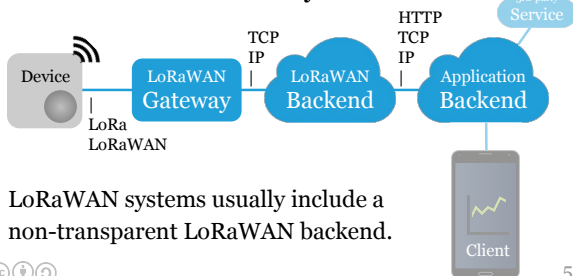
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IoT reference model



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LoRaWAN connectivity



LoRaWAN systems usually include a non-transparent LoRaWAN backend.



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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.

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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.

*) RFM95W [10/30](#) mA vs. ESP8266 [50/150](#) mA.

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LoRaWAN terminology

The LoRaWAN community uses the following terms:

Node — device with sensors, LoRaWAN connectivity.

Gateway — LoRaWAN (to Internet) gateway.

Network server — LoRaWAN backend.

Application server — app backend.

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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.

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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.

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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](#).

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Mapping network coverage

[TTNMapper](#) is a community effort to map [coverage](#).

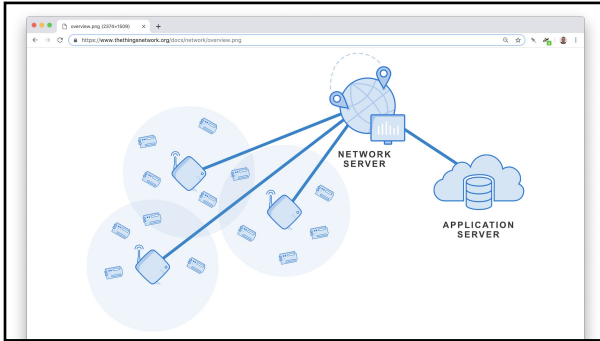
The [iOS](#) or [Android app](#) provides GPS location data.

The data is correlated with metadata from gateways.

Any LoRaWAN device sending* packets works fine.

*) Actually *broadcasting*, as LoRa is radio.

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LoRaWAN gateways

Gateways forward *uplink* data packets to the backend. There, they are deduplicated & routed to applications. *Downlink* packets are "broadcast" to nearby devices. Everybody can operate a gateway in unlicensed band.

See [products](#), [indoor](#) & [outdoor](#), or [build your own](#). 14

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 are unique per device and per "session".

They are generated with OTAA, or static with ABP.

See, e.g. [TTN security docs](#) and [this whitepaper](#). 15

Over The Air Activation (OTAA)

OTAA uses an *AppKey* 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 *End-device activation* in the [LoRaWAN spec](#). 16

Activation by Personalization (ABP)

ABP stores application 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, e.g. [LoRaWAN OTAA or ABP?](#) 17

Registering an application on TTN

An *application* is required to register devices later on.

On The Things Network, to register a new application:

- Open <https://console.thethingsnetwork.org/>
- Go to *Applications* > *Add application*
- Enter a name, e.g. *fhnw-iot*
- Click *Add application*

The steps are similar for most backend providers. 18

Registering a device on TTN

On The Things Network, to register a new device:

- Open <https://console.thethingsnetwork.org/>
- Go to *Applications* > click, e.g. fhnw-iot
- Click *Register device*
- Enter a *Device ID*, e.g. fhnw-iot-arduino-0
- Click the *Device EUI* icon, so it *will be generated*
- Click *Register*

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Getting OTAA keys on TTN

On The Things Network, to get keys for OTAA:

- Open <https://console.thethingsnetwork.org/>
- Go to *Applications* > click, e.g. fhnw-iot
- Go to *Devices* > click, e.g. fhnw-iot-arduino-2
- OTAA is the default, device registration generates a *Device EUI*, and sets *Application EUI* and *App key*

Use either OTAA or ABP depending on the code.

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Getting ABP keys on TTN

- Open <https://console.thethingsnetwork.org/>
- Go to *Applications* > click, e.g. fhnw-iot
- Go to *Devices* > click, e.g. fhnw-iot-arduino-2
- Go to *Settings* > as *Activation Method* click *ABP*
- Deactivate *Frame Counter Checks* (testing only!)
- Click *Save*
- This generates a *Device Address* as well as a *Network Session Key* and *App Session Key*

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LoRaWAN hardware modules

Some LoRaWAN modules, based on Semtech [SX127x](#):

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

[RFM95W](#) — via SPI, stack runs on separate controller.

[Murata](#) — SoC including an ARM STM32 Cortex Mo.

Always make sure the frequency fits your [region](#).

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FeatherWing RFM95W

[RFM95W](#) is a popular 868 MHz LoRa radio module. The [RFM95W FeatherWing](#) needs a microcontroller. Both Feather boards work, nRF52840 and ESP8266. The [pin mapping](#) has to be adapted in the code.

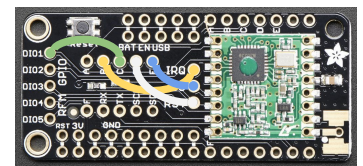
Note: Always add an antenna before using it.

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Jumpers

These FeatherWing RFM95W jumpers must be connected.

- IRQ — B
- DI01 — C
- RST — D
- CS — E



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Here is a simple [adapter PCB](#) to replace jumpers.

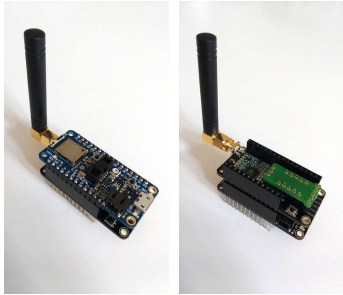
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Setup

The nRF52840 goes on top* of the FeatherWing.

The ESP8266 fits below* the wing.

*) Depending on the headers used.



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nRF52840 pin mapping

```
const lmhc_pinmap lmhc_pins = { // nRF52840
  .nss = 5, // E = CS
  .rxtx = LMHC_UNUSED_PIN,
  .rst = 6, // D = RST
  .dio = {
    10, // B = DIO0 = IRQ
    9,  // C = DIO1
    LMHC_UNUSED_PIN
  }
};
```

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ESP8266 pin mapping

```
const lmhc_pinmap lmhc_pins = { // ESP8266
  .nss = 2, // E = CS
  .rxtx = LMHC_UNUSED_PIN,
  .rst = 16, // D = RST
  .dio = {
    15, // B = DIO0 = IRQ
    0,  // C = DIO1
    LMHC_UNUSED_PIN
  }
};
```

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Arduino LoRaWAN

The following examples work on a range of boards*.

LMIC is a network stack library used with RFM95W.

We use the [IBM LMIC library \(v1.5.0+arduino-2\)](#).

Library Manager doesn't work, [get the .ZIP](#) and use

Sketch > Include Library... > Add .ZIP Library...

*) Including nRF52840 and ESP8266.

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Arduino LoRaWAN ABP [.ino^{ESP}](#), [.ino^{nRF}](#)

Set the *NwkKey*, *AppKey* and *Device Address*:

```
static const PROGMEM u1_t NWKEY[16] = {...}
static const u1_t PROGMEM APPKEY[16] = {...}
static const u4_t DEVADDR = 0x01234567;
```

Double check to use the pin mapping for your board:
const lmhc_pinmap **lmhc_pins** = {...} // nRF52...

Set a custom message:

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

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Arduino LoRaWAN OTAA [.ino^{ESP}](#), [.ino^{nRF}](#)

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

```
static const u1_t PROGMEM APPEUI[8] = { ... }
static const u1_t PROGMEM DEVEUI[8] = { ... }
static const u1_t PROGMEM APPKEY[16] = { ... }
```

Double check to use the pin mapping for your board:
const lmhc_pinmap **lmhc_pins** = {...} // nRF52...

Set a custom message:

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

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Hands-on, 15': Arduino LoRaWAN

Get an account at <https://thethingsnetwork.org/>
Register an application with two (Arduino) devices.
Get ABP keys for one device, OTAA keys for another.
Run the previous Arduino LoRaWAN *.ino* examples.

Make sure to set the pinout, keys in the source.

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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.

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MQTT integration

The TTN backend is also an [MQTT broker](#)/proxy.

To get uplink packets from a device:

```
$ mqtt sub -t "<AppID>/devices/<DevID>/up" \  
-h "eu.thethings.network" -u "<AppID>" \  
-P "<AppAccessKey>" # see TTN console, apps
```

To send a packet downlink, Base64 encoded:

```
$ mqtt pub -t "<AppID>/devices/<DevID>/down" \  
-m '{"port":1,"payload_raw":"<Bytes>"}' -h ... 33
```

HTTP Webhook integration

The TTN backend provides a RESTful [HTTP API](#).

A PUT 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.

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How to debug Webhook calls

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

```
$ wget https://bitbucket.org/tamberg/  
iotworkshop/raw/tip/NodeJS/http-logger.js  
$ node http-logger.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.

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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 <https://console.thethingsnetwork.org/>
- Go to *Applications* > click, e.g. *fnhw-iot*
- Go to *Integrations* > click *Add integration*

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Hands-on, 15': TTN integrations

Read the TTN [HTTP](#) and [MQTT](#) data API docs.
Use the Raspberry Pi as an application backend.
Set up an HTTP Service to log TTN Webhook calls.
Run a MQTT (sub) client to log incoming messages.

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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`
The TTN backend has [payload decoders](#) & encoders.
TTN [works well](#) with the [CayenneLPP](#) binary format.

Consuming less Bytes means sending more often. 38

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 Access Policy](#) limits uplink [air time](#) to
30 s and downlink to 10 messages per 24 h per node.

*) See ETSI [EN300.220](#) standard, 7.2.3.

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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.

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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.

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Feedback?

Find me on <https://fhnw-iot.slack.com/>
Or email thomas.amberg@fhnw.ch

Slides, code & hands-on: tmb.gr/iot-8

