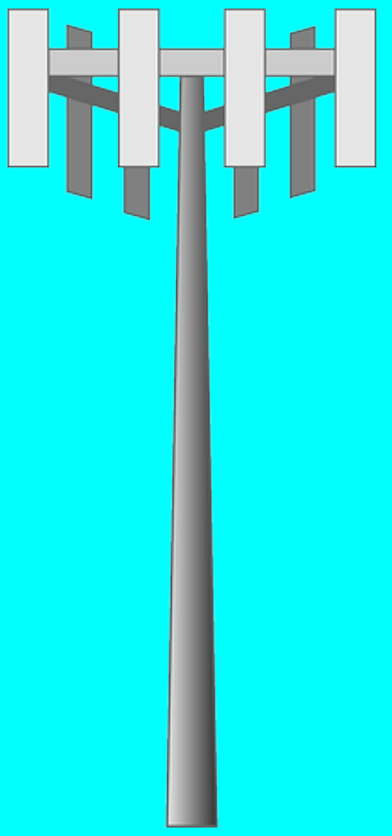
mobilefish.com

# LORA / LORAWAN TUTORIAL 51

## LoRaWAN Gateway with Cellular Backhaul – RAK7244C



v1.3.0

# INTRO

- In this tutorial I will demonstrate how to configure the RAK7244C Developer Gateway (aka WisGate Developer D4+).

# RAK

IoT Made Easy

# DISCLAIMER

- I would like to thanks RakWireless for sending me this sponsored product.
- It is the RAK7244C LoRaWAN Developer Gateway (aka WisGate Developer D4+).
- I find this particular gateway interesting because it has a cellular backhaul which has not been featured in my previous tutorials.

# PRESENTATION

- This presentation can be found at:
  https://www.mobilefish.com/download/lora/lora_part51.pdf

- All my LoRa/LoRaWAN tutorials and presentations can be found at:
  https://www.mobilefish.com/developer/lorawan/lorawan_quickguide_tutorial.html

# RAKWIRELESS MANY DEVELOPER GATEWAYS

- While going thru RAKWireless documentation I was a little bit confused of their many developer gateways.

- In case you are interested in one their developer gateways, in the next slides I will give you a quick explanation what the differences are.

- The RAK developer gateways or sometimes called RAK pilot gateways are ideal for prototyping, proof-of concept evaluation or for demonstration purposes.

# RAK831 Pilot Gateway

# RAK831 PILOT GATEWAY

- In tutorial 28 and 28.1 I have explained the RAK831 Pilot Gateway.


# RAK831 PILOT GATEWAY

- The RAK831 Pilot Gateway is shipped with:

**Raspberry Pi 3 model B+**


**Converter board with GPS**


**RAK831 LoRa Concentrator module**

- RAKWireless has discontinued manufacturing the RAK831 Pilot Gateway, but you can buy it as "LPWAN Gateway Developer Kit - Kit 7'' without the aluminium enclosure. https://store.rakwireless.com/collections/kits-bundles/products/lpwan-gateway-developer-kit

# LPWAN GATEWAY DEVELOPER KIT - KIT 7


**LPWAN Gateway Developer kit**

**LoRa Gateway with no aluminium enclosure**

# RAK7243 Developer Gateway (aka WisGate Developer D3)

&

# RAK7243C Developer Gateway (aka WisGate Developer D3+)

# RAK7243 AND RAK7243C DEVELOPER GATEWAY

- RAKWireless made improvements to the RAK 831 Pilot Gateway and its successor (upgrade) is called the RAK7243 Developer Gateway.
  This gateway uses the Raspberry Pi 3 model B+ and has two variants:
  - No LTE (cellular) functionality: **RAK7243 Developer Gateway**.
  - With LTE (cellular) functionality: **RAK7243C Developer Gateway**.


# RAK7243 AND RAK7243C DEVELOPER GATEWAY

- The RAK7243 and RAK7243C Developer Gateway is shipped with:

**Raspberry Pi 3 model B+**

**RAK2245 Pi Hat**
**Concentrator module**
**LoRa + GPS**

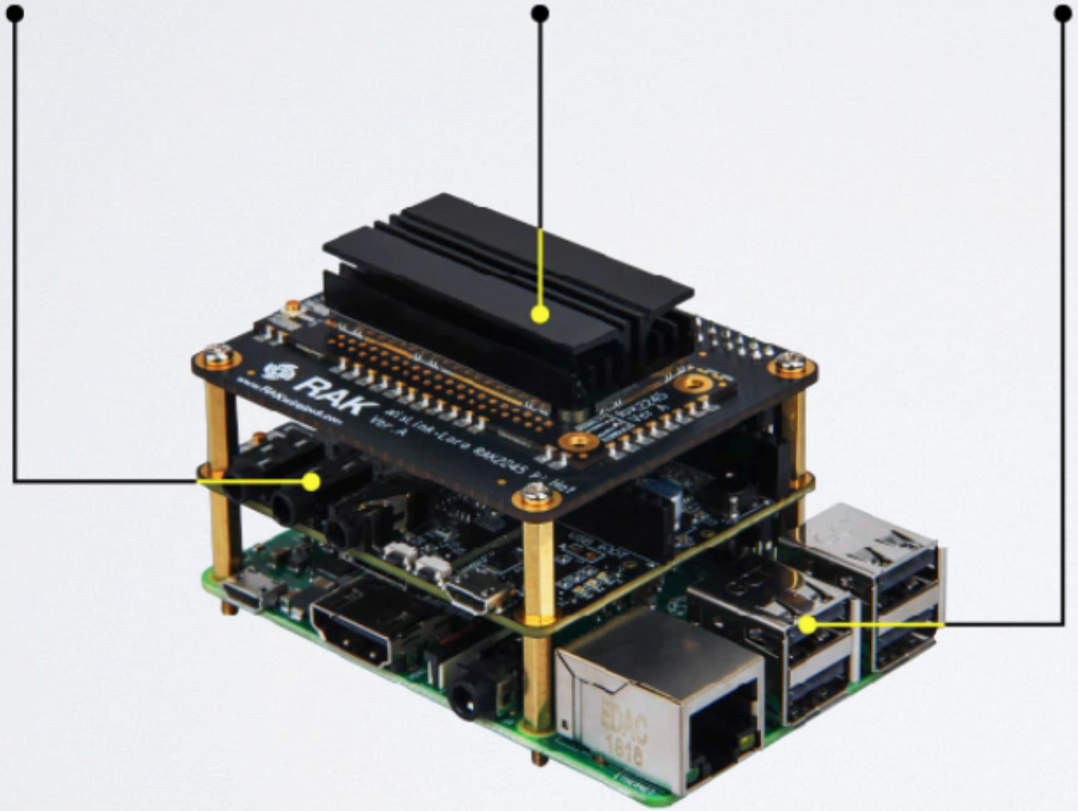
**(Optional) RAK2013 Pi Hat**
**LTE module for**
**RAK7243C Developer Gateway**

# RAK7243 AND RAK7243C DEVELOPER GATEWAY

**(Optional)**
**RAK2013 Pi Hat**
**LTE module for**
**RAK7243C**
**Developer Gateway**

**RAK2245 Pi Hat**
**Concentrator**
**module**

**Raspberry Pi 3 model B+**



# RAK7243 AND RAK7243C DEVELOPER GATEWAY

- More information about these gateways, see:
  - **RAK7243 Developer Gateway (WisGate Developer D3)**
    https://doc.rakwireless.com/rak7243--lorawan----developer-gateway
  - **RAK7243C Developer Gateway (WisGate Developer D3+)**
    https://doc.rakwireless.com/rak7243c-lorawan----developer-gateway
- Shop:
  https://store.rakwireless.com/products/rak7243c-pilot-gateway

# RAK7244 Developer Gateway (aka WisGate Developer D4)

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# RAK7244C Developer Gateway (aka WisGate Developer D4+)

# RAK7244 AND RAK7244C DEVELOPER GATEWAY

- The RAK7243 Developer Gateway is redesigned for the Raspberry Pi4, this new gateway is called the RAK7244 Developer Gateway.
  This gateway has two variants:
  - No LTE (cellular) functionality: **RAK7244 Developer Gateway**.
  - With LTE (cellular) functionality: **RAK7244C Developer Gateway**.


# RAK7244 AND RAK7244C DEVELOPER GATEWAY

- The RAK7244 and RAK7244C Developer Gateway is shipped with:

**Raspberry Pi 4 model B**


**RAK2245 Pi Hat**
**Concentrator module**
**LoRa + GPS**

**(Optional) RAK2013 Pi Hat**
**LTE module for**
**RAK7244C Developer Gateway**

# RAK7244 AND RAK7244C DEVELOPER GATEWAY

**(Optional)**
**RAK2013 Pi Hat**
**LTE module for**
**RAK7244C**
**Developer Gateway**

**RAK2245 Pi Hat**
**Concentrator**
**module**

**Raspberry Pi 4**
**model B**

# RAK7244 AND RAK7244C DEVELOPER GATEWAY

- More information about these gateways, see:
  - **RAK7244 Developer Gateway (WisGate Developer D4)**
    https://doc.rakwireless.com/rak7244-lorawan----developer-gateway
  - **RAK7244C Developer Gateway (WisGate Developer D4+)**
    https://doc.rakwireless.com/rak7244c-lorawan----developer-gateway
- Shop:
  https://store.rakwireless.com/collections/lora-gateways-concentrators/products/rak7244-developer-lorawan-gateway

# RAK7244 AND RAK7244C DEVELOPER GATEWAY

- This video is mainly focussed on the RAK7244C LoRaWAN developer gateway.
- The RAK7244 and RAK7244C are almost identical with the exception of the cellular hardware components.

# RAKWIRELESS ONLINE STORES

- RAKWireless has their own online web store:
  https://store.rakwireless.com/

- RAKWireless also offer the same products on AliExpress, which is a Chinese online retail service where businesses can sell products to international online buyers.
  On AliExpress the store is called RAK Wireless Store:
  https://www.aliexpress.com/store/2805180

- One of the major differences between the two shops is they way the products are shipped. On their own web store they are using the well know shipping companies: DHL/UPS and FedEx. On AlixExpress you can also choose "AliExpress Standard Shipping", with lower shipping costs but the delivery is not fast compared to DHL/UPS and FedEx.

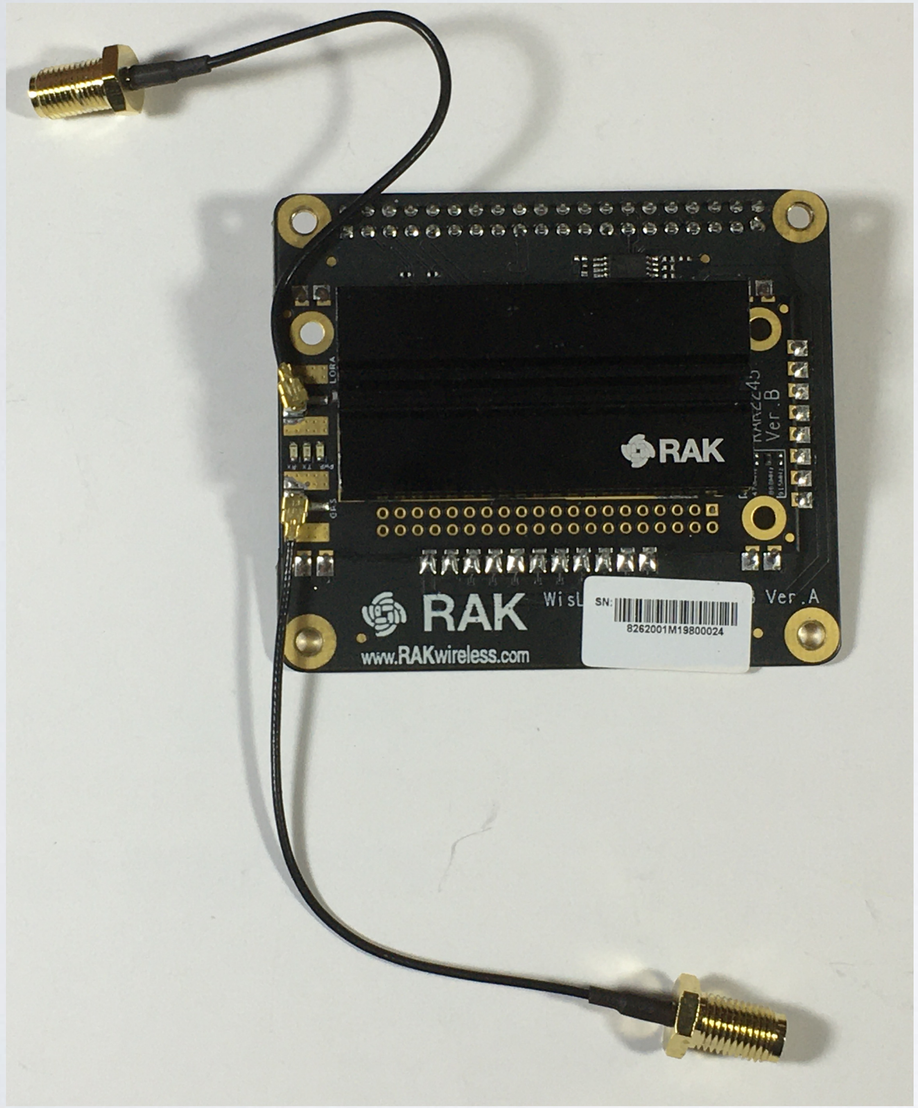
# RAK7244C LoRaWAN Developer Gateway (WisGate Developer D4+)

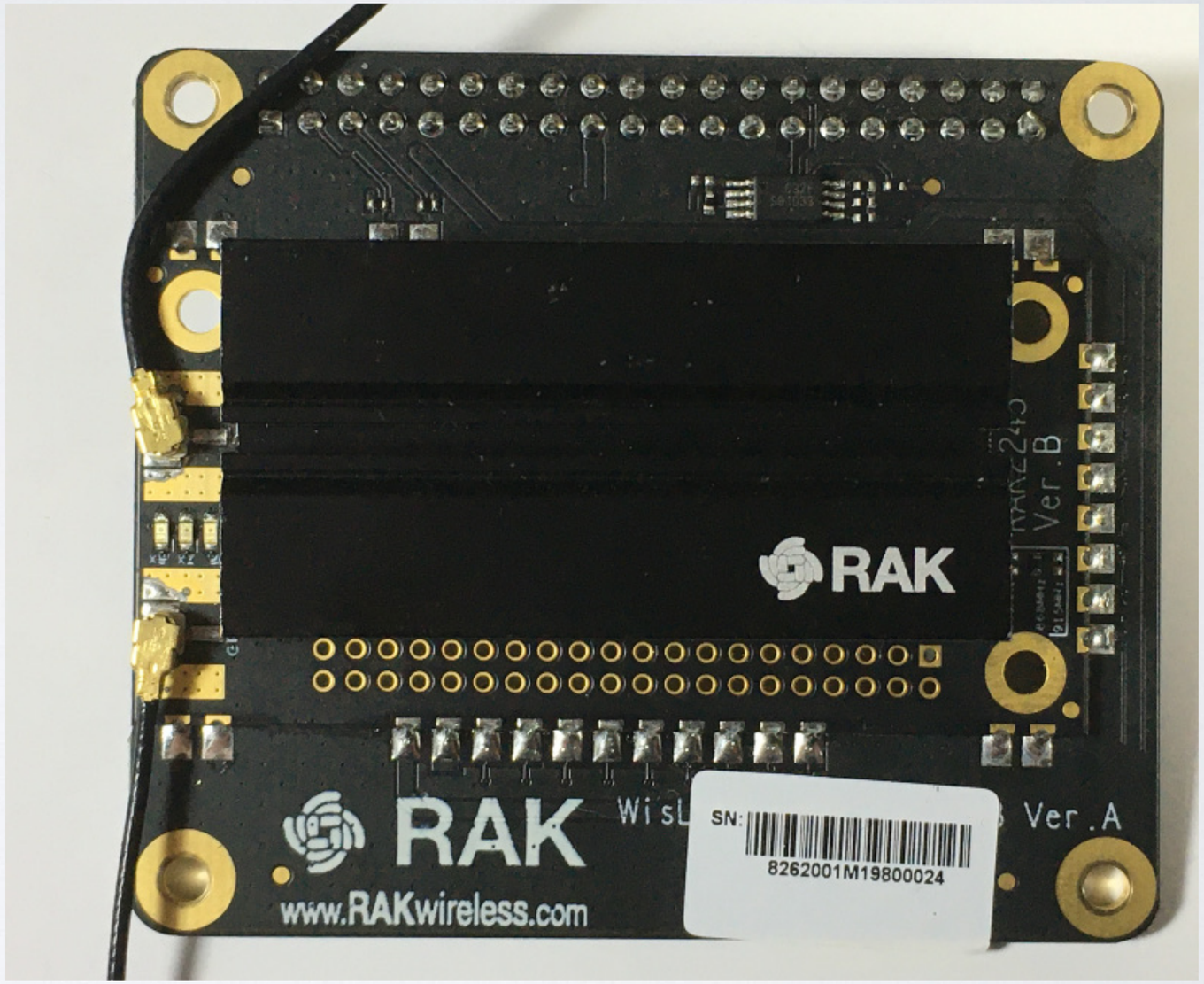
# RAK7244C FEATURES

- Aluminium enclosure with Raspberry Pi 4 model B
  Full LoRaWAN Stack support version 1.0.2
  Supports for 8 channels and spreading factors (SF7-SF12)
  Band support: 433MHz, 470MHz, 865MHz, 868MHz, 915MHz, 920MHz, 923MHz
  Tx Power max: 27 dBm
  Rx Sensitivity: -139 dBm
  Ublox MAX-7Q GPS module
  Quectel EG95 LTE module

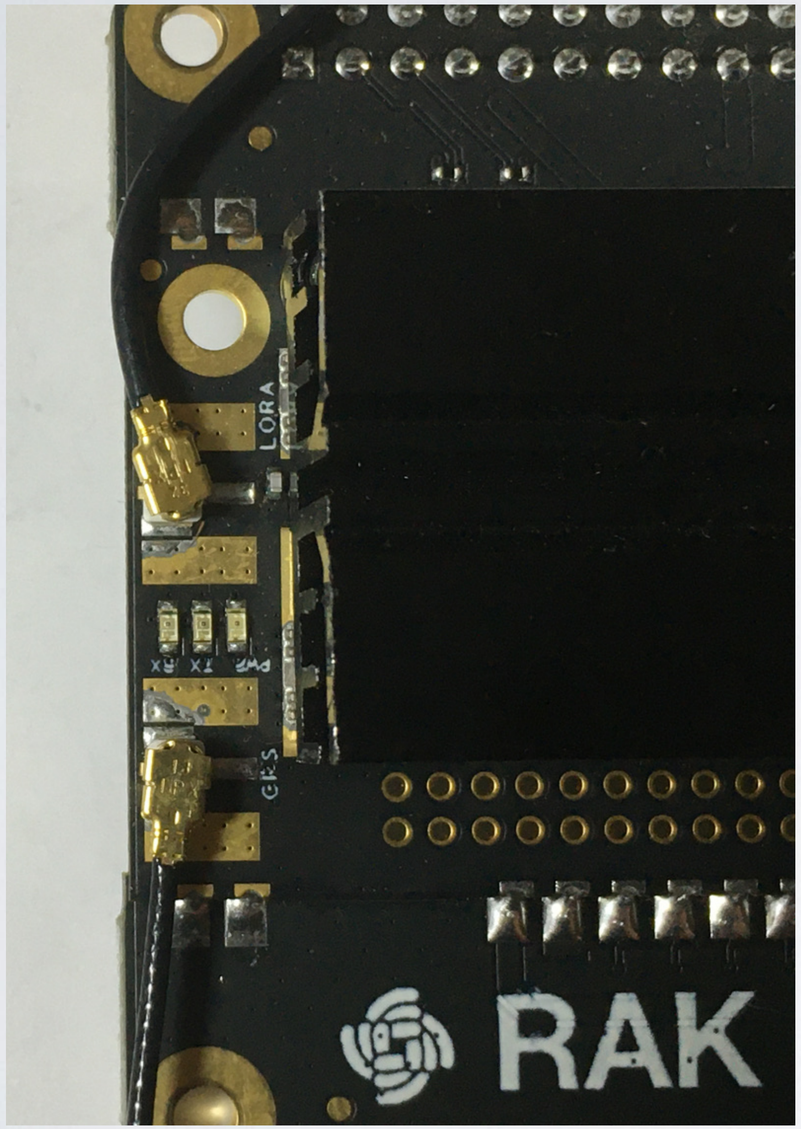
- Datasheet
  https://doc.rakwireless.com/datasheet/rakproducts/rak7244c-lorawan-developer-gateway-datasheet

# RAK2245 PI HAT CONCENTRATOR MODULE

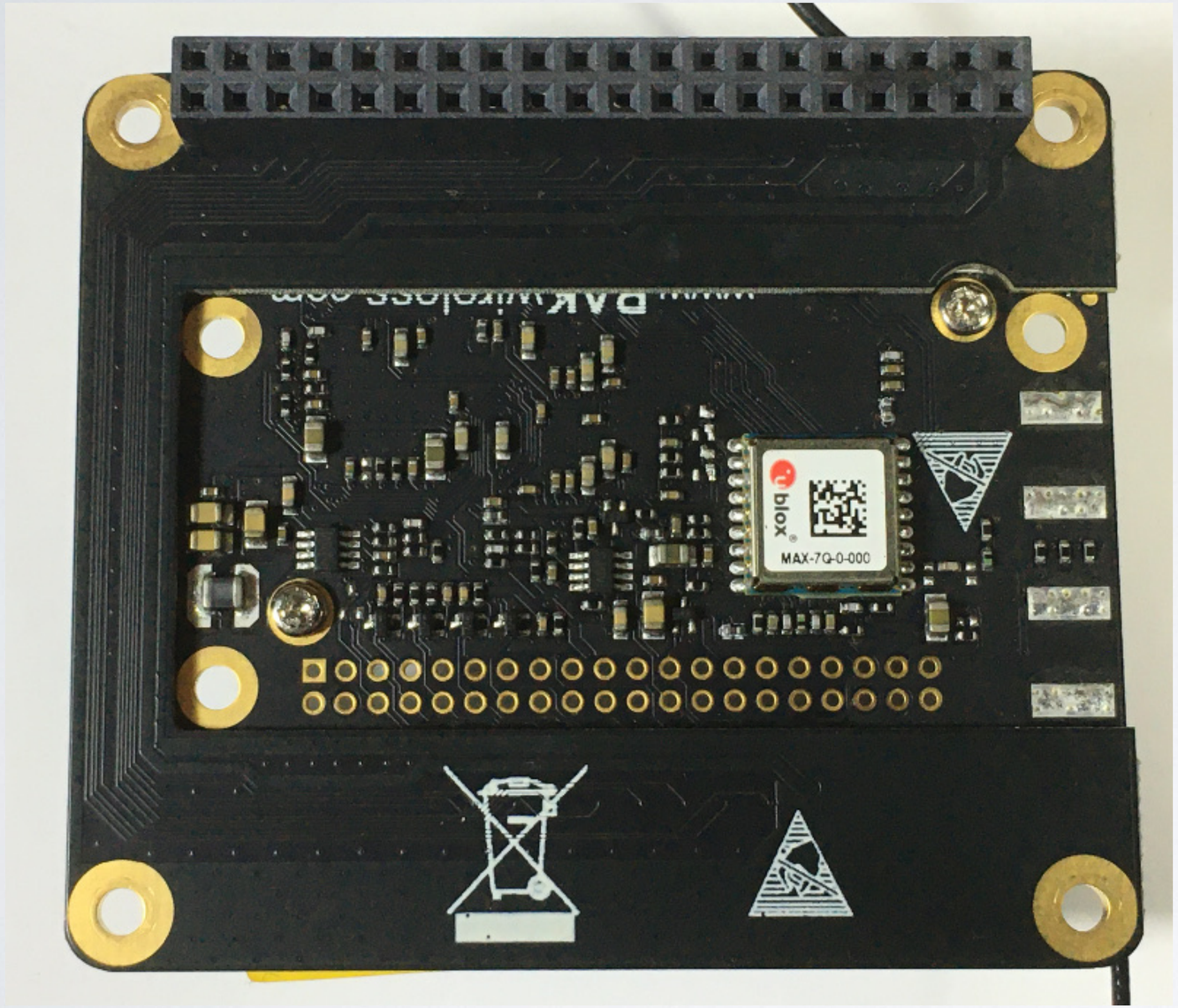


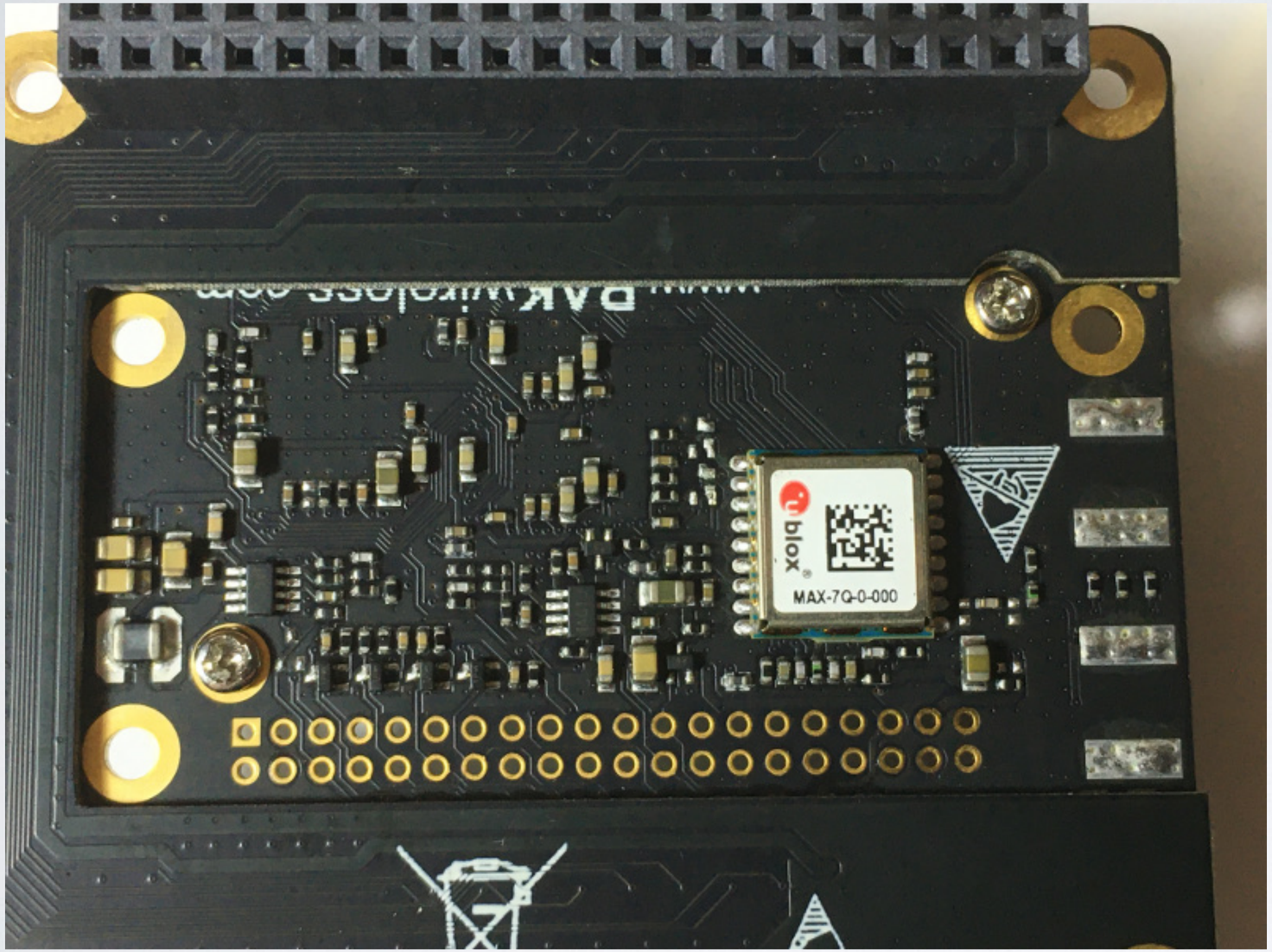
# RAK2245 PI HAT CONCENTRATOR MODULE



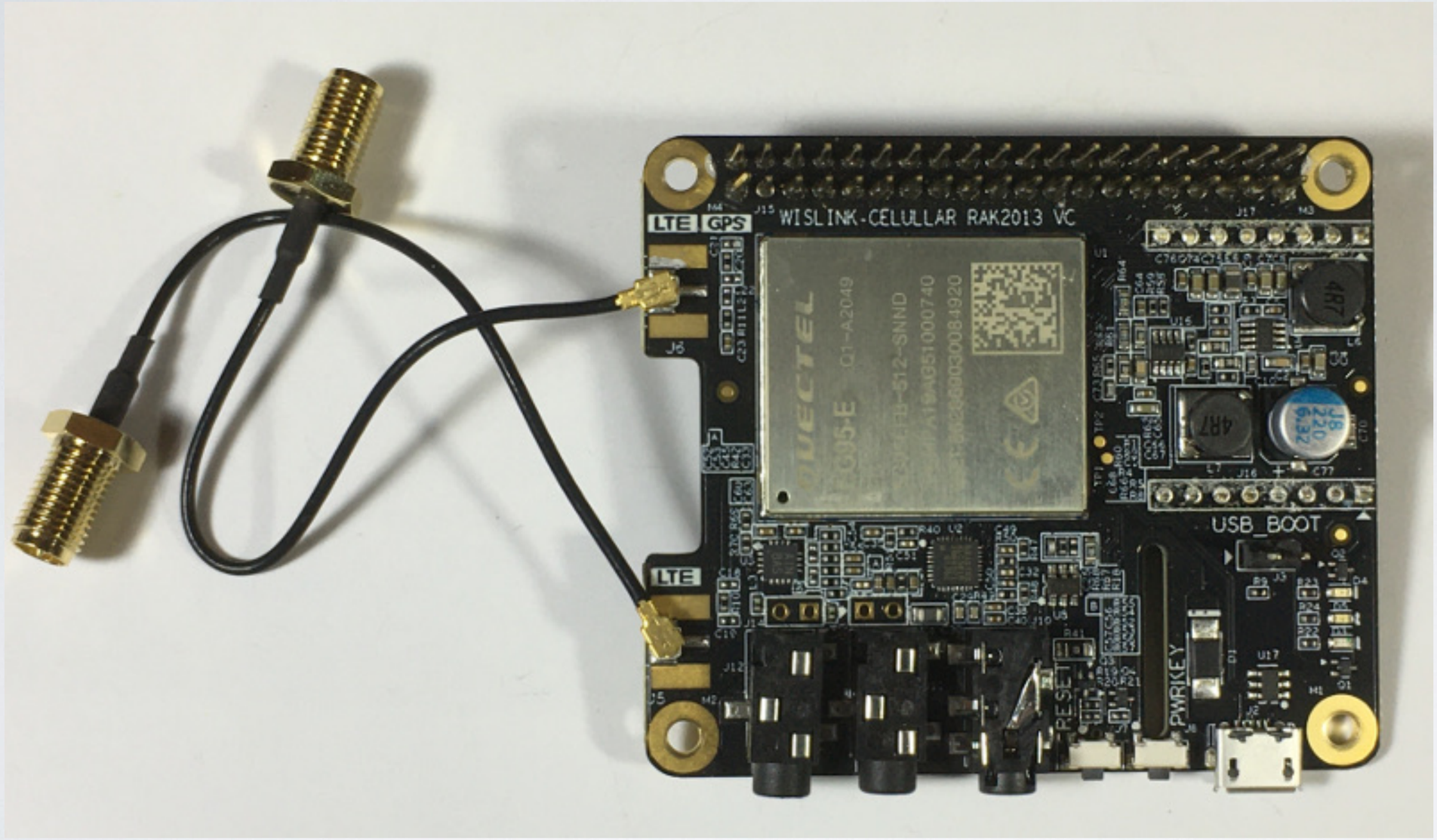
# RAK2245 PI HAT CONCENTRATOR MODULE



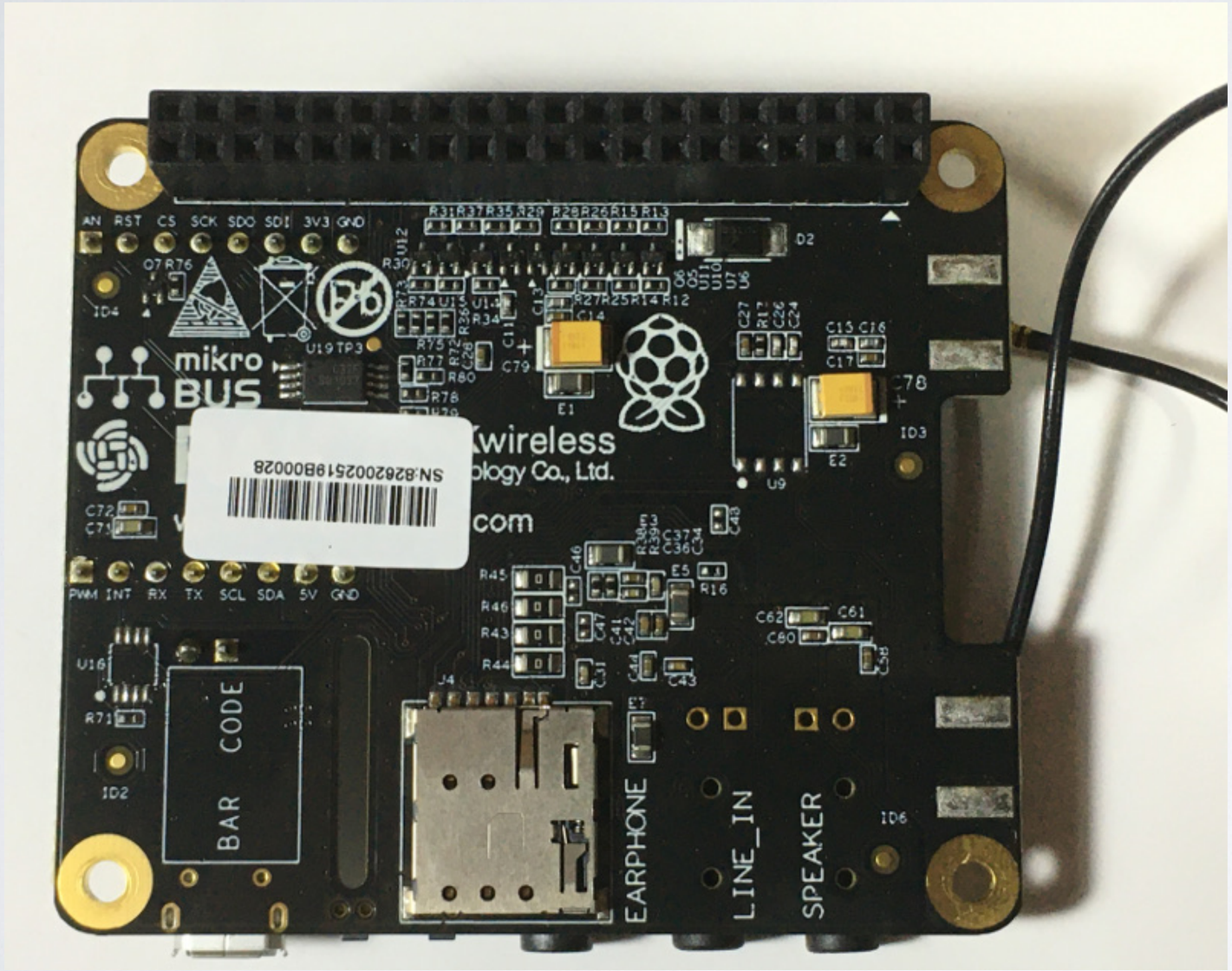
# RAK2245 PI HAT CONCENTRATOR MODULE



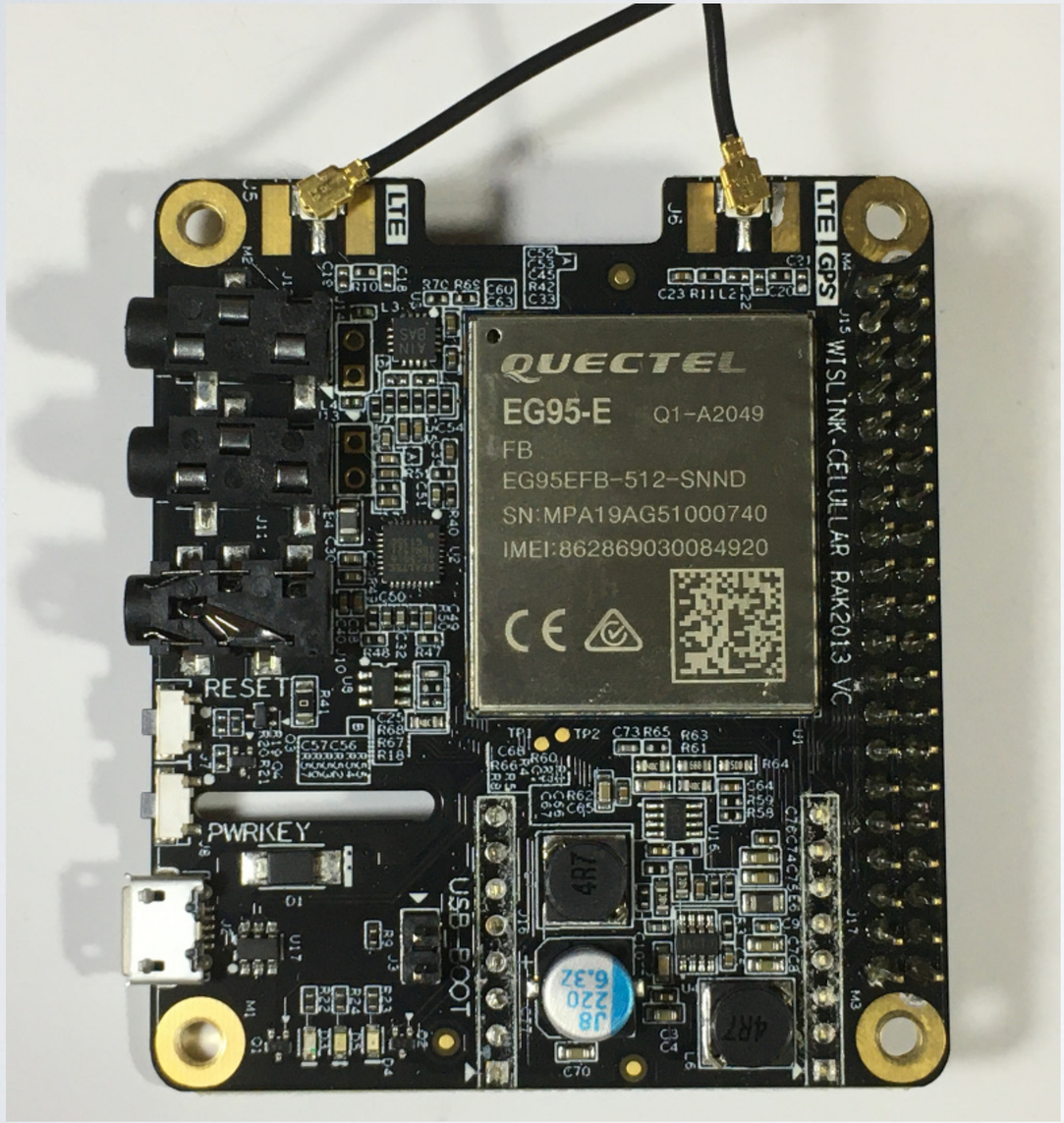
# RAK2013 PI HAT LTE MODULE



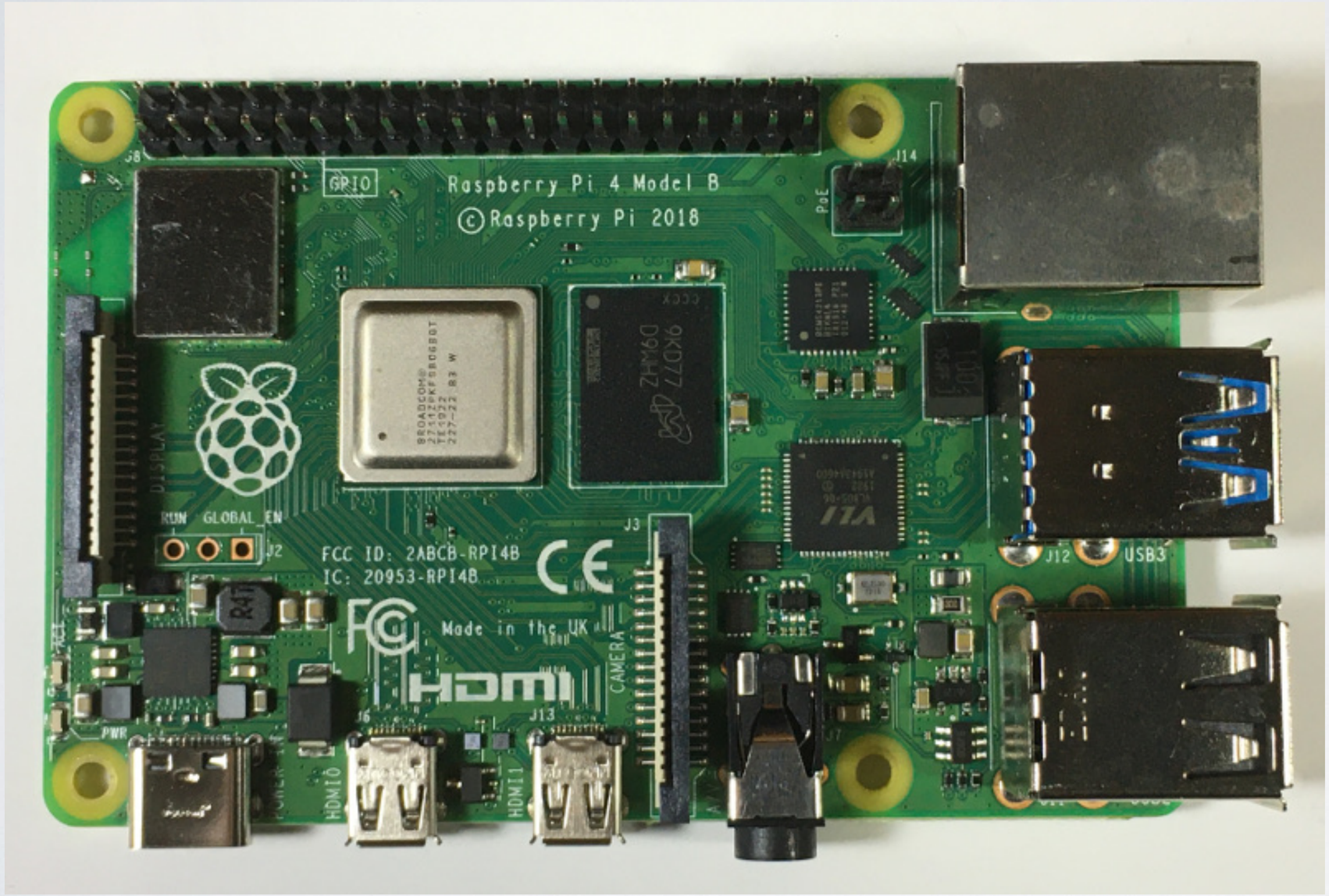
# RAK2013 PI HAT LTE MODULE



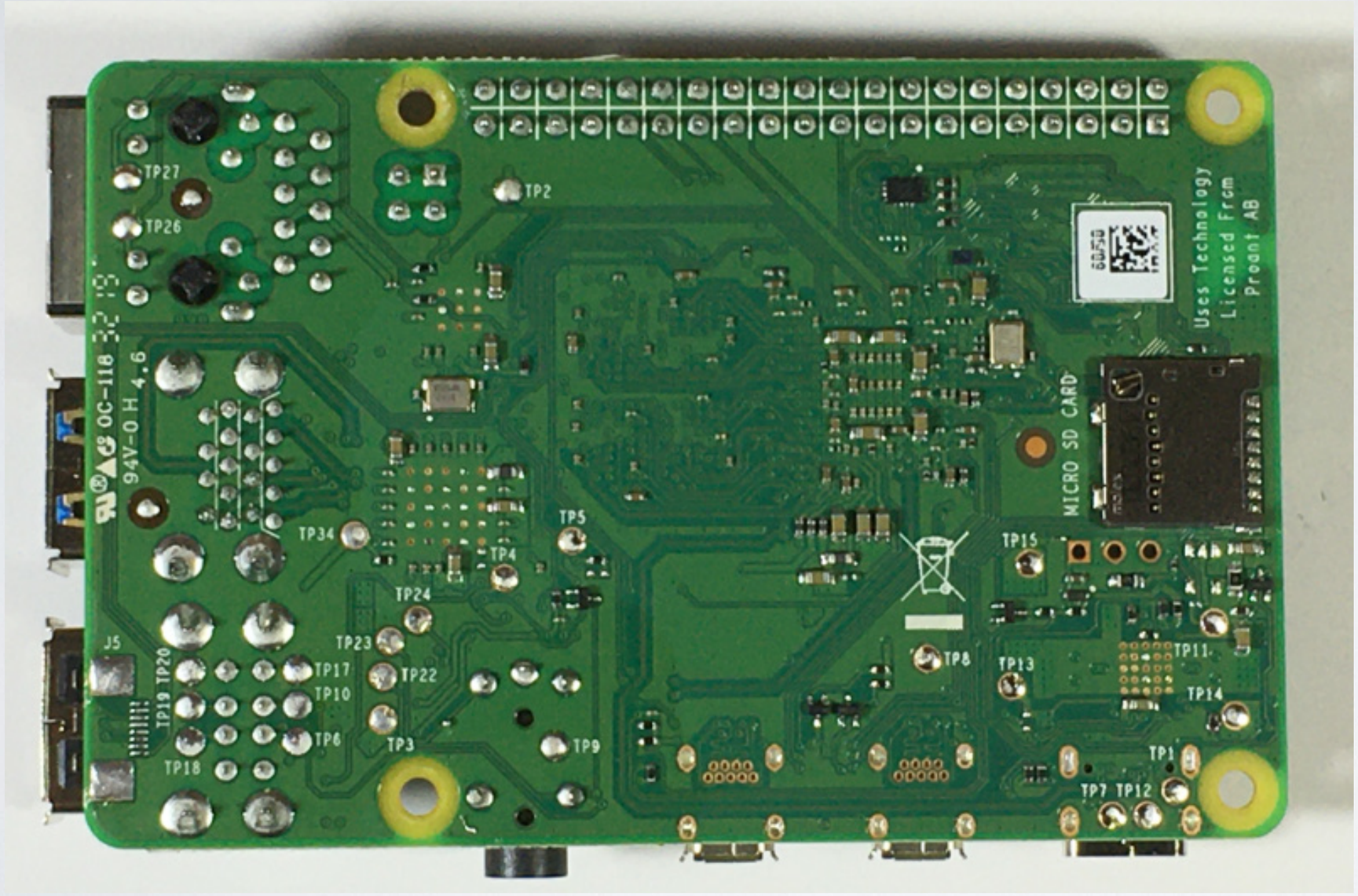
# RAK2013 PI HAT LTE MODULE



# RASPBERRY PI 4 MODEL B



# RASPBERRY PI 4 MODEL B



# ALUMINIUM ENCLOSURE

# RAK7244C Quick Start Guide

# RAK7244C QUICK START GUIDE

- The RAK7244C Quick Start Guide:
  https://doc.rakwireless.com/rak7244c-lorawan----developer-gateway/quick-start-guide

- Software download:
  https://downloads.rakwireless.com/en/

- RAK7244C firmware:
  https://downloads.rakwireless.com/en/LoRa/Developer-LoRaWAN-Gateway-RAK7244C/Firmware/

- The firmware version downloaded and demonstrated in the video is:
  RAK7244C(RAK7244_LTE)_based_on_Raspbian_V4.1.0_20191202

# FIRMWARE INSTALLED SOFTWARE

- The firmware RAK7244C(RAK7244_LTE)_based_on_Raspbian_V4.1.0_20191202 has the following software pre-installed.

  - Raspbian Buster Lite
    https://www.raspberrypi.org/downloads/raspbian

  - Semtech LoRa library (V5.0.1)
    https://github.com/Lora-net/lora_gateway
    **/opt/ttn-gateway/lora_gateway**

  - Semtech UDP Packet Forwarder (V4.0.1)
    https://github.com/Lora-net/packet_forwarder
    **/opt/ttn-gateway/packet_forwarder**

# RAKWIRELESS GITHUB

- RakWireless Github:
  https://github.com/RAKWireless

- The firmware source code:
  https://github.com/RAKWireless/rak_common_for_gateway

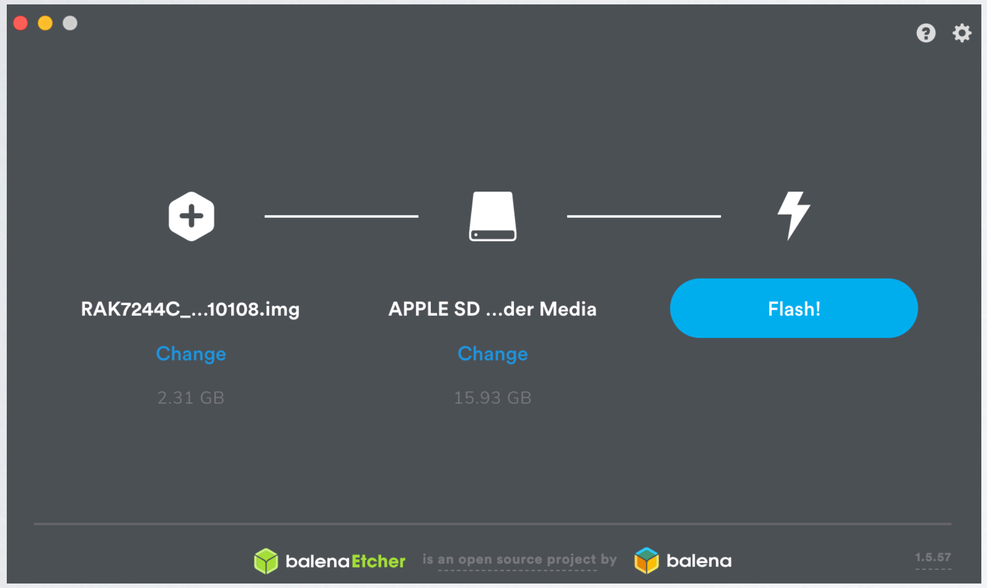
- The firmware (binary image):
  https://downloads.rakwireless.com/LoRa/Developer-LoRaWAN-Gateway-RAK7244C/Firmware/

# INSTALL FIRMWARE ON SD CARD

- Install BalenaEtcher: https://www.balena.io/etcher/
- Download firmware (for example: RAK7244C_Latest_Firmware.zip) https://downloads.rakwireless.com/LoRa/Developer-LoRaWAN-Gateway-RAK7244C/Firmware/
- Unzip the zip file: RAK7244C_4.2.6_20210108.img
- Insert 16GB (or more) SD Card in your card reader.
- Start BalenaEtcher

# INSTALL FIRMWARE ON SD CARD

- Select the .img file and make sure the SD card is selected.
- Press the Flash button.

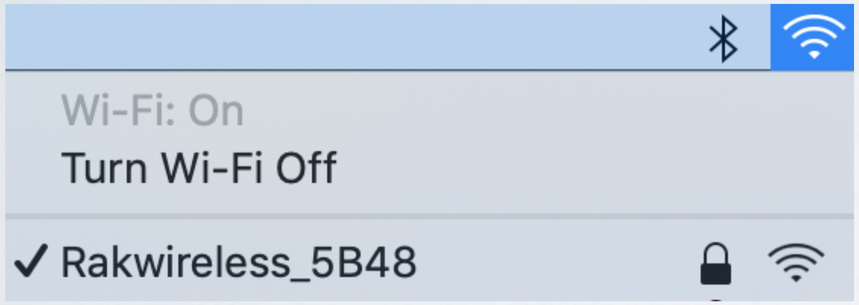



- After SD card is flashed, insert the SD card in the RAK7244C Developer Gateway and power up the gateway.

# RAK7244C QUICK START GUIDE

- By default the RAK7244C Developer Gateway is in WiFi Access Point (AP) mode.

- Connect your computer to this AP.
  It may take few minutes before you see this SSID when the Gateway is started up.




**SSID = Rakwireless_XXXX**
**Password = rakwireless**

- From your computer you can access the RAK7244C Developer Gateway via WiFi or via an Ethernet cable.

# RAK7244C QUICK START GUIDE

- Via WiFi (RECOMMENDED)
  The RAK7244C Developer Gateway IP = **192.168.230.1** (always)
  Login to the gateway via SSH:
  **ssh pi@192.168.230.1**
  **password: raspberry**

- Via Ethernet cable (NOT RECOMMENDED)
  Attach an Ethernet cable between your computer and the RAK7244C Developer Gateway but your computer must still be connected via WiFi to the AP.
  The RAK7244C Developer Gateway IP = **192.168.10.10** (always)
  Login to the gateway via SSH:
  **ssh pi@192.168.10.10**
  **password: raspberry**

# RAK7244C QUICK START GUIDE

- Open the gateway configuration menu:
  **`sudo gateway-config`**

- Select: **Setup RAK Gateway Channel Plan**
  Select: **Server is TTN**
  Select: **EU_863_870** (If gateway is located in Europe)
  Check which channel plan to use:
  https://www.thethingsnetwork.org/docs/lorawan/frequencies-by-country.html

- Select **Edit packet-forwarder config**
  Change the server_address from router.eu.thethings.network (V2) to eu1.cloud.thethings.network (V3)

# RAK7244C QUICK START GUIDE

- Select **Configure WIFI**

- Select **Change WiFi country**

- Select **Enable Client Mode/Disable AP Mode**

- Select **Add New SSID for Client**
  Enter your router SSID and password
  Note:
  To check if the SSID and password are correctly set, check file:
  sudo nano /etc/wpa_supplicant/wpa_supplicant.conf

# RAK7244C QUICK START GUIDE

- Select **Set pi pasword**
  Change the Raspberry pi password.

- Reboot Raspberry pi: **sudo shutdown -r now**

# RAK7244C QUICK START GUIDE

- After the gateway is rebooted, the gateway gets a new ip address from the router.
  To find the ip address use the Net Analyzer App or log into the router.

- Alternative way to find gateway ip address:

  - Type: **ifconfig** to find computer ip address, for example 192.168.2.1

  - Type: **nmap -sn 192.168.2.0/24**
    This will display all ip addresses found on the same network.

- Assume the gateway ip address is: 192.168.2.9
  Access the gateway: ssh pi@192.168.2.9
  Use the changed raspberry pi password!

# CHECKS

- Check if you have access to the internet:
  **`ping www.google.com`**

- The local_conf.json and global_conf.json file can be found at:
  **`/opt/ttn-gateway/packet_forwarder/lora_pkt_fwd`**

- Open the local_conf.json file and check the gateway ID.

# CHECKS

- Check if your gateway has the correct frequency.


# CHECKS

- Open the global_conf.json file and check the server_address parameter.

| TTN Frequency plan | **V2** server_address |
|---|---|
| AS 923-925 (AS2) | **router.as2.thethings.network** |
| AU 915-928 | **router.au.thethings.network** |
| CN 470-510 | **router.cn.thethings.network** |
| EU 863-870 | **router.eu.thethings.network** |
| EU 433 | **router.eu.thethings.network** |
| IN 865-867 | **router.in.thethings.network** |
| KR 920-923 | **router.kr.thethings.network** |
| RU 864-870 | **router.ru.thethings.network** |
| US 902-928 | **router.us.thethings.network** |

# CHECKS

- Open the global_conf.json file and check the server_address parameter.
  <region> = au1, eu1 or nam1

| TTN Frequency plan | **V3** server_address |
|---|---|
| AS 923-925 (AS2) | **<region>.cloud.thethings.network** |
| AU 915-928 | **au1.cloud.thethings.network** |
| CN 470-510 | **<region>.cloud.thethings.network** |
| EU 863-870 | **eu1.cloud.thethings.network** |
| EU 433 | **eu1.cloud.thethings.network** |
| IN 865-867 | **<region>.cloud.thethings.network** |
| KR 920-923 | **<region>.cloud.thethings.network** |
| RU 864-870 | **<region>.cloud.thethings.network** |
| US 902-928 | **nam1.cloud.thethings.network** |

# CHECKS

- Check the ttn-gateway service status:
  **`systemctl status ttn-gateway -l`**

- Check the log file:
  **`tail -f /var/log/syslog`**

- Check the system time:
  **`date`**

- If the system time is wrong, change this using the Raspberry Configuration Tool:
  **`sudo raspi-config`**
  **`Select 4. Localisation Option`**
  **`I2 Change Timezone`**

# CHECKS

- Check if the router SSID and password is correctly set:

```
cd /etc/wpa_supplicant
sudo nano wpa_supplicant.conf
```

```
ctrl_interface=DIR=/var/run/wpa_supplicant GROUP=netdev
update_config=1
country=NL
network={
ssid="MY-ROUTER-SSID"
psk="MYSECRET"
}
```

# CHECKS

- Check the disk space:
  **`df -h`**

- Check the Raspberry Pi 4 model B ram size:
  **`free -h`**
  Note:
  On the board, see chip with marking:
  1GB: 4HBMGCJ (+ QR code)
  2GB: D9WHZ (M - micron logo). The shipped RAK7244C RaspPi 4 had this ram size.
  4GB : D9WHV (M - micron logo)

# USEFUL COMMANDS

- Open the gateway configuration menu:
  **`sudo gateway-config`**

- Show gateway ID and RAK gateway model and version:
  **`sudo gateway-version`**

- Reboot Raspberry Pi:
  **`sudo reboot now`** or **`sudo shutdown -r now`**

- Shutdown Raspberry Pi:
  **`sudo shutdown -h now`**

- Check installed Raspbian version:
  **`cat /etc/os-release`**

# USEFUL COMMANDS

- Restart the ttn-gateway service:
  **`sudo service ttn-gateway restart`**

- Stop the ttn-gateway service:
  **`sudo service ttn-gateway stop`**

- Start the ttn-gateway service:
  **`sudo service ttn-gateway start`**

# SYSTEMD SERVICES & UNITS

- The systemd services & units: /lib/systemd/system
  Usage: **`systemctl status <service-or-unit>`**
  Example: systemctl status ttn-gateway

| Service name | Description |
|---|---|
| create_ap | Create Access Point Service |
| chirpstack-network-server | ChirpStack Network Server |
| chirpstack-application-server | ChirpStack Application Server |
| chirpstack-gateway-bridge | ChirpStack Gateway Bridge |
| ttn-gateway | Rak LoRaWAN concentrator |
| rak-pppd | Rak pppd for LTE Module |
| hciuart | Configure Bluetooth Modems connected by UART |
| serial-getty@ttyAMA0 | GPS  TTY path (/dev/ttyAMA0) |

# RAK7244C GATEWAY CONFIGURATION SETTINGS

- The RAK7244C gateway configuration settings are stored in:
  **`/usr/local/rak/gateway-config-info.json`**
  Note: value "1" = enabled, "2" = disabled.

- The gateway model and version are stored in:
  **`/usr/local/rak/rak_gw_model.json`**

- The shell scripts /usr/local/rak/gateway-config and /usr/local/rak/gateway-version are copied to /usr/bin.

# MORE INFORMATION

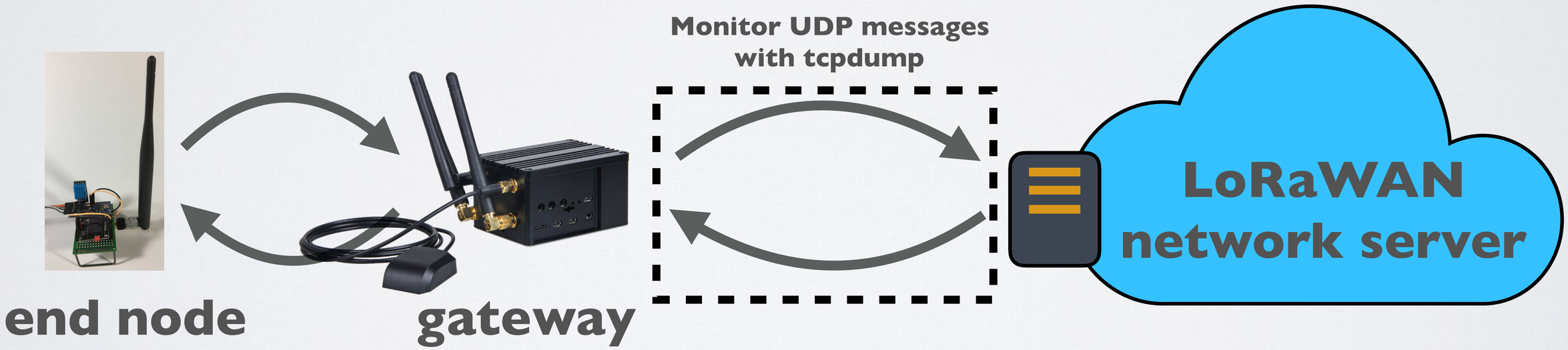
- The RAK831 and RAK7244C uses the same Semtech LoRa library (V5.0.1) and Semtech UDP Packet Forwarder (V4.0.1).

| Tutorial | Description |
|---|---|
| 28 | How to use GPS. |
| 28.1 | Information about the global_conf.json and local_conf.json file. |
| 28.2 | Enable debug logging for Semtech LoRa Gateway and Semtech UDP packet forwarder. |
| 29 | Semtech UDP packet forwarder and the Semtech UDP protocol. |
| 30 | Semtech UDP packet forwarder configuration files explained. |

# TCPDUMP

- Install tcpdump on the gateway, see tutorial 29.

- Monitor UDP messages between the RAK7244C and TTN server:
  **sudo tcpdump -XUq port 1700 (ASCII and Hex)**
  **sudo tcpdump -AUq port 1700 (only ASCII)**



# NODE-RED

- Install Node-Red on the gateway, see tutorial 29. Use Node-Red:

  - Goto pi's home directory:
    **`cd ~`**

  - Start Node-Red:
    **`node-red-start`**

  - View the recent Node-Red logs:
    **`node-red-log`**

  - Stop Node-Red:
    **`CTRL+C`** (Node-Red is still running in the background)
    **`node-red-stop`**

# NODE-RED

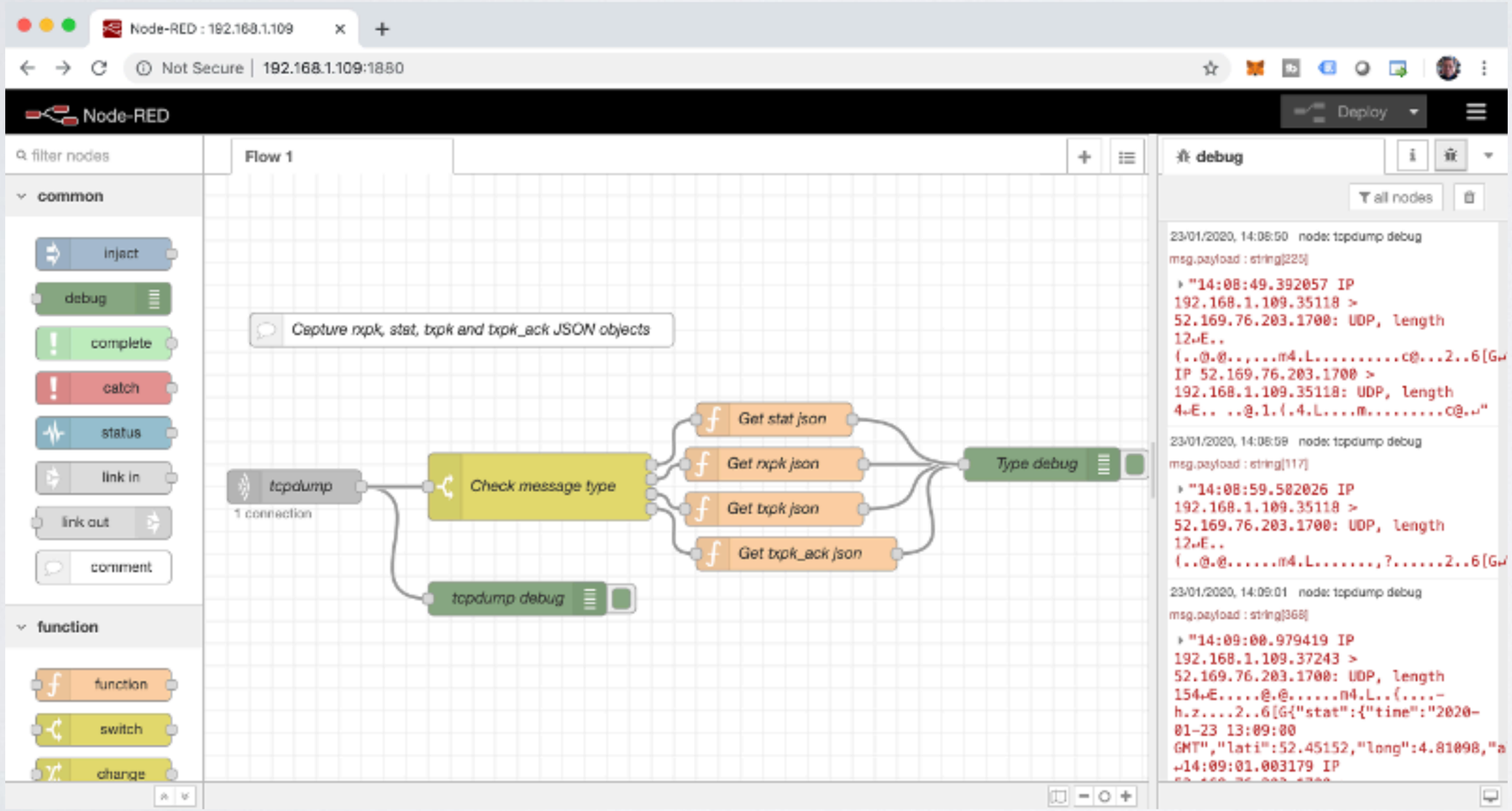
- To make the Node-Red flow work, a command need to be executed:
  **`sudo tcpdump -Alqn port 1700 | nc localhost 8888 &`**

- To stop the running background process:
  **`jobs`** (show list of background jobs)
  **`fg <number>`** (Eg: `fg 2`, bring job 2 to foreground)
  **`CTRL+C`** (Stop the job)

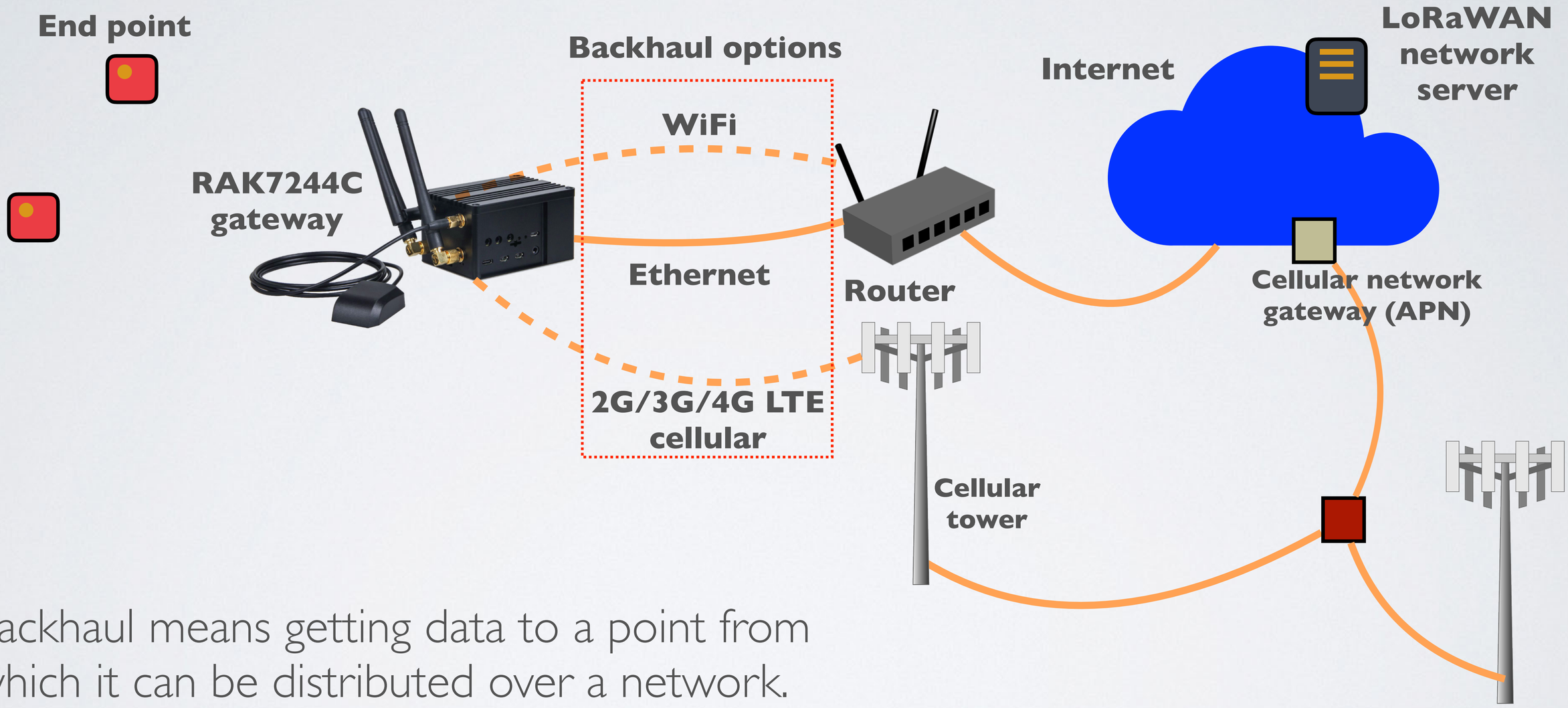
- Import a very simple Node-Red flow to capture the rxpk (received packet), stat (status), txpk (transaction packet) and txpk_ack (transaction packet acknowledge) JSON objects which are sent to/from the gateway:
  https://www.mobilefish.com/download/lora/capture_gateway_lorawan_network_server_packets.json

# NODE-RED

- Open a browser and enter:
  **`http://<gateway_ip>:1880`** For example: http://192.168.1.109:1880



# RAK7244C LORAWAN GATEWAY BACKHAUL OPTIONS



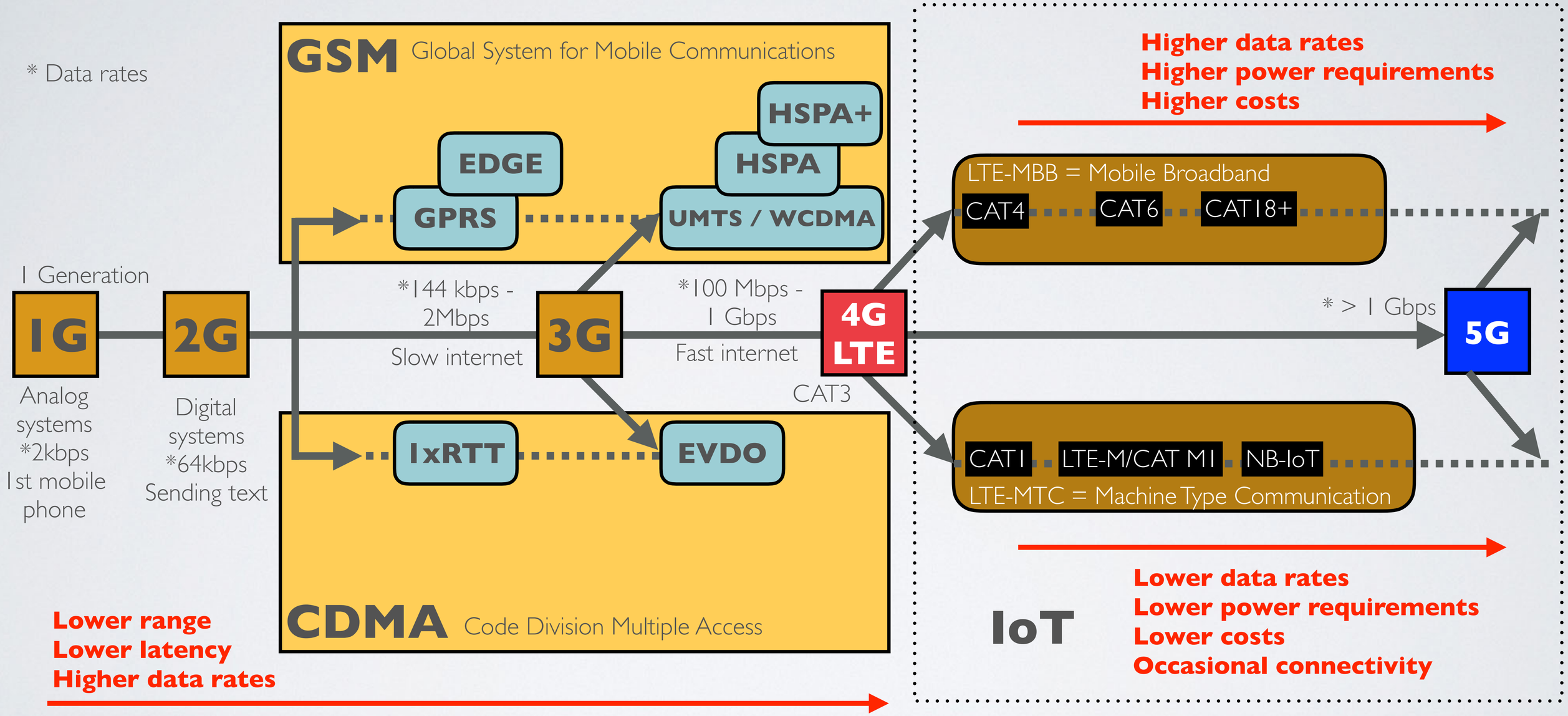

Backhaul means getting data to a point from which it can be distributed over a network.

# Evolution of cellular standards

# EVOLUTION OF CELLULAR STANDARDS

- Before I demonstrate how to connect the RAK7244C LoRaWAN gateway to an LTE network it is useful to understand the evolution of cellular standards.

# EVOLUTION OF CELLULAR STANDARDS




**Each generation brought new functionality.**

# 4G LTE CATEGORIES

- The LTE UE (User Equipment) categories are used to describe the LTE network capabilities from a consumer perspective. These are theoretical speeds.

| LTE UE CAT | Downlink (Mbps) | Uplink (Mbps) |
|---|---|---|
| 0 | ~1 | ~1 |
| 1 | ~10 | ~5 |
| 2 | ~50 | ~25 |
| 3 | ~100 | ~50 |
| 4 | ~150 | ~50 |
| 5 | ~300 | ~75 |
| 6 | ~300 | ~50 |
| 7 | ~300 | ~100 |
| 8 | ~3000 | ~1500 |
| 9 | ~450 | ~50 |
| 10 | ~450 | ~100 |
| 11 | ~600 | ~50 |
| 12 | ~600 | ~100 |
| 13 | ~390 | ~150 |
| 14 | ~3900 | ~9500 |
| 15 | ~750 | ~225 |

# GSM & CMDA

- In the world of cellar communications, GSM (Global System for Mobile Communications) and CDMA (Code Division Multiple Access) were the two dominant cellular standards. Most of the world uses GSM standard.

- GSM uses SIM cards, CMDA does not.
  In CMDA each mobile phone is verified against a whitelist at the carrier side.

- SIM (Subscriber Identification Module) cards are in many different form factors and contains the information of the subscriber.

- This means in a GSM system a user can easily switch from one mobile to another just by swapping the SIM card. In a CDMA system this is not possible.

# 4G LTE & 4G LTE-A

- 4G LTE ( Long Term Evolution) is a standard for wireless high speed data communications. It is developed and standardised by 3GPP (Third Generation Partnership Project).

- 4G LTE means that this standard does not fully adhere to the 4G standards. Often the word LTE is used, referring to 4G LTE.

- 4G LTE-A, A stands for advanced, means that this standard is close to proper 4G.

- In 4G LTE, SIM cards are used.

# QUECTEL E95

- Quectel EG95 is a series of LTE category 4 module optimised specially for M2M and IoT applications. More information: https://www.quectel.com/product/eg95.htm

- Quectel EG95 has 4 variants: **EG95-E**, **EG95-NA**, EG95-EX, and EG95-NAX. RAK7244C LoRaWAN gateway supports EG95-E or EG95-NA.

| Frequency | Generation | EG95-E | EG95-NA |
|---|---|---|---|
| LTE FDD | 4G LTE | B1/B3/B7/B8/B20/B28A | B2/B4/B5/B12/B13 |
| WCDMA | 3G | B1/B8 | B2/B4/B5 |
| GSM/EDGE | 2G | B3/B8 | - |
| Region | - | EMEA (**E**urope, **M**iddle **E**ast and **A**frica) | North America |

# QUECTEL E95

- LTE FDD (4G LTE): Long Term Evolution - Frequency Division Duplex
- WCDMA (3G): Wideband Code Division Multiple Access
- EDGE (2G): Enhanced Data rates for GSM Evolution

# 3GPP FREQUENCY BANDS

| Band | Freq. name | Uplink (MHz) | Downlink (MHz) | Used in region |
|---|---|---|---|---|
| 1 | 2100 | 1920-1980 | 2110-2170 | **Europe**, Asia, Israel, Japan, South Korea, Philippine |
| 2 | 1900 | 1850-1910 | 1930-1990 | |
| 3 | 1800 | 1710-1785 | 1805-1880 | **Europe**, Australia, Hong Kong, Japan, South Africa, Singapore, South Korea, New Zealand |
| 4 | 1700 | 1710-1755 | 2110-2155 | Canada, South America, US |
| 5 | 850 | 824-849 | 869-894 | Middle/South America, South Korea, Israel, US |
| 6 | 800 | 830-840 | 875-885 | |
| 7 | 2600 | 2500-2570 | 2620-2690 | **Europe**, Australia, Canada, South America, Singapore, Hong Kong, Russia, Malaysia |
| 8 | 900 | 880-915 | 925-960 | **Europe**, Australia, Japan |
| 9 | 1700 | 1749.9-1784.9 | 1844.9-1879.9 | |
| 10 | 1700/2100 | 1710-1770 | 2110-2170 | |
| 11 | 1500 | 1427.9-1447.9 | 1475.9-195.9 | |
| 12 | 700 | 699-716 | 729-746 | US (US Cellular) |
| 13 | 750 | 777-787 | 746-756 | US (Verizon) |
| 14 | 700 | 788-798 | 758-768 | |
| 17 | 700 | 704-716 | 734-746 | US (AT&T) |
| 18 | 800 | 815-830 | 860-875 | |
| 19 | 850 | 830-845 | 875-890 | Japan |
| 20 | 800 | 832-862 | 791-821 | **Europe**, Russia |

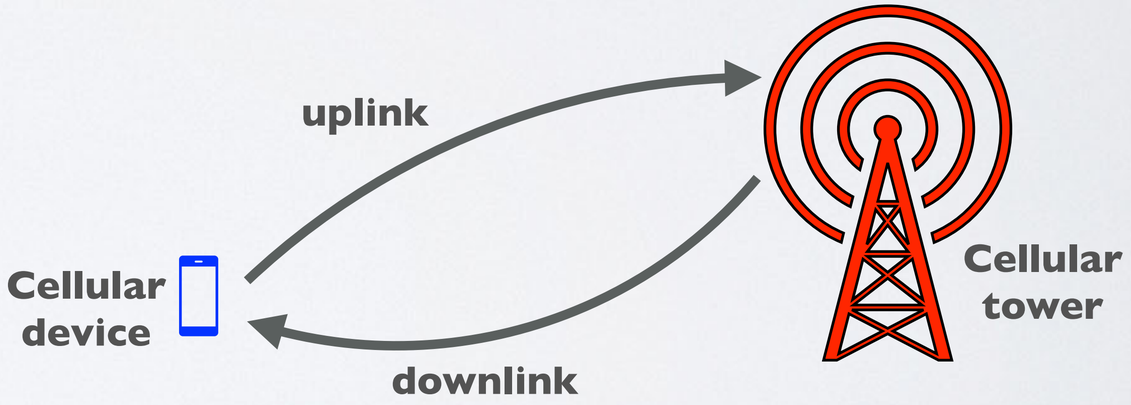
# 3GPP FREQUENCY BANDS

| Band | 3GPP name | Uplink (MHz) | Downlink (MHz) | Used in region |
|---|---|---|---|---|
| 21 | 1500 | 1447.9-1462.9 | 1495.9-1510.9 | |
| 22 | 3500 | 3410-3490 | 3510-3590 | |
| 23 | S-band | 2000-2020 | 2180-2200 | |
| 24 | L-Band | 1626.5-1660.5 | 1525-1559 | |
| 25 | | 1850-1915 | 1930-1995 | |
| 26 | | 814-849 | 859-894 | |
| 27 | | 807-824 | 852-869 | |
| 28 | | 703-748 | 758-803 | |
| 28A | | 703-718 | 758-773 | |
| 28B | | 718-748 | 773-803 | |

Frequencies, source: ETSI TS136 104 V13.5.0

Note:
Band 1, 3, 7, 8 and 20 are used in the Netherlands.

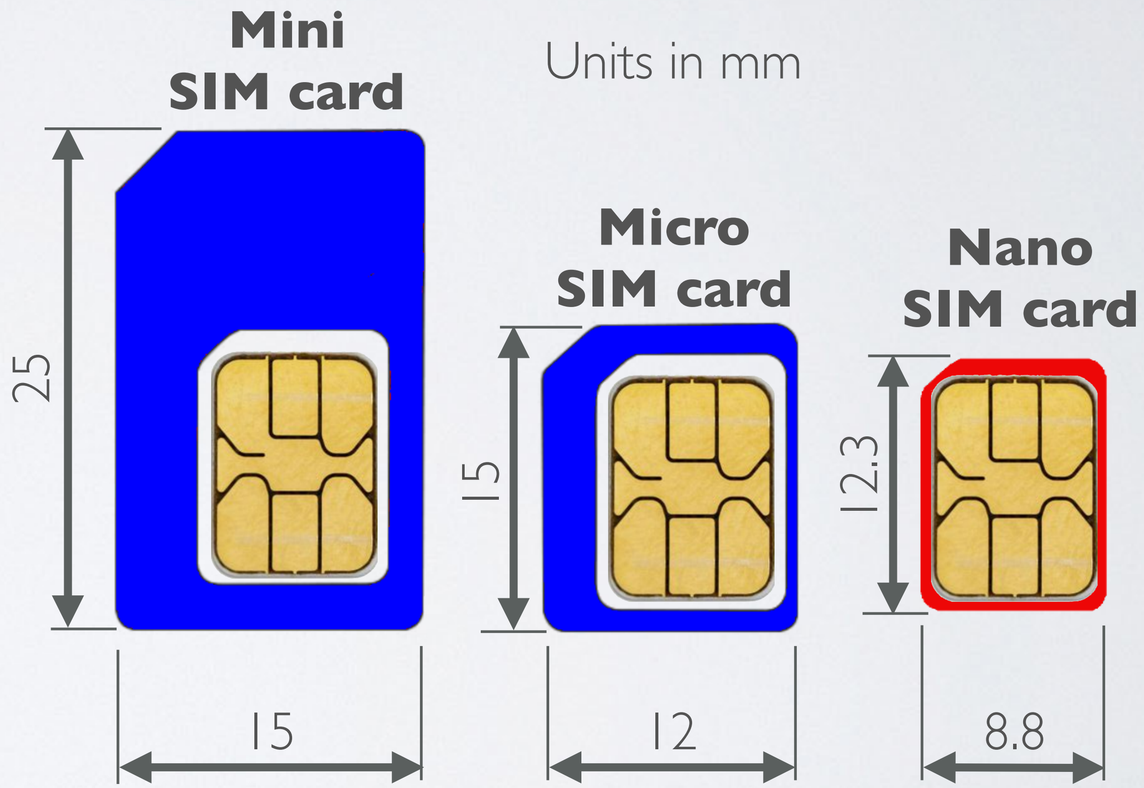
Example: Network operator XYZ
(2G) GSM: 900 (B8)
(3G) UMTS: 900 / 2100 (B8/B1)
(4G) LTE: 800 /1800 / 2600 (B8 / B3 / B7)



# SIM CARDS FORM FACTORS

- SIM (Subscriber Identity Module) cards are available in the form factors 2FF – 4FF. Industrial grade SIM card are also available in the form factors 2FF – 4FF but they have thicker pin plate to safeguard the device from corrosion, vibrations and other environmental factors.

| SIM | Form Factor | Dimensions (mm) |
|---|---|---|
| Mini | 2FF | 25x15x0.76 |
| Micro | 3FF | 15x12x0.76 |
| Nano | 4FF | 12.3x8.8x0.67 |



# RAK7244C SIM CARD USE

- The RAK7244C LoRaWAN Developer gateway uses the nano SIM card.
- Make sure that the card's gold contact face upwards when inserting it into the SIM card slot.
- This gateway has no anti theft features for stealing or replacing the SIM card.
- If the chosen cellular network supports, for example GSM, UMTS and 4G LTE and in all three cases the signal strength is sufficient, the Quectel modem will by default use the highest possible speed, which in this case is 4G LTE.

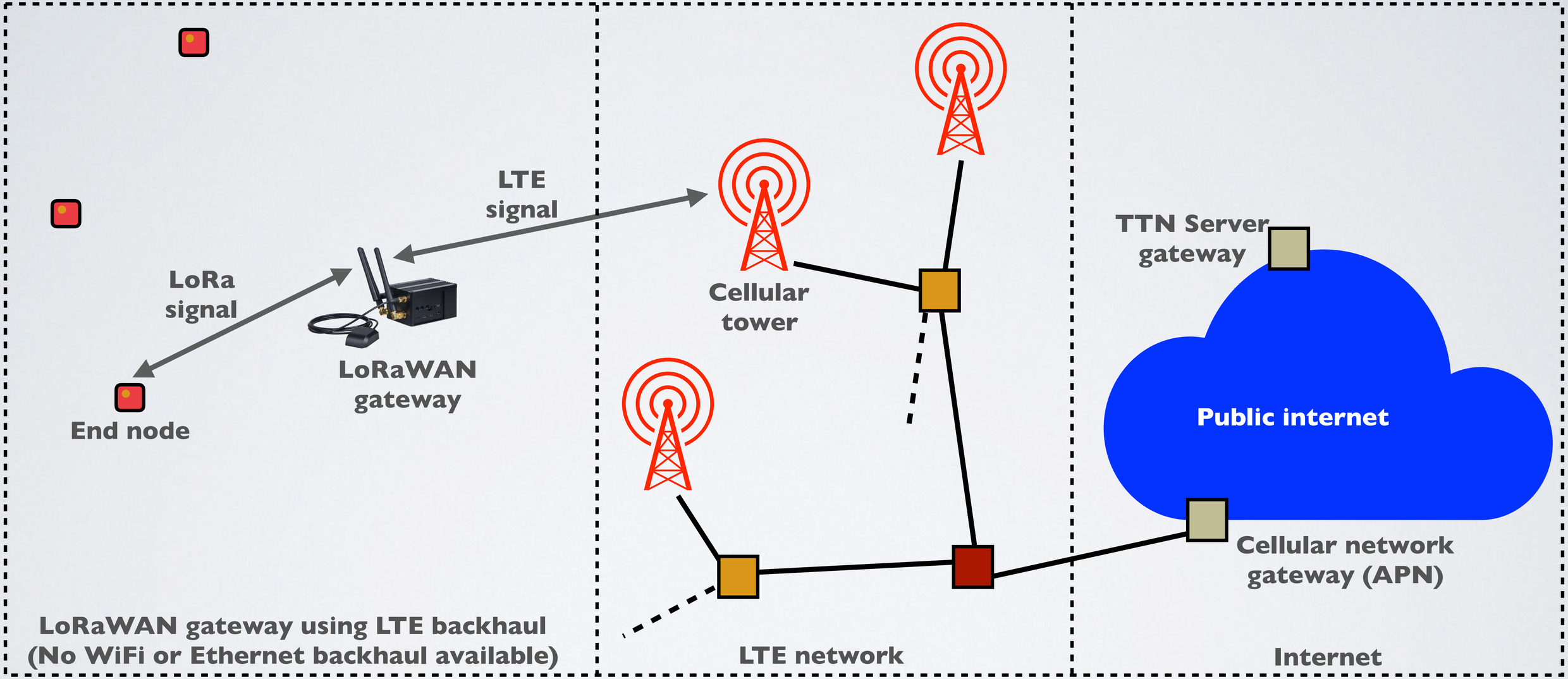
# SIM CARD

- For **demonstration** purpose I bought a 4G data bundle with 500 MB.
  The SIM card is free and the 4G data bundle costs €5.00.
  The bundle is only valid for 28 days and can only be used in the Netherlands.
  See: https://mobile.lebara.com/nl/en/data/c/prepaid-mobiel-internet-data
  Notes:
  - The costs is €0.01 per 1 MB
  - Lebara is a telecommunications company operating in many countries.
  - I am not paid/sponsored by lebara.com

- Lebara Netherlands uses the KPN network which supports GSM(2G), UMTS (3G) and 4G LTE.

- An Access Point Name (APN) is the name of a gateway between a cellular network and the public internet. Lebara APN (Access Point Name): **internet**

# CONNECTING TO CELLULAR NETWORK



# RAK7244C CELLULAR ANTENNAS

- Cellular communication systems uses two antennas:
  - The primary antenna aka main antenna
  - The diversity antenna aka div antenna

- The primary antenna is used to transmit and receive.
  The diversity antenna is used to receive only.

- The diversity antenna is used to filter out the usable signal from the background noise which increases the quality and reliability of the cellular system.

- The RAK7244C LoRaWAN gateway also has two cellular antennas.

# RAK7244C CELLULAR ANTENNAS

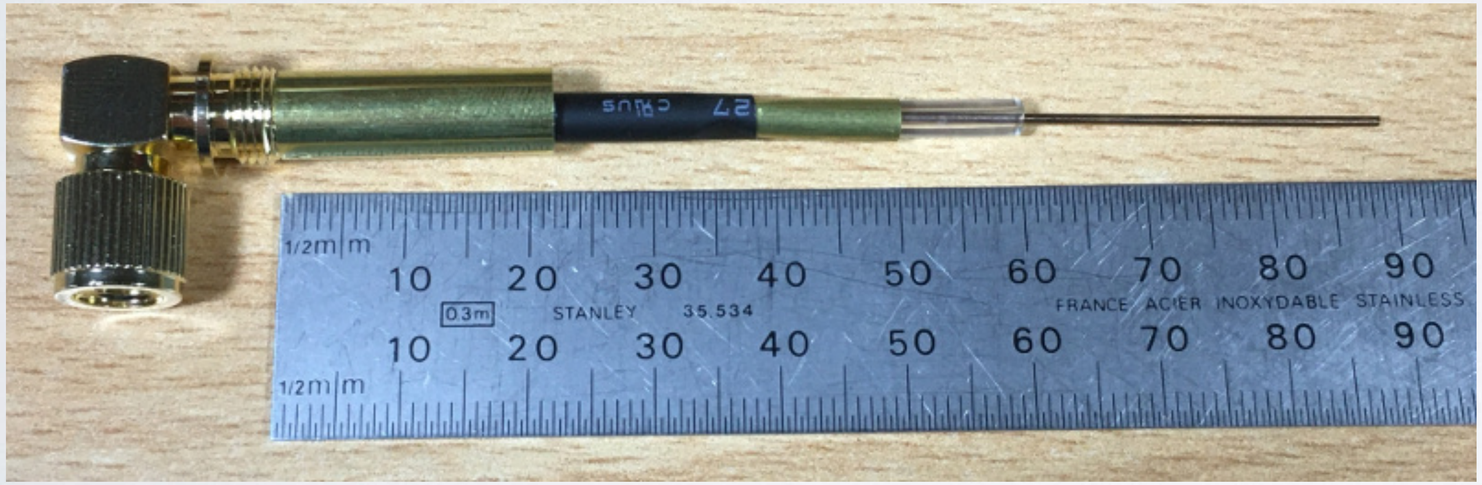
- RAK7244C cellular antenna parameters:

Antenna Parameters

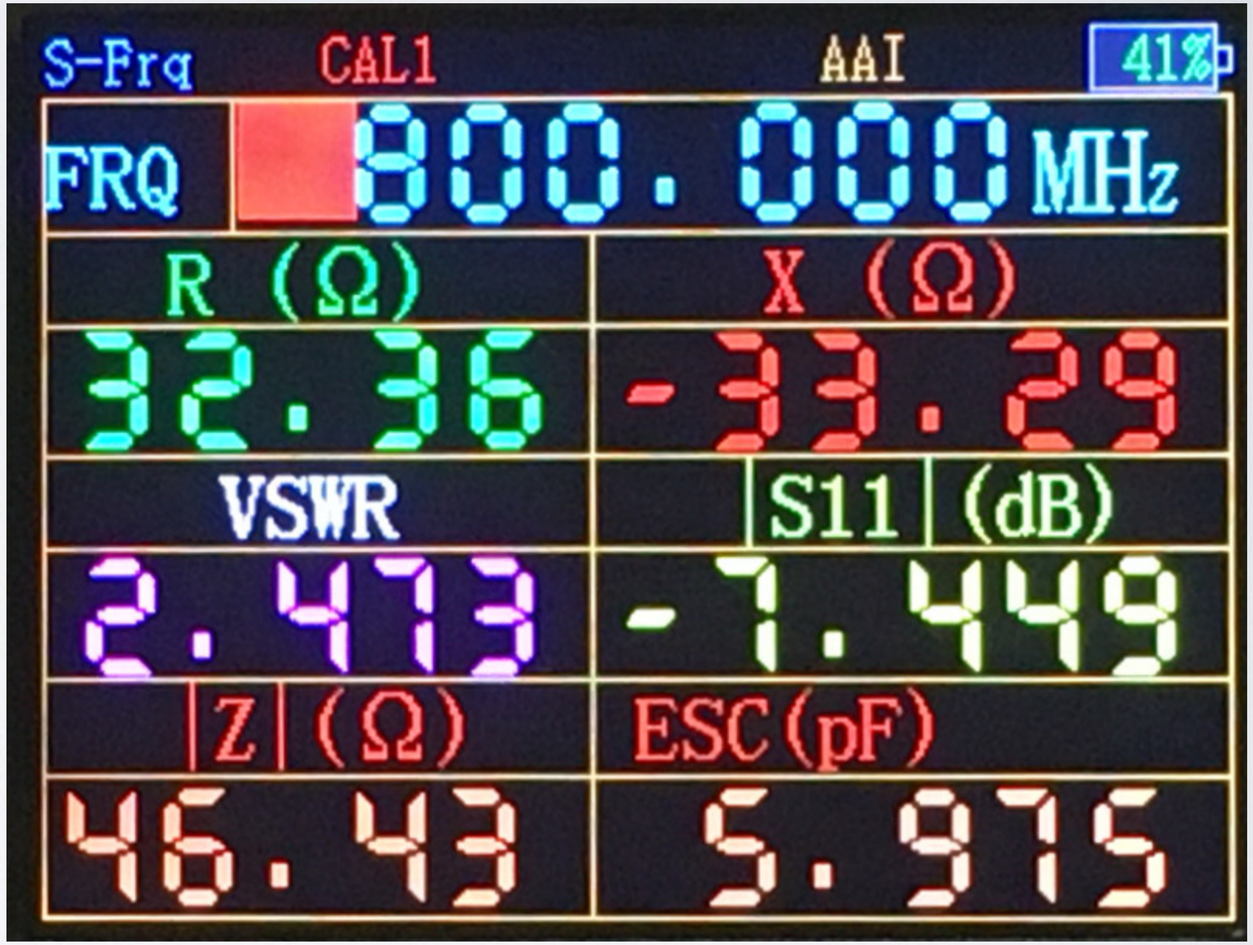
| Items | Specifications |
|---|---|
| **Frequency (MHz)** | 700 / 800 / 880 / 960 / 1710 / 1880 / 2170 |
| **Voltage Standard Wave Radio (VSWR)** | 9.3 / 4.6 / 3.6 / 4.9 / 9.3 / 4.4 / 15 |
| **Gain (dBi)** | 1.63 / 1.84 / 1.96 / 2.23 / 0.03 / 0.01 / 1.97 |
| **Working Temperature & Humidity** | T:-35 °C ~ +80 °C, H: 0% ~ 95% |
| **Storage Temperature & Humidity** | T:-40 °C ~ +85 °C, H: 0% ~ 95% |

Source: https://doc.rakwireless.com/datasheet/rakproducts/antenna-specifications---rak7244

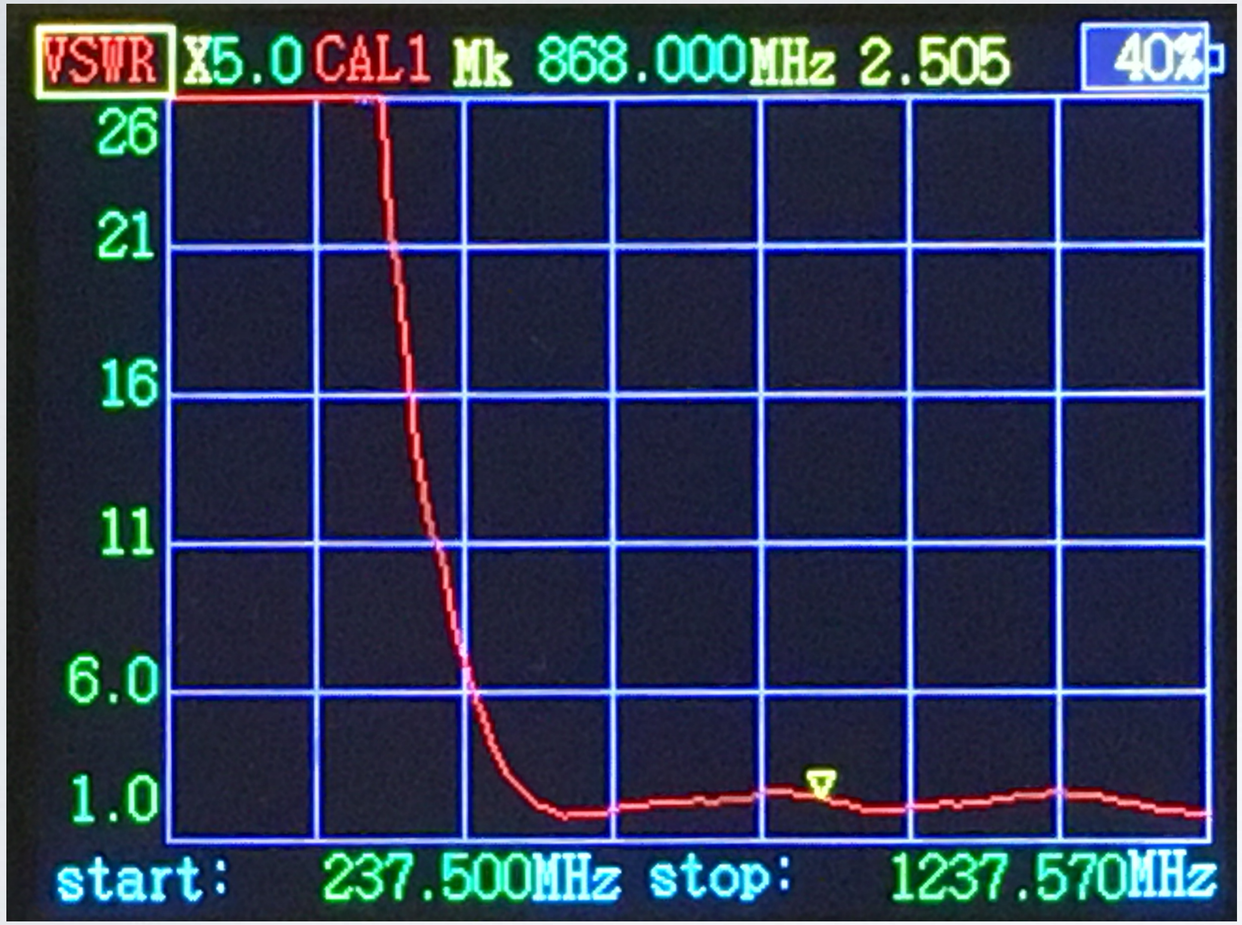
# RAK7244C CELLULAR ANTENNAS

# RAK7244C CELLULAR ANTENNAS

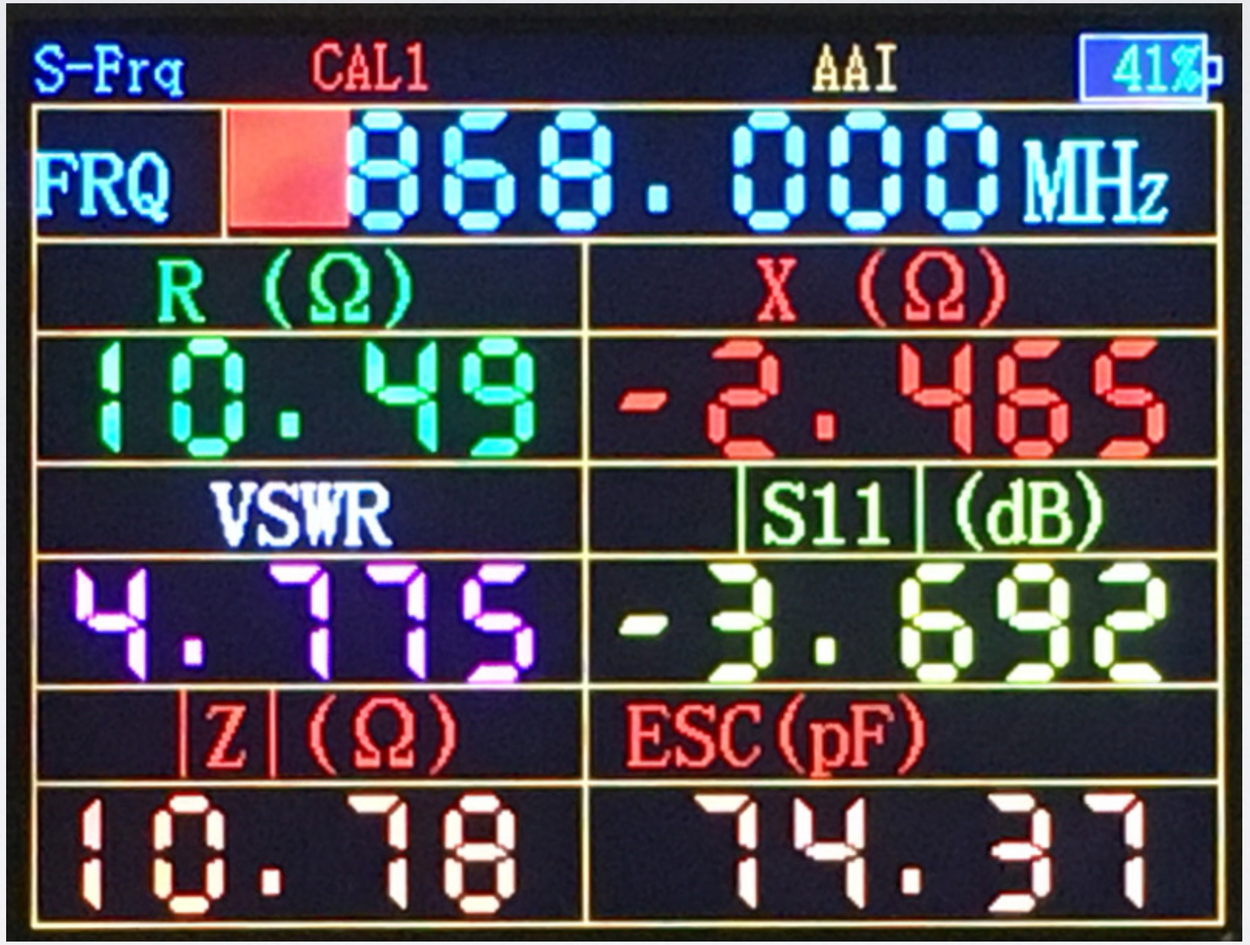
# RAK7244C CELLULAR ANTENNAS




# RAK7244C CELLULAR ANTENNAS

# RAK7244C LORA ANTENNA

# RAK7244C LORA ANTENNA

# RAK7244C LORA ANTENNA


# RAK7244C LORA ANTENNA

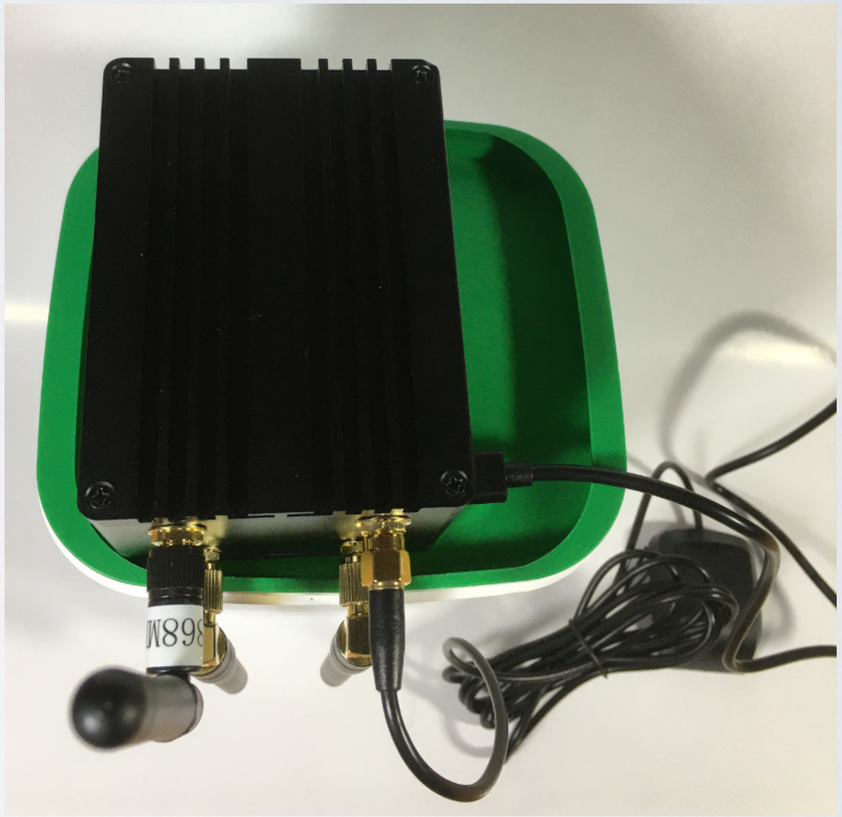
# LORA AND CELLULAR ANTENNA ORIENTATION

- For the best wireless communication performance, it recommended to align both the cellular antennas and LoRa antenna **vertically**.

The LoRa and cellular antennas are not vertically polarised. Don't do this!

# LORA AND CELLULAR ANTENNA ORIENTATION

- Alternatively place the gateway on a platform, for example: box, pile of books, etc.



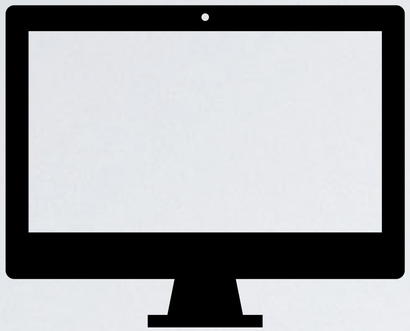
# RAK7244C LORA & CELLULAR ANTENNAS

- The RakWireless shop offers different antennas with better gains, see:
  https://store.rakwireless.com/collections/antennas
  Or you can build your own LoRa antenna with a better gain, see tutorial 41, 44 or 46.

- If the RAK7244C gateway is using the Ethernet or WiFi backhaul it is recommended to leave the cellular antennas connected. Unconnected ports can cause reflections which can fry the cellular modem.
  Note: Unconnected ports can also gather dust.

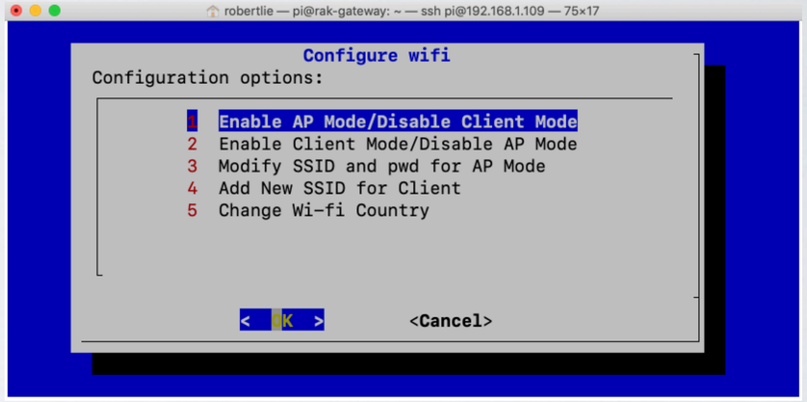
# RAK7244C Connecting to cellular network

# RAK7244C QUICK START GUIDE



**Login to the gateway via SSH**
**ssh pi@192.168.230.1**
**password: xxxxx**

**Gateway in WiFi AP mode**
**Gateway IP = 192.168.230.1**
**SSID = Rakwireless_XXXX**
**Password = xxxxx**

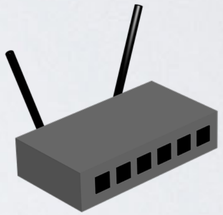



**End node**

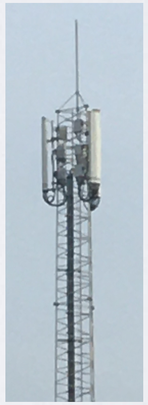
**Sensor data**

**LoRaWAN gateway**

**Ethernet/WiFi backhaul**



**Cellular backhaul**



# CONTROL QUECTEL E95 WITH MINICOM

- The Quectel E95 modem can be controlled with the minicom program.

- Minicom is a text-based modem control and terminal emulator program for Unix-like operating systems.

- Open Minicom:
  **`sudo minicom -D /dev/ttyAMA0 -b 115200`**
  Port is: /dev/ttyAMA0
  To find the port: **`dmesg | grep tty`**

- Show Minicom command summary:
  **`CTRL+A Z`**

# CONTROL QUECTEL E95 WITH MINICOM

- Show Quectel EG95 model and revision:

  **ATI**

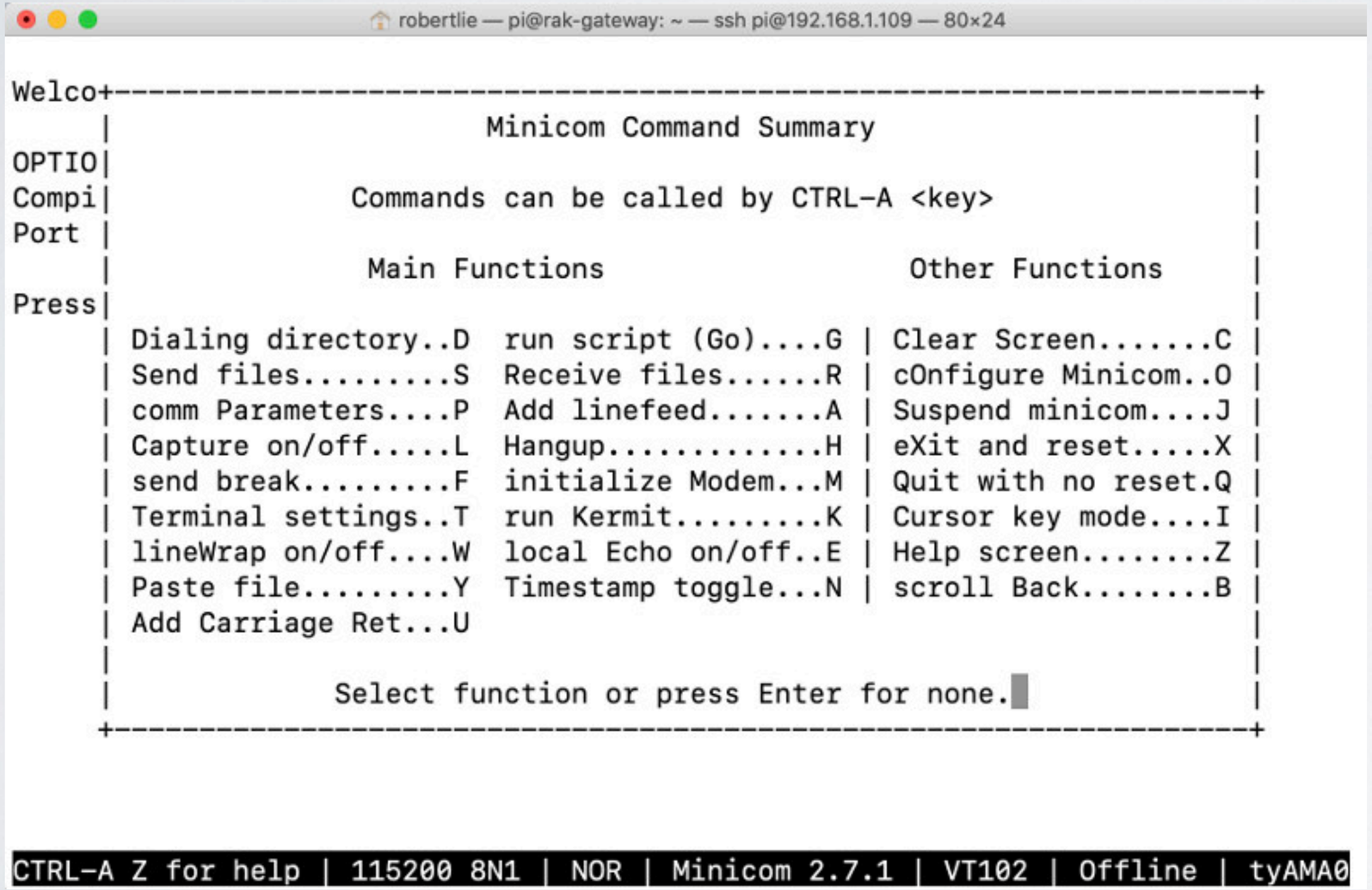
  Output:
  Quectel
  EG95
  Revision: EG95EFBR06A05M4G

- Exit Minicom:

  **CTRL+A Z Q**

# CONTROL QUECTEL E95 WITH MINICOM

- Minicom command summary:



# AT COMMANDS

- AT commands are instructions which are used to control modems.

- AT is the abbreviation for Attention.

- Each command starts with the prefix "AT" or "at" followed by the command itself.

- There are two types of AT commands:
  - Basic AT commands: These commands do not start with +
  - Extended AT commands: These commands starts with +

- More information about the Quectel EG9x AT commands:
  https://www.quectel.com/UploadImage/Downlad/Quectel_EG9x_AT_Commands_Manual_V1.1.pdf

# CELLULAR DATA USAGE

- When an end device transmits sensor data, the LoRaWAN gateway does not only transmit this data to the cellular network it also adds meta data to the sensor data.

- Besides the sensor data the LoRaWAN gateway also:
  - transmits at regular time interval (stat_interval) the gateway status to the LoRaWAN network server (See tutorial 29).
  - transmits at regular time interval (keepalive_interval) a keep alive message to the LoRaWAN network server (See tutorial 29).

  Both intervals are set in the global_conf.json or local_conf.json file.

- In both cases acknowledge messages are send back from the LoRaWAN network server to the LoRaWAN gateway.

# CELLULAR DATA USAGE

- The LoRaWAN network server can also send downlink (DL) responses back to LoRaWAN gateway.

- The cellular data usage not only depends on the actual sensor data size and response data size but it also depends on the stat_interval, keepalive_interval settings and of course how often sensor data and responses are transmitted.

# CELLULAR DATA USAGE

gateway

1. PUSH_DATA (0)
[Max 2408 bytes]
rxpk / stat

2. PUSH_ACK (1)
[4 bytes]

LoRaWAN network server

## Upstream

- Sending sensor data
- Sending the gateway status and is set by "stat_interval" parameter.

## Downstream

- Sending keepalive message and is set by "keepalive_interval" parameter.
- Sending downlink response to the gateway.

gateway

1. PULL_DATA (2)
[12 bytes]
keepalive

2. PULL_ACK (4)
[4 bytes]

LoRaWAN network server

gateway

4. TX_ACK (3)
12-41 bytes
txpk_ack

3. PULL_RESP (5)
[Max 1000 bytes]
txpk

port 1700

LoRaWAN network server

Notes:

- Semtech UDP protocol version 2
- (**x**) are identifiers
- More information, see tutorial 29.

# WHITELISTING NODES NOT POSSIBLE

- The RAK7243C and RAK7244C LoRaWAN gateway can not whitelist end nodes.
- This means when using the cellular backhaul, you will also pay for cellular data packages from other end nodes not owned by you.