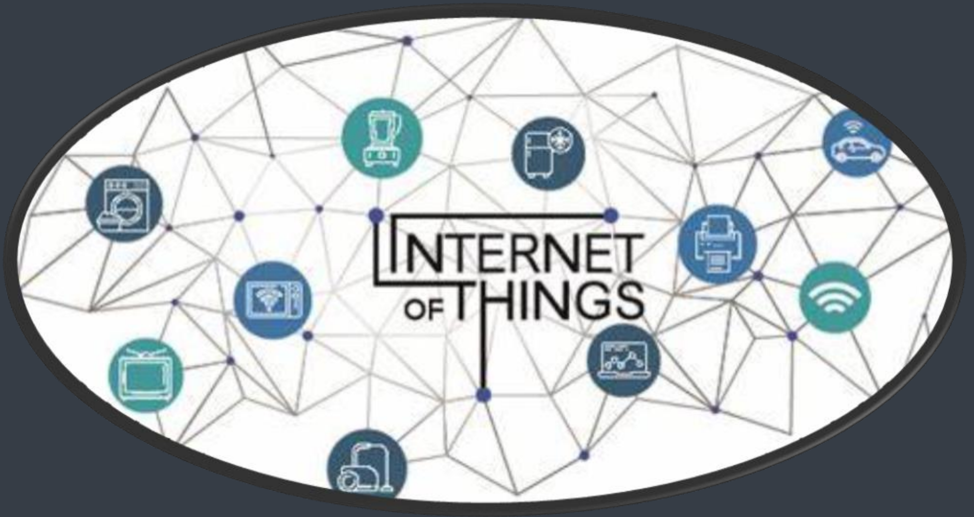
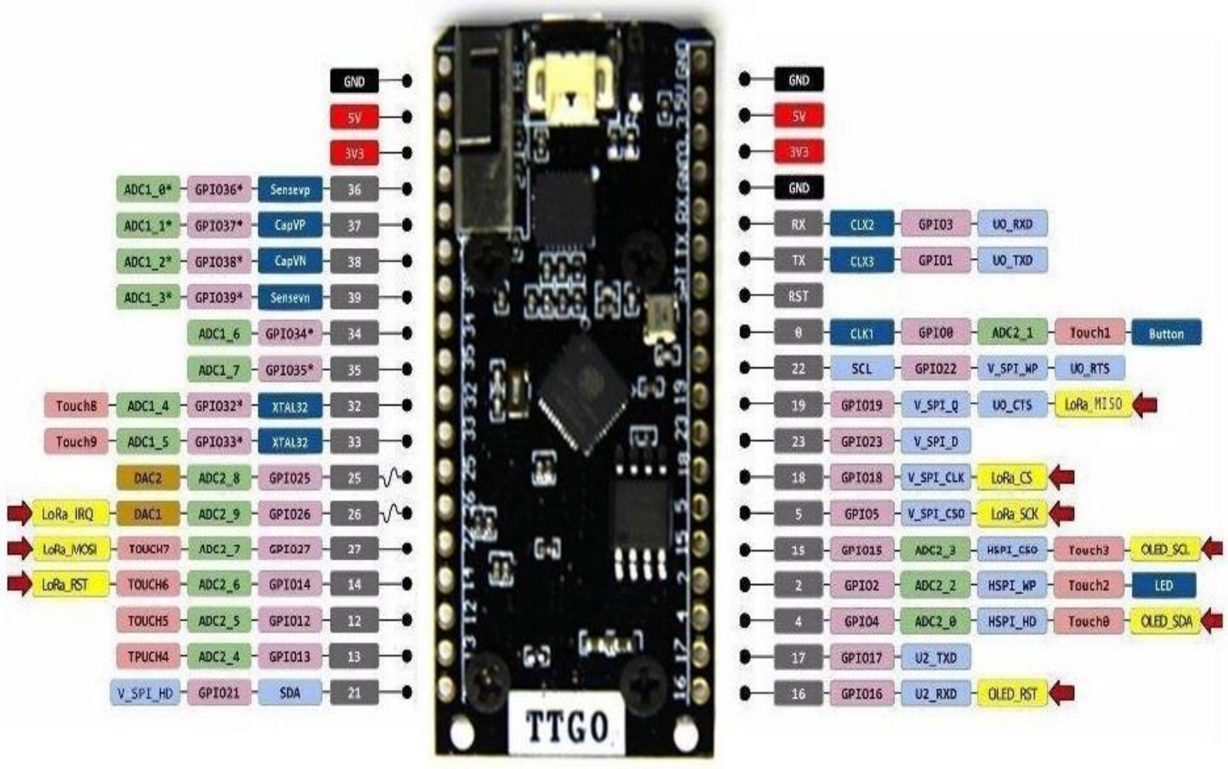
TTGO LORA32 V1 AS NODE FOR LORAWAN SERVER



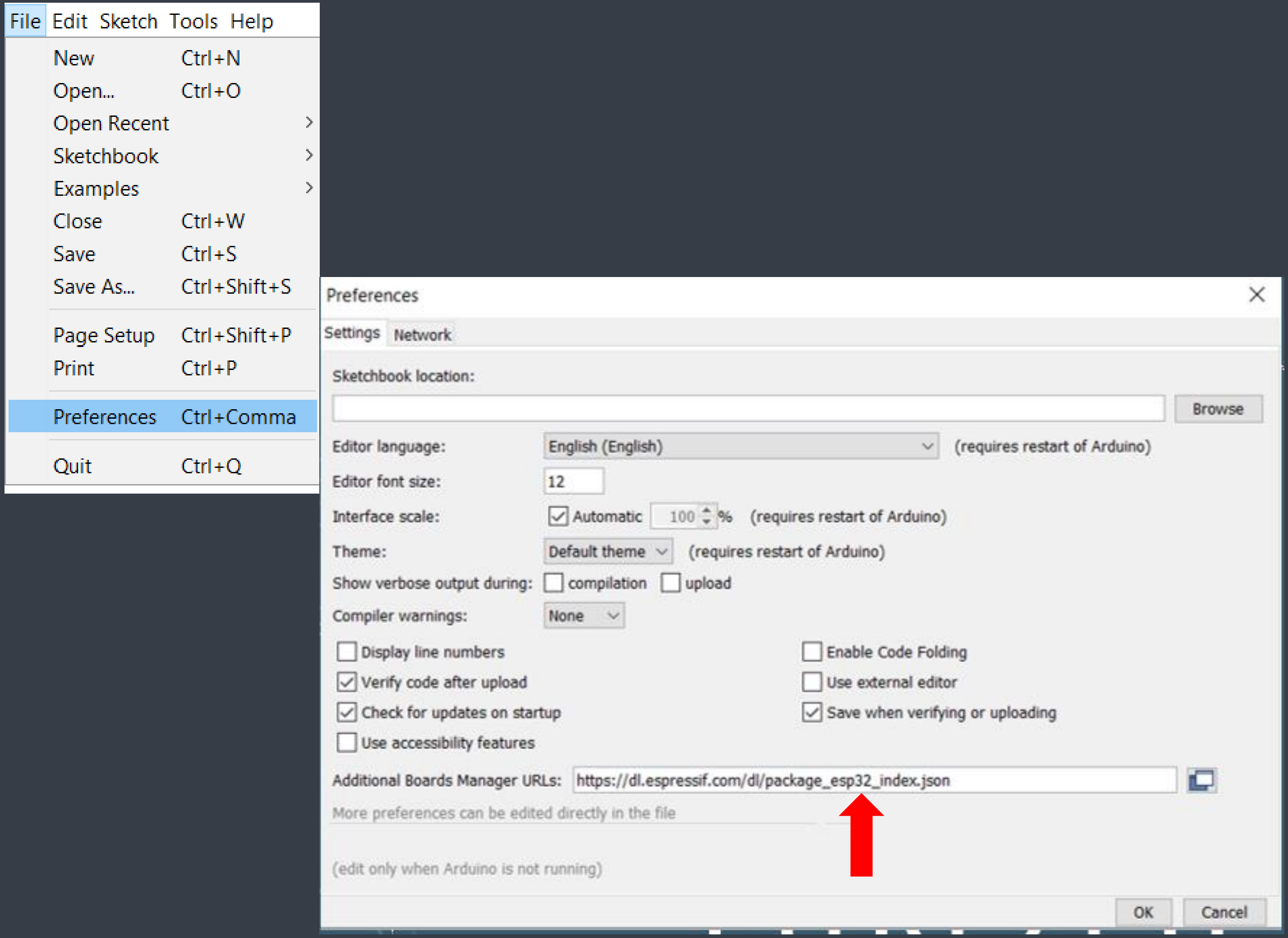
Introduction

This presentation contains the instructions for connecting a TTGO LoRa32 V1 module to a LoraWan-Server and transmitting data from a sensor (in this example temperature and humidity) into the server. In order to carry out this example the following hardware and software will be needed:

- Arduino IDE environment
- Arduino-LMIC library
- CayenneLPP library
- Dht12 library
- TTGO LoRa32 V1
- ESP32 firmware
- ChirpStack Server
- M5Stack ENV Unit with Temperature Humidity Pressure Sensor
- USB to MicroUSB cable
- Wire (for connecting the sensor to the ESP32)



ESP32 Firmware



- In order to add the ESP32 firmware open the menu **"File"**, select then **"preferences"** and a window will pop up. Add the following URL in the **"Additional Boards Manager URLs"** field and click ok:

https://dl.espressif.com/dl/package_esp32_index.json

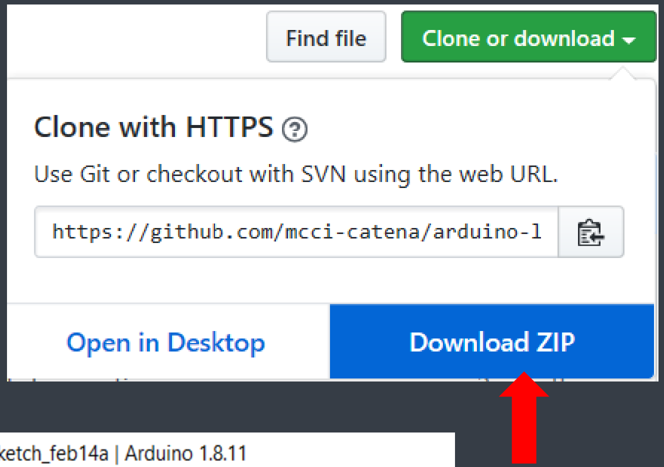
DOWNLOADING THE LIBRARIES

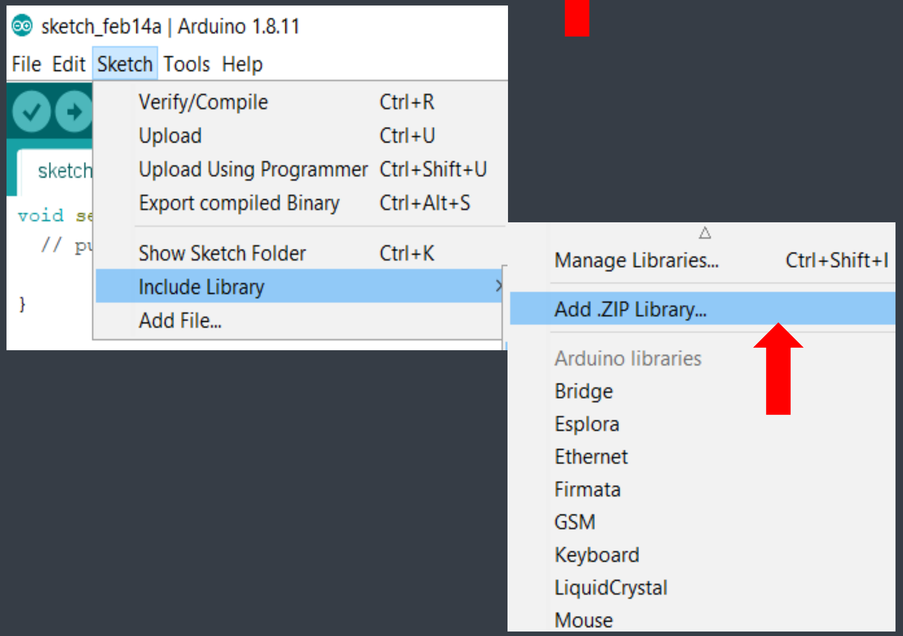
The following links contain the libraries needed for this example:

- **LoRaWAN-MAC-in-C library:** https://github.com/mcci-catena/arduino-lmic
- **CayenneLPP library:** https://github.com/ElectronicCats/CayenneLPP
- **Dht12 library:** https://github.com/Bobadas/DHT12_library_Arduino

Once you have entered to the Website look for the **"Clone or download"** button, click on it and then select **"Download ZIP"**. Save the ZIP-folders wherever is easy for you to find them (we won´t be needing them for too long).

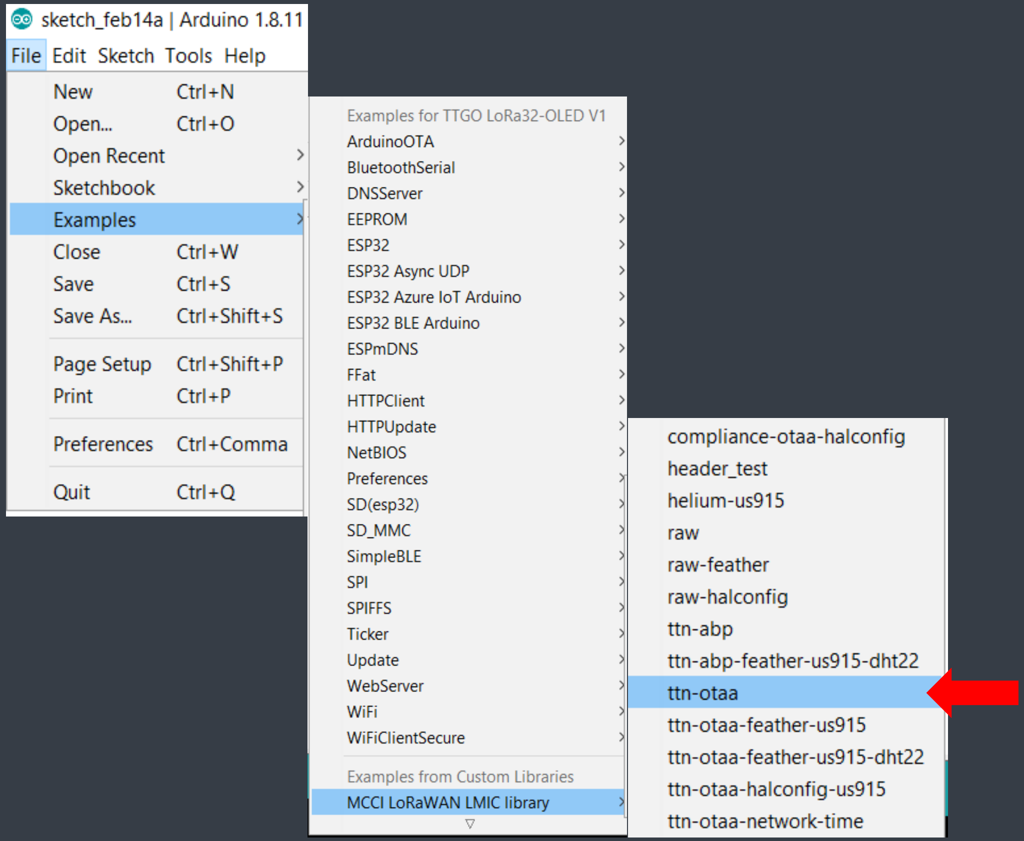
For the next step, open the Arduino IDE environment and go to the Sketch menu, then select **"Include Library"** and **"Add .ZIP Library"**. Here you will select the ZIP-folders downloaded in the step before and the libraries will be added to the Libraries folder of Arduino (After this step the ZIP-folders won´t be needed anymore).





THE CODE

- Inside the Arduino environment go to the File menu, select “**Examples**”, search for the **MCCI LoRaWAN LMIC library** and then click on the “**ttn-otaa**” example.



- The first three Libraries showed below are already included in the example, the other three need to be added as well as the **CayenneLPP lpp(51)** and **DHT12 dht12** instructions. They are important for the functioning of the sensor and encryption of the data.

```
#include <lmic.h>
#include <hal/hal.h>
#include <SPI.h>
#include <CayenneLPP.h>
#include <Dht12.h>
#include <Wire.h> //The DHT12 uses I2C comunication.
CayenneLPP lpp(51);
DHT12 dht12;      //Preset scale CELSIUS and ID 0x5c.
```

- **Note:** The **Wire.h** library is a default library of Arduino, we do not need to download it.

- Next thing that will come up in the program is this chunk of code, it needs to be **removed** or it will cause problems when trying to compile and upload to the board.

```
//
// For normal use, we require that you edit the sketch to replace FILLMEIN
// with values assigned by the TTN console. However, for regression tests,
// we want to be able to compile these scripts. The regression tests define
// COMPILE_REGRESSION_TEST, and in that case we define FILLMEIN to a non-
// working but innocuous value.
//
#ifdef COMPILE_REGRESSION_TEST
# define FILLMEIN 0
#else
# warning "You must replace the values marked FILLMEIN with real values from the TTN control panel!"
# define FILLMEIN (#dont edit this, edit the lines that use FILLMEIN)
#endif
```

- This part of the program plays a very important role but it requires a further explanation, for now we will leave it as it is.

```
// This EUI must be in little-endian format, so least-significant-byte
// first. When copying an EUI from ttnctl output, this means to reverse
// the bytes. For TTN issued EUIs the last bytes should be 0xD5, 0xB3,
// 0x70.
static const u1_t PROGMEM APPEUI[8]={ FILLMEIN };
void os_getArtEui (u1_t* buf) { memcpy_P(buf, APPEUI, 8);}

// This should also be in little endian format, see above.
static const u1_t PROGMEM DEVEUI[8]={ FILLMEIN };
void os_getDevEui (u1_t* buf) { memcpy_P(buf, DEVEUI, 8);}

// This key should be in big endian format (or, since it is not really a
// number but a block of memory, endianness does not really apply). In
// practice, a key taken from ttnctl can be copied as-is.
static const u1_t PROGMEM APPKEY[16] = { FILLMEIN };
void os_getDevKey (u1_t* buf) {  memcpy_P(buf, APPKEY, 16);}
```

- The value of **TX_INTERVAL** can be changed to increase or decrease the time the board will wait to send a payload. The given value represent the amount of seconds.

```
// Schedule TX every this many seconds (might become longer due to duty
// cycle limitations).
const unsigned TX_INTERVAL = 60;
```

- The Pin mapping needs to be changed so that it matches the Pins of the TTGO LoRa32 V1.

PIN Mappings

Heltec Wifi LoRa 32, TTGO LoRa and TTGO LoRa32 V1:

```
ESP32          LoRa (SPI)     Display (I2C)  LED
-----------    ----------     -------------  ------------------
GPIO5  SCK     SCK
GPIO27 MOSI    MOSI
GPIO19 MISO    MISO
GPIO18 SS      NSS
GPIO14         RST
GPIO26         DIO0
GPIO33         DIO1
GPIO32         DIO2
GPIO15                        SCL
GPIO4                         SDA
GPIO16                        RST
GPIO25                                       Heltec, TTGO LoRa32
GPIO2                                        TTGO LoRa
```

BEFORE

```
// Pin mapping
const lmic_pinmap lmic_pins = {
    .nss = 6,
    .rxtx = LMIC_UNUSED_PIN,
    .rst = 5,
    .dio = {2, 3, 4},
};
```

AFTER

```
// Pin mapping
const lmic_pinmap lmic_pins = {
    .nss = 18,
    .rxtx = LMIC_UNUSED_PIN,
    .rst = 14,
    .dio = {26, 33, 32},
};
```

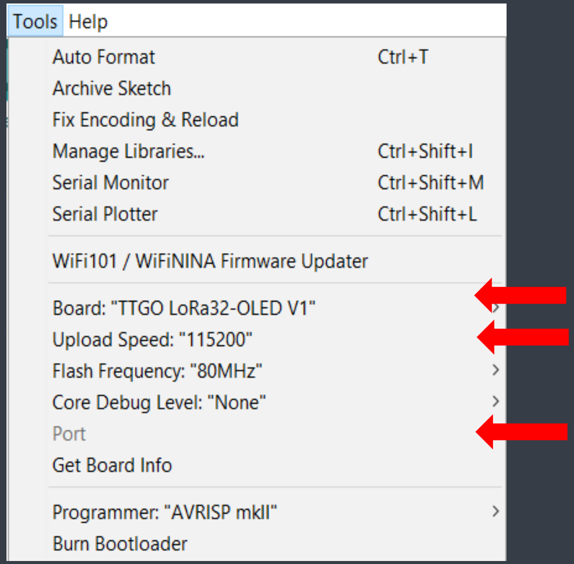
- **OPTIONAL:** This two chunks of code can be deleted or just be ignored, they have no influence on the functioning of the program.

```
/*
|| This event is defined but not used in the code. No
|| point in wasting codespace on it.
||
|| case EV_RFU1:
||      Serial.println(F("EV_RFU1"));
||      break;
*/
```

```
/*
|| This event is defined but not used in the code. No
|| point in wasting codespace on it.
||
|| case EV_SCAN_FOUND:
||     Serial.println(F("EV_SCAN_FOUND"));
||     break;
*/
```

- The **Wire.h** library has to be initialized in the **void setup()** with the instruction **Wire.begin().**
- The value of **Serial.begin()** should correspond to the **upload speed**, we can see this value in the **Tools** menu.
- Inside the Tools menu the **“TTGO LoRa32-OLED V1”** board and the **port** that is being used have to be selected, or the program won´t function.

```
void setup() {
    Serial.begin(115200);
    Serial.println(F("Starting"));

    Wire.begin();
    Serial.println(F("Wire begin"));
```



- The original program was written to send “Hello, world!” through LoRa, since we will be sending information from a sensor, the next line of code won´t be needed anymore.

```
static const u1_t PROGMEM APPKEY[16] = { FILLMEIN };
void os_getDevKey (u1_t* buf) {  memcpy_P(buf, APPKEY, 16);}

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

static osjob_t sendjob;
```

- The **void do_send(osjob_t*j)** function will contain the code and data wished to send. Start by writing inside of the else brackets, the following function from the Cayenne library and the temperature and humidity readings (which will be stored into variables).

```
void do_send(osjob_t* j){
    // Check if there is not a current TX/RX job running
    if (LMIC.opmode & OP_TXRXPEND) {
        Serial.println(F("OP_TXRXPEND, not sending"));
    } else {
        lpp.reset();
        float temp = dht12.readTemperature();
        float hum = dht12.readHumidity();
```

- Write then the following lines of code to print the values of temperature and humidity into the serial monitor, encrypt the values and set the data that will be sent by the board.

```
        Serial.printf("T:%2.2f°C H:%0.2f%%\n",temp,hum);
        lpp.addTemperature(1, temp);
        lpp.addRelativeHumidity(2, hum);
        LMIC_setTxData2(1,lpp.getBuffer(), lpp.getSize(), 0);
        Serial.println(F("Packet queued"));
    }
    // Next TX is scheduled after TX_COMPLETE event.
}
```

BAND AND VERSION CONFIGURATION

- In the **Libraries** folder of Arduino, look for the **“Arduino-lmic-master”** folder. Inside of it you will find another folder called **“project_config”** that contains the file **“lmic_project_confic.h”.** Open and edit this file so that it contains what it is shown in the picture.

- This is the configuration for choosing a LoRaWAN version, defining the region and frequency the program will be working with and selecting the transceiver our ESP32 module possesses.

- Our program is configurated to work with the designated frequency for Europe (868MHz), it uses the LoRaWAN version 1.0.2 and it has selected the sx1276 radio transceiver.

C lmic_project_config.h ×

C: > Projects > libraries > arduino-lmic-master > project_config > C lmic_project_config.h

```
// project-specific definitions
#define CFG_eu868 1
//#define CFG_us915 1
//#define CFG_au915 1
//#define CFG_as923 1
// #define LMIC_COUNTRY_CODE LMIC_COUNTRY_CODE_JP   /* for as923-JP */
//#define CFG_kr920 1
//#define CFG_in866 1
#define CFG_sx1276_radio 1
//#define LMIC_USE_INTERRUPTS
#define LMIC_LORAWAN_SPEC_VERSION   LMIC_LORAWAN_SPEC_VERSION_1_0_2
#define DISABLE_PING
#define LMIC_ENABLE_DeviceTimeReq 1
#define LMIC_PRINTF_TO Serial
```

EUIS AND KEY INFORMATION

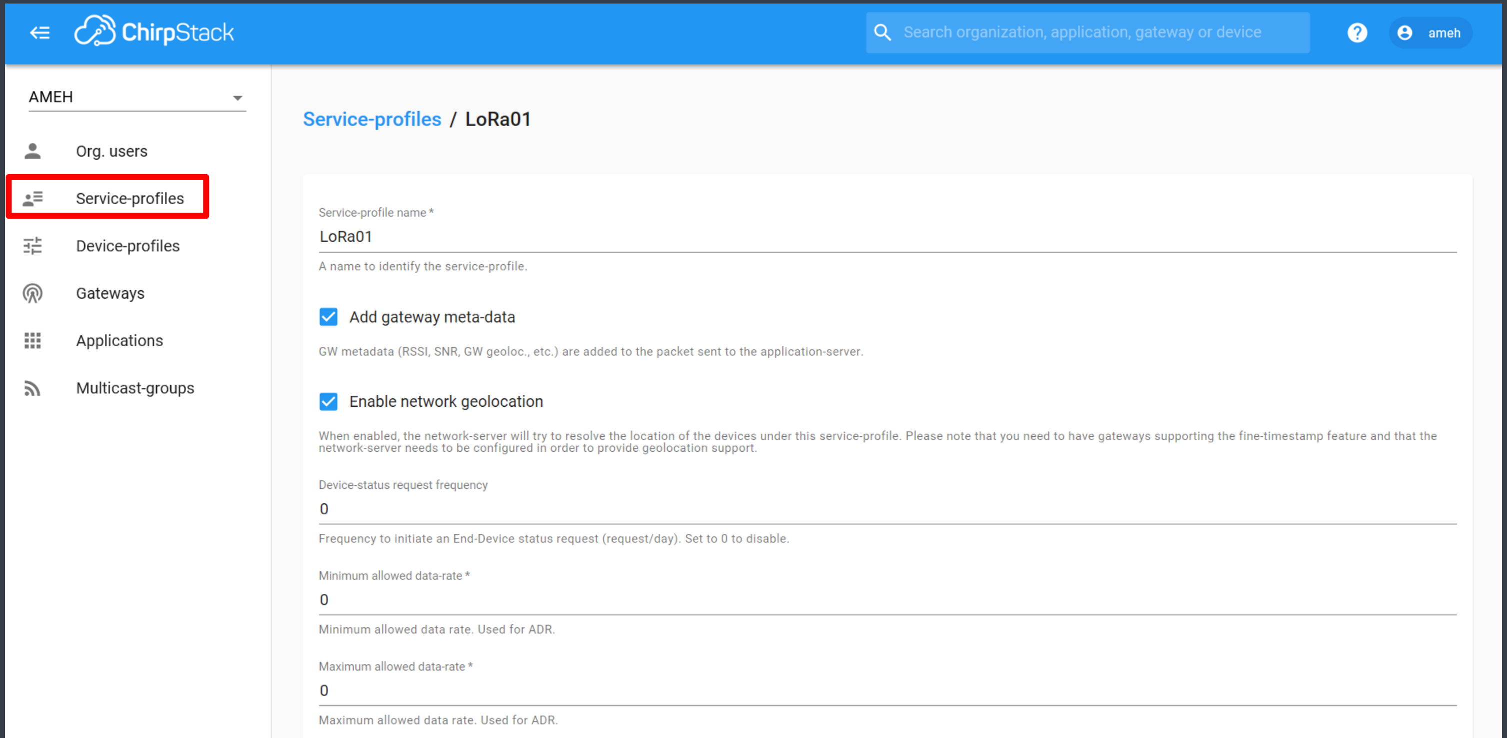
- **Device EUI**: It is a global end device ID in IEEE EUI64 address space that uniquely identifies the end device. The user can derive their own DevEUI.

- **Application Key**: The AppKey is an AES128 root key specific to the end device. Whenever an end device joins a network via over the air activation(OTAA), the AppKey is used to derive the session keys NwkSKey and AppSKey specific for that end device to encrypt and verify network communication and application data. The AppKey should be unique for each device.The user can derive their own AppKey.

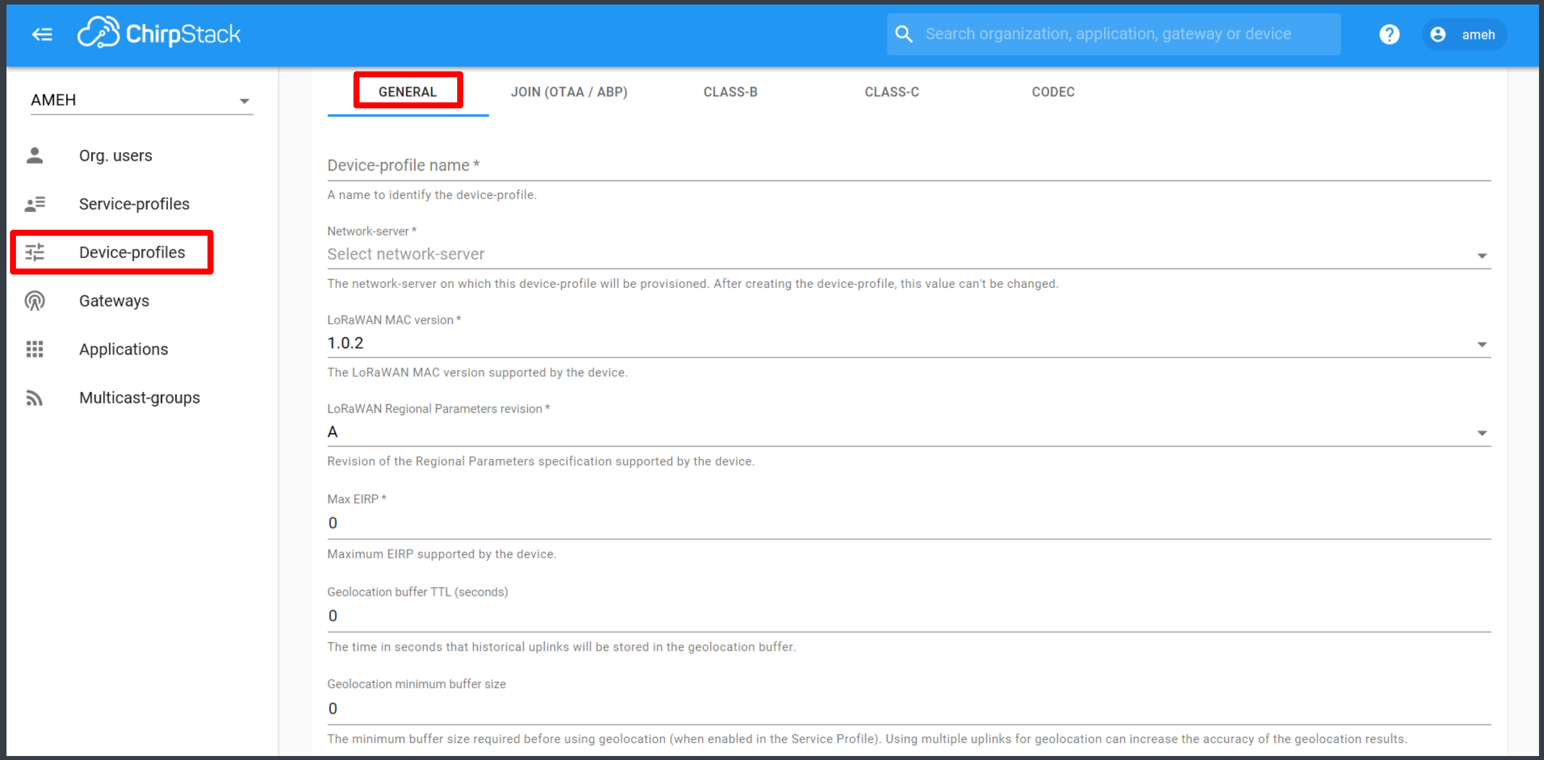
- **Application EUI**: It is a global application ID in IEEE EUI64 address space that uniquely identifies the entity able to process the JoinReq frame. The AppEUI is stored in the end-device before the activation procedure is executed. The AppEUI can be different for each device or it can also be same for all device. It also depends on what kind of application server you are using. The user can derive their own AppEUI.

SETTING UP THE SERVER

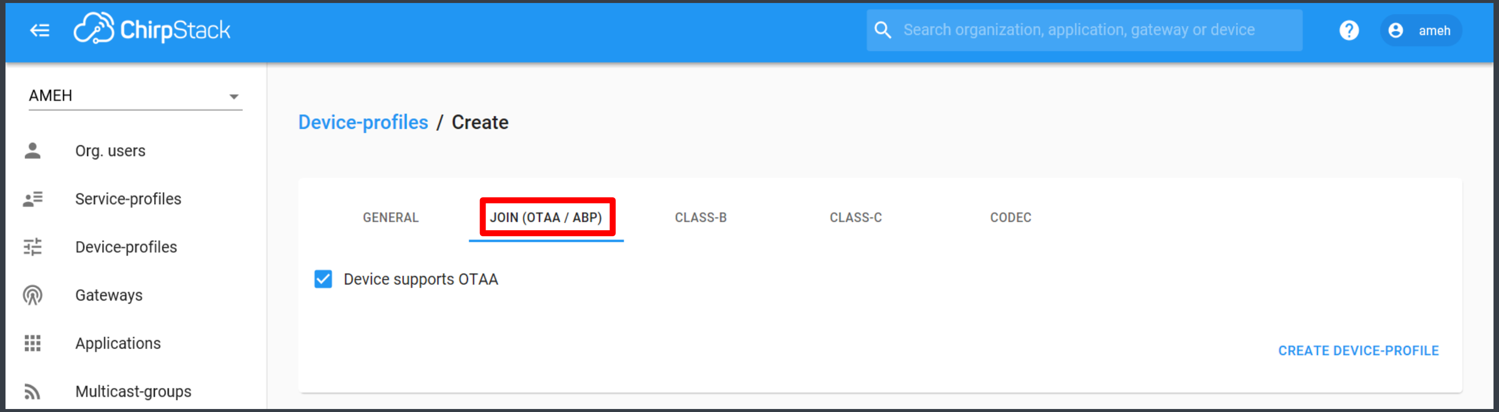
- For this project a ChirpStack server was used to receive the data from the board. After logging into the server a **Service-profile** needs to be created if there no existing one yet. Click in "**Service-profiles**" and create a new one with the following specifications (the name given is completely optional):

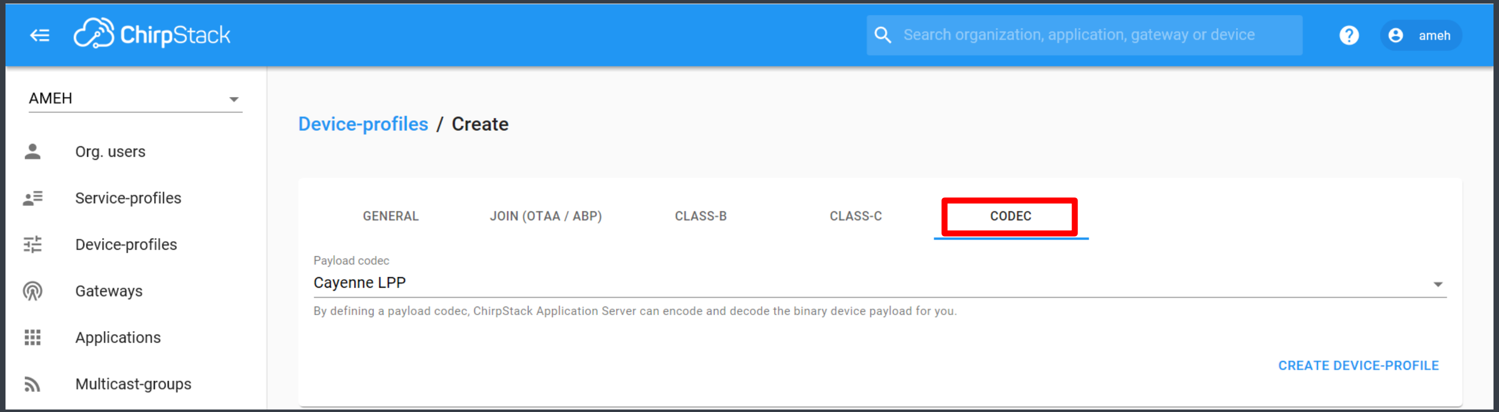


- As following click on “**Device-profiles**” and create a new one, give in the following specifications and select the created **Service-profile** for the “**Network server**” field. There are still other configurations that need to be done, so **do not create** the profile yet.



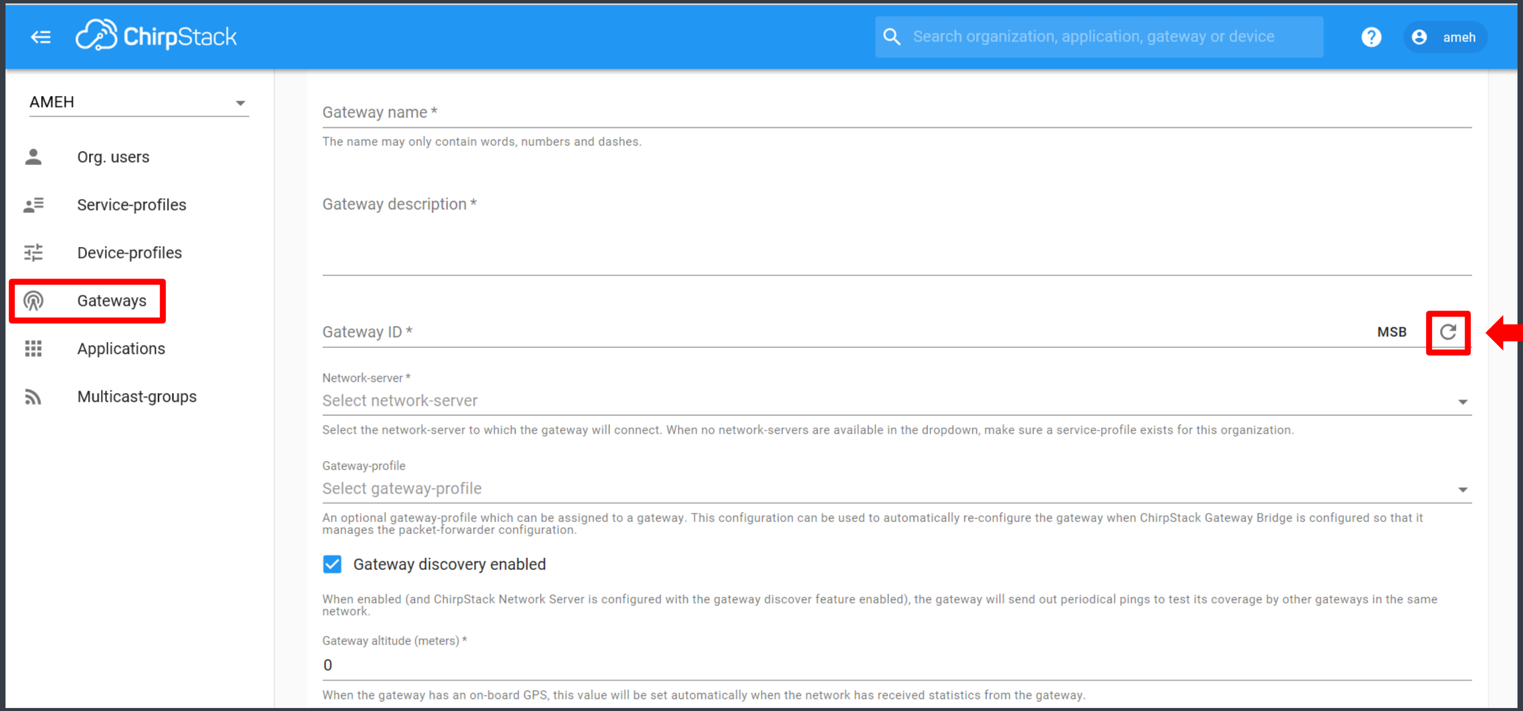
- Enable **“Device supports OTAA”** (over the air activation) and select **“Cayenne LPP”** as codec for the Payload. After this two steps click on **“create Device-profile”**:





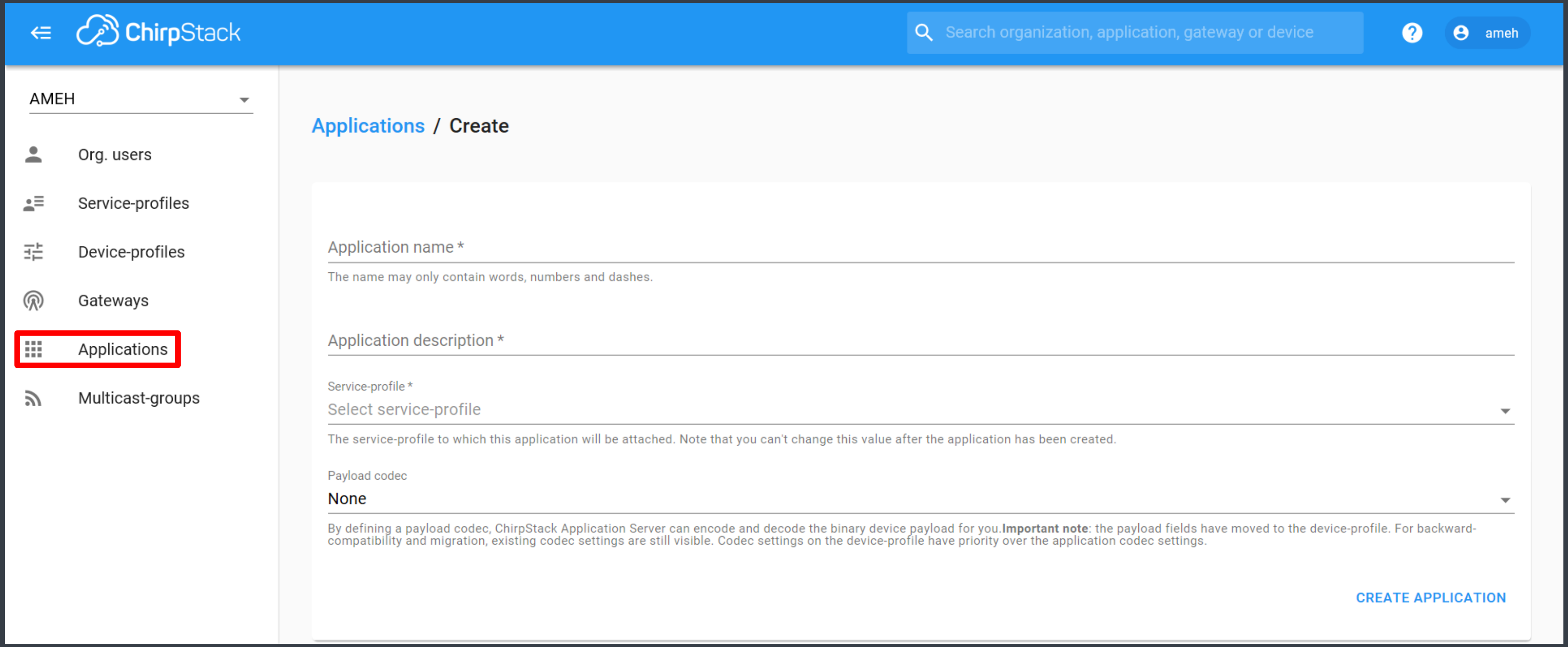
- In order to receive data from the board a gateway needs to be created. Important here is the **Gateway ID**, most antennas and gateway devices have their own ID. If the device has no ID, one can be randomly generated by clicking in the arrow on the right side of the window.

- Select the created Service-profile for the **“Network server”** field, enable **the “Gateway discovery”** and then create the gateway.

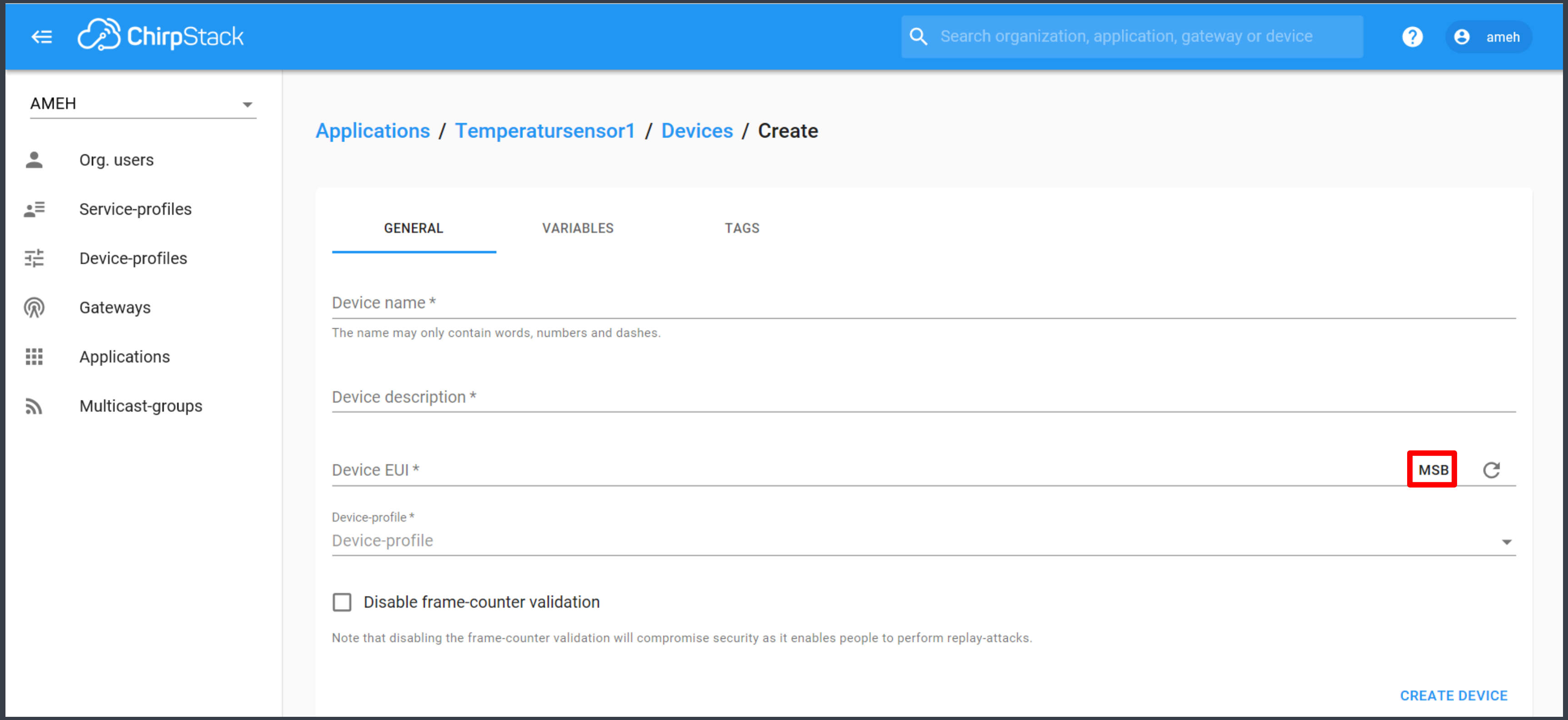


Generate random ID

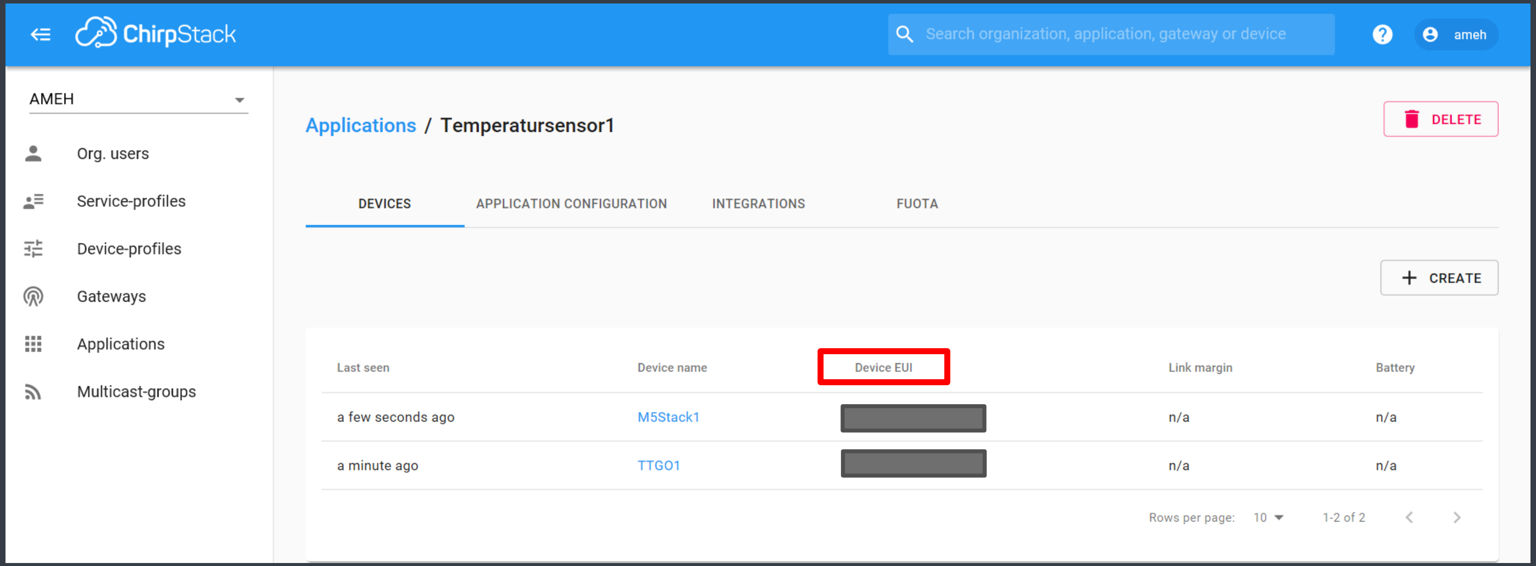
- Go to “**Applications**” and create a new application. Write a name and a description, give in the Service-profile and select “**None**” as Payload codec.



- Once the application is created, click on it and it will allow you to create devices inside of the chosen application. Some devices already have their own **Device EUI**. If there is no given EUI, a random one can be generated by clicking on the arrow button.
- It is important to change the **DevEUI** format from **"Most Significant Byte" (MSB)** to **"Least Significant Byte" (LSB)** before generating the EUI. This can be done by clicking on MSB.

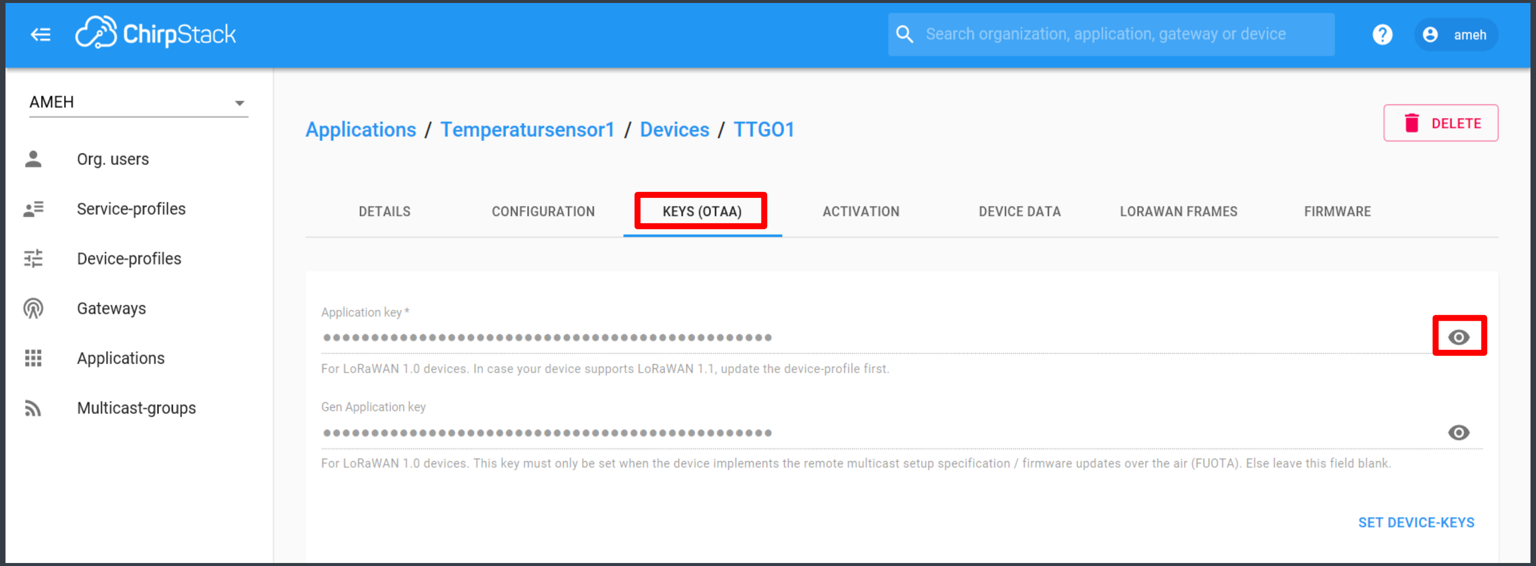


- Once the device is created it should be visible every time the application where it was created is open. The **Device EUI** of each device will be also shown.

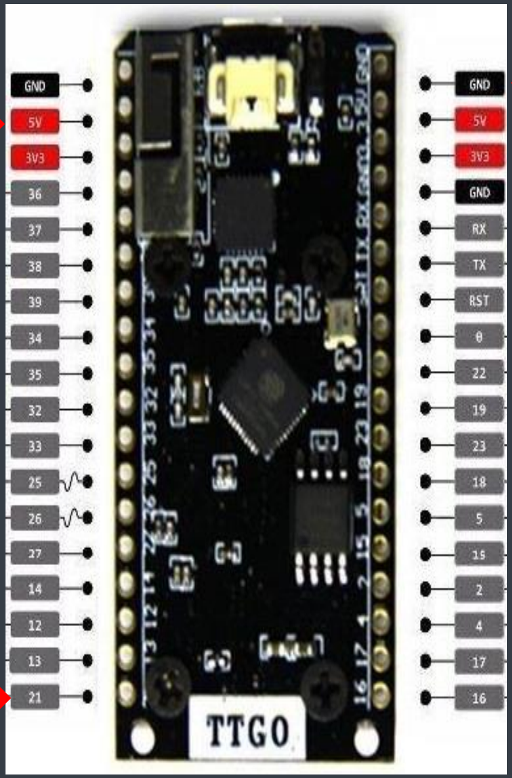


- By clicking on the device name a new window will be open. All the device information will be shown here as well as the **Application key**, which will be later needed for the over the air activation.

- Clicking on the eye symbol will allow you to see the Appkey.



CONNECTING THE SENSOR



- Ground has to be connected to any of the **“GND”** pins in the board.
- The voltage wire should go to any of the **“5V”** pins.
- Connect **“SDA”** to pin 21.
- Connect **“SCL”** to pin 22.

APPLYING THE KEYS TO THE PROGRAM

- The **AppEUI** and **DevEUI** have to be written in <u>**little endian format**</u> this means least significant byte first. If the DevEUI was generated in LSB format then the EUI can be written in the order it appears. If not, the order has to be reversed. Here is an example:

    DevEUI (MSB): ab12cd34ef56gh78
    DevEUI (LSB): 78gh56ef34cd12ab
    DevEUI (program): 0x78, 0xgh, 0x56, 0xef, 0x34, 0xcd, 0x12, 0xab

- Since the ChirpStack server does not provide us with the **AppEUI** one has to be made up. The format to write it, is the same as in the example above.

    AppEUI: 0x45, 0x23, 0x01, 0x89, 0x67, 0x45, 0x23, 0x01

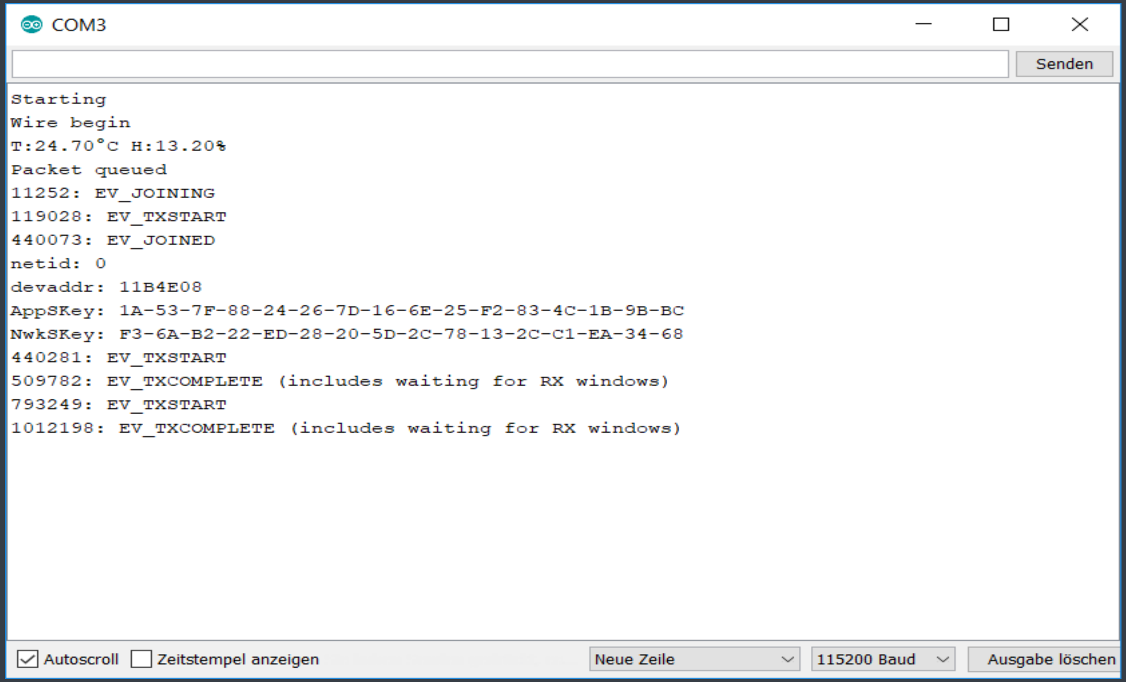
- The **AppKey** can be written in the format given by the server (MSB), it will only be needed to add **"0x** _ _ **,"** every two characters, so that it can be accepted in the array.

    Appkey: 0x11, 0x2a, 0x33, 0x4b, 0x55, 0x6c, 0x77, 0x8d, 0x99, 0x1e, 0x22, 0x3f, 0x44, 0x5g, 0x66, 0x7h

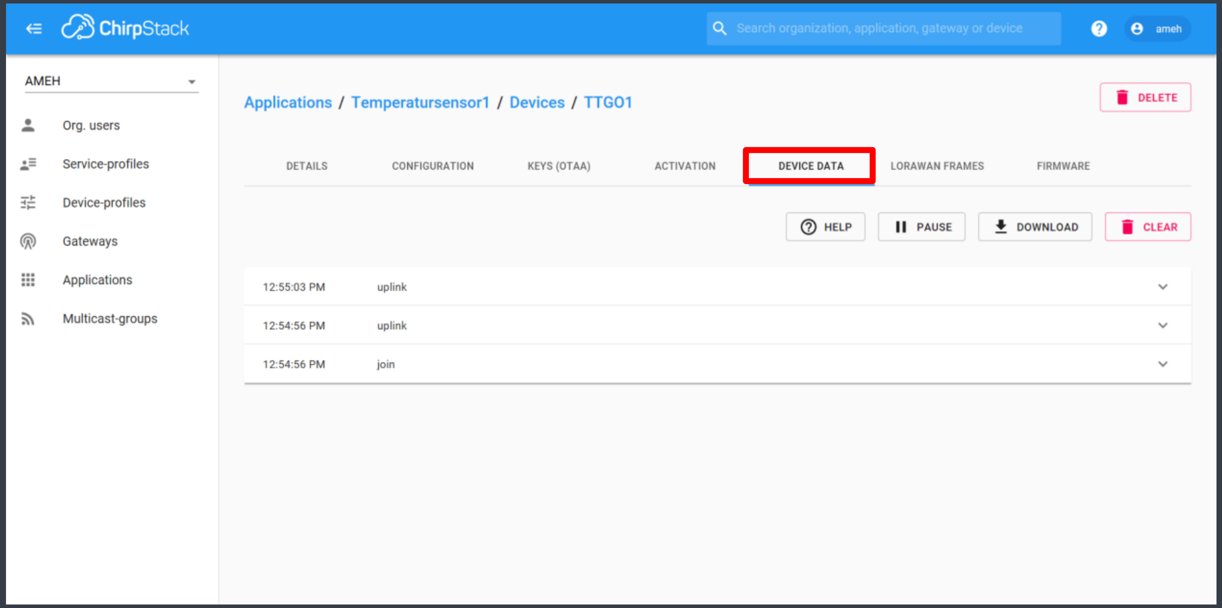
```
// This EUI must be in little-endian format, so least-significant-byte
// first. When copying an EUI from ttnctl output, this means to reverse
// the bytes. For TTN issued EUIs the last bytes should be 0xD5, 0xB3,
// 0x70.
static const u1_t PROGMEM APPEUI[8]={ 0x78, 0xgh, 0x56, 0xef, 0x34, 0xcd, 0x12, 0xab };
void os_getArtEui (u1_t* buf) { memcpy_P(buf, APPEUI, 8);}

// This should also be in little endian format, see above.
static const u1_t PROGMEM DEVEUI[8]={ 0x45, 0x23, 0x01, 0x89, 0x67, 0x45, 0x23, 0x01 };
void os_getDevEui (u1_t* buf) { memcpy_P(buf, DEVEUI, 8);}

// This key should be in big endian format (or, since it is not really a
// number but a block of memory, endianness does not really apply). In
// practice, a key taken from ttnctl can be copied as-is.
static const u1_t PROGMEM APPKEY[16] = { 0x11, 0x2a, 0x33, 0x4b, 0x55, 0x6c, 0x77, 0x8d, 0x99, 0x1e,0x22, 0x3f, 0x44, 0x5g, 0x66, 0x7h };
void os_getDevKey (u1_t* buf) {  memcpy_P(buf, APPKEY, 16);}
```

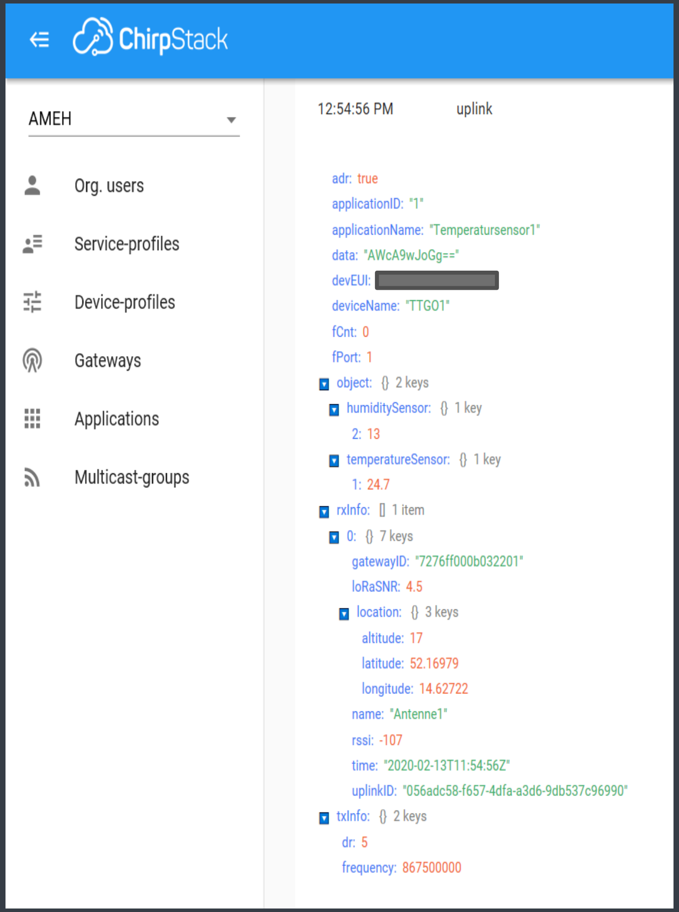
RUNNING THE PROGRAM

- Make sure the board is connected to the PC with the USB to MicroUSB cable and that the correct upload speed and port are selected so that you can compile and upload the program. Once you have uploaded all the code, open the serial monitor and something like this should come up. The **device address** will be generated as well as the **AppSKey** and **NwkSKey**.



- Open the application and select the created device, if everything was correct the server should be receiving the data from the board. The data can be seen in the menu **“Device Data”**. The data displayed should look like this





SOURCES

- https://www.thethingsnetwork.org/forum/t/big-esp32-sx127x-topic-part-3/18436
- https://www.bjoerns-techblog.de/2019/02/adr-mit-the-things-network/
- https://www.thethingsnetwork.org/forum/t/solved-adafruit-feather-m0-to-connect-to-ttn-over-otaa-unknown-event-20/29990
- https://stackoverflow.com/questions/54096980/lorawan-deveui-appeui-and-appkey
- https://m5stack.com/products/mini-env-sensor-unit?variant=16804795940954
- https://github.com/mcci-catena/arduino-lmic/blob/master/README.md