MINES Saint-Étienne

Une école de l'IMT

Weather Station

A multi-sensor, self-sufficient, modular, educational device

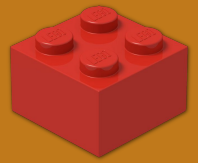
Raphaël COMPS, Adrien KOMAROFF-KOURLOFF, Étienne GOZILLON, Savinien THIEBAUT, Axel GUICHAOUA, Louis MAINIX-CHIRIO

1. Station overview
2. Embedded system
    a. Sensors overview
    b. Mode of operation and optimizations
        i. Software
        ii. Hardware
    c. Energy harvesting circuit
    d. Energy balancing
3. Indoor system
    a. Wireless Communication
    b. Indoor Sensors
    c. Database and dashboard
4. Troubleshooting

1. Station overview : *Challenges*

10+2

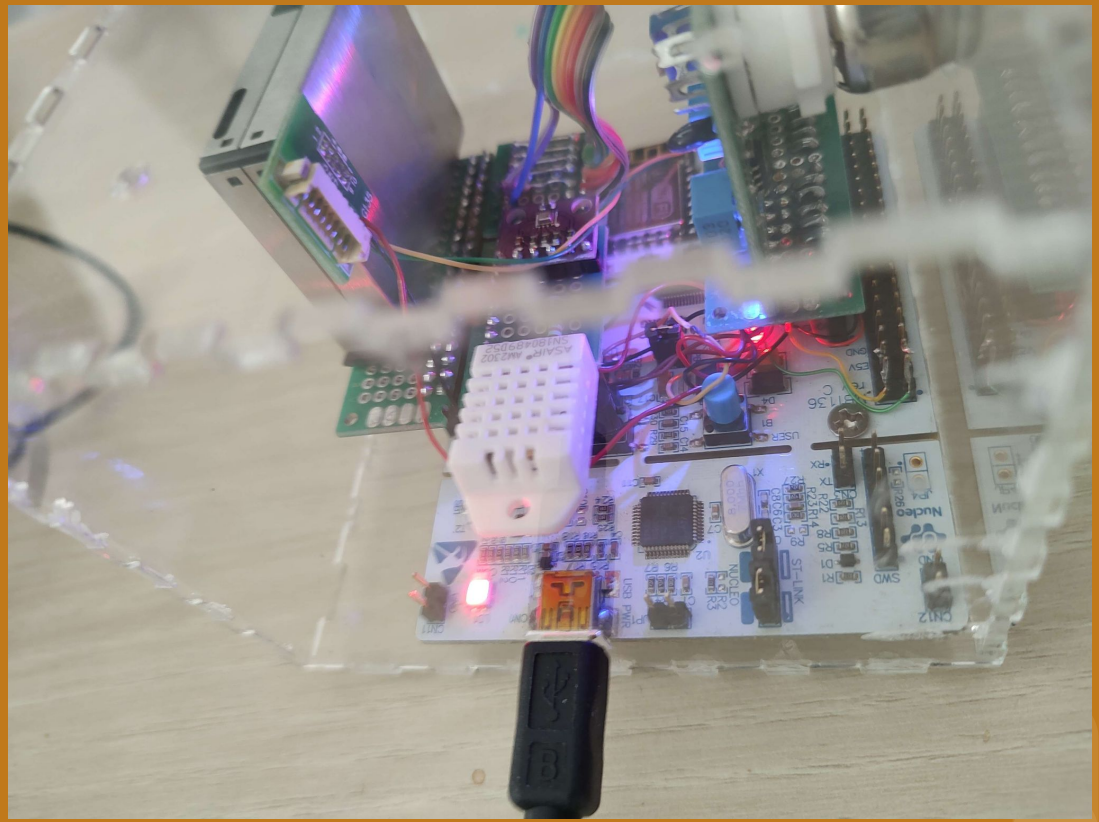
Modular



Educational

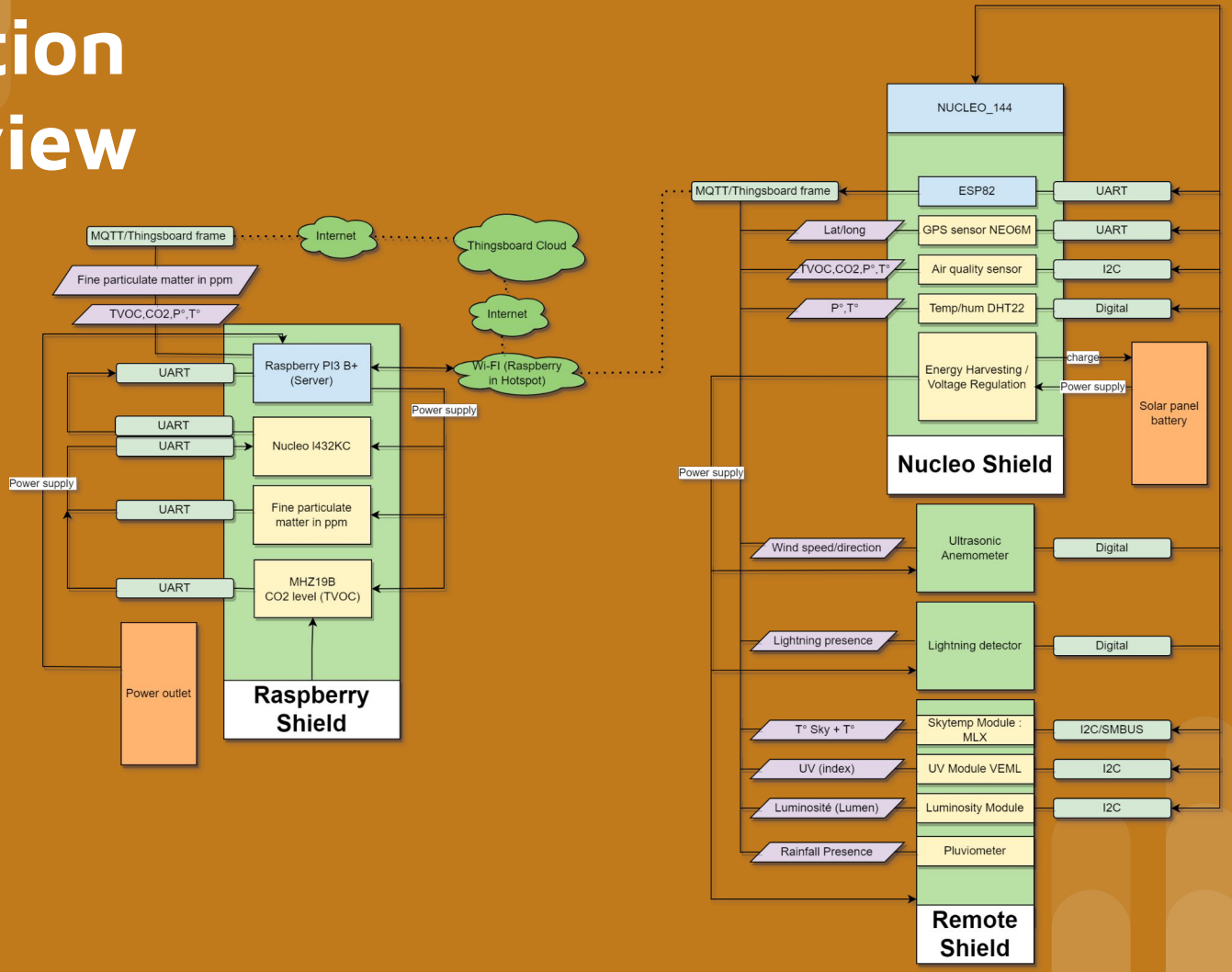
Low Power

1. Station overview : *History*



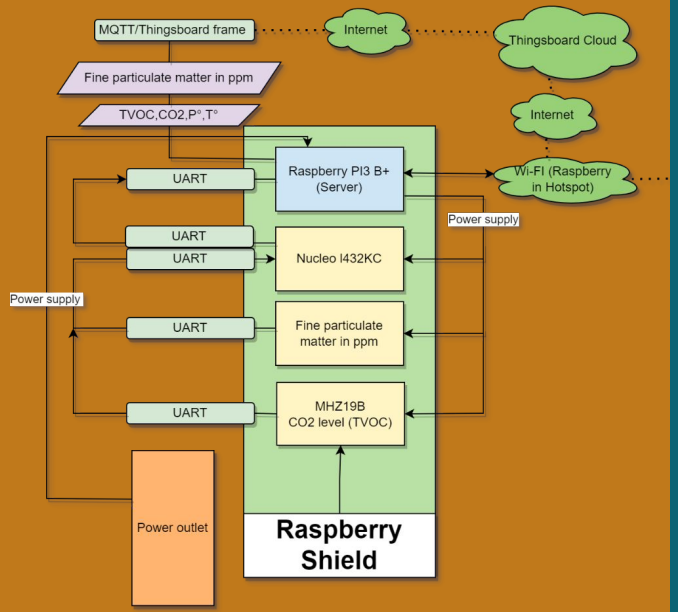
1. Station overview：*Constraints from client*

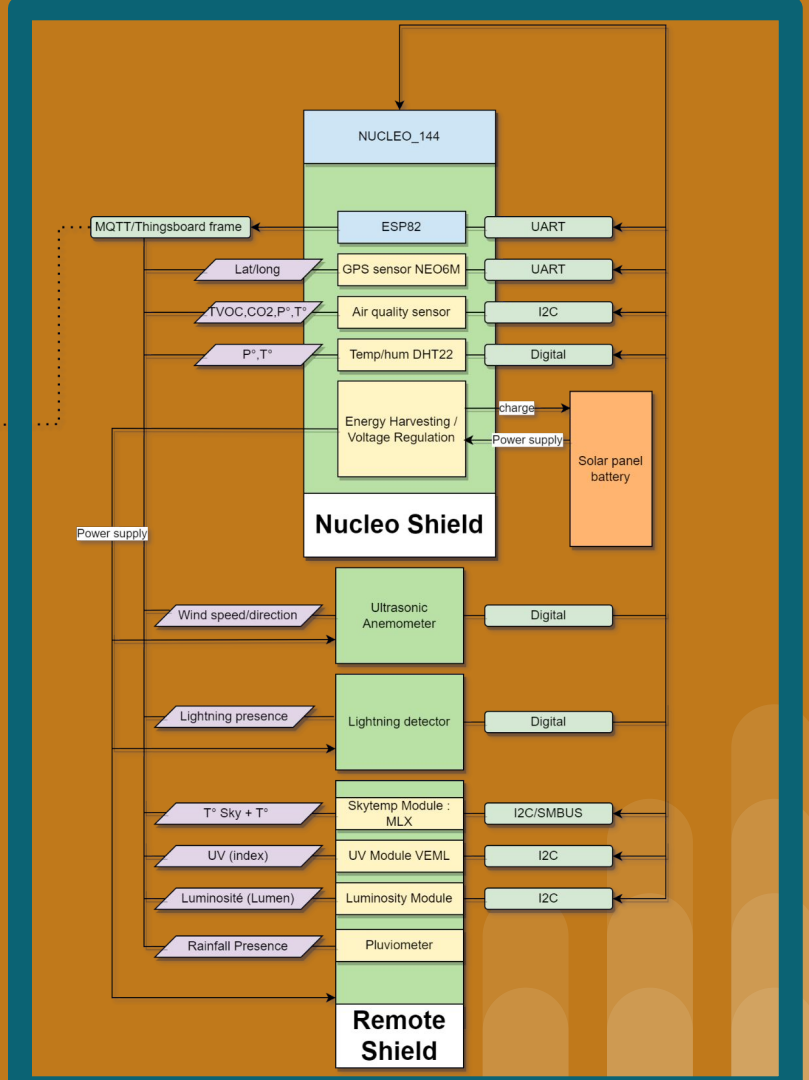
1. Station overview



2. Embedded system

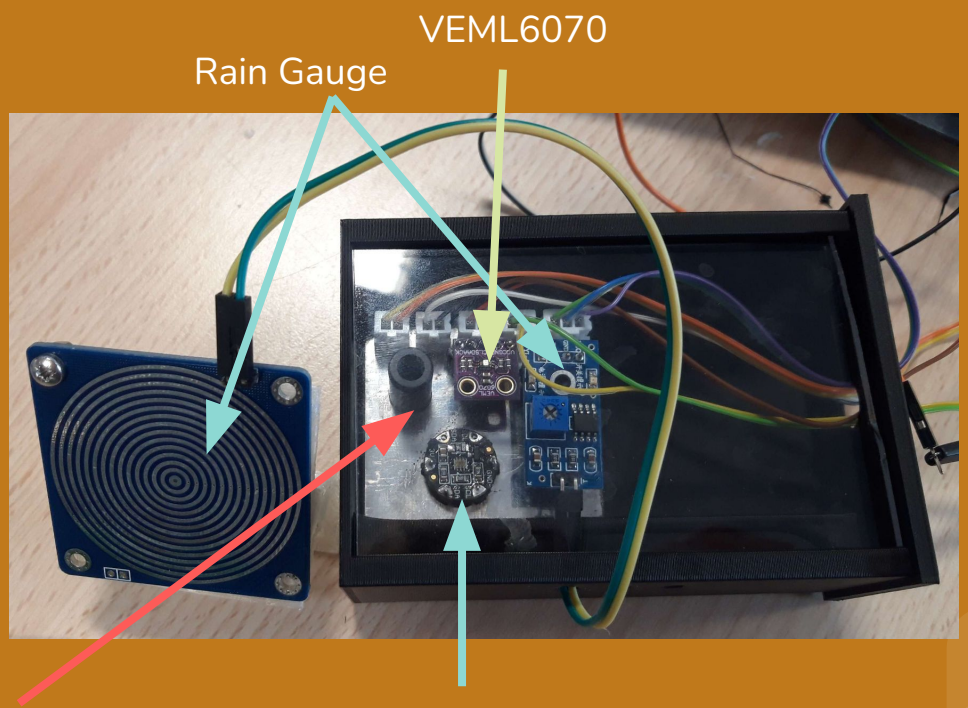
2. Embedded System





2. Embedded system

a. Components & sensors overview



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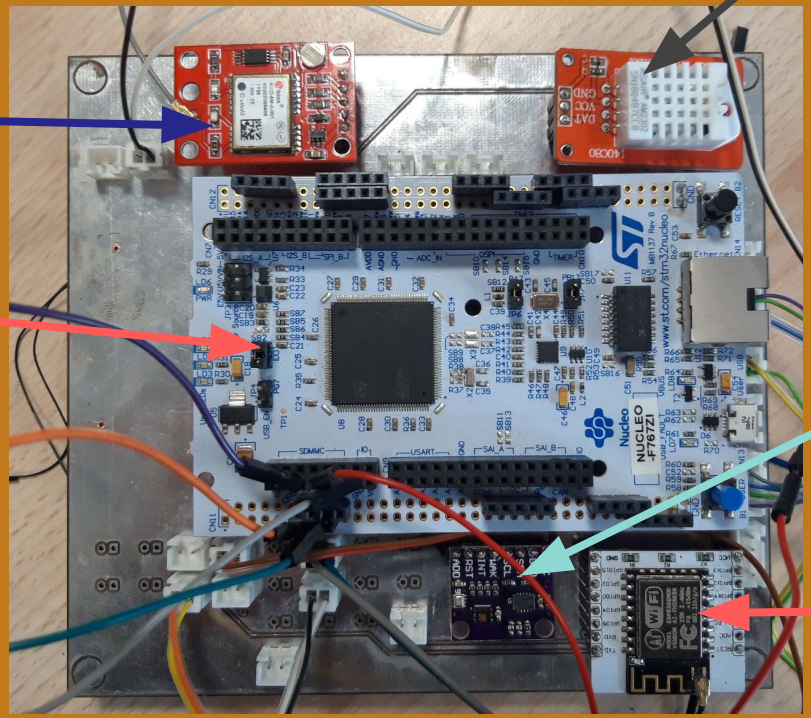

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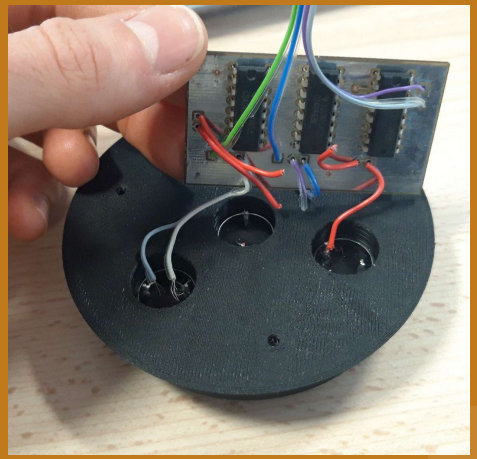
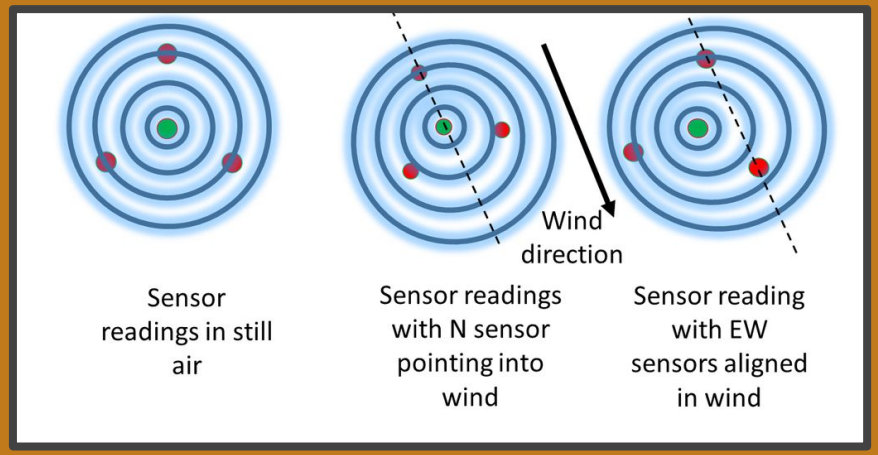


Custom sensor: supersonic anemometer

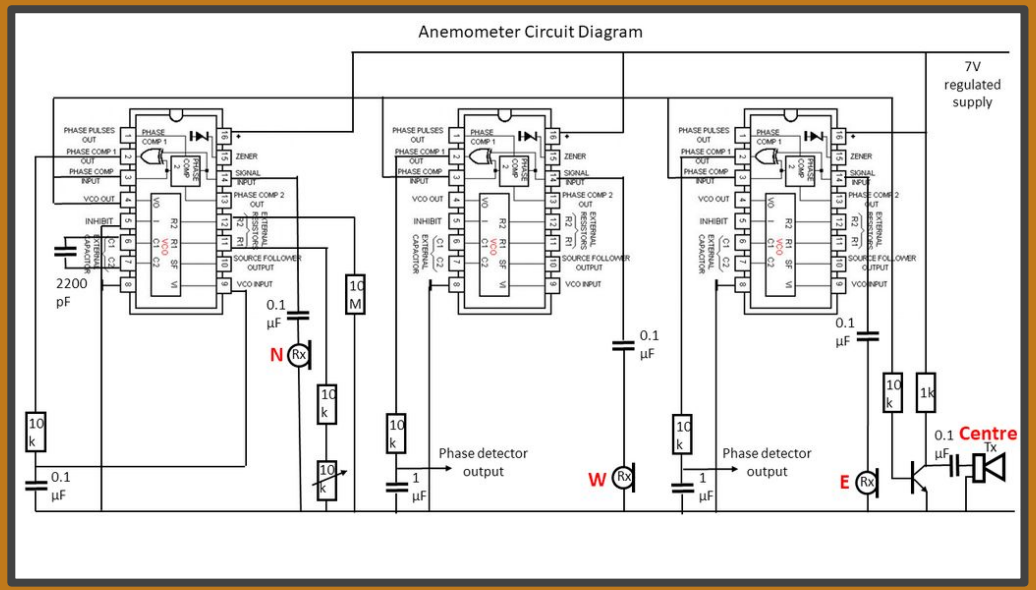
2. Embedded system

a. Components & sensors overview



2. Embedded system

a. Components & sensors overview



2. Embedded system

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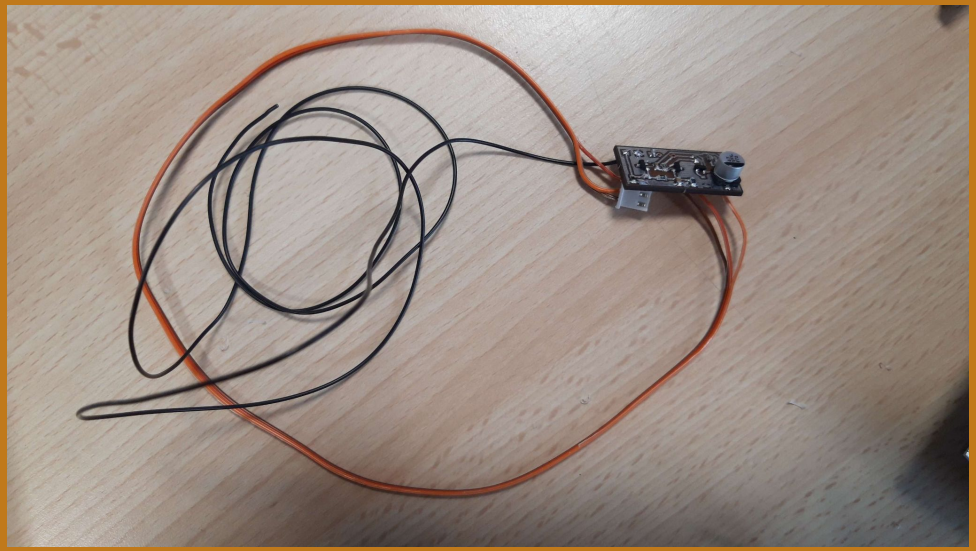
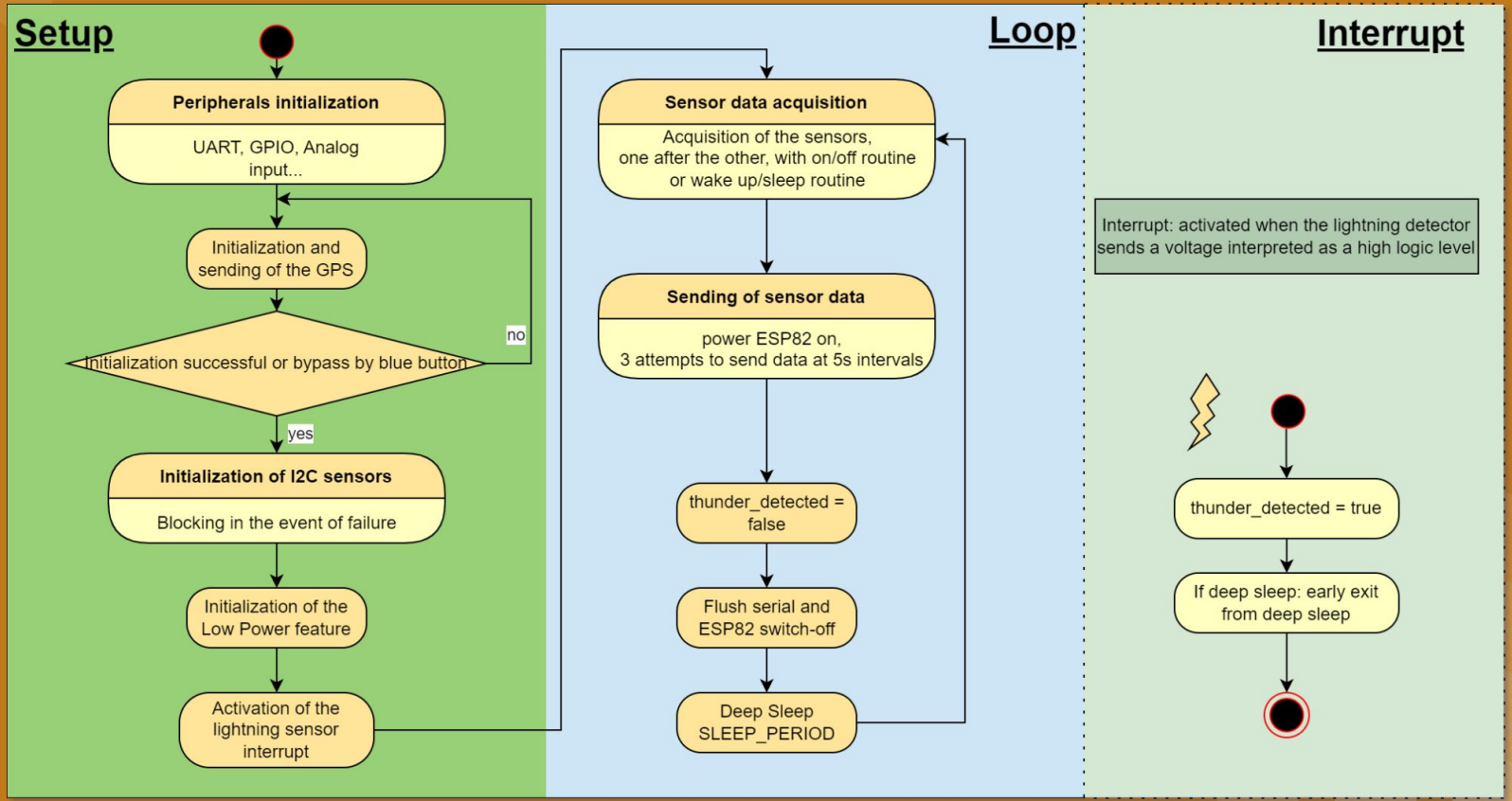


Custom sensor: lightning detector

2. Embedded system

b. Mode of operation and optimizations



2. Embedded system

b. Mode of operation and optimizations

i. Software

Clock speed reduction on main microcontroller

(Voltage regulator, overdrive mode)

Parameter	f_{HCLK} (MHz)	Typ	Max(1)			Unit
			T_A = 25 °C	T_A = 85 °C	T_A = 105 °C	
Supply current in RUN mode	216	92	104	150	-	mA
	200	86	97	143	170	
	180	76	85	119	140	
	168	67	75	107	126	
	144	52	58	84	101	
	60	23	28	54	71	
	25	11	15	42	56	

- F_{hclk} from 216MHz to 24MHz
- MCU current from 45mA to 15mA in RUN mode

2. Embedded system

b. Mode of operation and optimizations

i. Software

Use of STOP mode when idle with...

Table 35. Typical and maximum current consumptions in Stop mode

Symbol	Parameter	Conditions	Typ	Max(1)			Unit
				V_{DD} = 3.6 V			
			T_A = 25 °C	T_A = 25 °C	T_A = 85 °C	T_A = 105 °C	
$I_{DD\_STOP\_NM}$ (normal mode)	Supply current in Stop mode, main regulator in Run mode	Flash memory in Stop mode, all oscillators OFF, no IWDG	0.55	3	18	27	mA
		Flash memory in Deep power down mode, all oscillators OFF	0.5	3	18	27	
	Supply current in Stop mode, main regulator in Low-power mode	Flash memory in Stop mode, all oscillators OFF, no IWDG	0.42	2.5	15	24	
		Flash memory in Deep power down mode, all oscillators OFF, no IWDG	0.37	2.5	15	24	
$I_{DD\_STOP\_UDM}$ (under-drive mode)	Supply current in Stop mode, main regulator in Low voltage and under-drive modes	Regulator in Run mode, Flash memory in Deep power down mode, all oscillators OFF, no IWDG	0.18	1.2	6	10	
		Regulator in Low-power mode, Flash memory in Deep power down mode, all oscillators OFF, no IWDG	0.13	1.1	6	10	

- RTC wakeup
- configured for low-power (LSI clock and LP voltage regulator)

⟶MCU and sensors current consumption down to ≈1mA

2. Embedded system

b. Mode of operation and optimizations

ii. Hardware

Power supply of the sensors

- accessibility and energy self-sufficiency compromise
- delays
- improvements are possible

VEML6070	I2C-induced sleep
TCS34725	I2C-induced sleep
MLX90614	Transistor-driven supply
Rain Gauge	Transistor-driven supply
DHT 22	Transistor-driven supply
CCS811	Always on, low-power
BMP280	Always on
HDC1080	Always on
GPS	Transistor-driven supply
ESP8266	Transistor-driven supply
Anemometer	Transistor-driven supply
Lightning detector	Always on

2. Embedded system

b. Mode of operation and optimizations

ii. Hardware

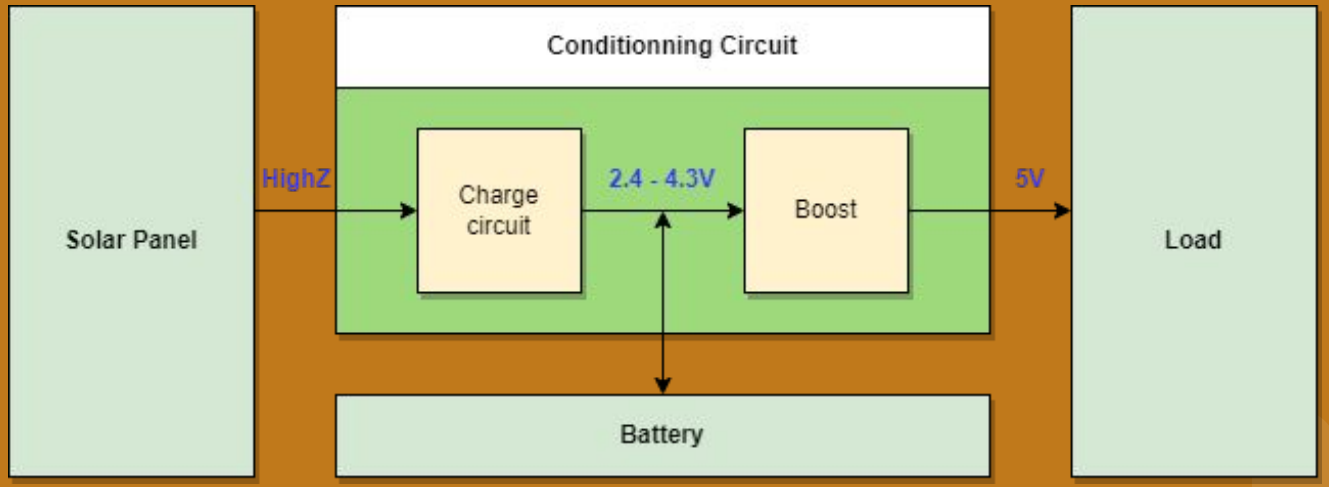
Nucleo board configuration

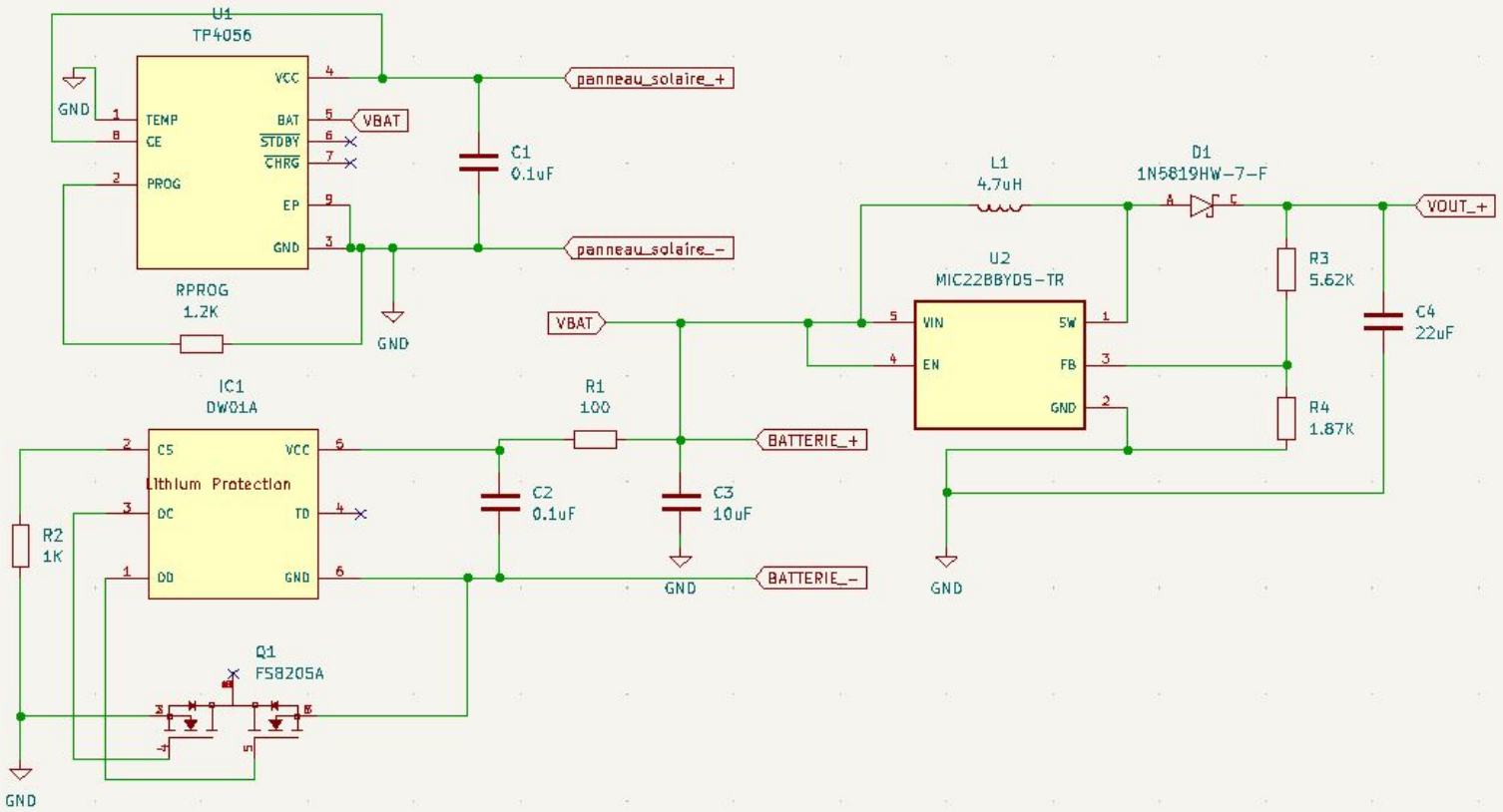
Modification	Gain	Loss/Comment
ST-Link cut	≈50mA	debug/programming are more complex
Ethernet module clock disabled	≈50mA	functionality disabled
3V3_PER power supply disabled (SB2)	≈60mA	ethernet module, on-board ST-Link, LEDs, buttons are disabled

→current fed to Nucleo w/o MCU from ≈160mA to 0mA

2. Embedded system

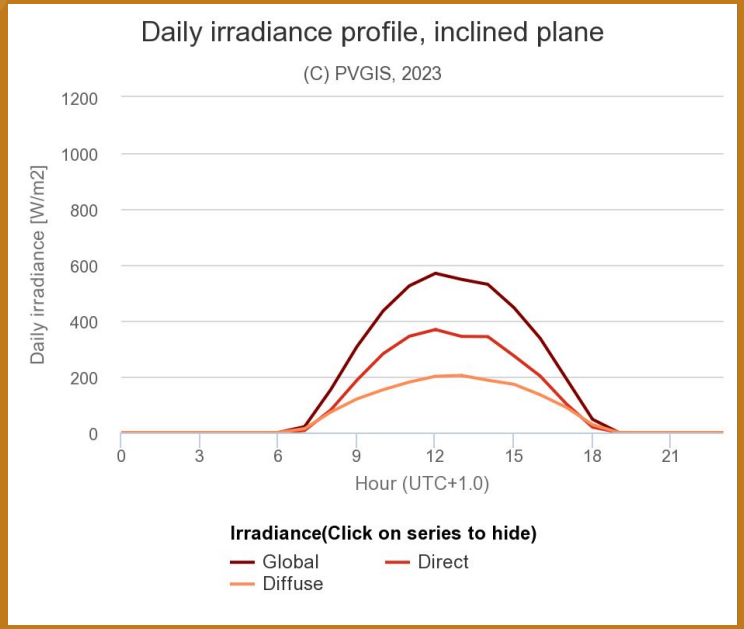
c. Energy harvesting circuit




U1
TP4056
GND
TEMP
CE
PROG
VCC
BAT
STDBY
CHRG
EP
GND
VBAT
panneau_solaire_+
panneau_solaire_-
C1
0.1uF
RPROG
1.2K
GND
L1
4.7uH
D1
1N5819HW-7-F
A
C
VOUT_+
U2
MIC22BBYD5-TR
VIN
EN
SW
FB
GND
R3
5.62K
R4
1.87K
C4
22uF
GND
VBAT
IC1
DW01A
CS
Lithium Protection
OC
OD
VCC
TD
GND
R1
100
BATTERIE_+
BATTERIE_-
C2
0.1uF
C3
10uF
GND
R2
1K
Q1
FS8205A
GND

2. Embedded system

c. Energy balancing



Average empiric efficiency of the solar panel deduced from march average irradiance :

$$\eta_{Avg} \approx 11\%$$

Average available power in december (before conditioning circuit consumption)

$$P_{PV,Avg,Dec} = 171mW$$

TP4056

SYMBOL	PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
V_{CC}	Input Supply Voltage		●	4.0	5	8.0	V
I_{CC}	Input Supply Current	Charge Mode, R_{PROG} = 1.2k	●		150	500	μA
		StandbyMode(Charge Terminated)	●		55	100	μA
		Shutdown Mode (R_{PROG} Not Connected, V_{CC} < V_{BAT}, or V_{CC} < V_{UV})	●		55	100	μA

DW01A

PARAMETER	TEST CONDITIONS	SYMBOL	Min	Typ	Max	UNIT
Supply Current	Vcc=3.6V	Icc		3.0	6.0	μA
Power-Down Current	Vcc=1.8V	Ipd			4	μA
OD Pin Output “H” Voltage		Vdh	Vcc-0.1	Vcc-0.02		V
OD Pin Output “L” Voltage		Vdl		0. 1	0.5	V
OC Pin Output “H” Voltage		Vch	Vcc-0.1	Vcc-0.02		V
OC Pin Output “L” Voltage		Vcl		0.1	0.5	V

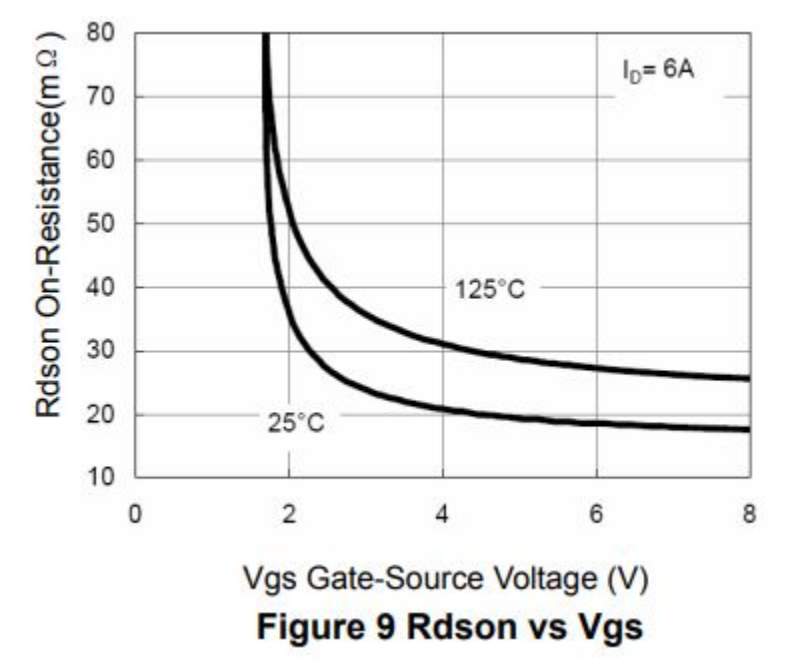
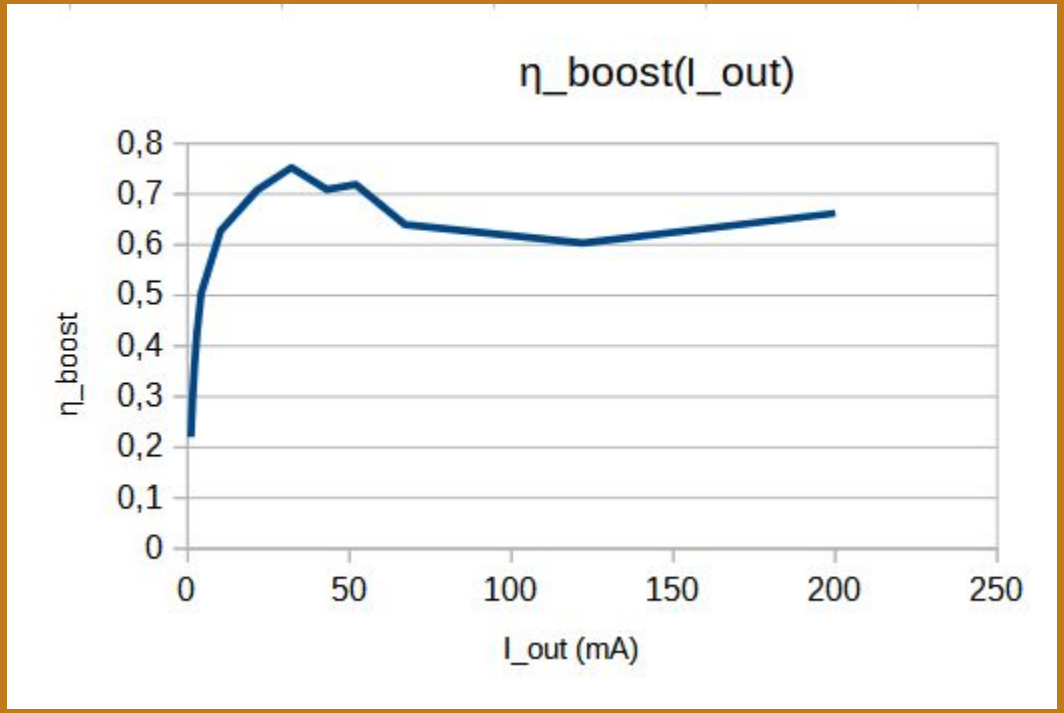


Figure 9 Rdson vs Vgs

$$P_{8205A} = R_{DS(ON)} \times \frac{|P_{PV} - P_{LOAD}|^2}{V_{BAT}^2}$$


η_boost(I_out)
η_boost
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
0
50
100
150
200
250
I_out (mA)

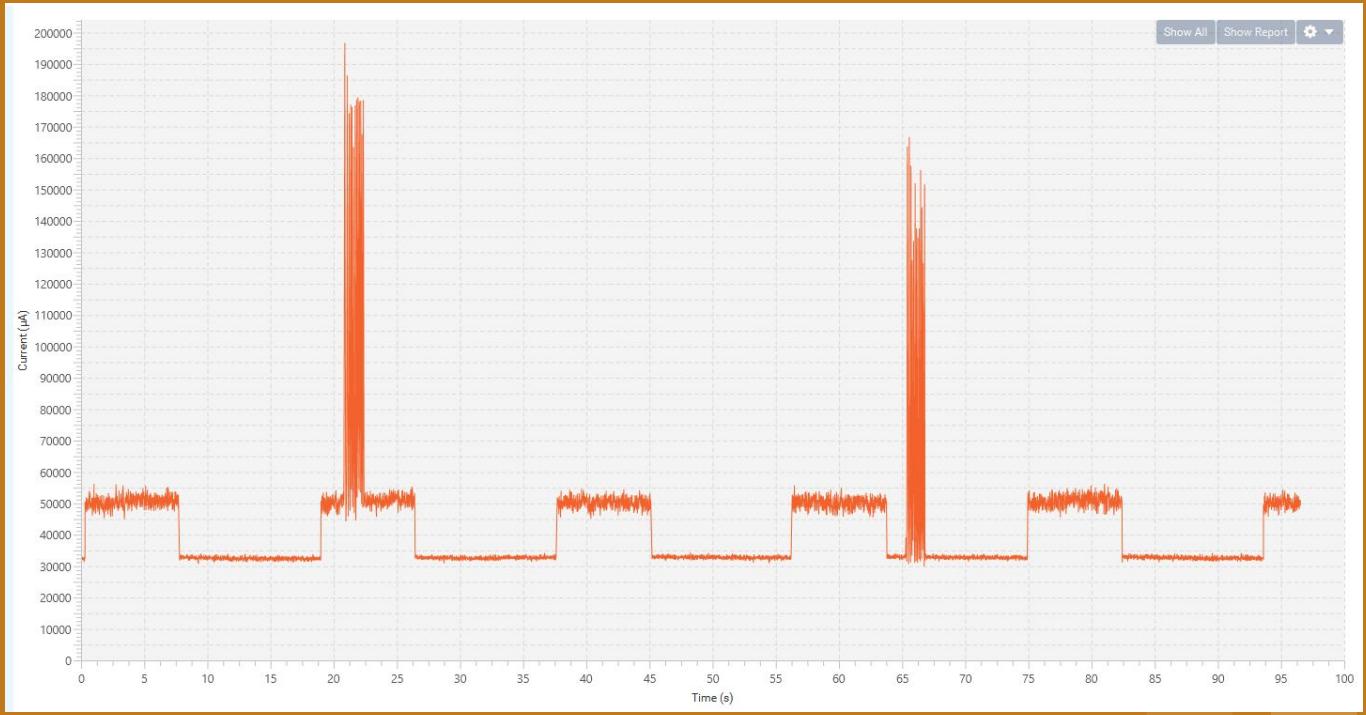
Exact formula :

$$P_{Available} = \eta_{boost}(P_{PV} - P_{TP4056} - P_{DW01A} - P_{8205A})$$

Estimation :

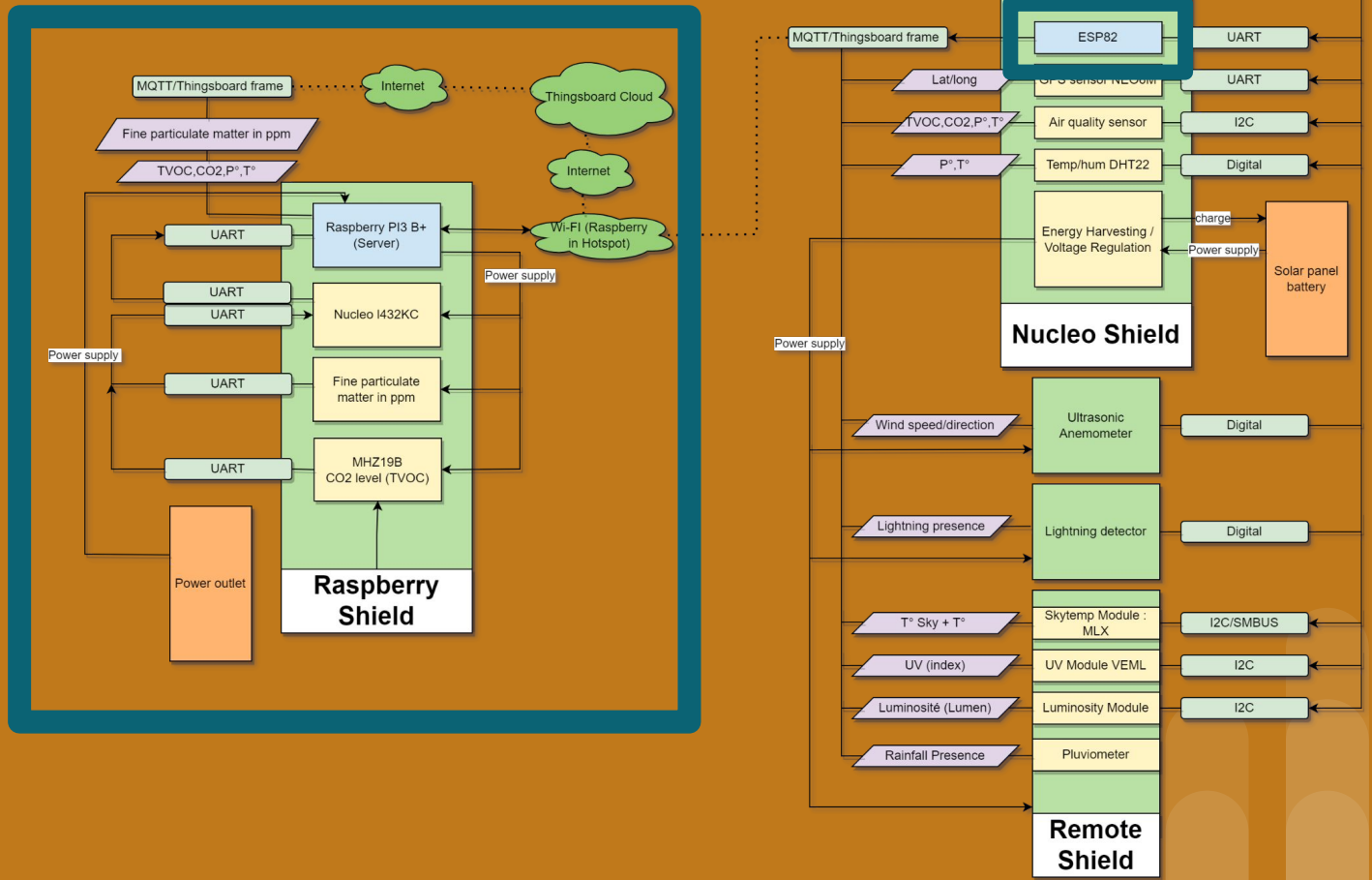
$$P_{Available,Avg} < P_{PV,Avg} - P_{TP4056,Avg} - P_{DW01A,Avg} \approx 168.9mW$$

Load consumption



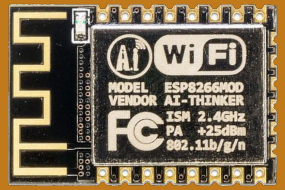
3. Indoor System

3. Indoor System



3. Indoor System

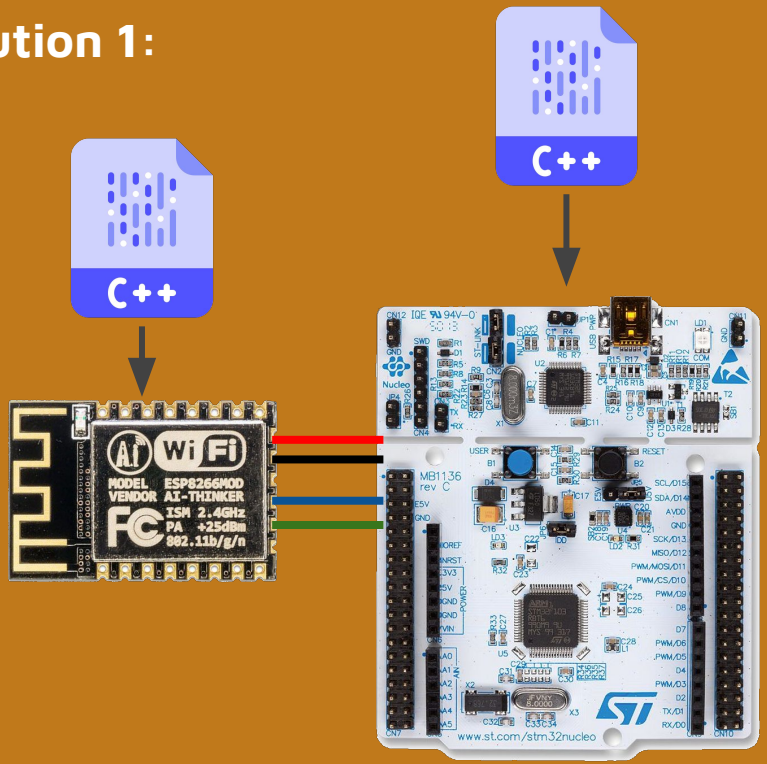
a. Wireless Communication



3. Indoor System

a. Wireless Communication

Solution 1:



Pros:

- Shorter data frame

→ thus less power consumed

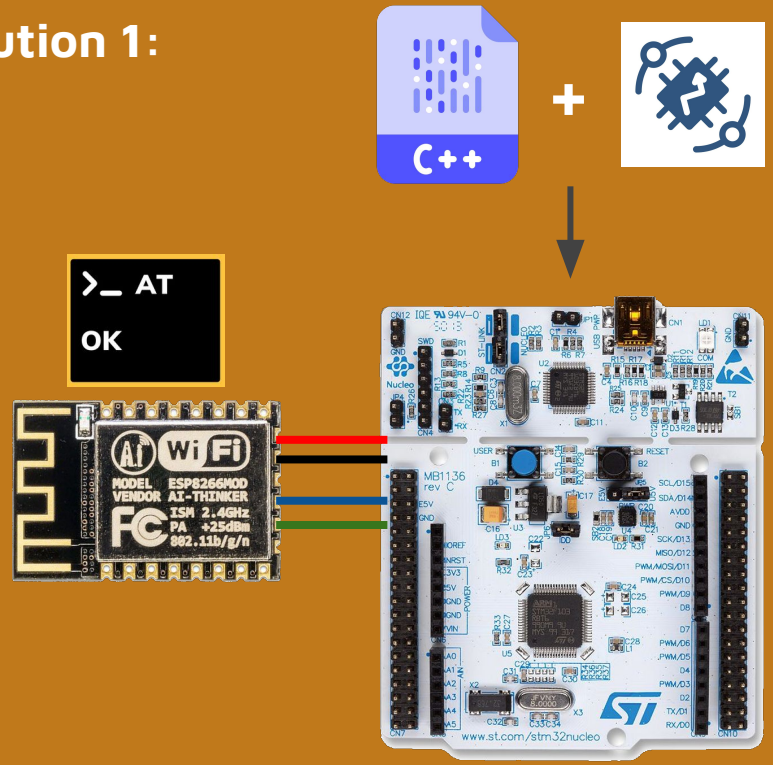
Cons:

- Must program both
- Adding a sensor is harder

3. Indoor System

a. Wireless Communication

Solution 1:



Pros:

- Adding sensors is easy
- Only program the Nucleo

Cons:

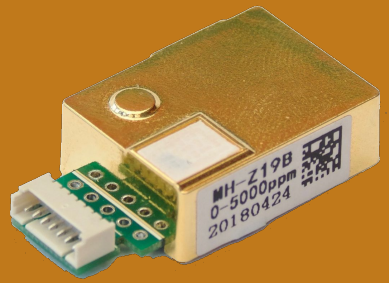
- Longer data frame
- Higher consumption

3. Indoor System

b. Sensors and measurements

- **Air quality sensor**
  → Particules count

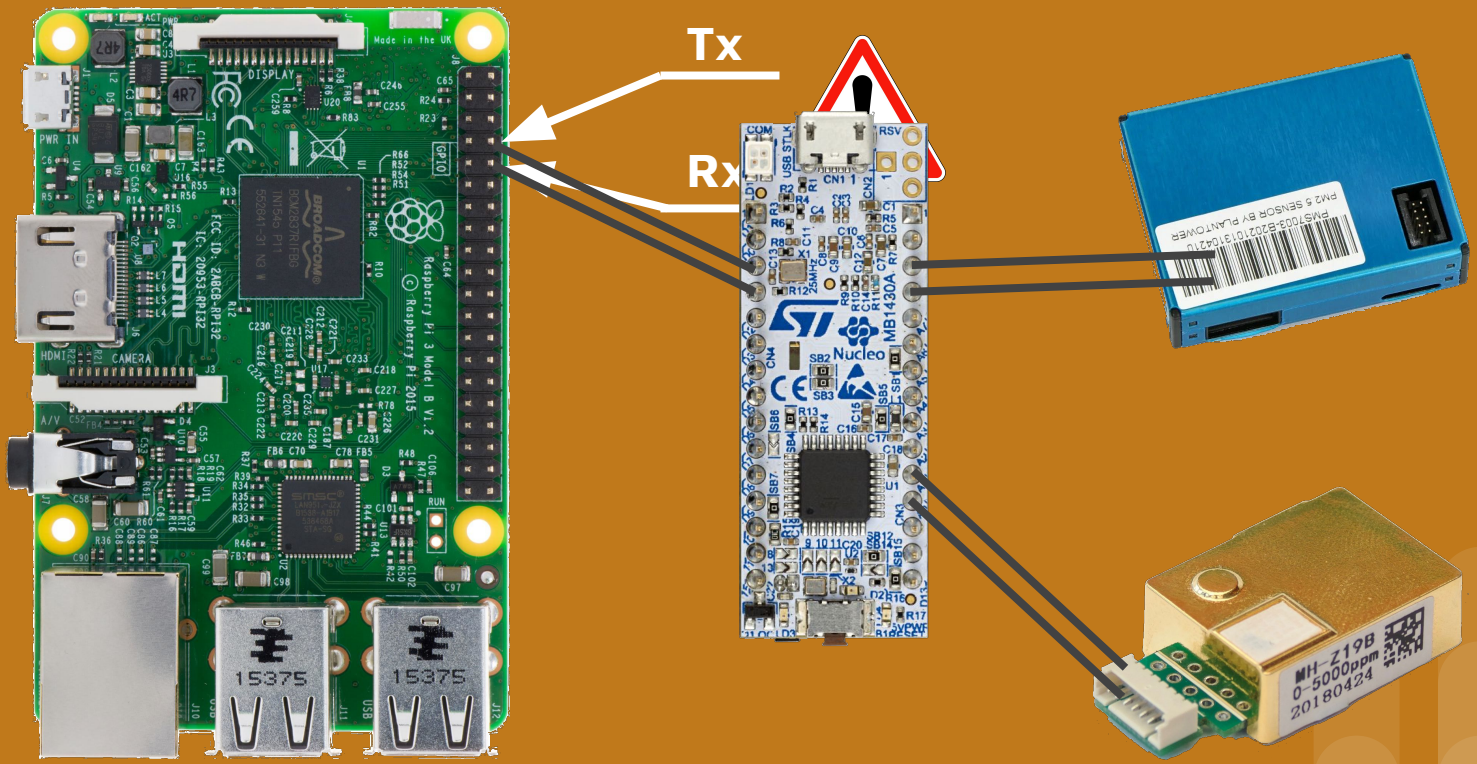
→ Both using UART



- **CO2 sensor**
  → rate in ppm

3. Indoor System

b. Sensors and measurements



3. Indoor System

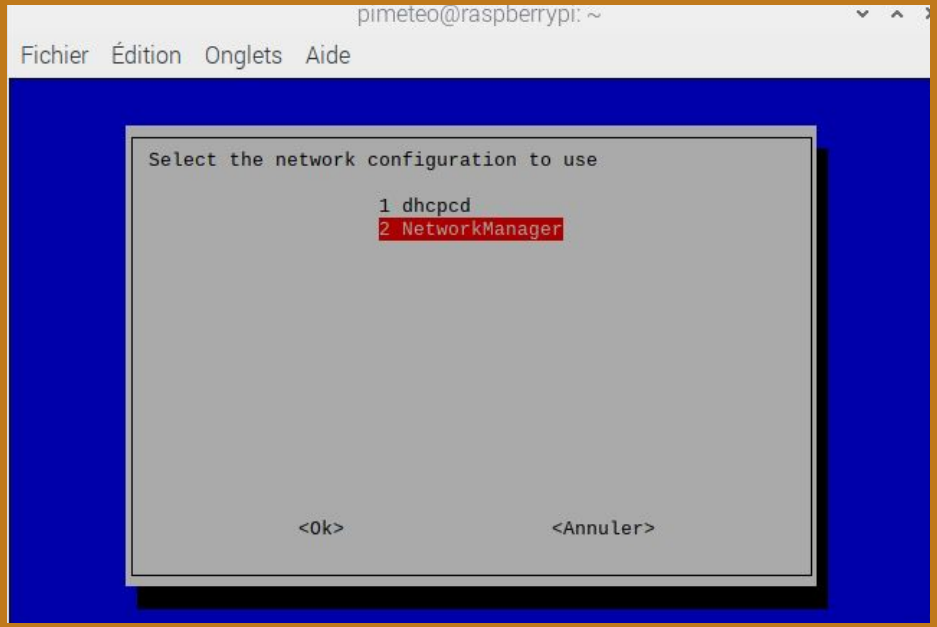
b. Sensors and measurements

3. Indoor System

b. Data and dashboard

1 - Configuration of the hot-spot

Enable NetworkManager with raspi-config



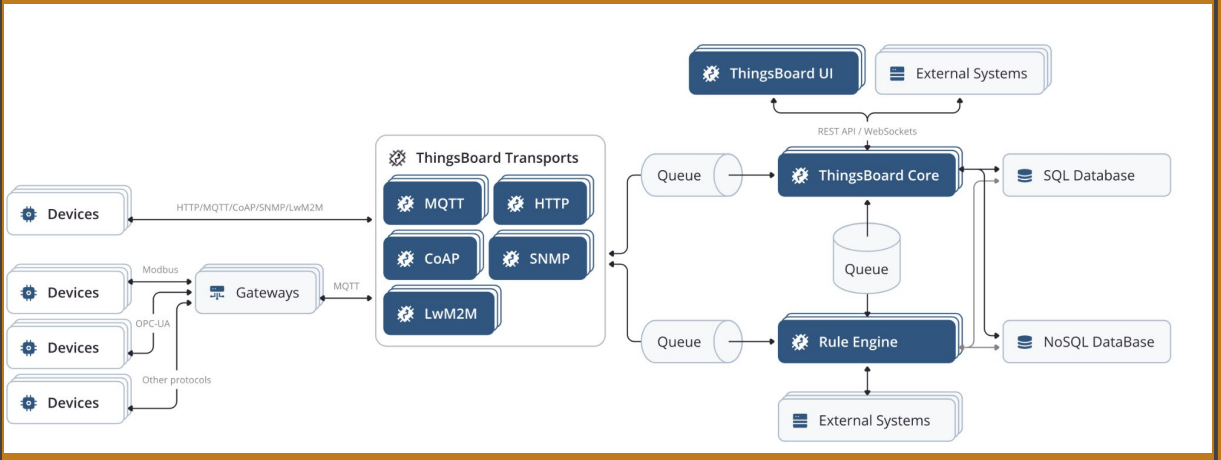
Configuration of the hot-spot

3. Indoor System

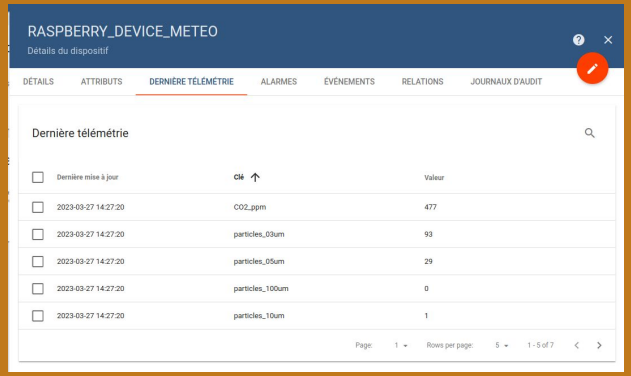
b. Data and dashboard

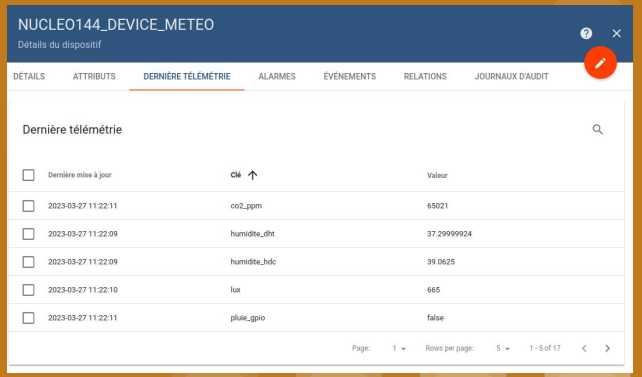
2- ThingsBoard setup

Architecture supplied by Thingsboard



Create devices and tokens





3. Indoor System

b. Data and dashboard

3 - Database

Database creation

```
> sudo service postgresql start
> sudo su - postgres
>> psql -U postgres -d postgres -h 127.0.0.1 -W
>> CREATE DATABASE thingsboard;
```

```
                  Liste des relations
 Schéma |         Nom          | Type  | Propriétaire
--------+----------------------+-------+--------------
 public | admin_settings       | table | postgres
 public | alarm                | table | postgres
 public | asset                | table | postgres
 public | attribute_kv         | table | postgres
 public | audit_log            | table | postgres
 public | component_descriptor | table | postgres
 public | customer             | table | postgres
 public | dashboard            | table | postgres
 public | device               | table | postgres
 public | device_credentials   | table | postgres
 public | entity_view          | table | postgres
 public | event                | table | postgres
 public | relation             | table | postgres
 public | rule_chain           | table | postgres
 public | rule_node            | table | postgres
 public | tb_user              | table | postgres
 public | tenant               | table | postgres
 public | ts_kv                | table | postgres
 public | ts_kv_latest         | table | postgres
 public | user_credentials     | table | postgres
 public | widget_type          | table | postgres
 public | widgets_bundle       | table | postgres
(22 lignes)
```

Add to Thingsboard's .conf file

```
# DB Configuration
export DATABASE_TS_TYPE=sql
export SPRING_DATASOURCE_URL=jdbc:postgresql://localhost:5432/thingsboard
export SPRING_DATASOURCE_USERNAME=postgres
export SPRING_DATASOURCE_PASSWORD=PUT_YOUR_POSTGRESQL_PASSWORD_HERE
# Specify partitioning size for timestamp key-value storage. Allowed values:
DAYS, MONTHS, YEARS, INDEFINITE.
export SQL_POSTGRES_TS_KV_PARTITIONING=MONTHS
```

3. Indoor System

b. Data and dashboard

3 - Database

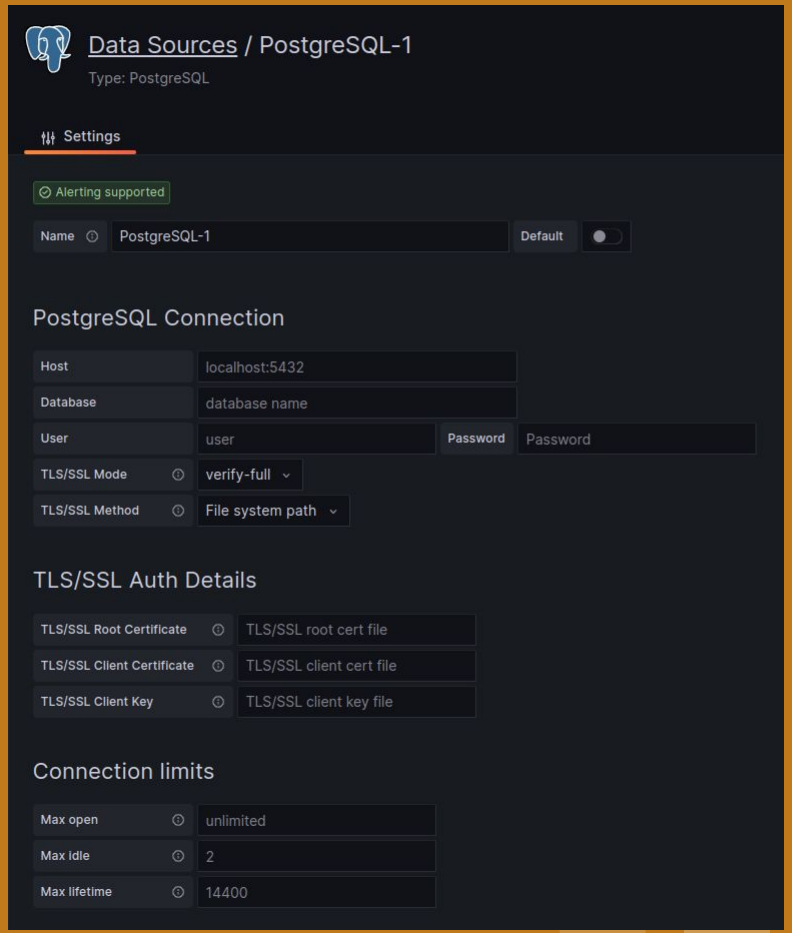
```
> sudo service postgresql start
> psql
>> \c thingsboard
>>>> select * from ts_kv ;
```

entity_type	entity_id	key	ts	bool_v	str_v	long_v	dbl_v
DEVICE	1edca470f76b500ae6c7b0bf40c9c35	particles_25um	1679920040794			1	
DEVICE	1edca470f76b500ae6c7b0bf40c9c35	particles_50um	1679920040794			0	
DEVICE	1edca470f76b500ae6c7b0bf40c9c35	particles_100um	1679920040794			0	
DEVICE	1edca470f76b500ae6c7b0bf40c9c35	particles_05um	1679920040794			29	
DEVICE	1edca470f76b500ae6c7b0bf40c9c35	particles_10um	1679920040794			1	
DEVICE	1edca470f76b500ae6c7b0bf40c9c35	particles_03um	1679920040794			93	
DEVICE	1edca470f76b500ae6c7b0bf40c9c35	CO2_ppm	1679920040794			477	
DEVICE	1edca47320572a0ae6c7b0bf40c9c35	wind_speed	1679908928368			4942	
DEVICE	1edca47320572a0ae6c7b0bf40c9c35	wind_heading	1679908928579			180	
DEVICE	1edca47320572a0ae6c7b0bf40c9c35	temp_amb_sky	1679908928799				22.30999184
DEVICE	1edca47320572a0ae6c7b0bf40c9c35	temp_obj_sky	1679908929033				22.62999916
DEVICE	1edca47320572a0ae6c7b0bf40c9c35	humidite_hdc	1679908929238				39.0625
DEVICE	1edca47320572a0ae6c7b0bf40c9c35	temp_hdc	1679908929450				23.52661133
DEVICE	1edca47320572a0ae6c7b0bf40c9c35	humidite_dht	1679908929669				37.29999924
DEVICE	1edca47320572a0ae6c7b0bf40c9c35	temp_dht	1679908929885				21.20000076
DEVICE	1edca47320572a0ae6c7b0bf40c9c35	pluie_pourcent	1679908930104				0.3307693
DEVICE	1edca47320572a0ae6c7b0bf40c9c35	pression_bmp	1679908930324				99171.5625
DEVICE	1edca47320572a0ae6c7b0bf40c9c35	temp_bmp	1679908930546				24.32999992
DEVICE	1edca47320572a0ae6c7b0bf40c9c35	lux	1679908930743			665	
DEVICE	1edca47320572a0ae6c7b0bf40c9c35	uv_level	1679908930947			2	
DEVICE	1edca47320572a0ae6c7b0bf40c9c35	co2_ppm	1679908931158			65021	

3. Indoor System

b. Data and dashboard

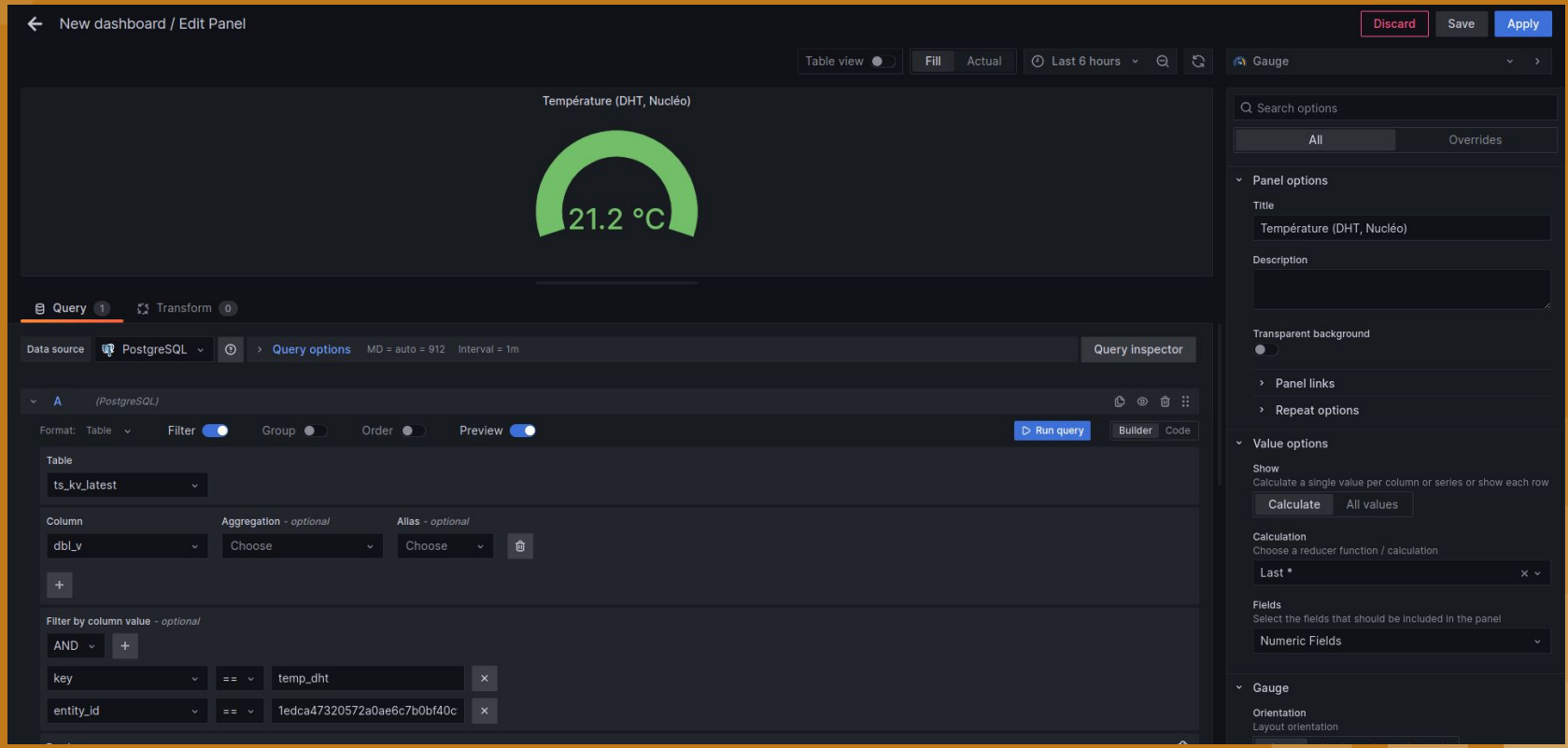
4 - Grafana



3. Indoor System

b. Data and dashboard

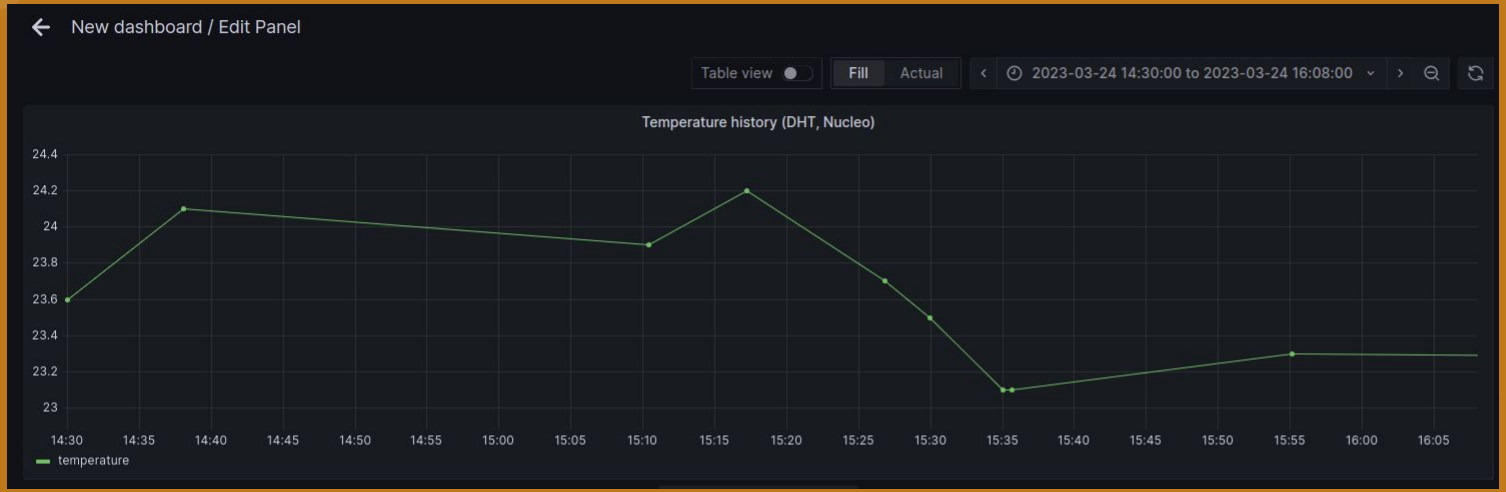
4 - Grafana



3. Indoor System

b. Data and dashboard

4 - Grafana




```
SELECT ts as “time”, dbl_v as “temperature”
WHERE key = “temp_dht”
```

Conclusion

4. Troubleshooting

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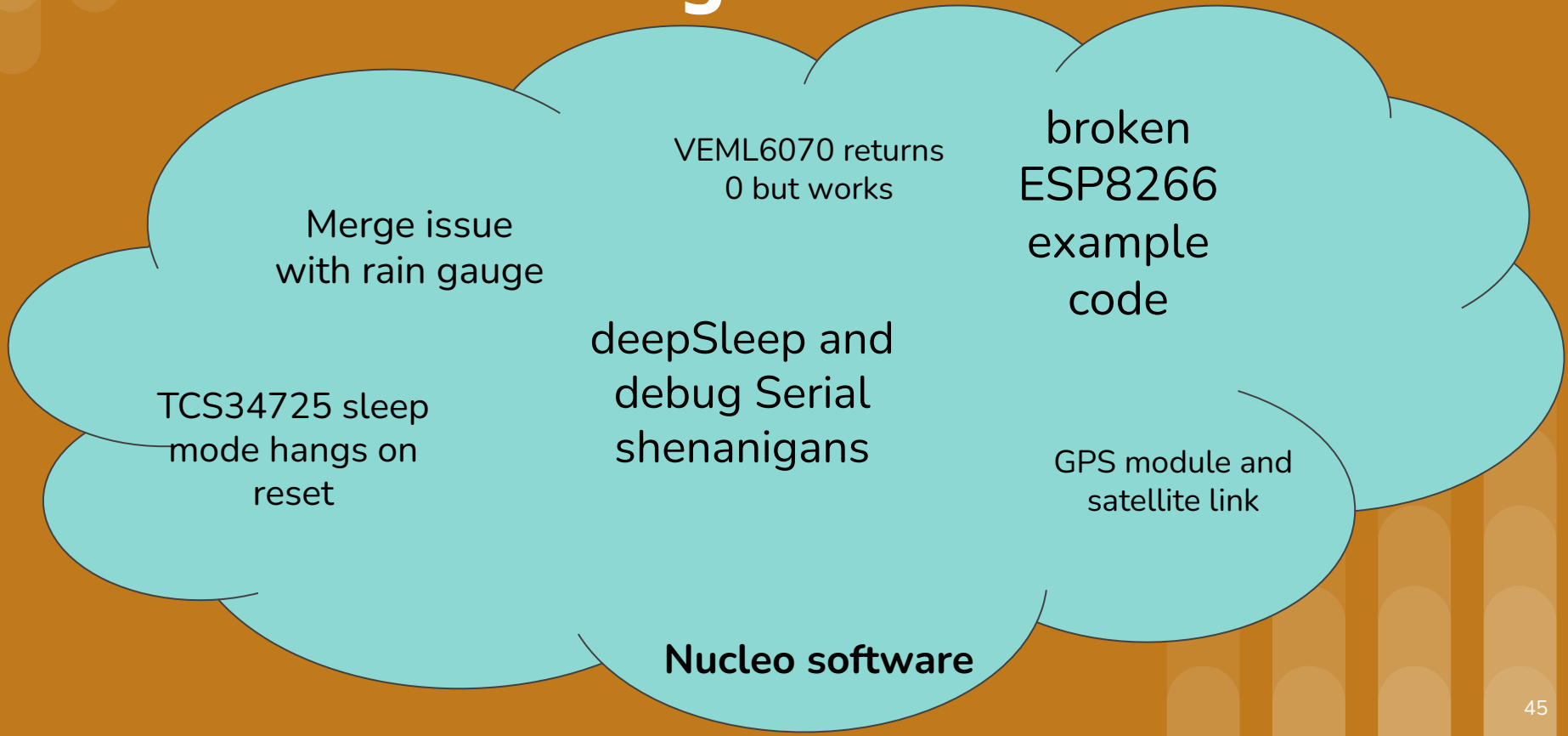
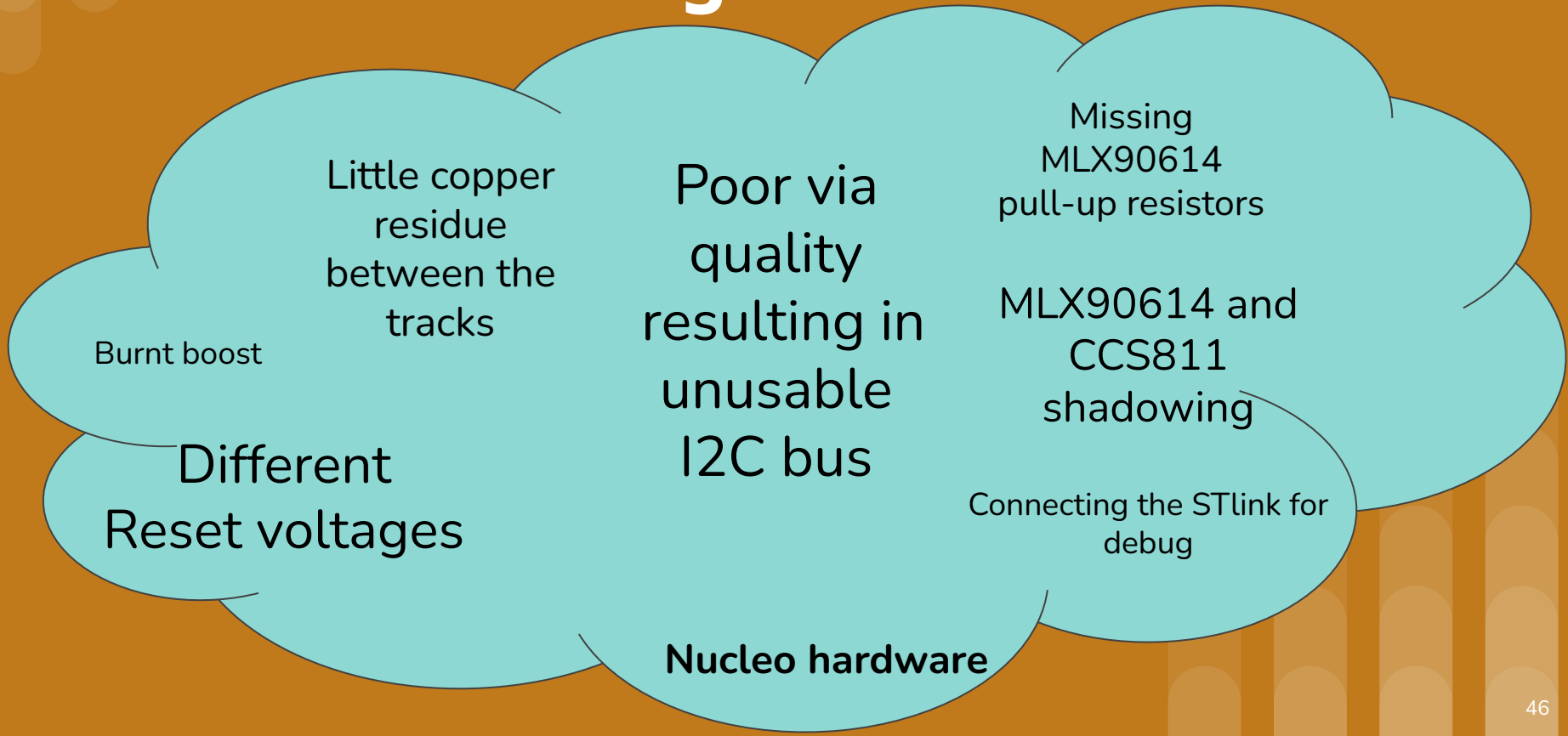
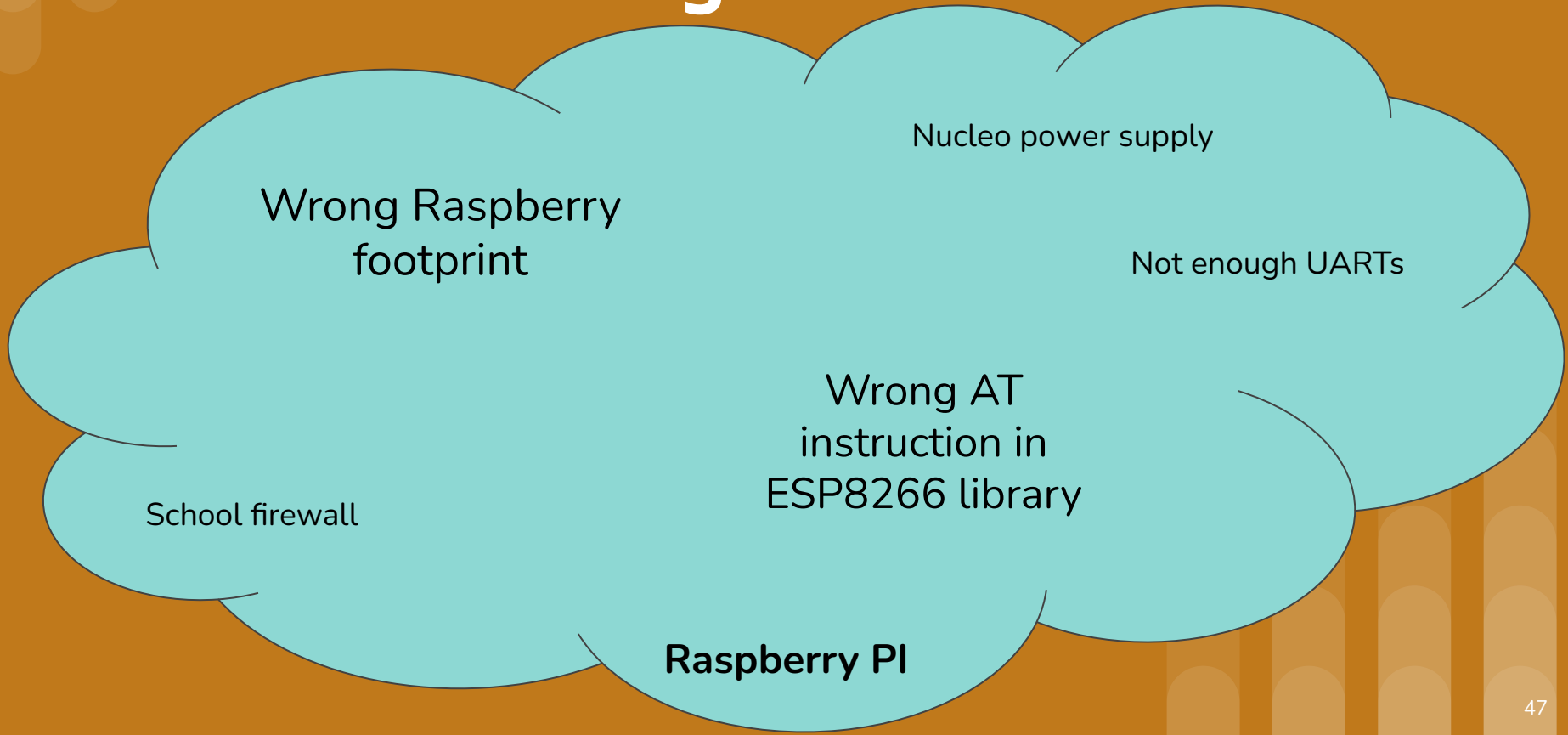


4. Troubleshooting



4. Troubleshooting



4. Troubleshooting

impossibility to propose a quantitative study of load consumption

difficulty to produce test PCBs to characterise CMS components separately

only a qualitative conclusion regarding self-sufficiency

Energy Balance