

The Things Network

Workshop on LPWAN Solutions for the Internet of Things
February 17-21 Makerere University, Kampala, Uganda
Sebastian Büttrich (IT University of Copenhagen / NSRC)

IoT – Internet of Things

within IoT

LPWAN – Low Power Wide Area Networks

one possible LPWAN: LoRaWAN

Physical Layer – LoRa

MAC Layer – LoRaWAN

one possible LoRaWAN: The Things Network

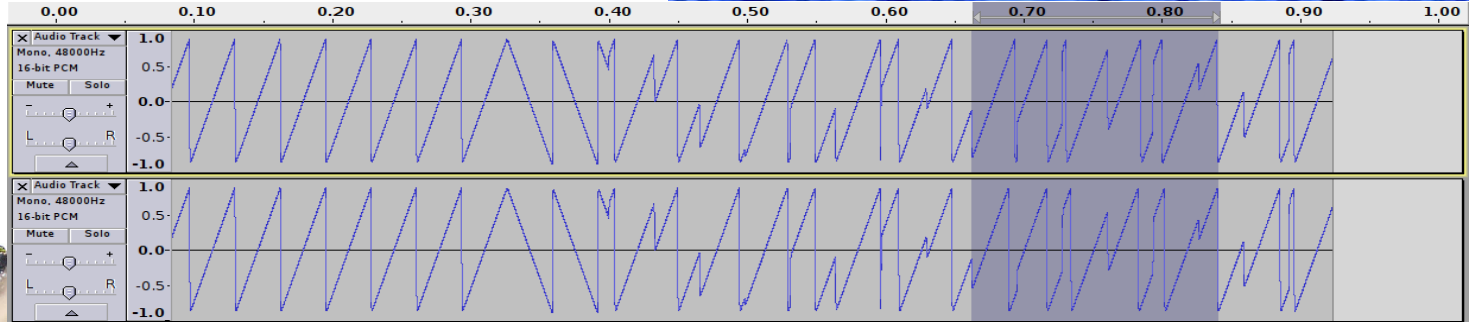
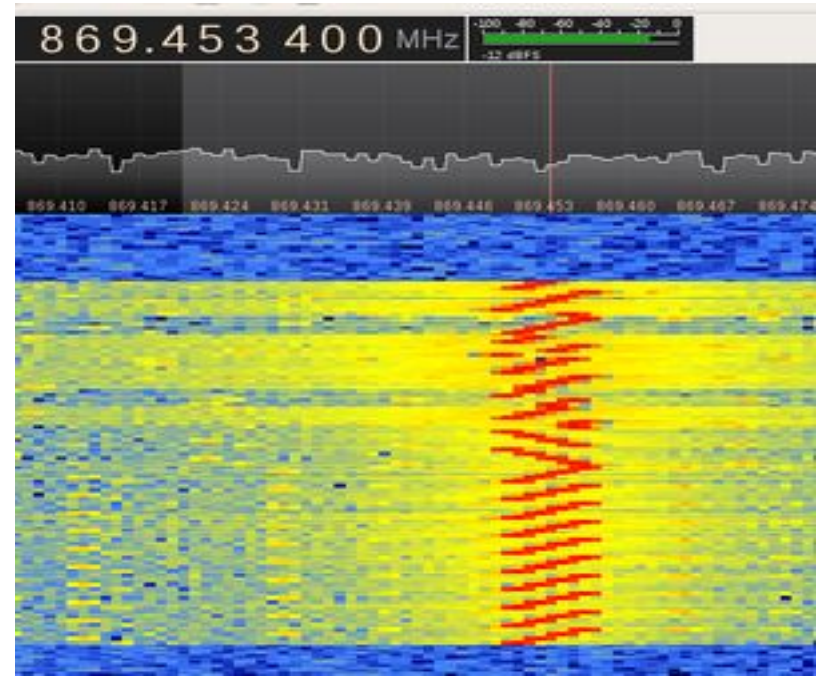


LoRa

A proprietary radio technology,
owned by Semtech,
licensed to chip makers

CSS Chirp Spread Spectrum

Often on **ISM bands** 868/915 & 433
MHz, but not limited to those



LoRa / recap / Spreading Factor SF

$$SF = \frac{\text{chip rate}}{\text{symbol rate}}$$

(think of it as “one bit is spread out over so and so many pulses” ... **one symbol = 2^{SF}**)

Control rate CR, determines depth of forward error coding

(Think of it as saying
CCCAAFFFFEEE or CAFECAFECAFE
instead of CAFE)

LoRa / recap / Data Rate

Data Rate depends on Bandwidth, CR, SF

$$R_b = SF * \frac{\left[\frac{4}{4+CR} \right]}{\left[\frac{2^{SF}}{BW} \right]} * 1000$$

SF = Spreading Factor (6,7,8,9,10,11,12)

CR = Code Rate (1,2,3,4)

BW = Bandwidth in KHz
(10.4,15.6,20.8,31.25,41.7,62.5,125,250,500)

Rb = Data rate or Bit Rate in bps

<http://www.rfwireless-world.com/calculators/LoRa-Data-Rate-Calculator.html>

LoRaWan / 1

- LoRaWan is an open LPWAN standard, building on top of LoRa
- <https://www.lora-alliance.org/>



LoRaWAN

An open specification, maintained by the LoRa-Alliance

143 Countries with
LoRaWAN® Deployments

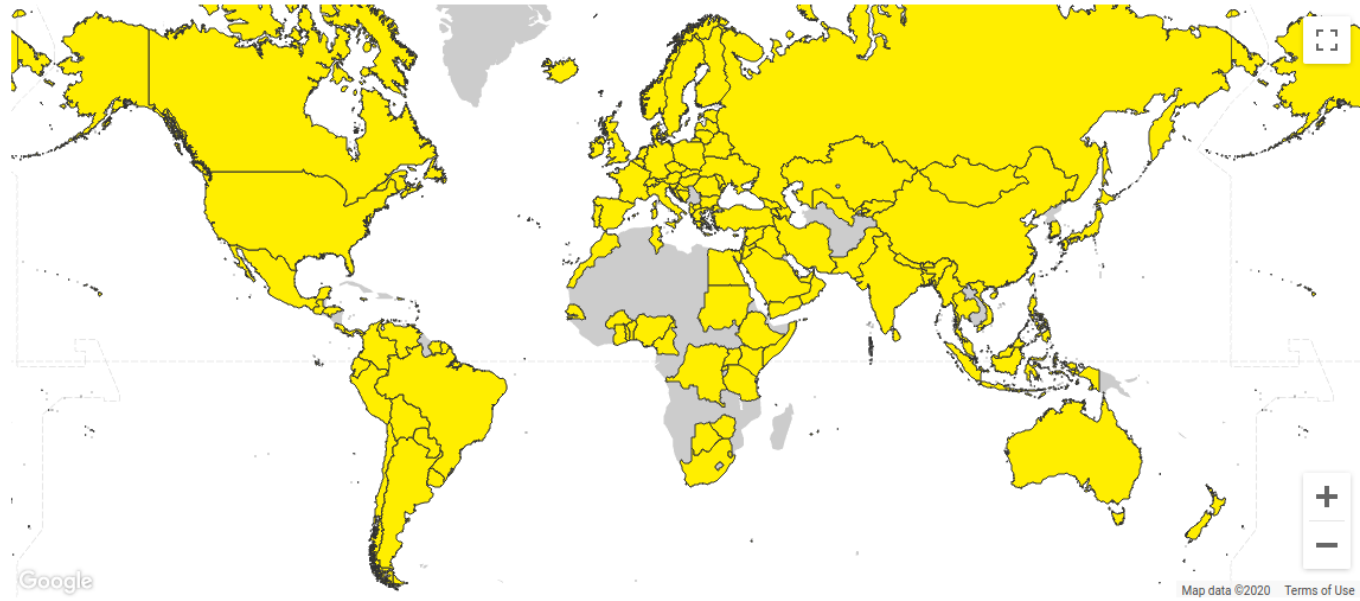
133 Network Operators in
58 countries

76 LoRa Alliance®
Member Operators

LoRaWAN®
Global Network Coverage

LoRaWAN®
Public Network Operators

LoRaWAN®
Open Community Networks



LoRaWAN

A variety of commercial and community operators

143 Countries with
LoRaWAN® Deployments

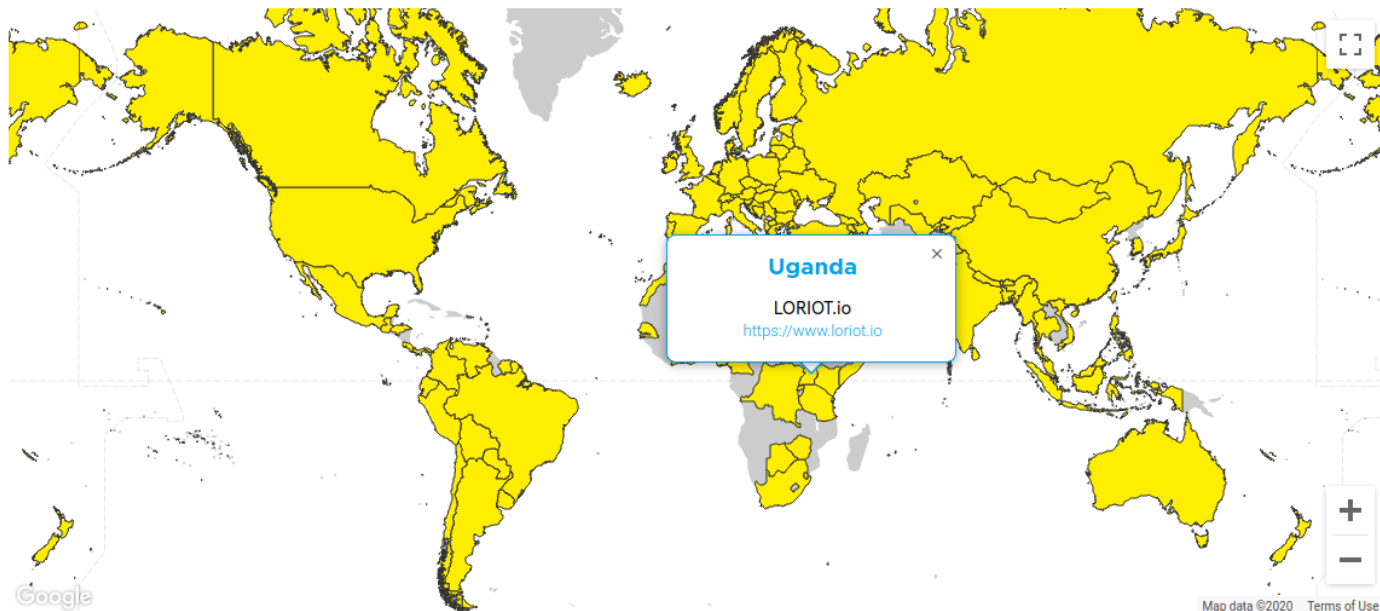
133 Network Operators in
58 countries

76 LoRa Alliance®
Member Operators

LoRaWAN®
Global Network Coverage

LoRaWAN®
Public Network Operators

LoRaWAN®
Open Community Networks



LoRaWAN specifies:

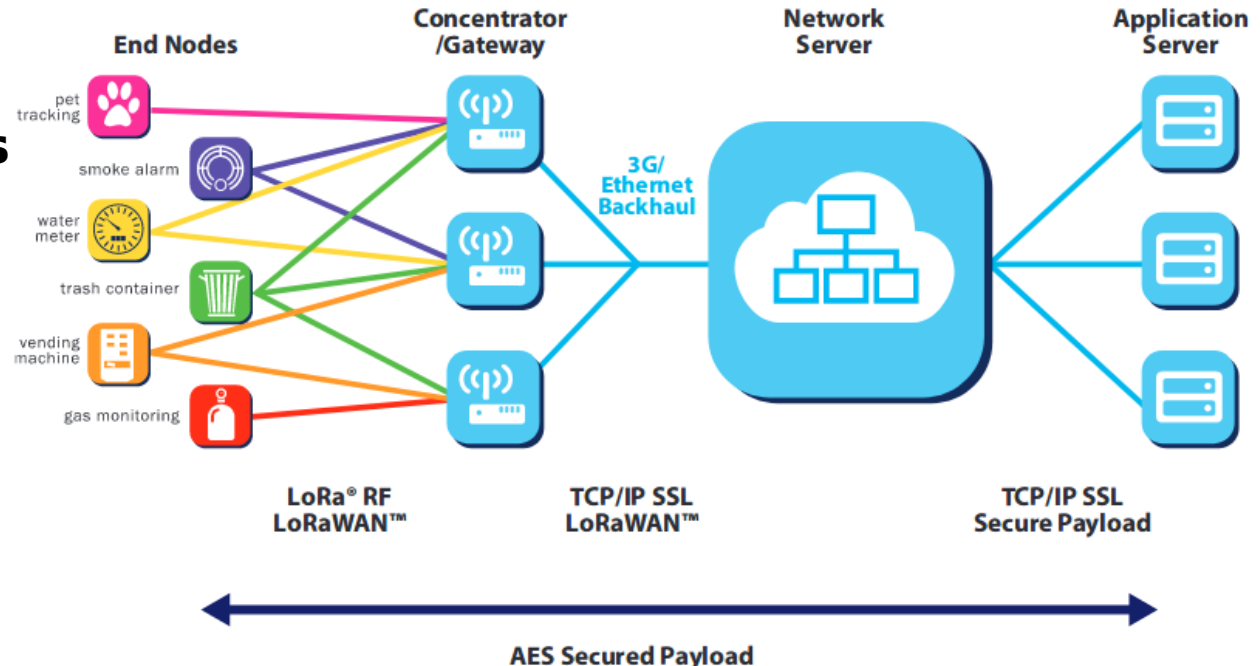
Topology

Device Classes

Data Rates

Security

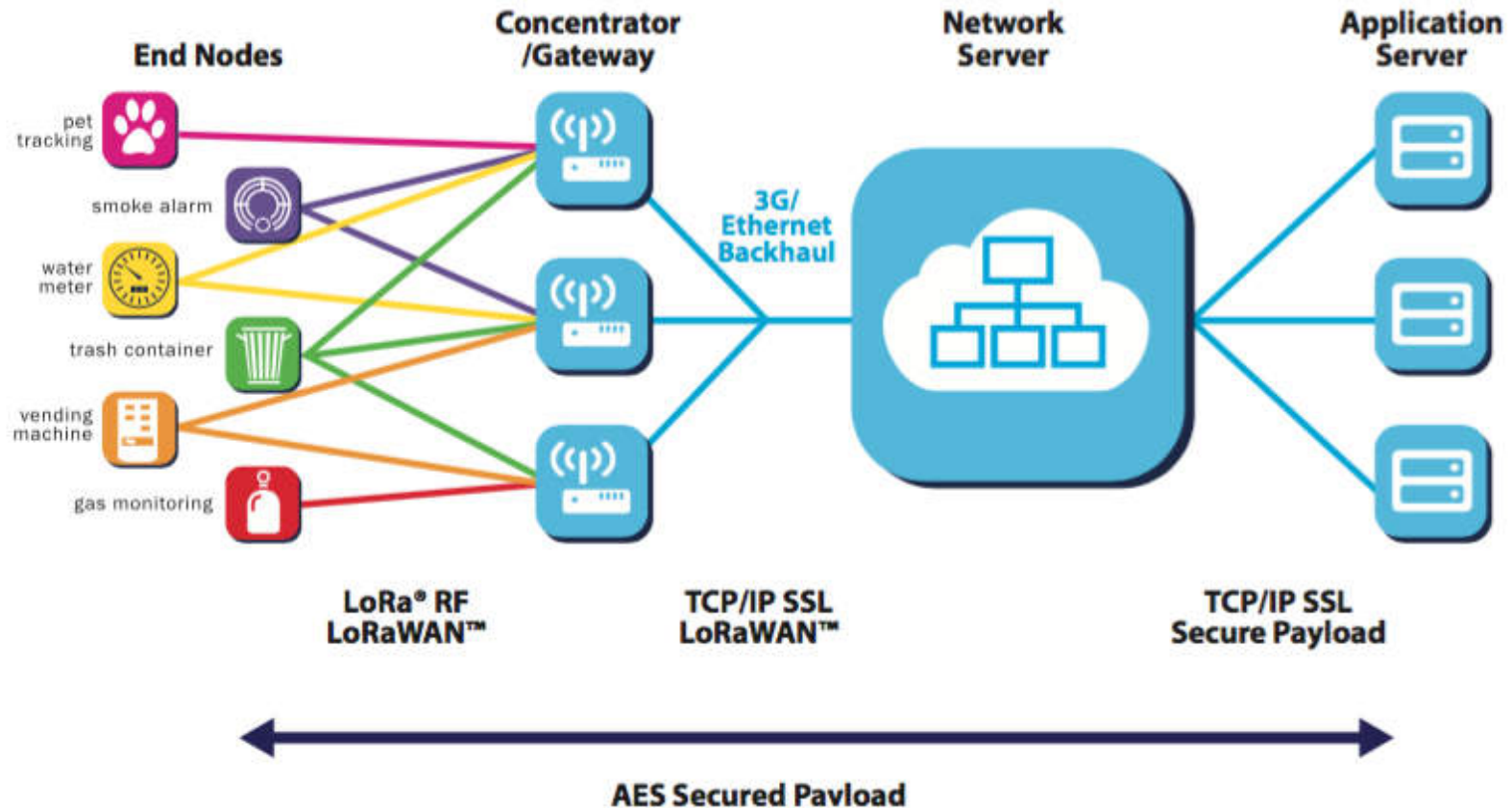
Regional Info



LoRaWan / topologies & entities

- **Star-of-stars topology**
- **Gateways** are transparent bridges relaying messages between **end-devices** and a central **network server** in the backend.
- **Gateways are connected** to the network server via **standard IP connections** while end-devices use single-hop wireless communication to one or many gateways.
- All end-point communication generally **bi-directional**, supports **multicast** enabling **software upgrade over the air** or other mass distribution messages

LoRaWan / architecture



LoRaWan / device classes

Device classes

A Battery powered, small loads, long breaks, long latency, unicast

B low latency, scheduled receive slots, periodic beacon from gateway, uni/multicast, higher power, 14-30 mA

C no latency, uni/multi, constantly receiving, power hungry

Classes can be dynamically assigned / changed

Source, Details:

<https://www.lora-alliance.org/What-Is-LoRa/Technology>

LoRaWan / addressing

Devices and applications

have a 64 bit / 8 byte unique identifier (DevEUI and AppEUI).

When a device joins the network, it receives a dynamic (non-unique) 32-bit / 4 byte address (DevAddr).

Source, Details:

<https://www.thethingsnetwork.org/docs/lorawan/>

LoRaWan / data rates

LoRaWAN abstracts the PHY data rates of LoRa - for EU / CN:

- EU 863-870 MHz (LoRaWAN Specification (2015), Page 35, Table 14)
- CN 779-787 MHz (LoRaWAN Specification (2015), Page 44, Table 25)
- EU 433 MHz (LoRaWAN Specification (2015), Page 48, Table 31)

DataRate	Modulation	SF	BW	bit/s
0	LoRa	12	125	250
1	LoRa	11	125	440
2	LoRa	10	125	980
3	LoRa	9	125	1'760
4	LoRa	8	125	3'125
5	LoRa	7	125	5'470
6	LoRa	7	250	11'000
7	FSK 50 kbps			50'000

<https://blog.dbrgn.ch/2017/6/23/lorawan-data-rates/>

LoRaWan / 11 / duty cycles

LoRaWAN implements duty cycle rules made by regulators:

In Europe, duty cycles are regulated by section 7.2.3 of the ETSI EN300.220 standard. This standard defines the following sub-bands and their duty cycles:

- g (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%

+ duty cycle for join channel: 1%

On top of that, specific networks might have **fairplay rules**.



THE THINGS
N E T W O R K



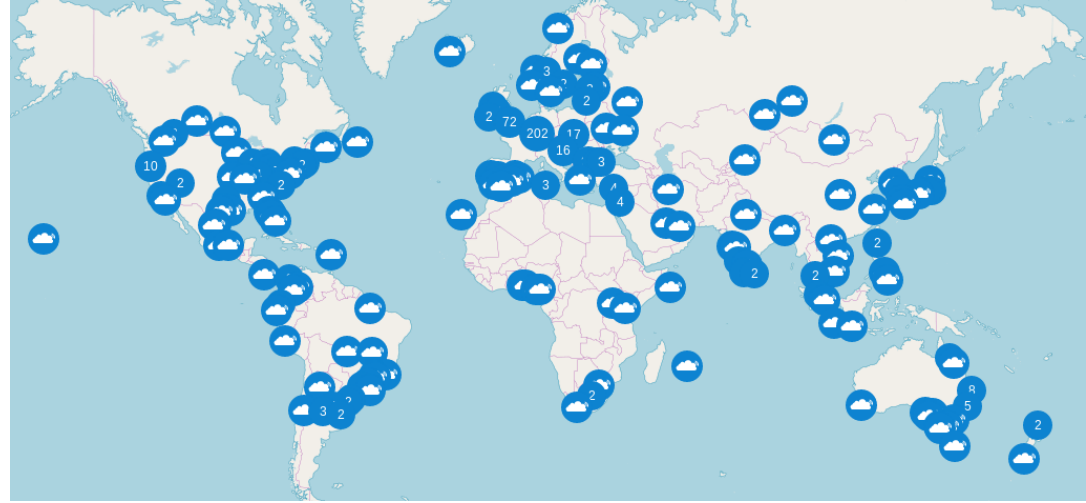
Our mission is to build a **DECENTRALIZED**,

OPEN and **CROWDSOURCED**

INTERNET OF THINGS data network

OWNED and **OPERATED** by its **USERS**

The Things Network



Anyone shall be [free](#) to set up "Things" and connect to "Things Gateways" that may or may not be their own.

Anyone shall be [free](#) to set up "Things Gateways" and connect to "Things Access" that may or may not be their own. Their "Things Gateways" will give [[free](#)] access to all "Things" in a net neutral manner, limited by the maximum available capacity alone.

The Things Network - Essentials



- Community project started in Netherlands, 2015
- Commercial side: The Things Industries
- Open source  TheThingsNetwork/lorawan-stack is licensed under the **Apache License 2.0**
- *This to some degree explains our current interest in TTN, in an educational context*
- **Great Learning resource:**
<https://www.thethingsnetwork.org/docs/>

The Things Network / Manifesto

Everything that carries power will be connected to Internet eventually.

Controlling the network that makes this possible means controlling the world. We believe that this power should not be restricted to a few people, companies or nations. Instead this should be distributed over as many people as possible without the possibility to be taken away by anyone. We therefore founded "The Things Network".

The Things Network is an open source, free initiative with the following properties:

It connects sensors and actuators, called "Things", with transceivers called "Things Gateways" to servers called "Things Access".

The first connection is "Over The Air", the second is "Over The Net". The distributed implementation of these concepts is called "The Things Network".

Anyone shall be free to set up "Things" and connect to "Things Gateways" that may or may not be their own.

Anyone shall be free to set up "Things Gateways" and connect to "Things Access" that may or may not be their own. Their "Things Gateways" will give access to all "Things" in a net neutral manner, limited by the maximum available capacity alone.

Anyone shall be free to set up "Things Access" and allow anonymous connections from the Internet. Their "Things Access" will give access to all "Things Gateways" in a net neutral manner, limited by the maximum available capacity alone. Furthermore their "Things Access" will allow connection of other "Things Access" servers for the distribution of data.

The "Over The Air" and "Over The Net" networks shall be protocol agnostic, as long as these protocols are not proprietary, open source and free of rights.

Anyone who perpetrates a "Things Access" or a "Things Gateway" will do so free of charge for all connecting devices and servers.

Anyone making use of the network is allowed to do so for any reason or cause, possibly limited by local law, fully at own risk and realizing that services are provided "as is" and may be terminated for any reason at any moment. The use may be open for anybody, limited to customers, commercial, not-for-profit, or in any other fashion. "The Things Network" providers will not pose restrictions upon its users.

We invite you to sign this Manifesto, and uphold its principles to the best of your abilities.

Source, Details:

<https://www.thingsnetwork.io/manifesto>

THE OPEN, COLLABORATIVE NETWORK



70K

DEVELOPERS



15M

PACKETS ROUTED
EVERY DAY



100

COUNTRIES



950

CITIES



7K

GATEWAYS

BUT THAT WAS 2019 ...

THE OPEN, COLLABORATIVE NETWORK 2020:



100K

DEVELOPERS



? M

PACKETS ROUTED
EVERY DAY



149

COUNTRIES



CITIES



>10k

GATEWAYS

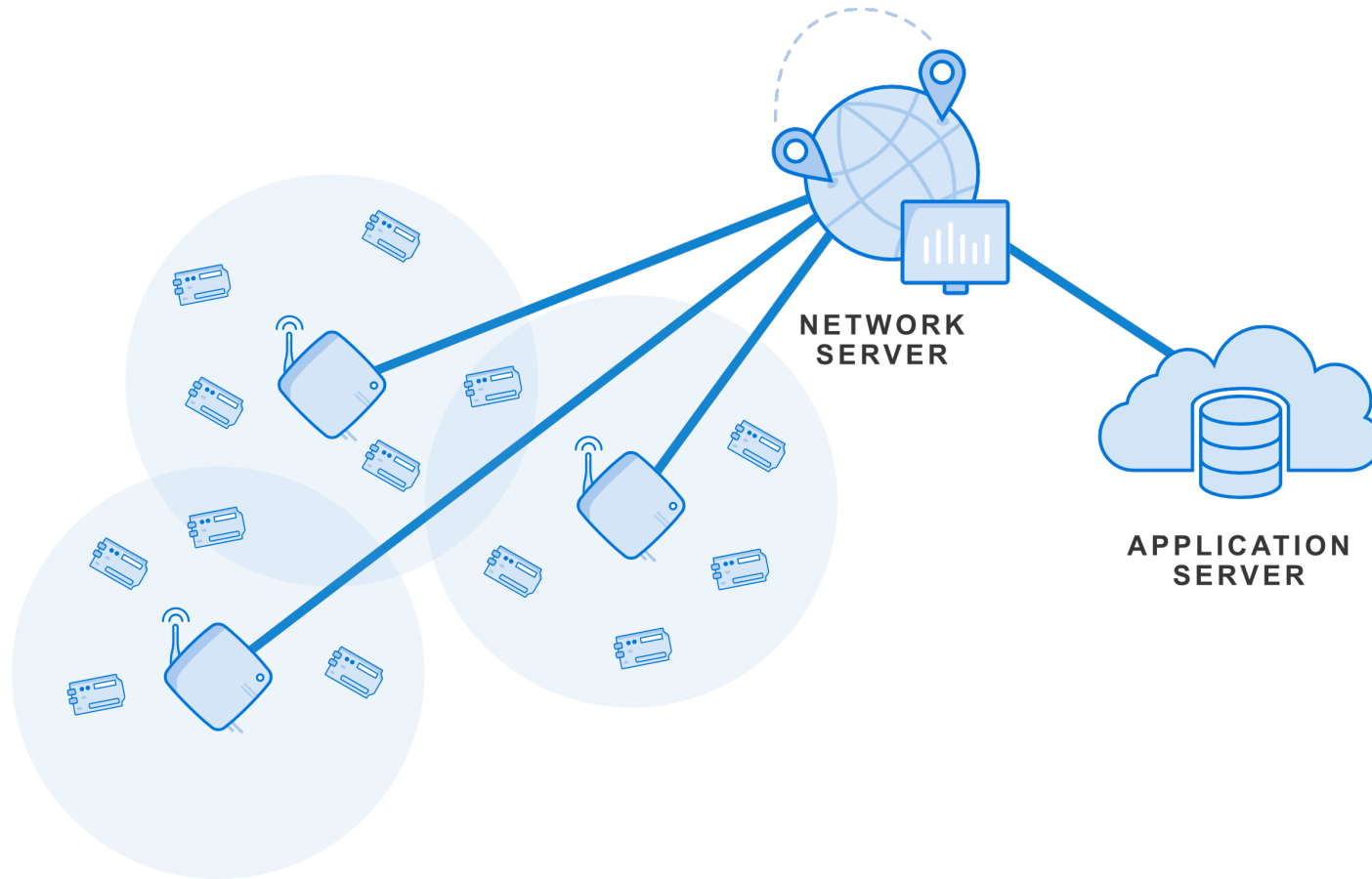
At this moment, there are 10619 gateways up and running



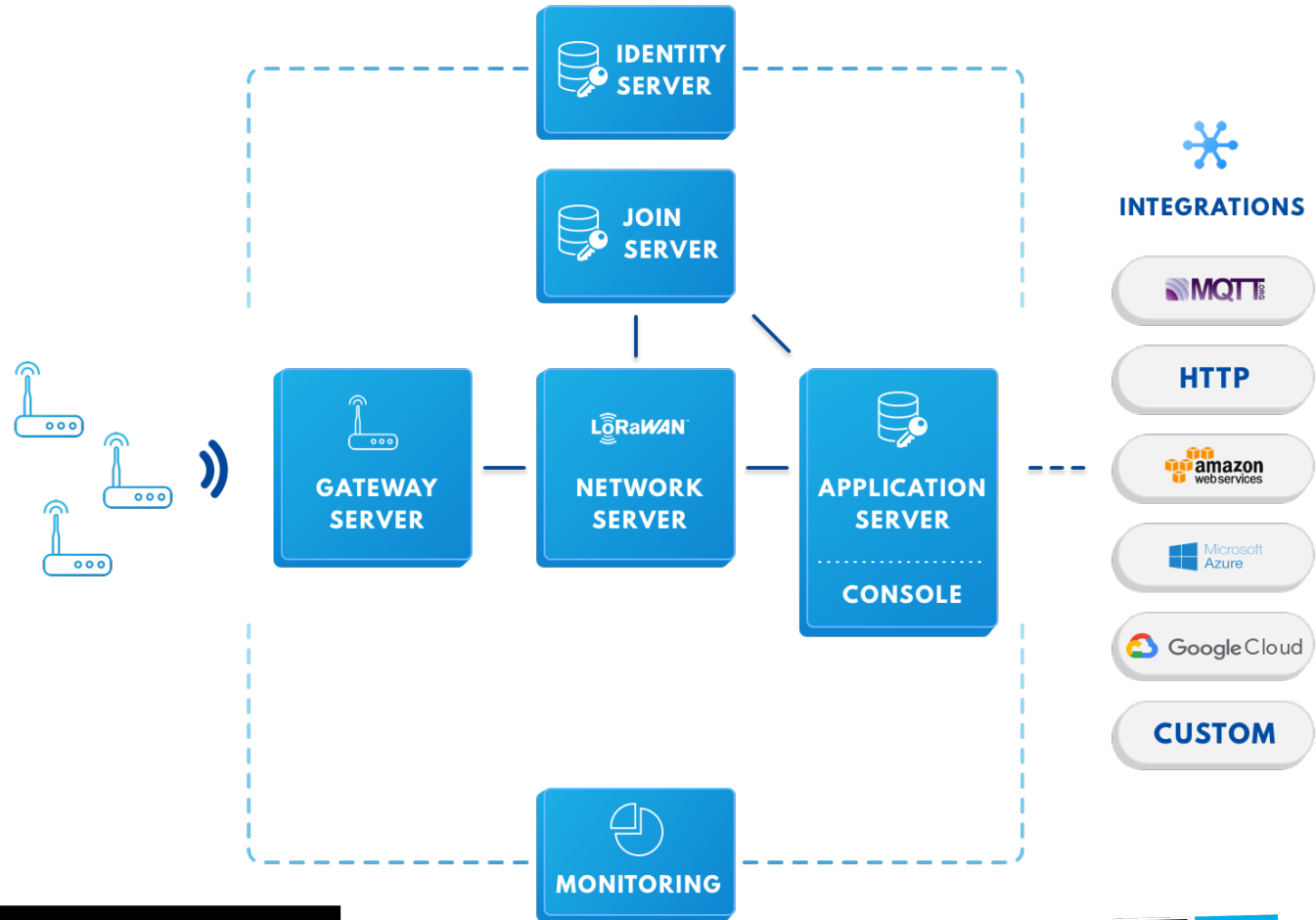


Leaflet | © OpenStreetMap contributors

The Things Network / Simplified



The Things Network / Stack in detail



The Things Network / Security / Keys

Security features defined by **LoRaWAN standard**:

Three keys: NwkSKey, AppSKey and AppKey

AES-128 bit keys

Challenge of key provision!

LoRaWan / Security / keys

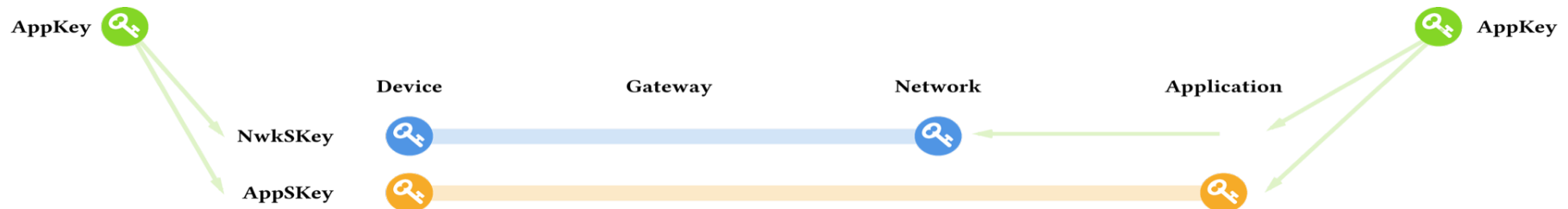
Security measures:

three distinct 128-bit AES keys:

The **application key AppKey** is only known by the device and by the application. When a device joins the network (this is called a join or activation), an application session key **AppSKey** and a network session key **NwkSKey** are generated. The NwkSKey is shared with the network, while the AppSKey is kept private.

Source, Details:

<https://www.lora-alliance.org/What-Is-LoRa/Technology>



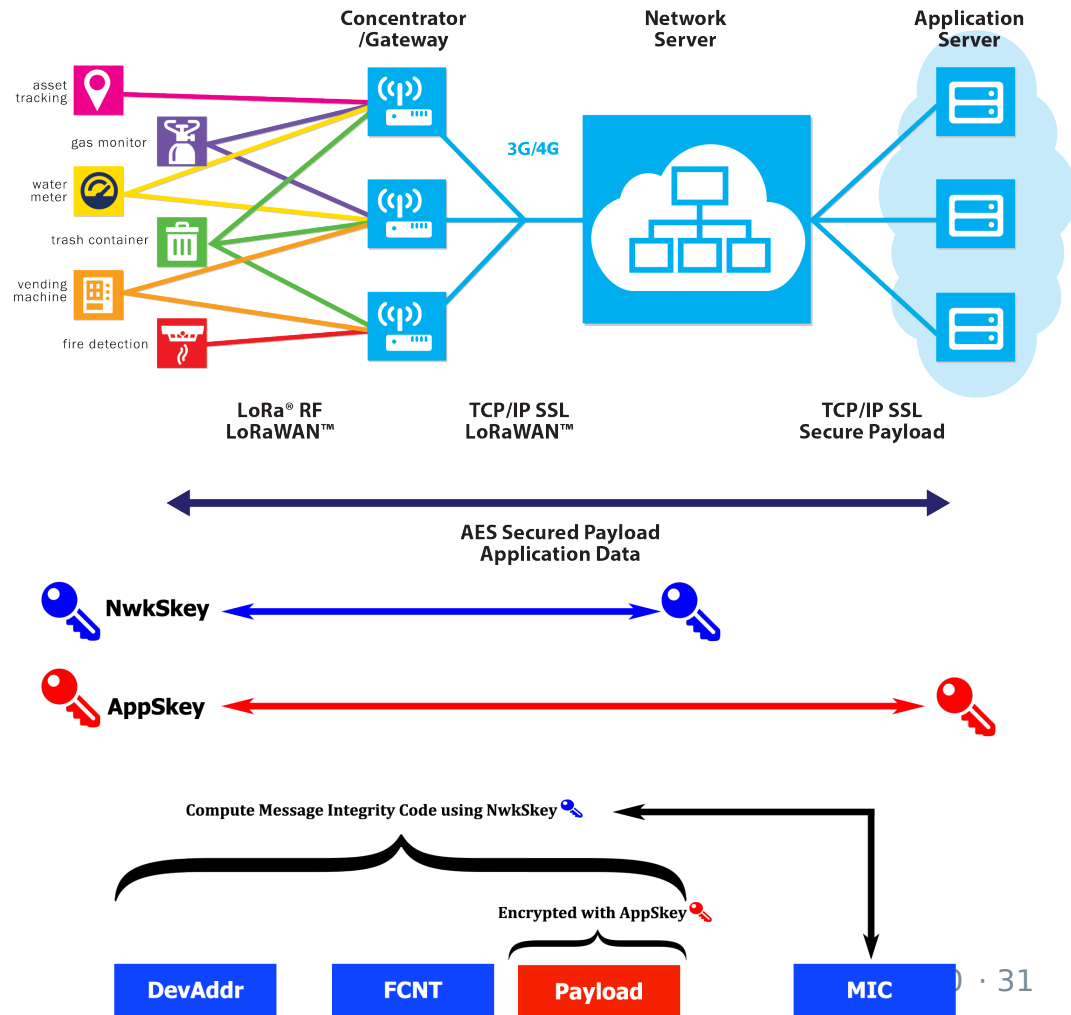
The Things Network / Security, cntd

LoRaWAN 1.0 specifies a number of security keys: **NwkSKey**, **AppSKey** and **AppKey**. All keys have a length of 128 bits.

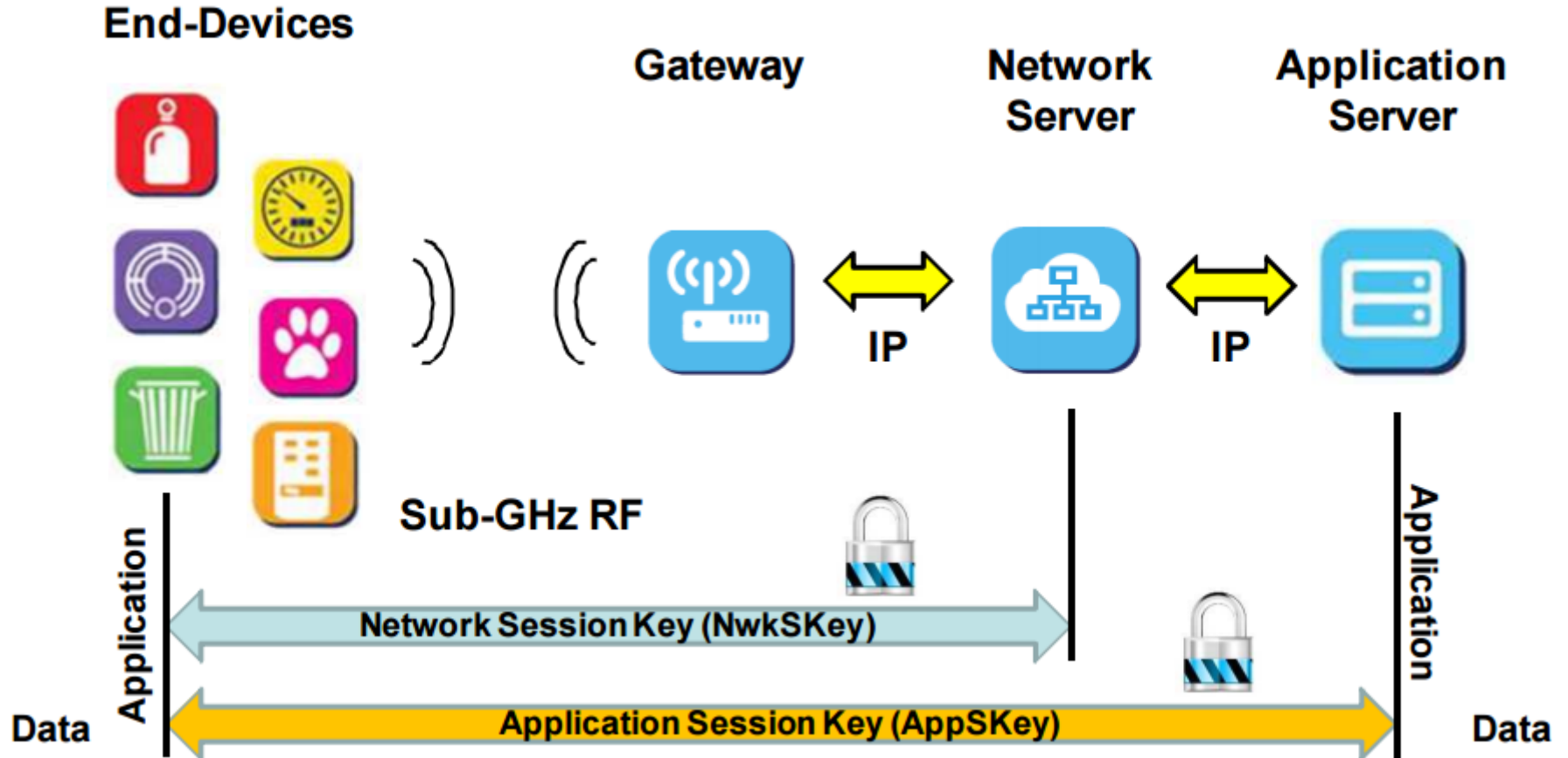
The **Network Session Key** (**NwkSKey**) is used for interaction between the Node and the Network Server. This key is used to check the validity of messages (MIC check). In the backend of The Things Network this validation is also used to map a non-unique device address (**DevAddr**) to a unique **DevEUI** and **AppEUI**.

The **Application Session Key** (**AppSKey**) is used for encryption and decryption of the payload. The payload is fully encrypted between the Node and the Handler/Application Server component of The Things Network (which you will be able to run on your own server). This means that nobody except you is able to read the contents of messages you send or receive.

The Things Network / Security, cntd



The Things Network / Security, cntd



LoRaWan / Security / frame counter

The **frame counter in LoRaWAN** messages is a security measure used to detect **replay attacks**. After validating the MIC, the Broker checks if the Frame counter is valid. As frame counters can only increase, a message with a frame counter that is lower than the last known frame counter should be dropped. Additionally, the Broker has to verify that the gap between the last known frame counter and the counter in the message is not too big. According to the LoRaWAN specification, the maximum gap is 16384.

Source, Details:

<https://www.lora-alliance.org/What-Is-LoRa/Technology>

The Things Network / Security / Activation

Two ways of activating a device:

OTAA Over the Air Activation

Interactive, Join request and answer

ABP Activation by Personalization

Hard coded credentials for session

The Things Network / Security / OTAA

Dynamically activated devices (**OTAA**) use the application key (AppKey) to derive the two session keys during the activation procedure. In The Things Network you can have a default AppKey which will be used to activate all devices, or customize the AppKey per device.

What you will use, in your code:

DevEUI, AppEUI, AppKey

Keys will be generated on TTN server, on registration
(but can be changed manually)

Source, Details: <https://www.thethingsnetwork.org/wiki/LoRaWAN/Security>

The Things Network / Security / ABP

ABP Activation by Personalization

What you will use, in your code:

NwkSKey, AppSKey, DevAddr

Source, Details:

<https://www.thethingsnetwork.org/wiki/LoRaWAN/Security>

Working with The Things Network Console

We have applications (and devices) and gateways

 **Hi, Sebastian!**

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

Working with The Things Network Console

Applications > Add Application

We create applications

ADD APPLICATION

Application ID

The unique identifier of your application on the network

uganda-workshop-2020



Description

A human readable description of your new app

Test application for the workshop



Application EUI

An application EUI will be issued for The Things Network block for convenience, you can add your own in the application settings page.

EUI issued by The Things Network

Handler registration

Select the handler you want to register this application to

ttn-handler-asia-se




Cancel

Add application

Working with The Things Network Console

Applications >

 uganda-workshop-2020

APPLICATION OVERVIEW

[documentation](#)


Application ID **uganda-workshop-2020**



Description Test application for the workshop

Created 1 minute ago

Handler ttn-handler-asia-se (current handler)

APPLICATION EUIs

 [manage euis](#)

<>  70 B3 D5 7E D0 02 AA A0 

In our applications, we create devices

DEVICES


 [register device](#)

 [manage devices](#)



0 registered devices

Working with The Things Network Console

Applications >  uganda-workshop-2020 > Devices

A new device

Overview

Devices

Payload Formats

Integrations

Data

Settings

REGISTER DEVICE

[bulk import devices](#)

Device ID

This is the unique identifier for the device in this app. The device ID will be immutable.

Device EUI


The device EUI is the unique identifier for this device on the network. You can change the EUI later.



0 bytes

App Key

The App Key will be used to secure the communication between you device and the network.



this field will be generated

App EUI

⌵

Working with The Things Network Console

Gateways > Register

A new gateway

REGISTER GATEWAY

Gateway ID

A unique, human-readable identifier for your gateway. It can be anything so be creative!

uganda-test-indoors

☐ I'm using the legacy packet forwarder

Select this if you are using the legacy [Semtech packet forwarder](#).

Description

A human-readable description of the gateway

our first indoor gateway

Frequency Plan

The [frequency plan](#) this gateway will use

Europe 868MHz

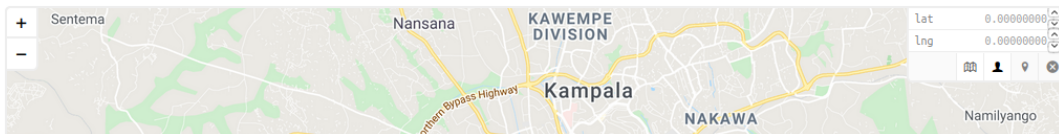
Router

The router this gateway will connect to. To reduce latency, pick a router that is in a region which is close to the location of the gateway.

ttn-router-eu

Location

The exact location of you gateway. This will be used if your gateway cannot determine its location by itself. Set a location by clicking on the map.



Labs

- 1/ Sign on to
<https://thethingsnetwork.org>
- 2/ Look around
- 3/ Let us know your username
- 4/ **We build and share gateways**
- 5/ Create applications
- 6/ Register devices (your LoPys)
- 7/ See the data flow!