Low Power IoT Architectures

"Mesures et analyse des consommations énergétiques d'une architecture IoT très faible puissance"

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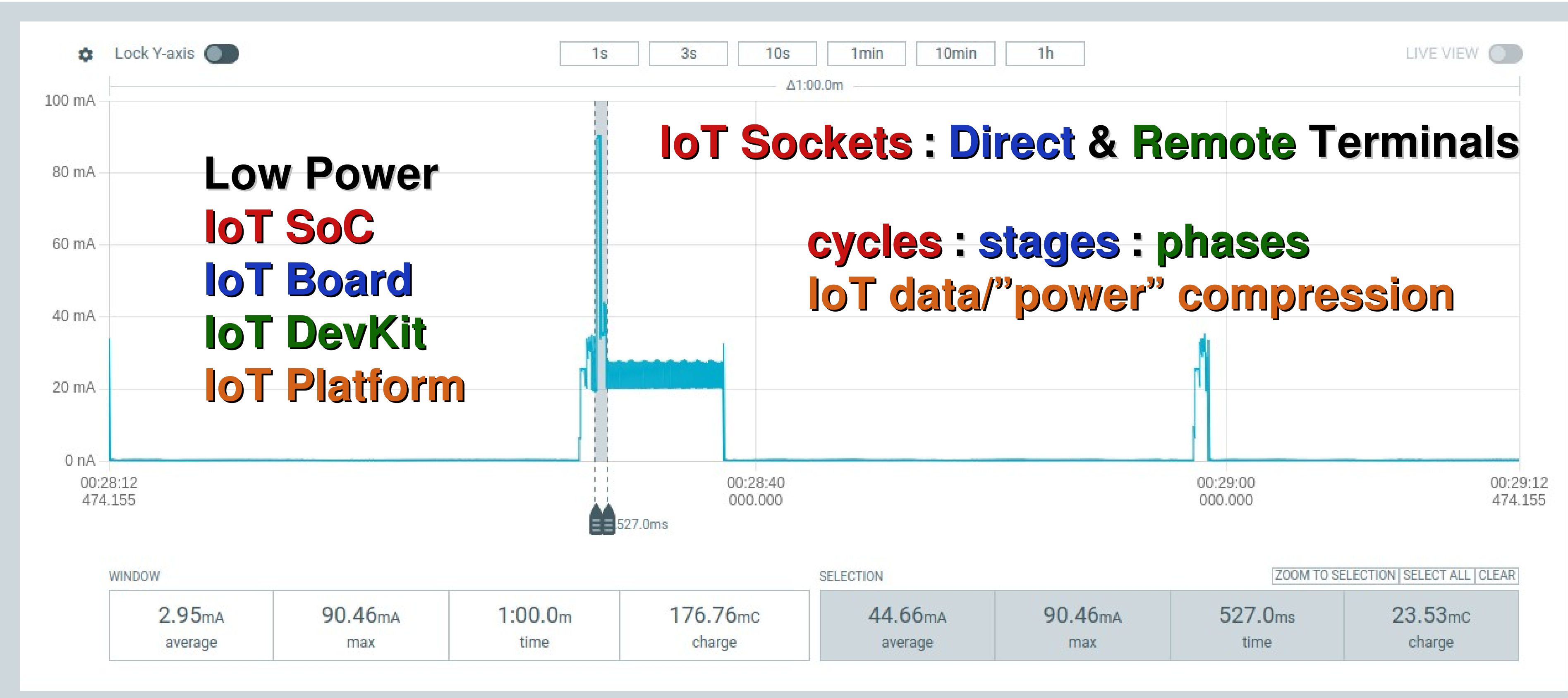
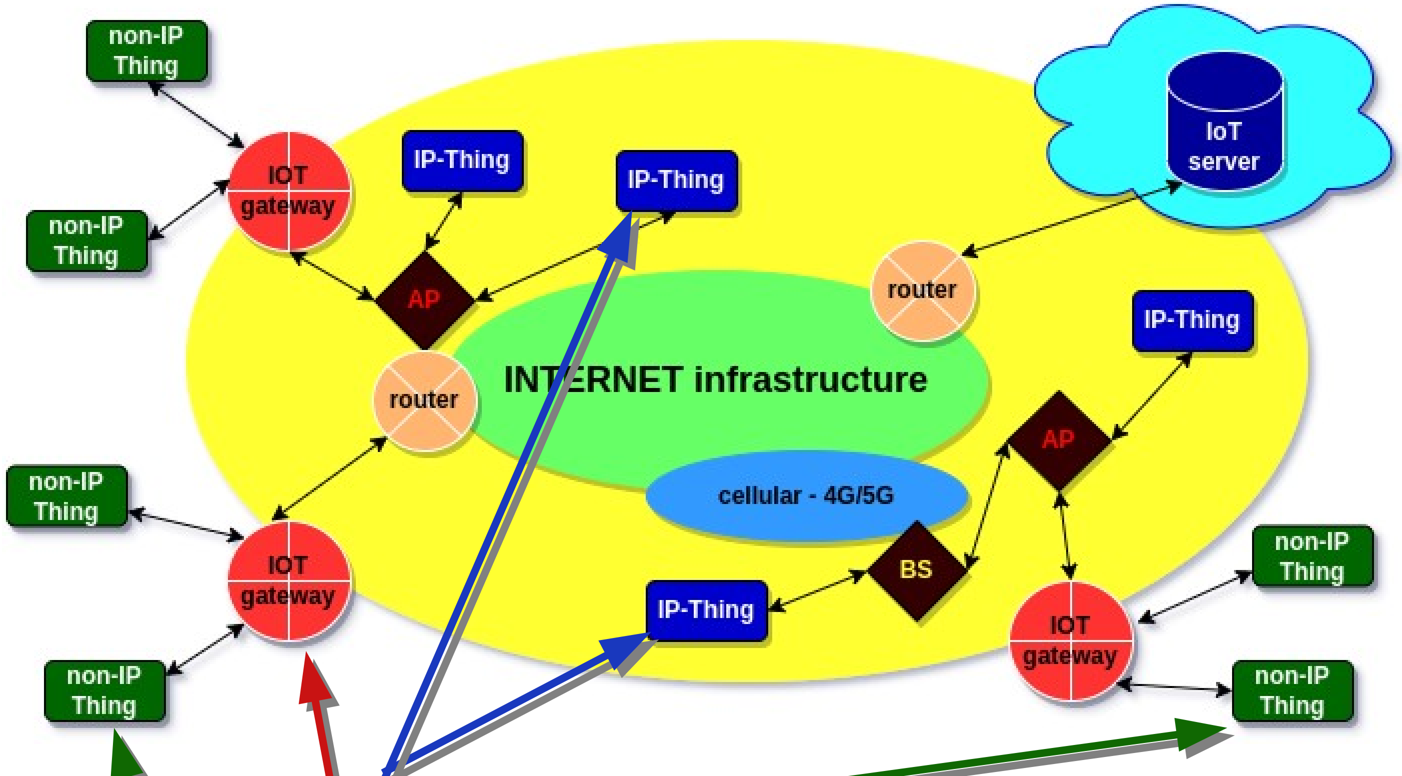


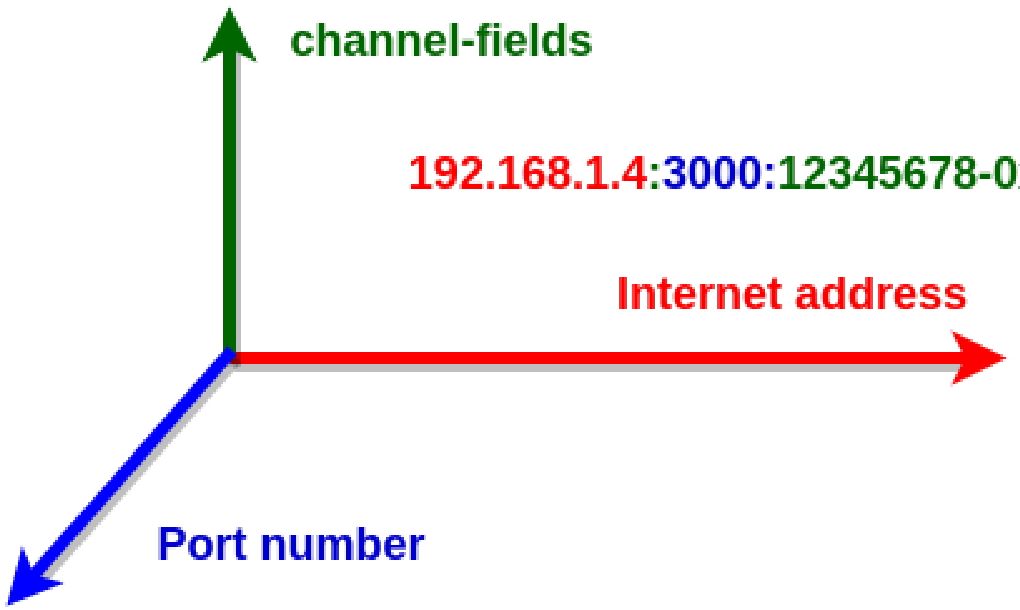
IoT : Direct & Remote Terminals



IP-Thing : **Direct Terminal** connected to INET via **WiFi**/4G/5G link

non-IP-Thing : **Remote Terminal** connected to INET via **LoRa** link and **IoT gateway**

IoT Sockets : @IP:port:channel



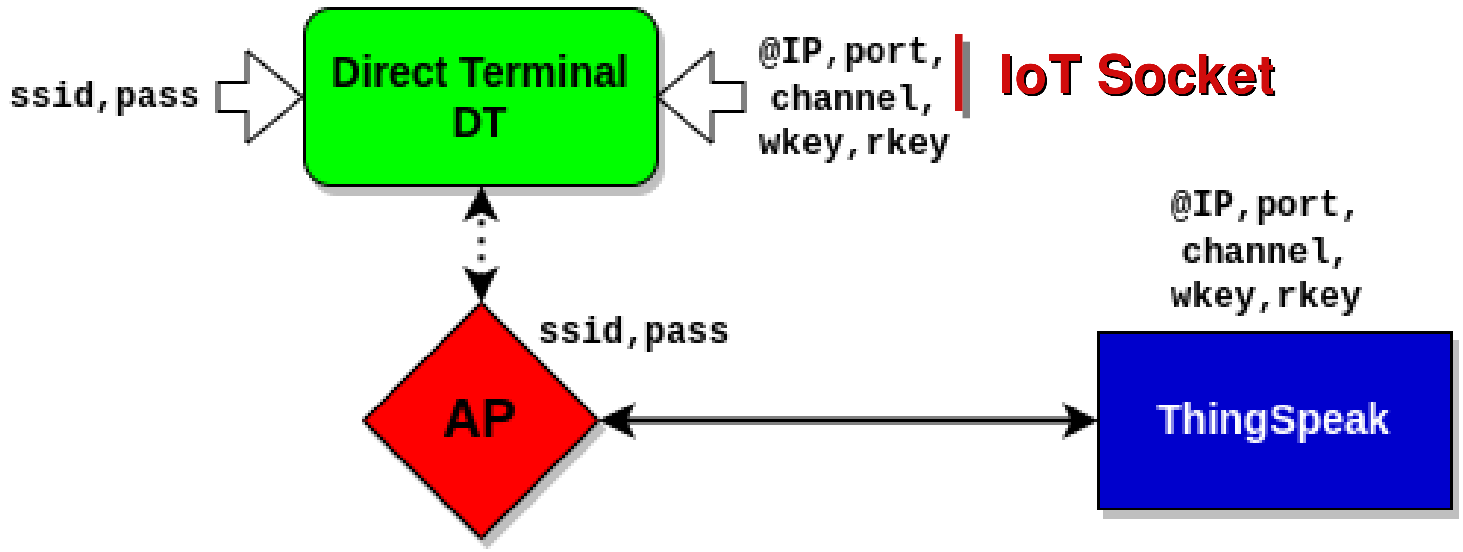
IoT socket => IP address: Service port:Channel number-fields

Direct Terminals know: IP address:Service port:Channel number

Gateways know: IP address:Service port

Remote Terminals know only: Channel number (identifier)

Direct Terminals and IoT Sockets

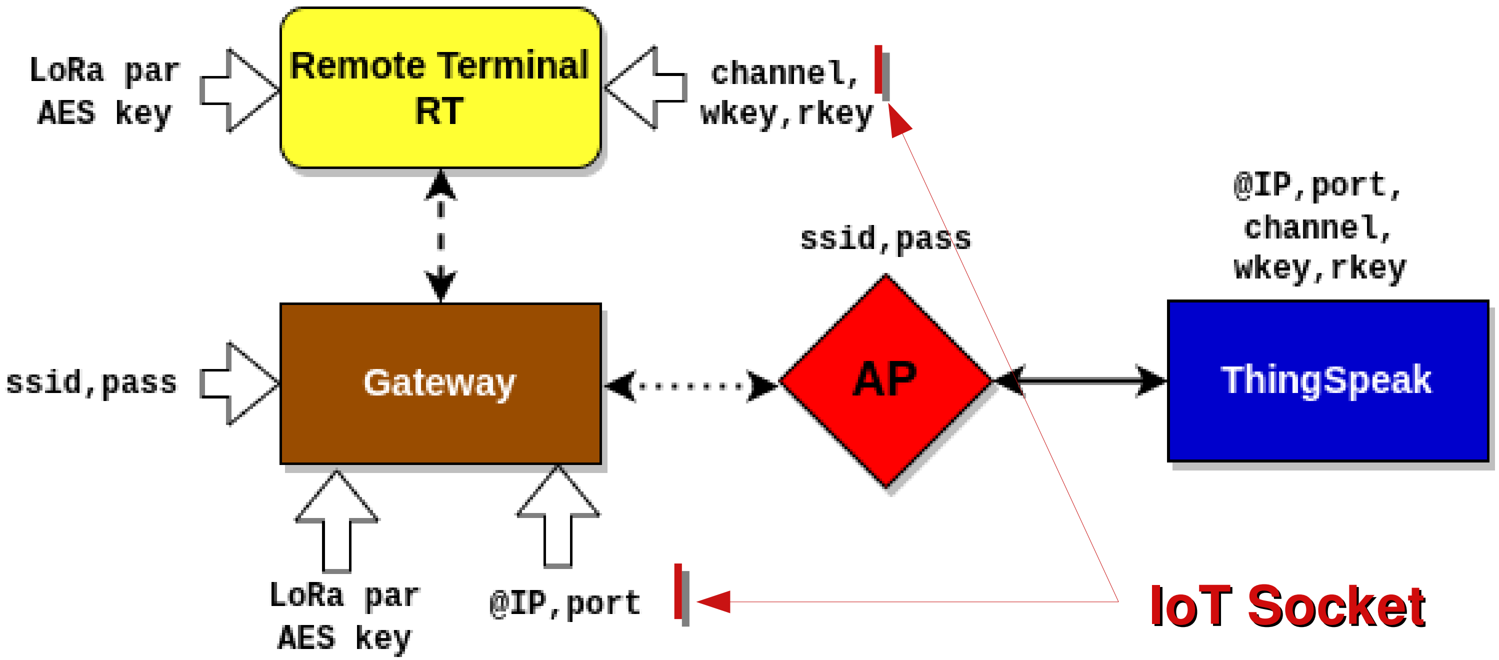


Direct Terminals know: IP address:Service port:Channel number

plus: write and optionally read key

A channel contains fields (max.8) that may be interpreted as IoT data streams to be “compressed”.

Remote Terminals and IoT Sockets



Gateways know IP address : Service port

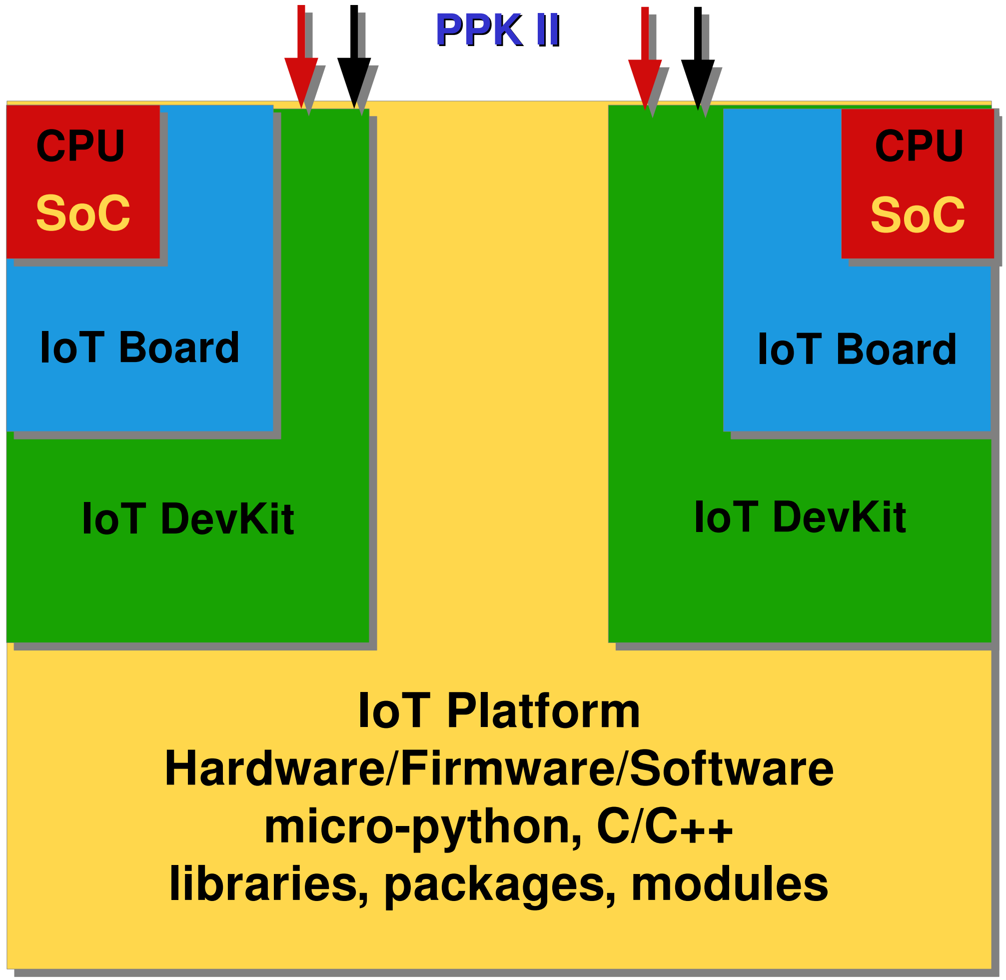
Remote Terminals know only Channel number (identifier)

From IoT SoC to IoT Platform

ARM-M0
SX1262
Bus I/O,..

EEPROM
USB, solar
Converters,
Bus I/O, ..

UART,I2C,SPI
sensors/actuators
solar panel, battery
supercapacitors, ..



RISC-V,Xtensa:
LX6,LX7
ESP32C3
ESP32C6
ESP32S6
WiFi/BLE
Bus I/O,..

EEPROM
USB,
Converters,
Bus I/O, ..

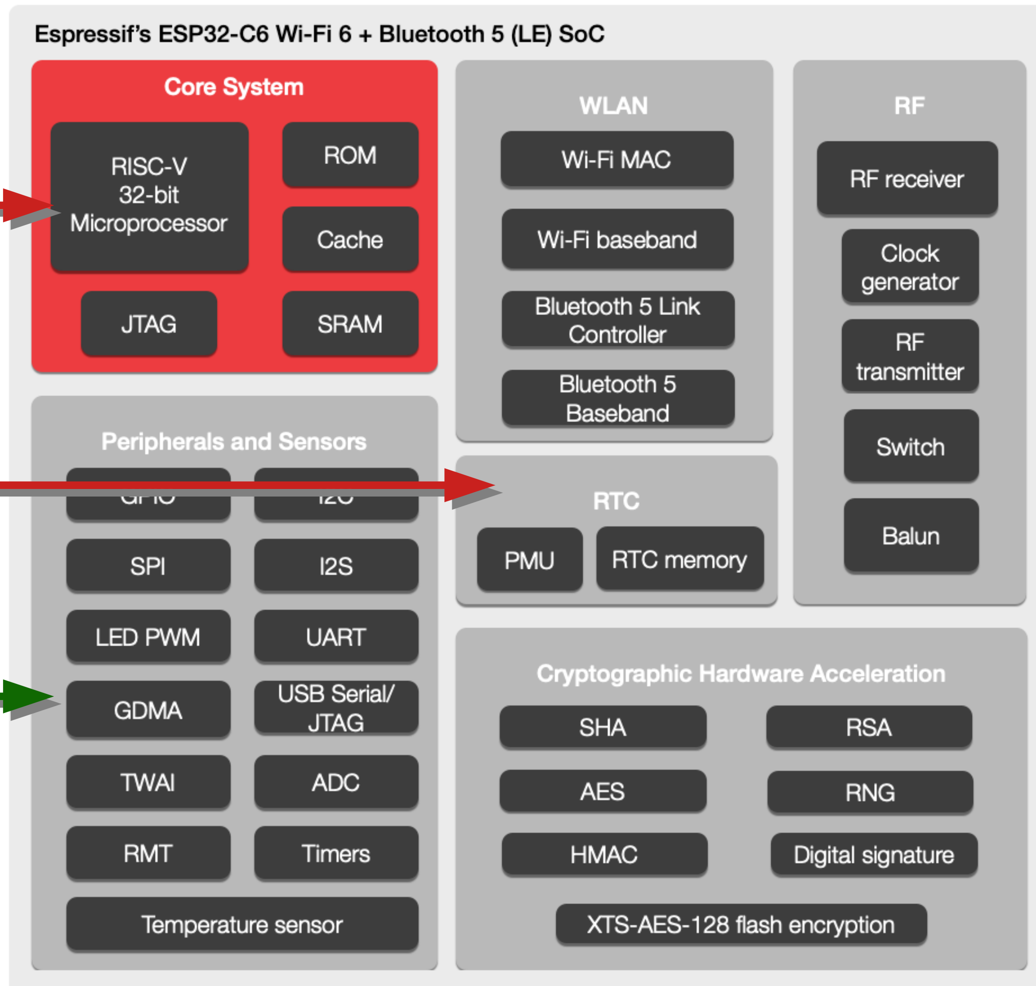
UART,I2C,SPI
sensors/actuators,
modems, solar
panel, battery
supercapacitors, ..

IoT SoC ESP32C6: low power features

RISC-V: RV32
5 stages pipeline

Low Power (2mA)
RISC-V: RV32
2 stages pipeline

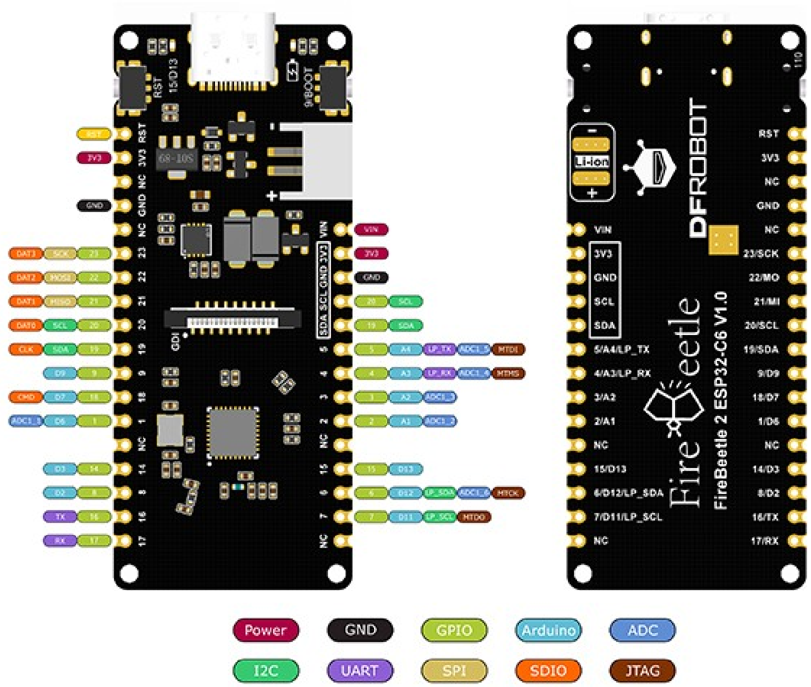
Buses including
Low Power
(I2C,UART)



WiFi6 with TWT -
Target Wake Time

Crypto and
Security

IoT Board (Direct Terminal)

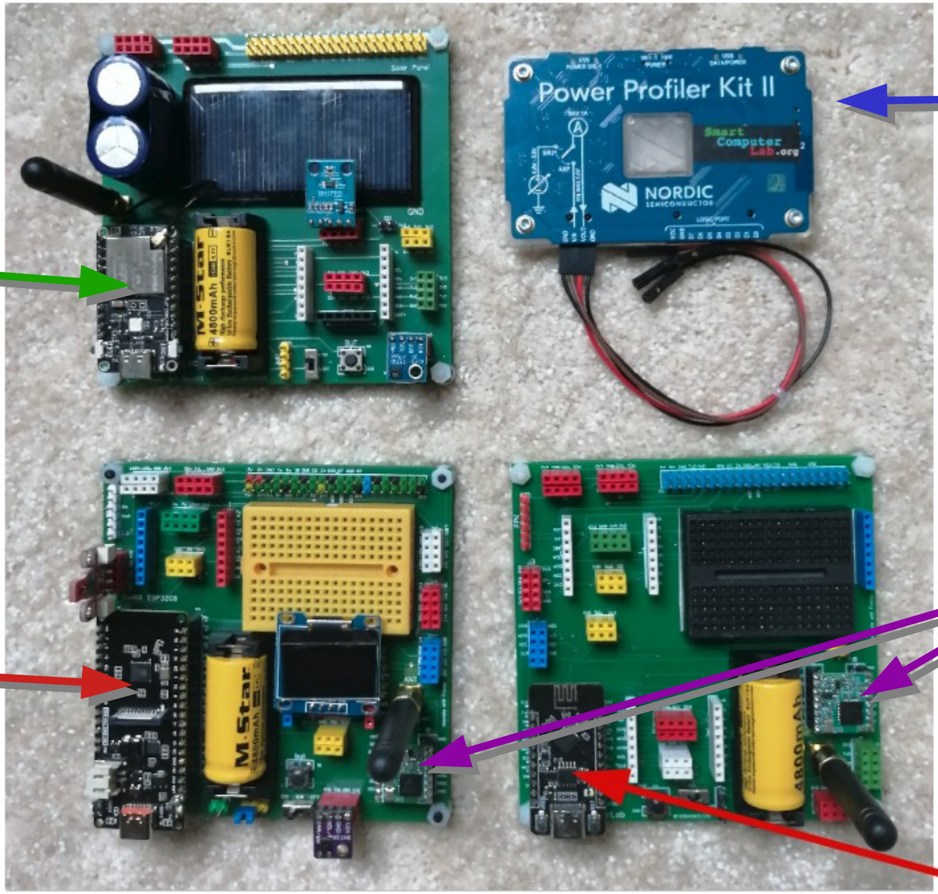


IoT Board: DFRobot FireBeetle2 (ESP32C6) : EEPROM, battery, solar converters, USB bus, I2C, UART,SPI, .. (low/high power)

IoT DevKits : RISC-V & ARM boards

CubeCell (ARM-M0 + SX1262): Remote Terminal

Nordic PPK II



SX1276 : Remote Terminal or Gateway

FireBeetle 2 (ESP32C6): Direct Terminal

Heltec (ESP32C3): Direct Terminal

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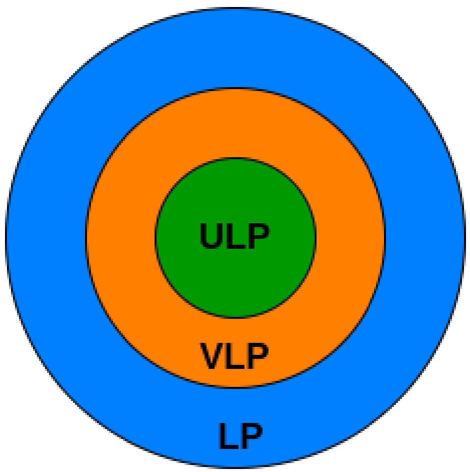
Low and Very Low Power consumption



ULP < 10 µA

VLP < 100 µA

LP < 1000 µA

Example of average current (power) consumption:
deepsleep mode for `low_power` stage : 10µA and 100s
normal mode for `high_power` stage : 40mA and 0.5s

`low_power` charge + `high_power` charge= 10µA*100s + 40 000µA*0.5s = 1000µC+20000µC= 21mC

average_current = charge/time = 21mC/100.5s = 0.21mA = 210µA (**LP**)

Let us calculate the same for `low_power` stage duration of 600s.

average_current = charge/time = 26mC/600.5s = 0.043mA = 43µA (**VLP**)

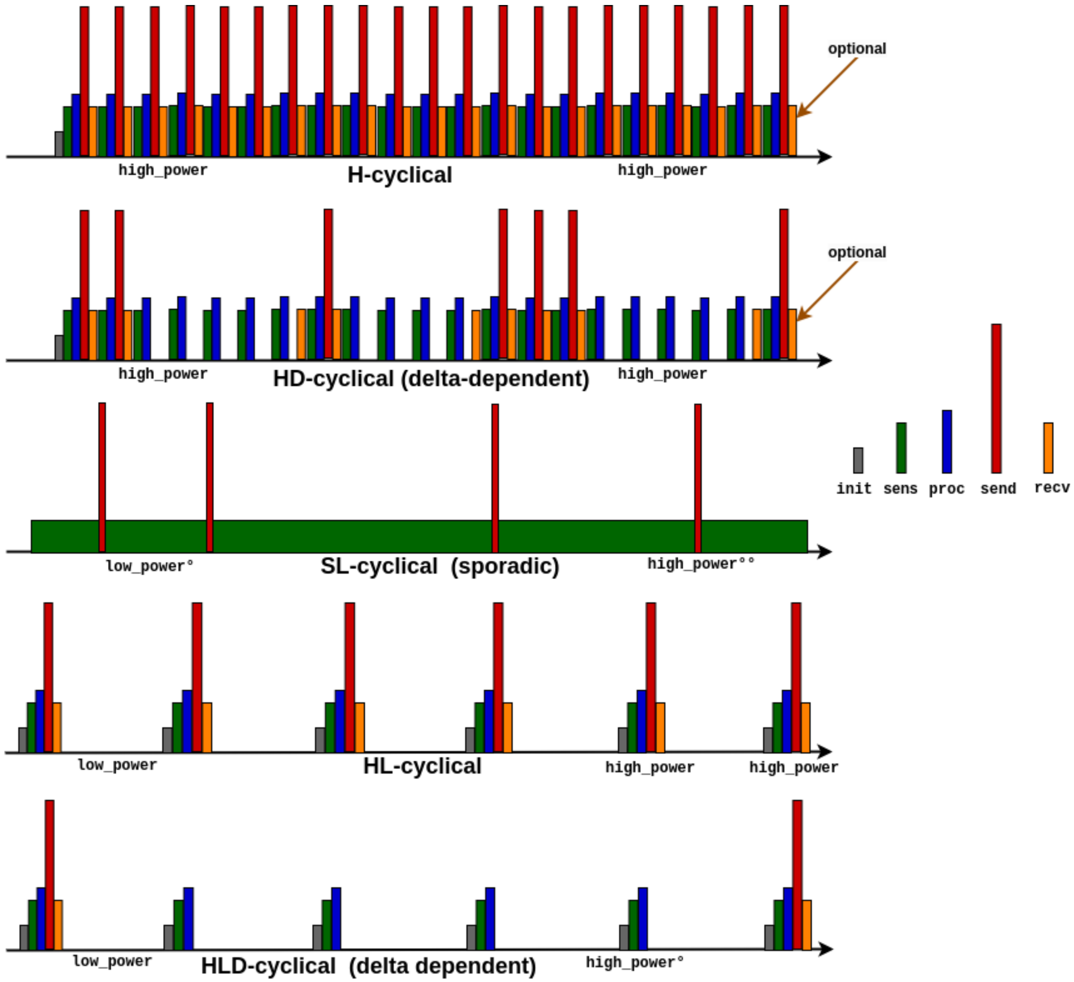
Terminals: Operational modes

high average current

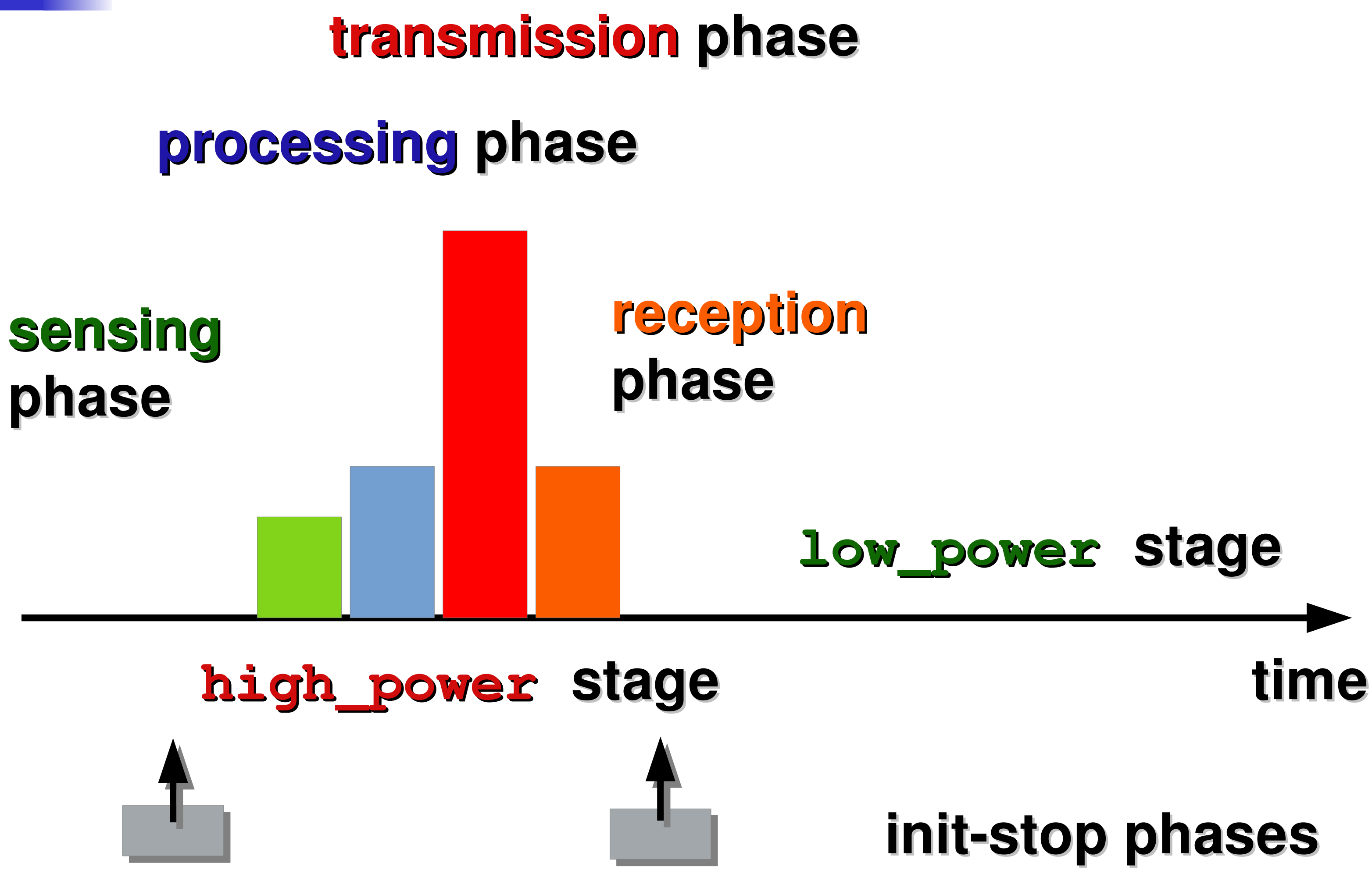
`delta` (δ) parameter defines required precision-difference

"sporadic cycle" – activated by an interruption (level change) signal

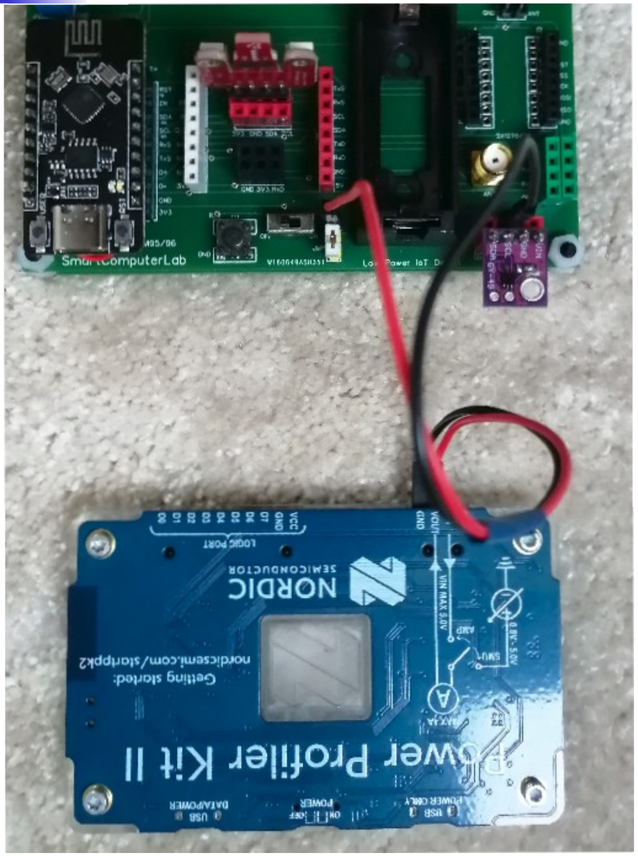
low average current

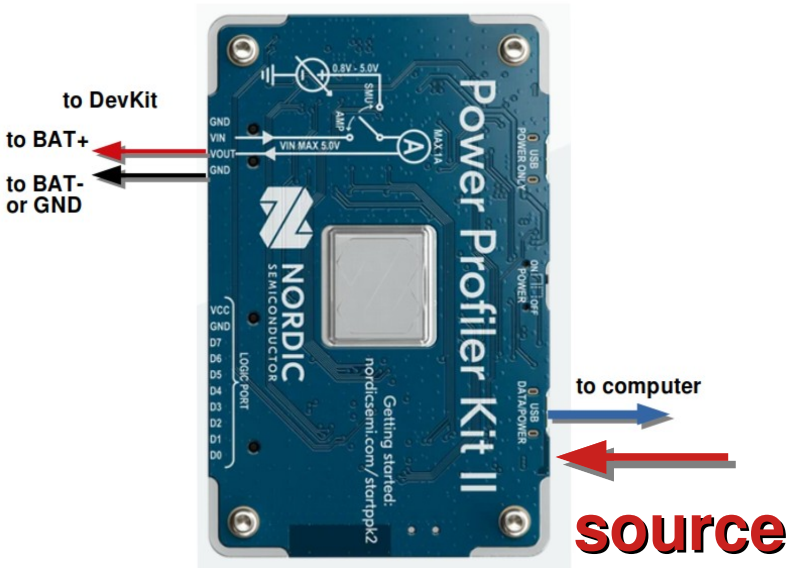


high_power stage - phases



Power Profiler Kit II : connection



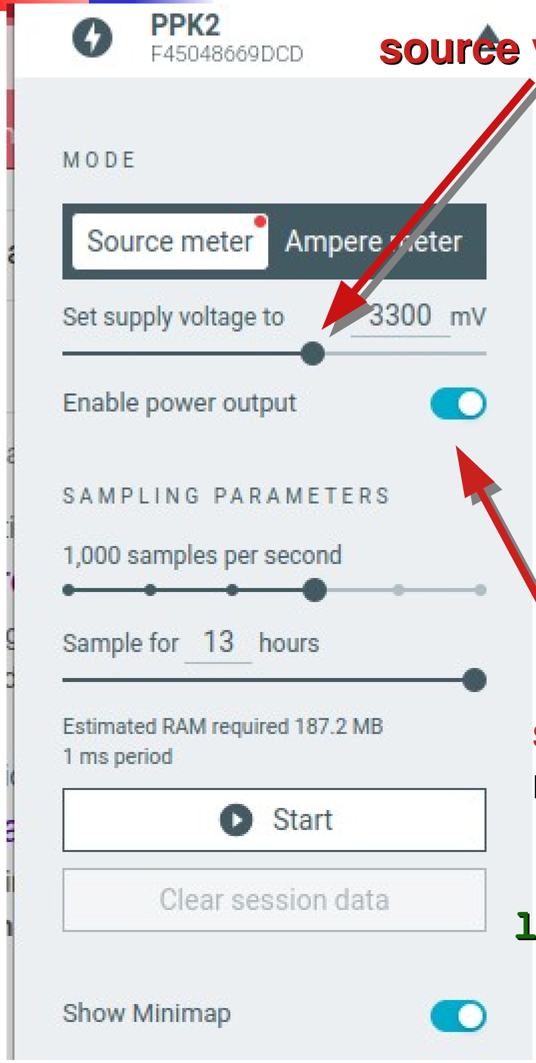


Power Profiler with source mode

Power Profiler Kit II - windows

source voltage

main window



source mode

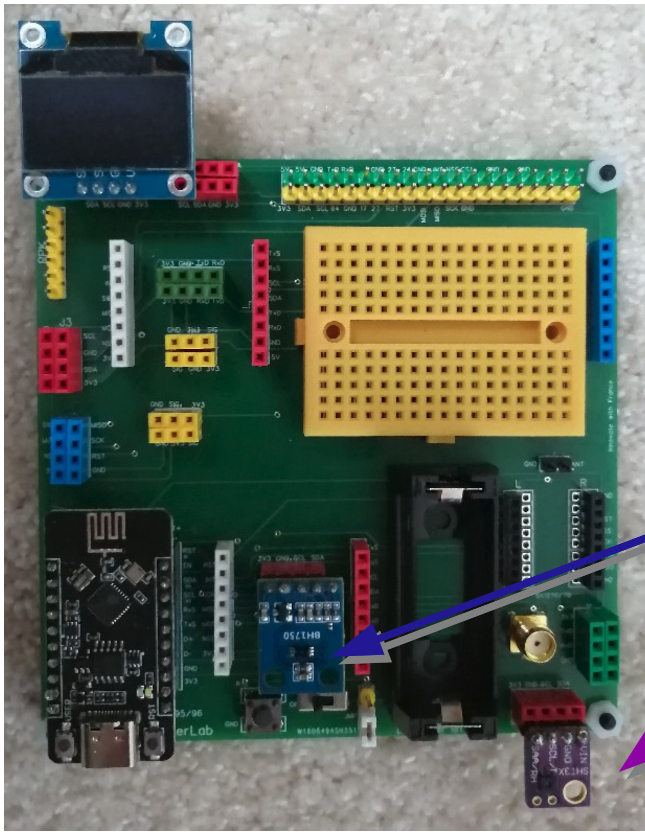
`high_power` stage

charge consumption (10.44µC)

`low_power` stage

average current consumption `in` `low_power` stage (10.39µA)

DevKit : HL cycle operation with sensors



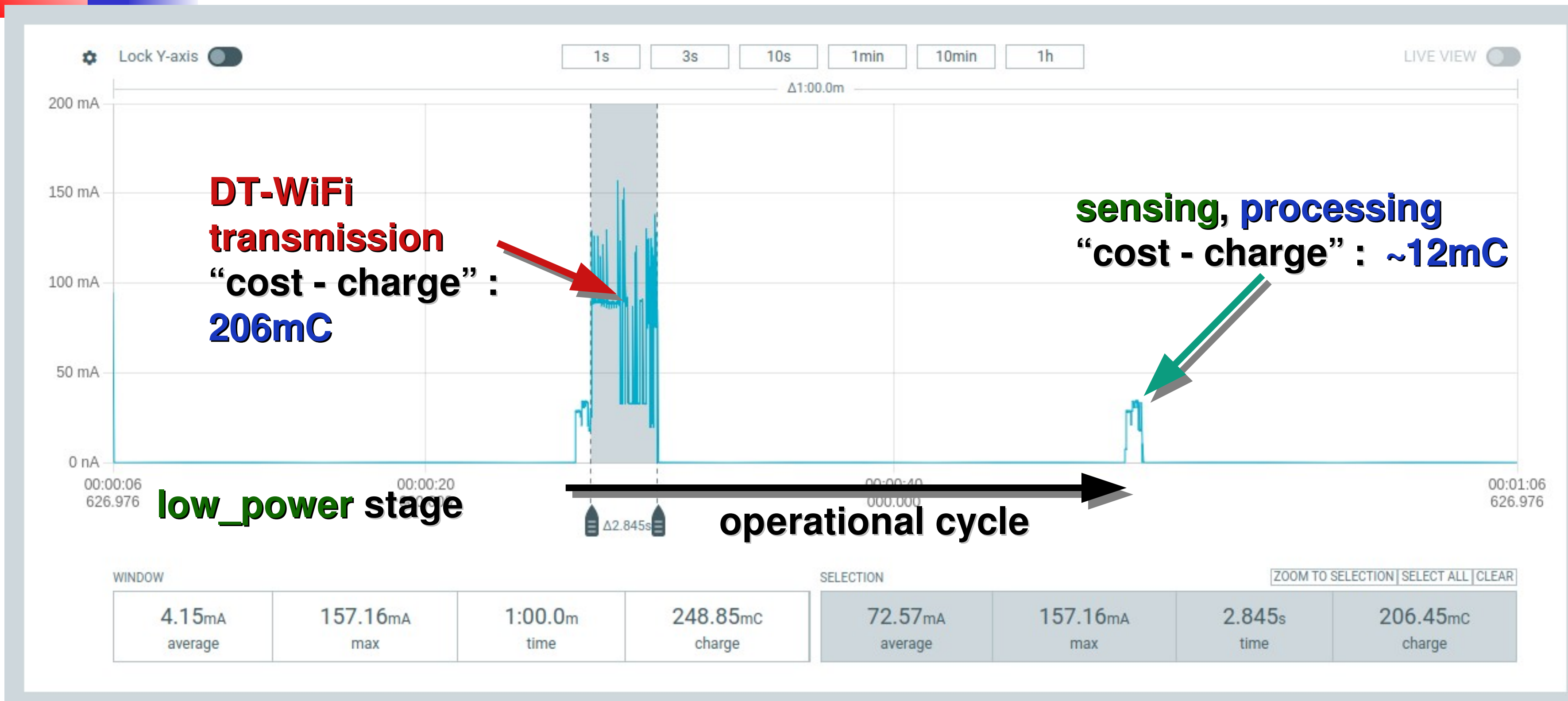
two sensors to capture
the **`temperature`**,
the **`humidity`**, and
the **`luminosity`** or **brightness**
values:

BH1750 (L) - luminosity

SHT31 (T/H) – temperature/humidity

Attention:
All these components communicate over the same (shared) I2C bus !

HL cycle operation : sensors, WiFi, delta



delta : the max difference between the last sent and current sensor value

high_power stage time << low_power stage time

delta as big as possible : example 0.01C° => 1.0C°

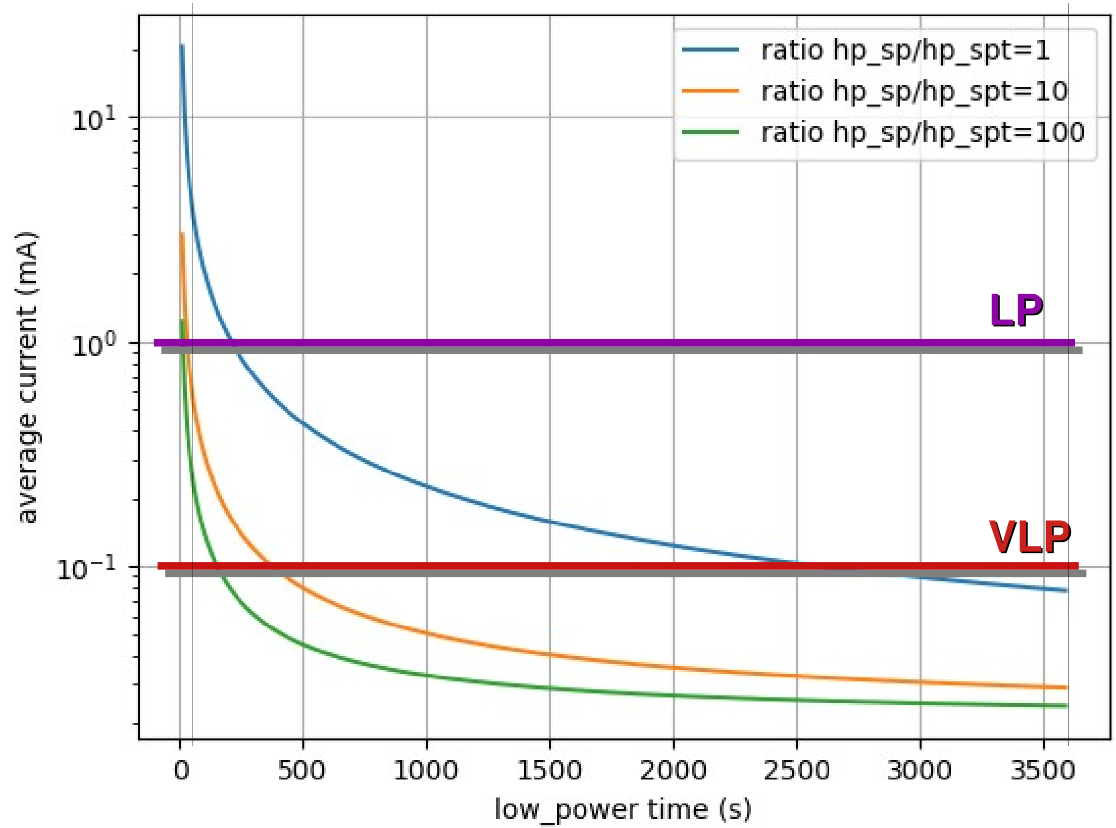
operational cycle frequency (16.6 mHz) >> transmission cycle frequency (278 µHz)

HL cycle operation : sensors, WiFi, delta

Ratio `hp_sp/hp_spt` :
the number of `high_power` cycles without transmission to the number of `high_power` cycles with transmission

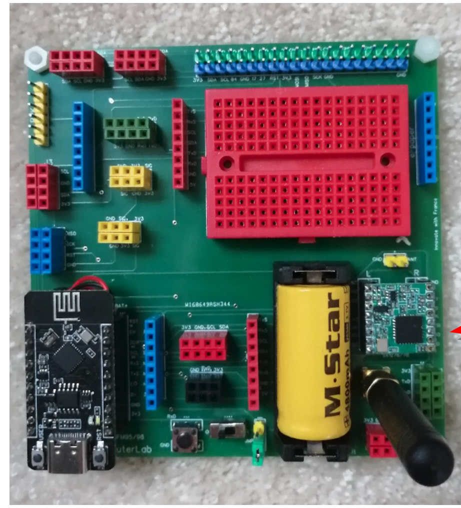
operational cycle frequency

(16.6 mHz) (278 µHz)

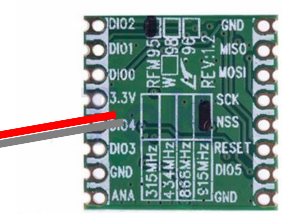


The use of delta parameter may be considered as "IoT data temporal compression"

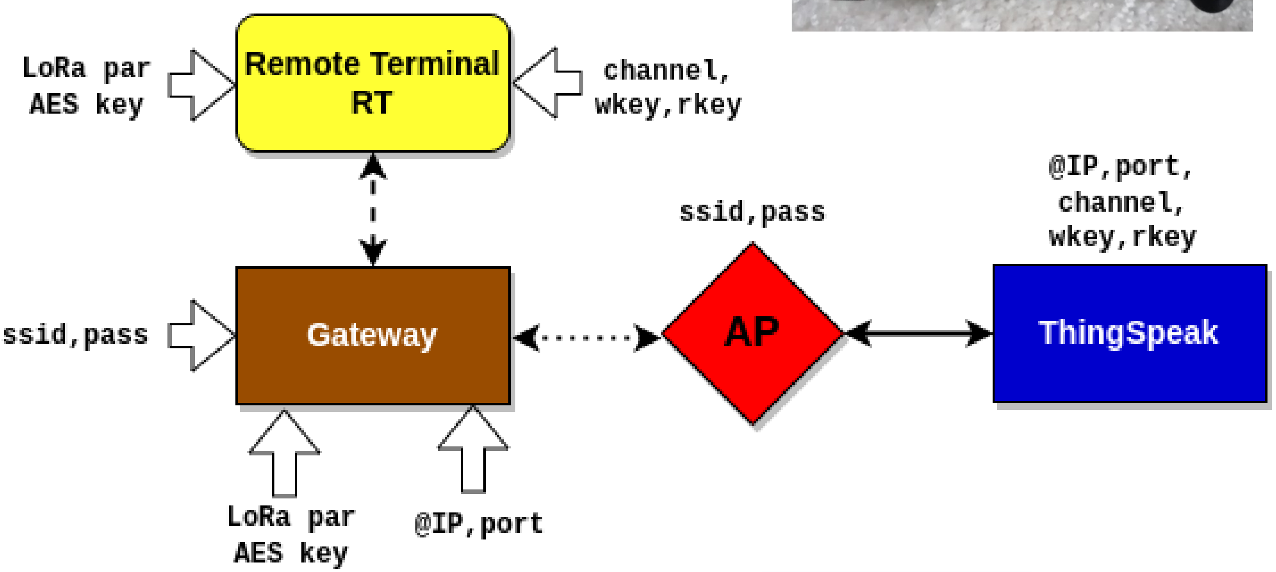
Long Range (LoRa) & Remote Terminals



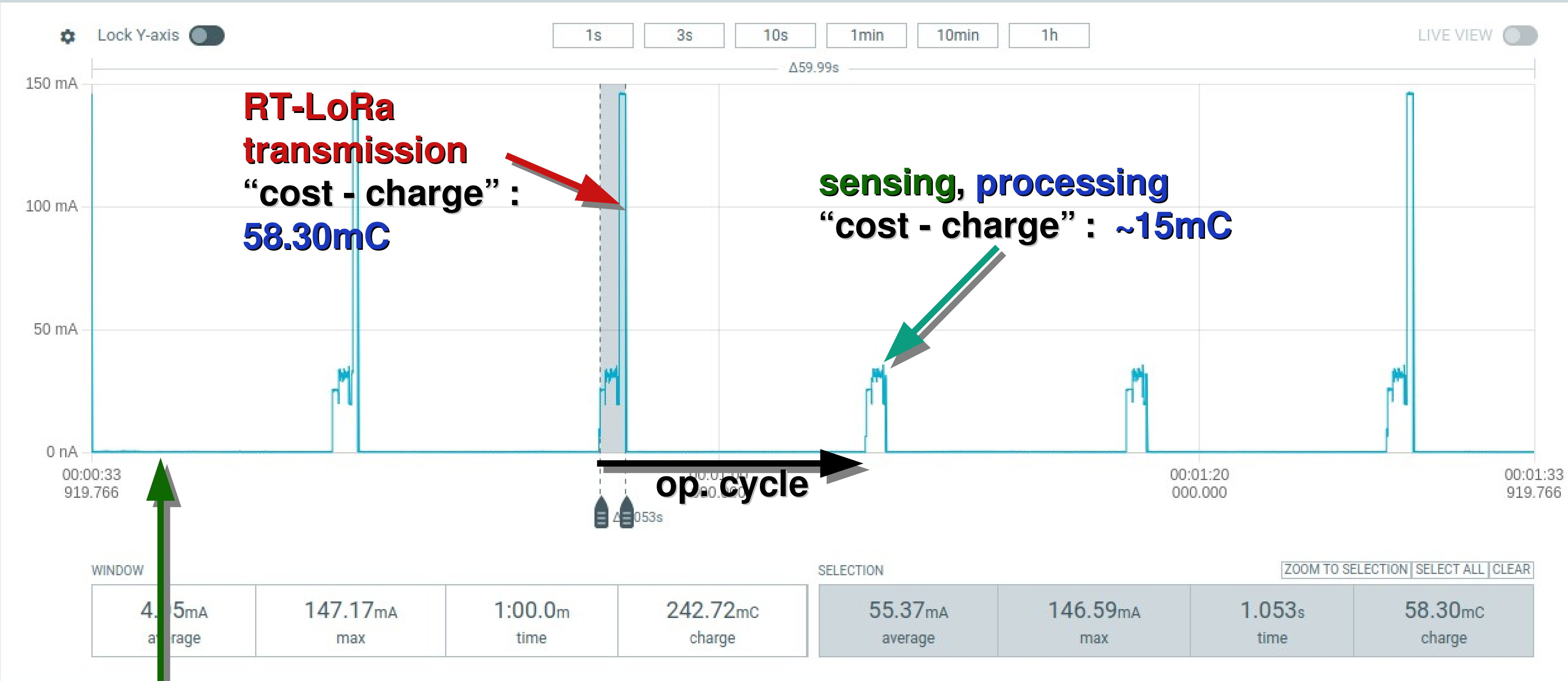
Remote Terminals or Lora-WiFi Gateway



RFM95 – SX1278



RT - Power consumption with LoRa link

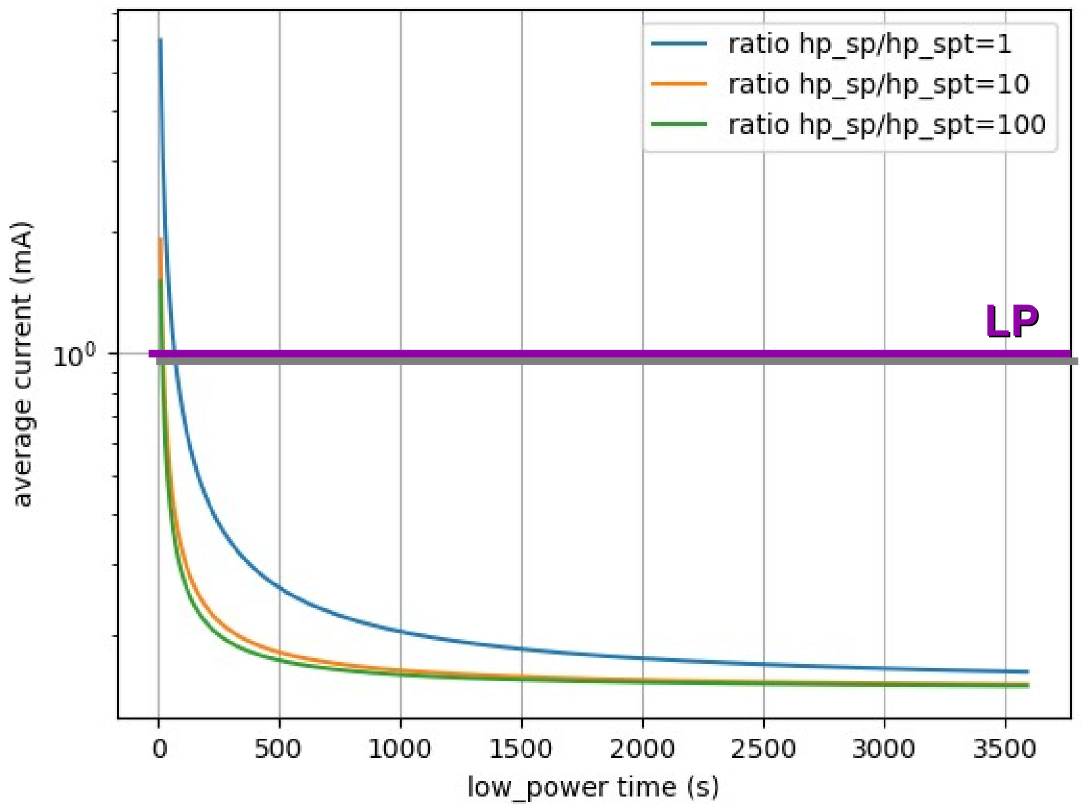


`low_power` stage – 146.05µA

transmission time: SF=9, CR=4/8,
BW=125KHz => 314 ms
transmission charge (avc.145mA) =>45mC

Power consumption with LoRa link : 146µA ?

Ratio hp_sp/hp_spt :
the number of `high_power`
cycles without transmission
to
the number of `high_power`
cycles with transmission

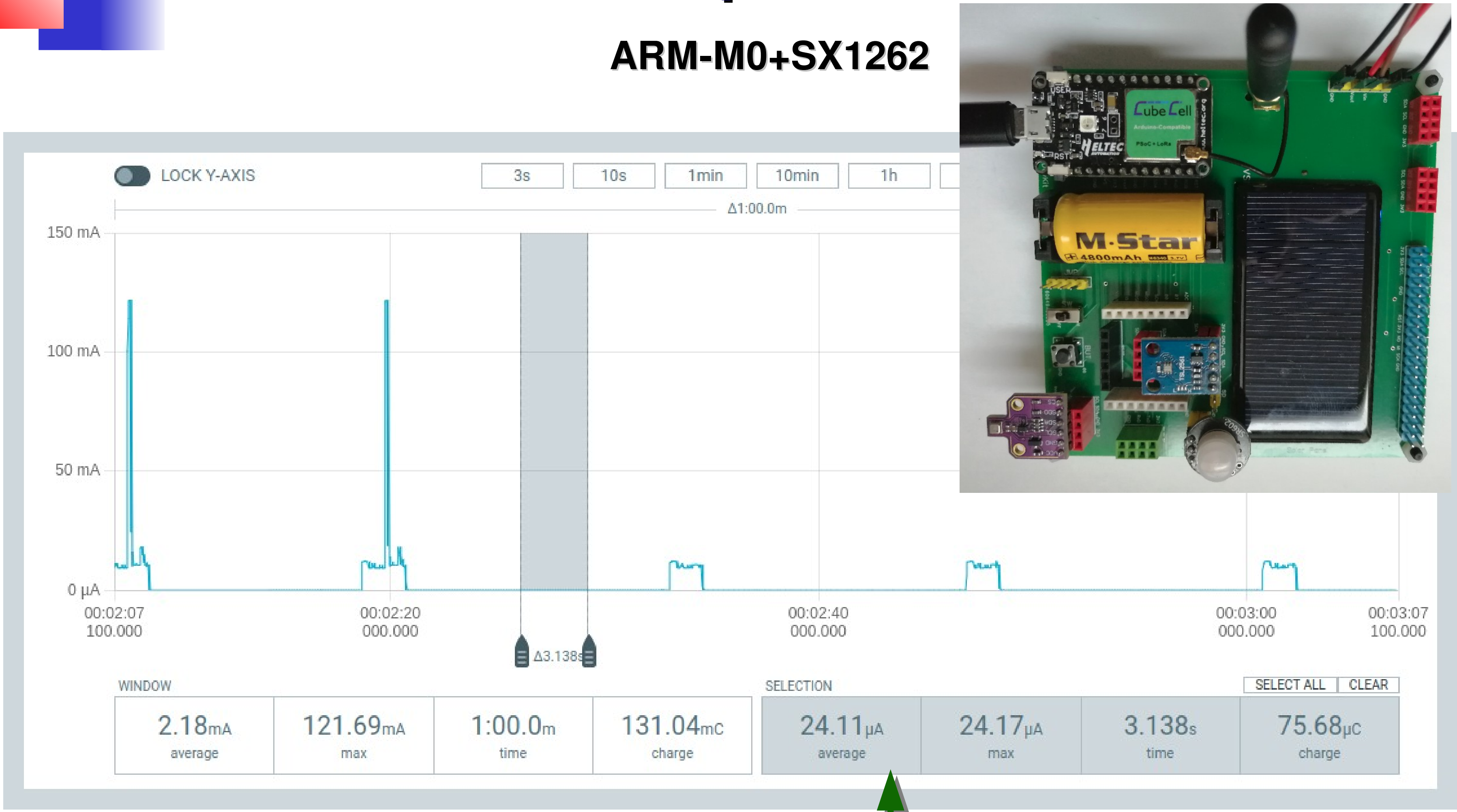


No VLP solution !
(for this board !)

Problem: `low_power` stage – 146.05µA (much to high !)

RT - Power consumption with LoRa link

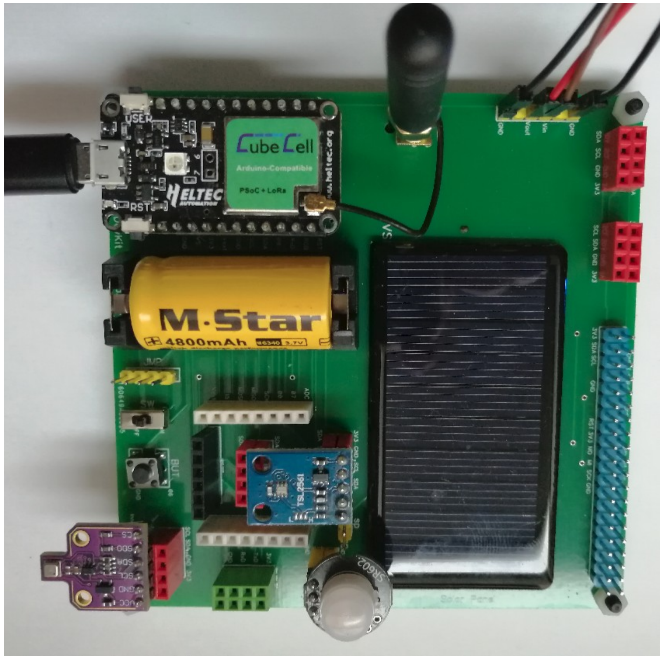
ARM-M0+SX1262

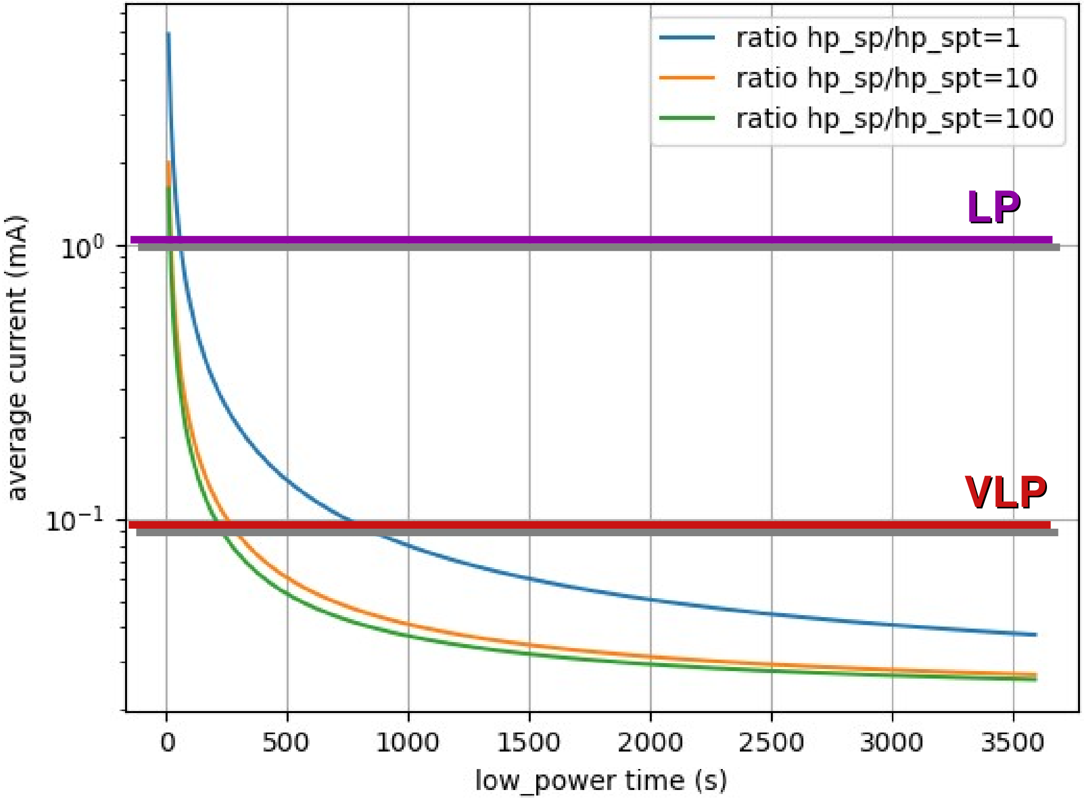


low_power stage = 24µA

RT - Power consumption with LoRa link

CubeCell





ARM-M0+SX1262

low_power stage = 32µA

Some conclusions

Direct Terminals - WiFi

Very High transmission "cost" (variable: ~150-300mC)
Usage of `delta` parameter ("compression") **very efficient**

Remote Terminals – LoRa

High transmission "cost" (fixed: ~60mC)
Usage of `delta` parameter ("compression") **quite efficient**

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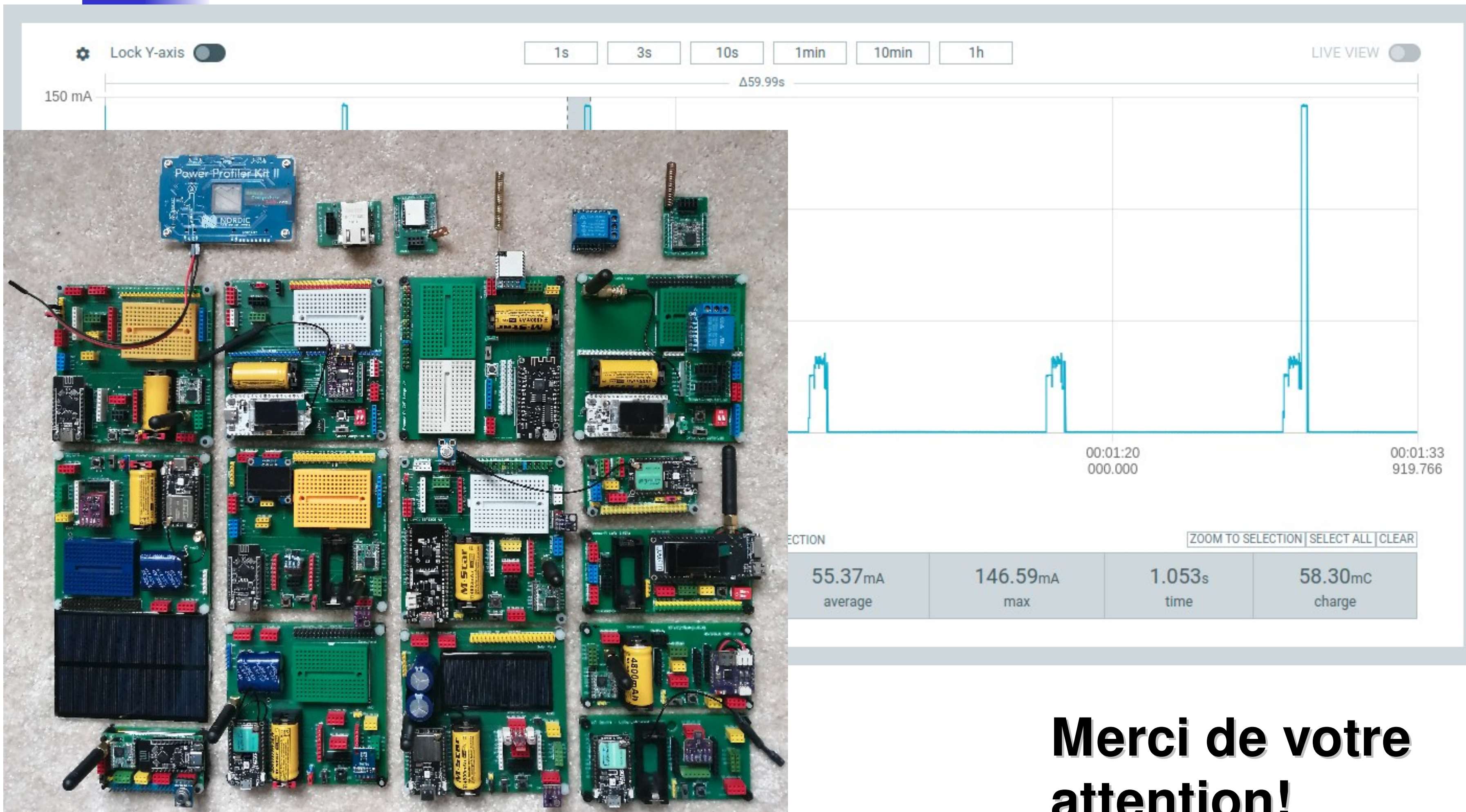
Implementation & test platform (s)



Merci de votre attention!