



Adaptive Low-Power IoT Protocols

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IoT Protocols:

Sending data from Terminals to IoT servers

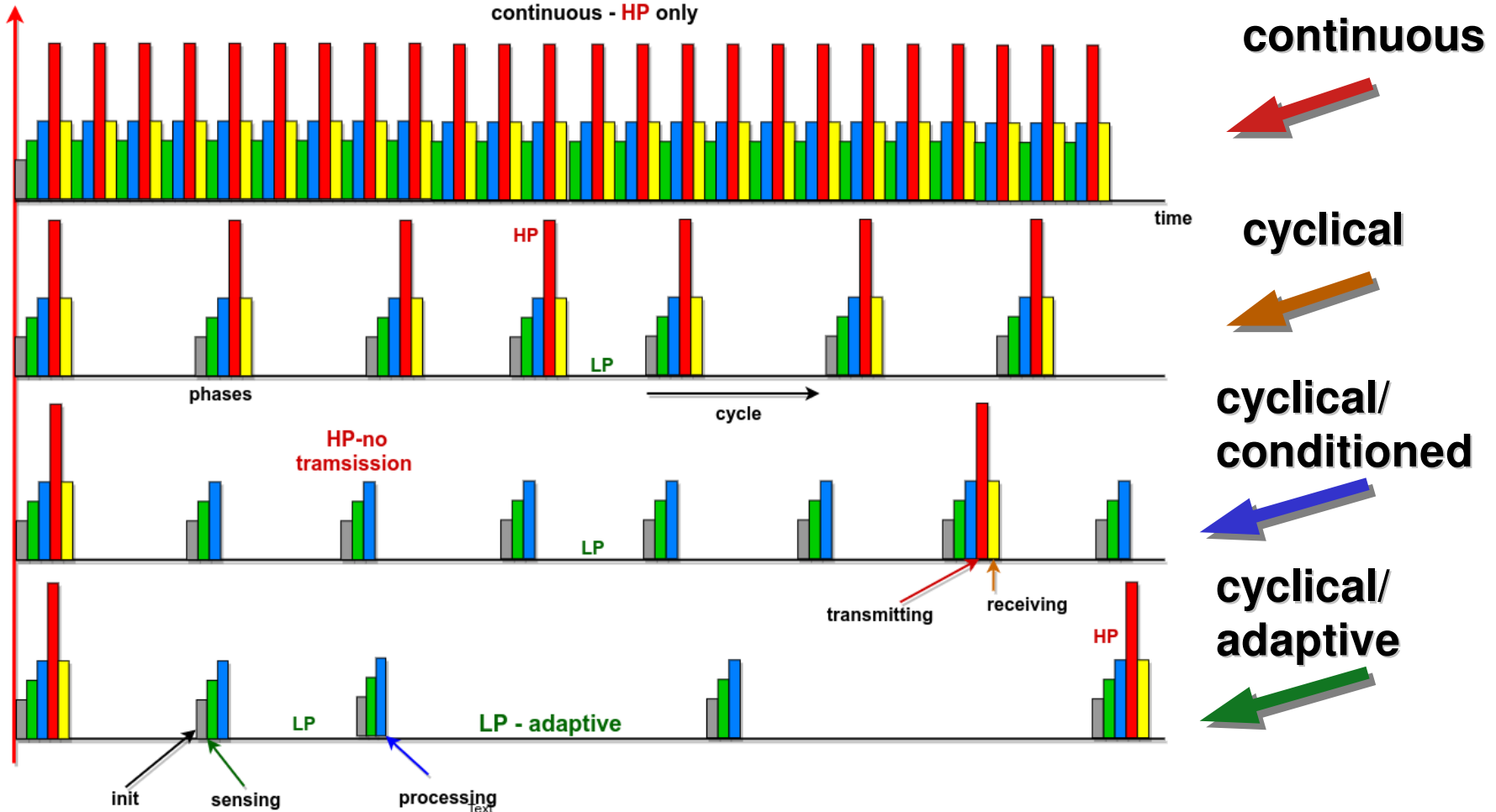
IoT Low-Power Protocols:

Sending data from Low-Power Terminals (LP IoT SoC) to IoT servers (average current $<1\text{mA}$)

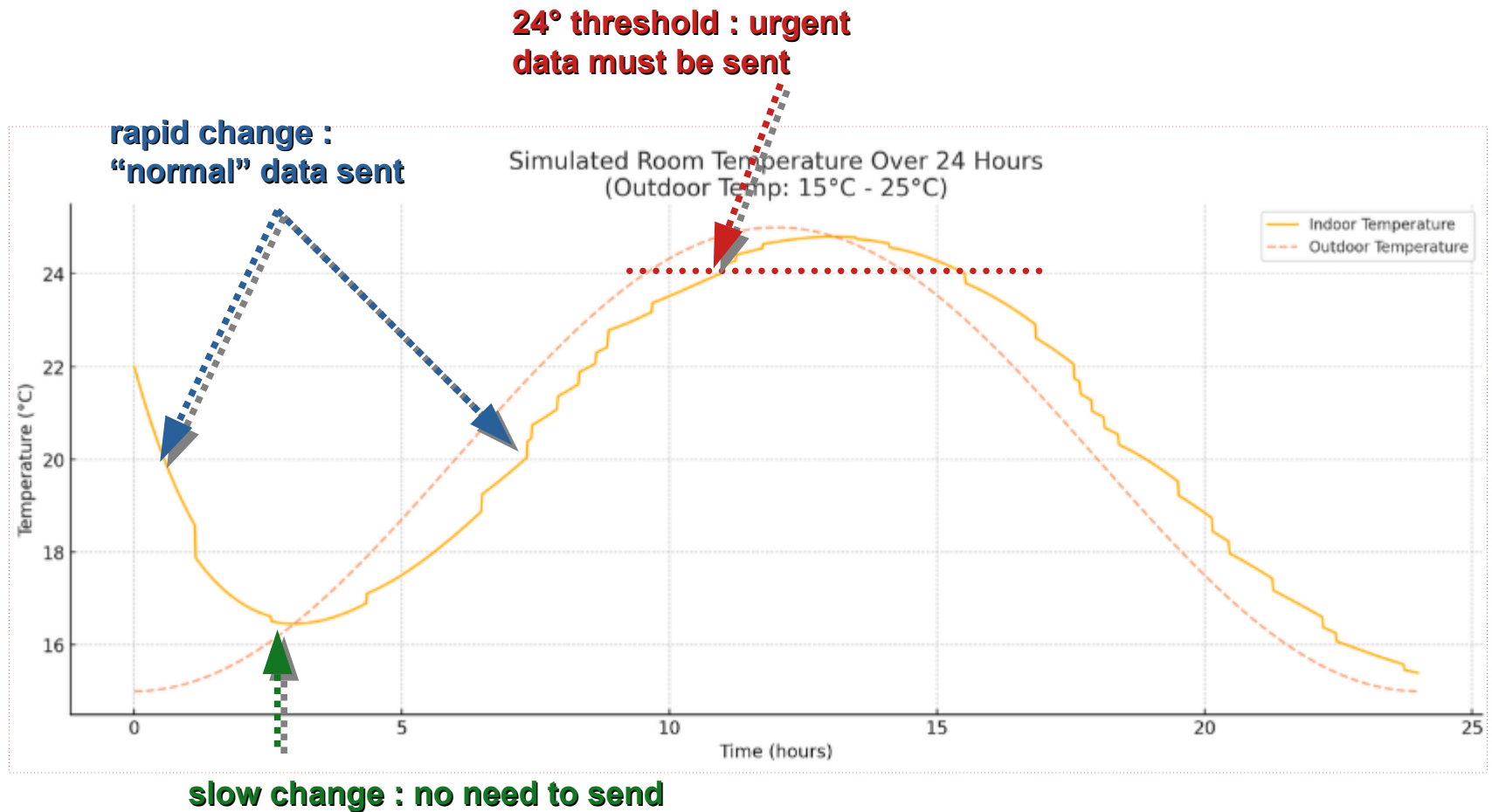
Adaptive IoT Low-Power Protocols:

Sending data from Low-Power Terminals (LP IoT SoC) to IoT servers with Adaptive Low-Power Protocols (average current $<300\mu\text{A}$)

From continuous to adaptive low-power modes

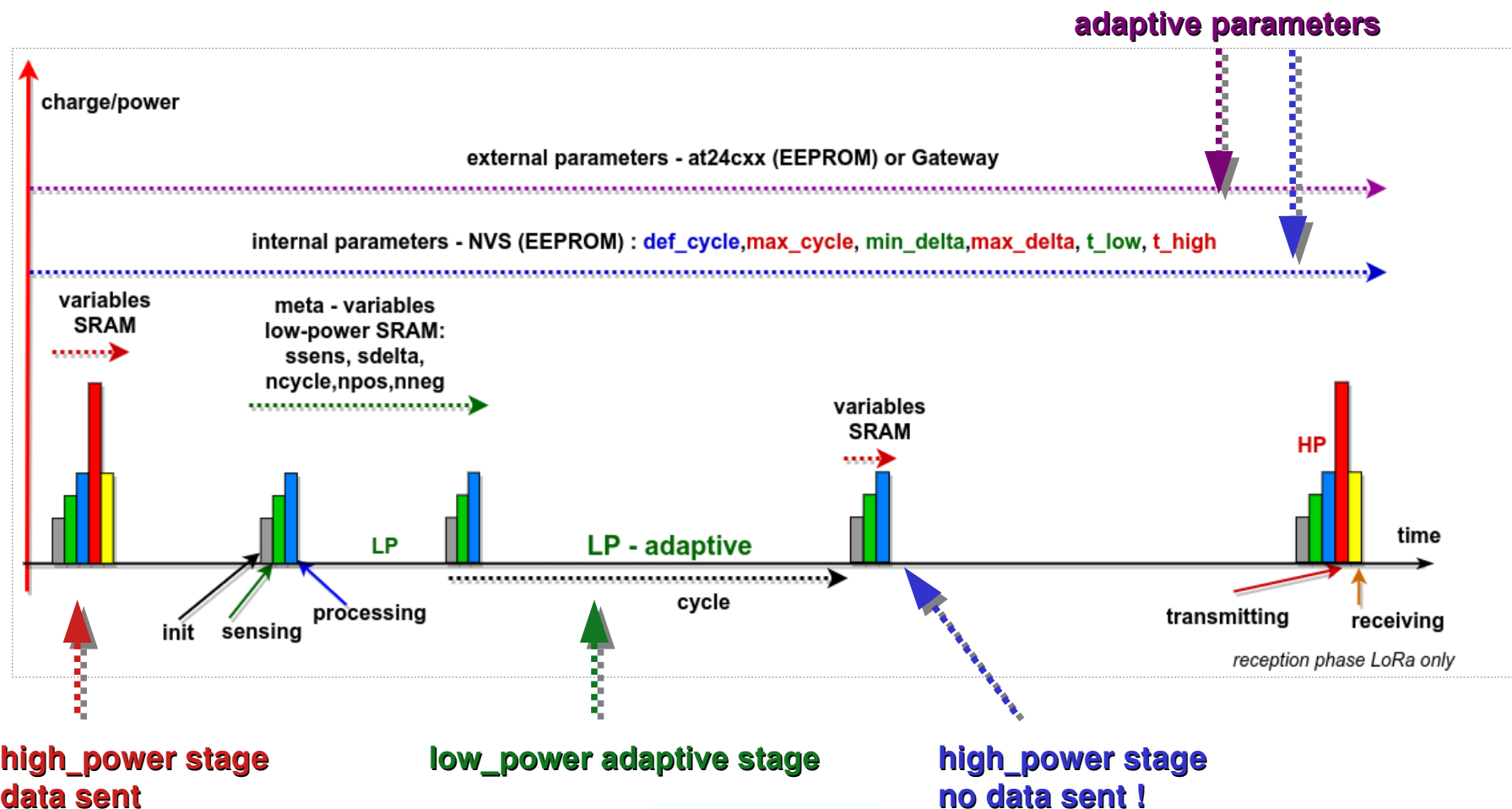


Sensor value (temperature) evolution



Adaptive Low-Power IoT Protocol

(principle: cycles, stages, phases)

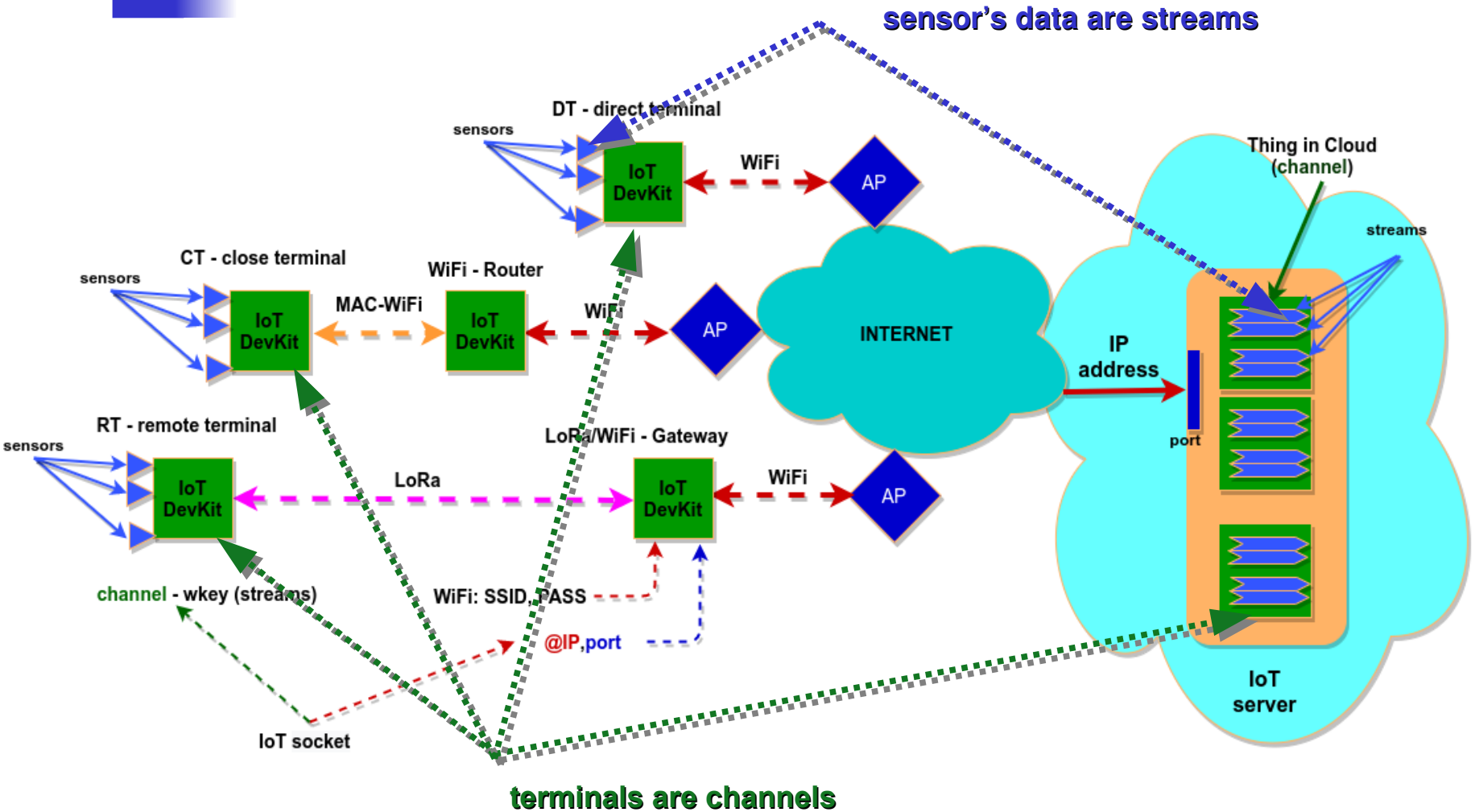


high_power stage
data sent

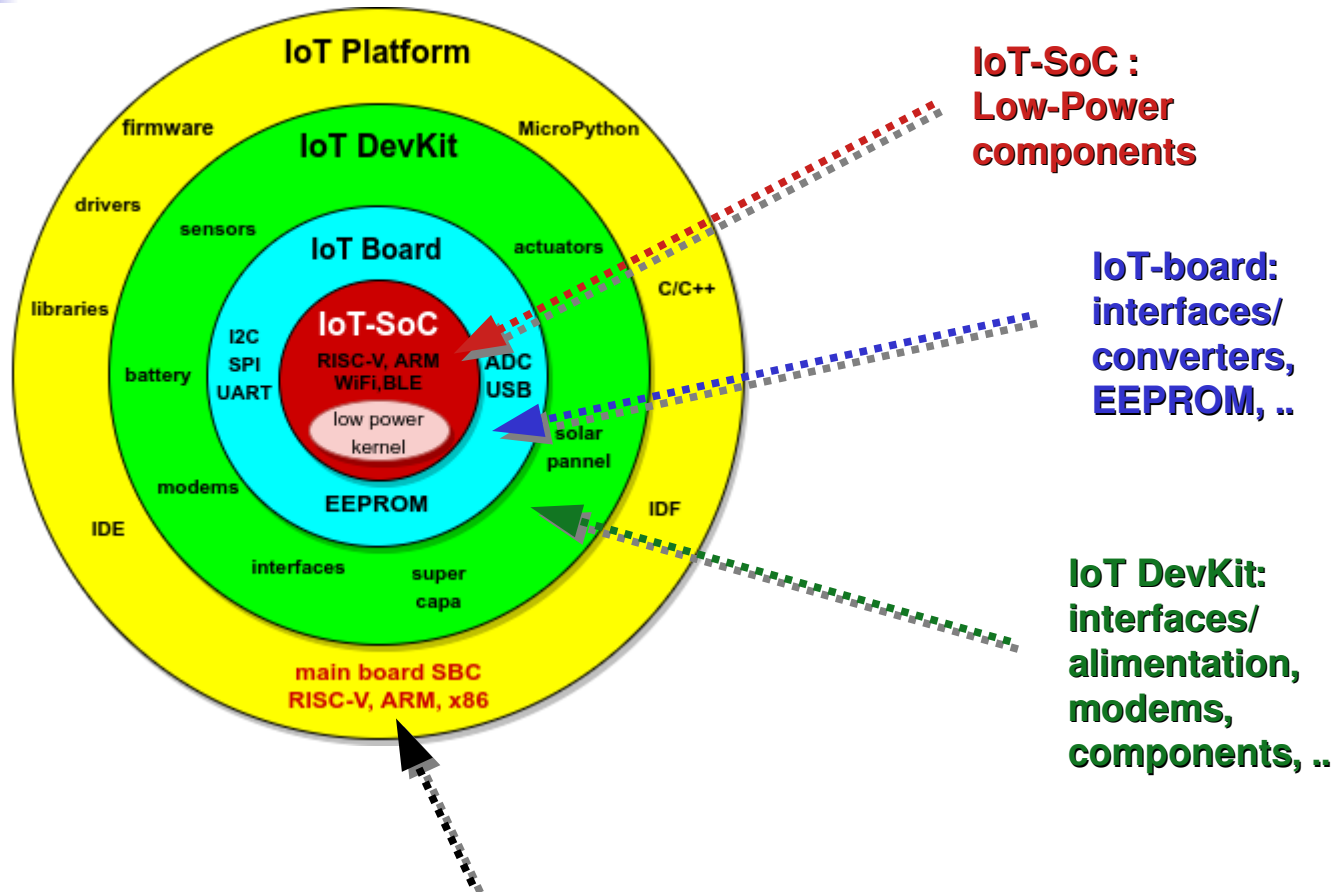
low_power adaptive stage

high_power stage
no data sent !

Mapping Things (terminals) on Services



From IoT SoC to Integrated IoT Platform



Integrated IoT Platform: SBCs, software IDE, IDF, libraries, drivers, ...

ESP32C3 IoT SoC

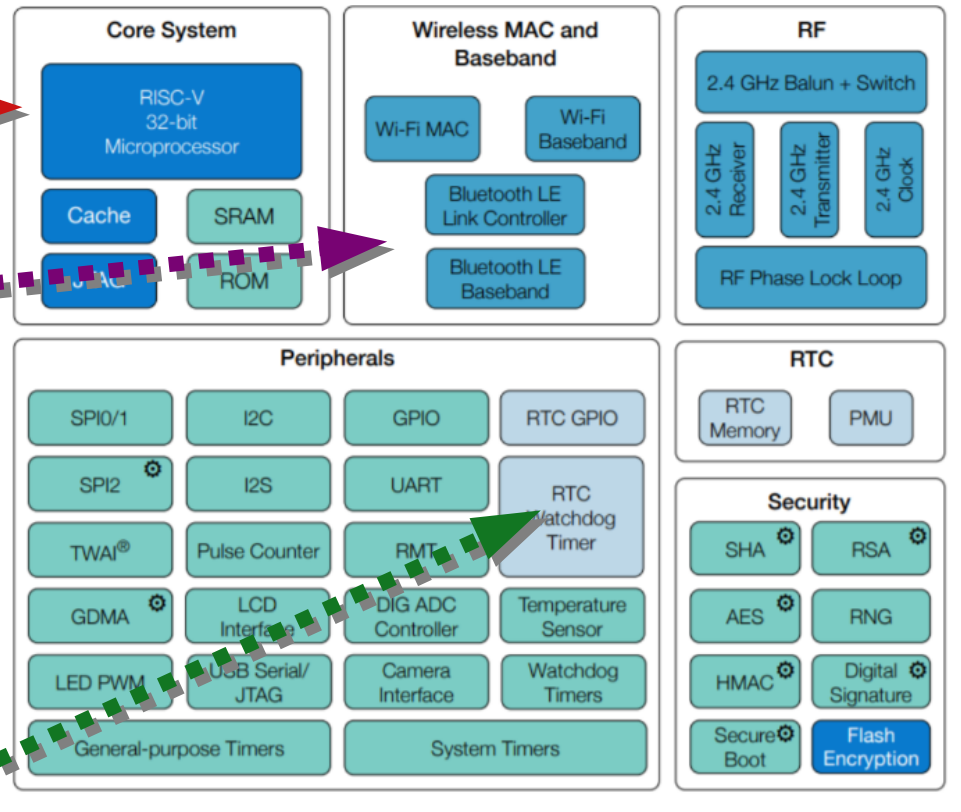
RISC-V : 5-stages pipeline

Radio: WiFi, BT/BLE

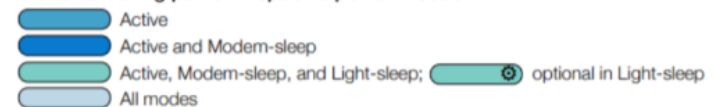
Serial interfaces: I2C, SPI, UART, I2S, ..

**low power : deepsleep
RTC clock, memory, ..**

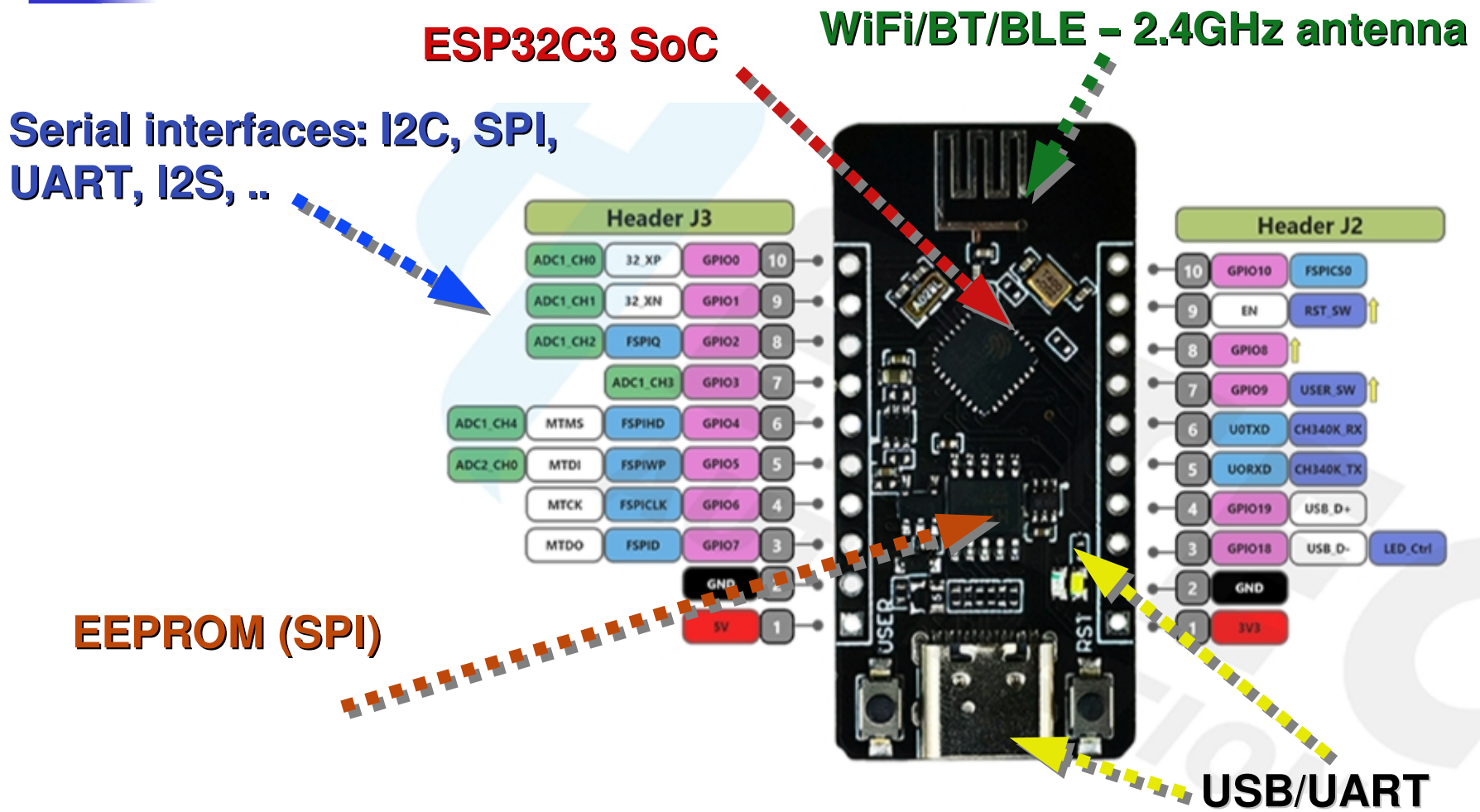
Espressif's ESP32-C3 Wi-Fi + Bluetooth® Low Energy SoC



Modules having power in specific power modes:



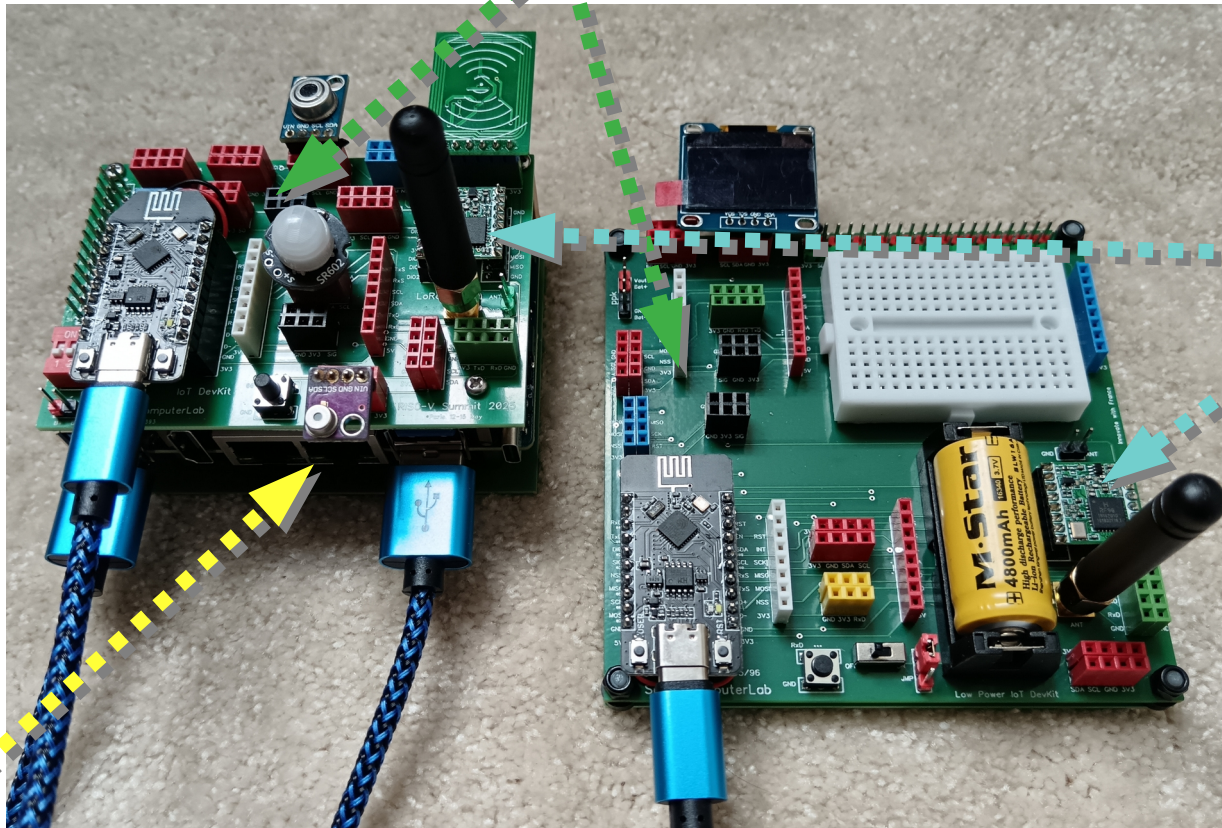
Heltec – ESP32C3 board



IoT Integrated DevKit with SBC (RV64GCVB)

IoT DevKit

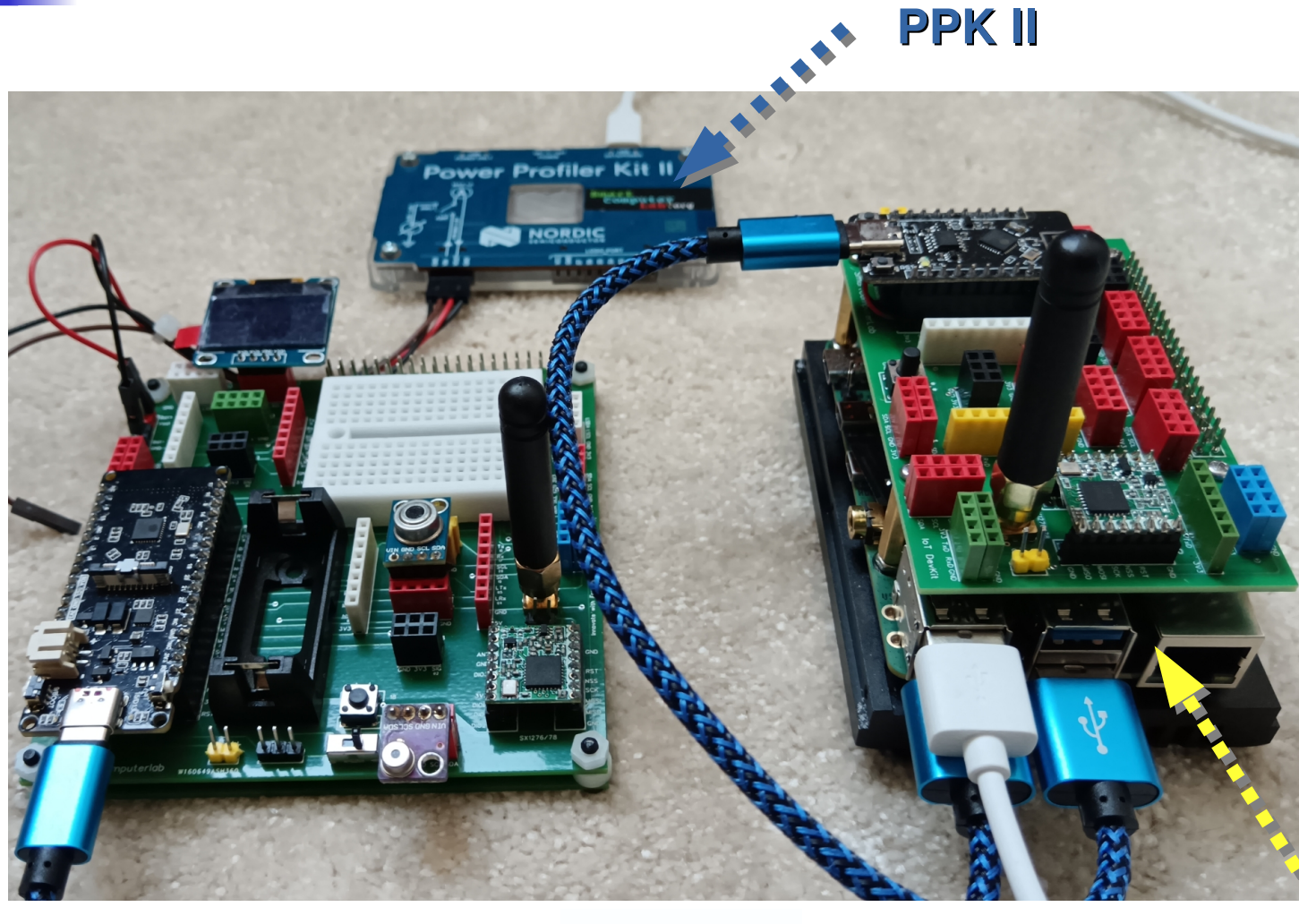
sx1276/8
modem



SBC board

Adaptive Low Power IoT Protocols

IoT Integrated DevKit with SBC (x86 - N100)



IoT SoC memories : SRAM & EEPROM

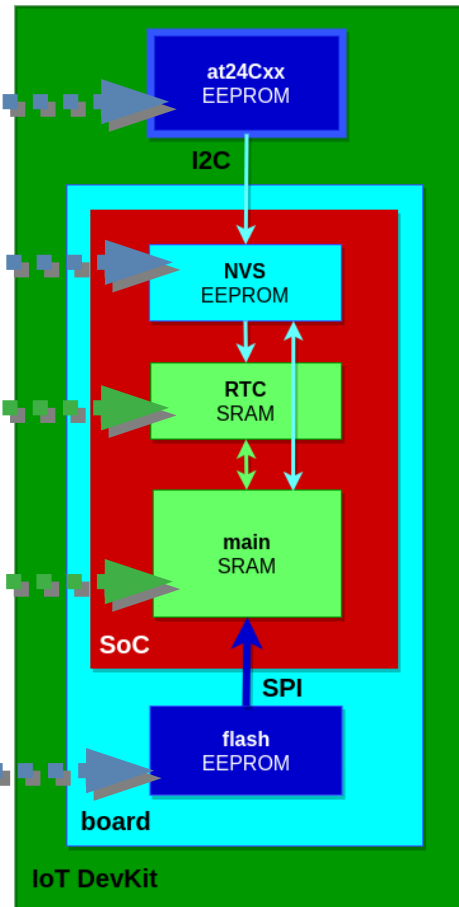
AT24Cxx EEPROM (32KB)

NVS EEPROM (1KB)

RTC SRAM (512B)

main SRAM (512KB)

flash EEPROM (4MB)



external permanent values
meta-parameters
base_cycle, max_cycle, min_delta,
max_delta, thresholds, ...

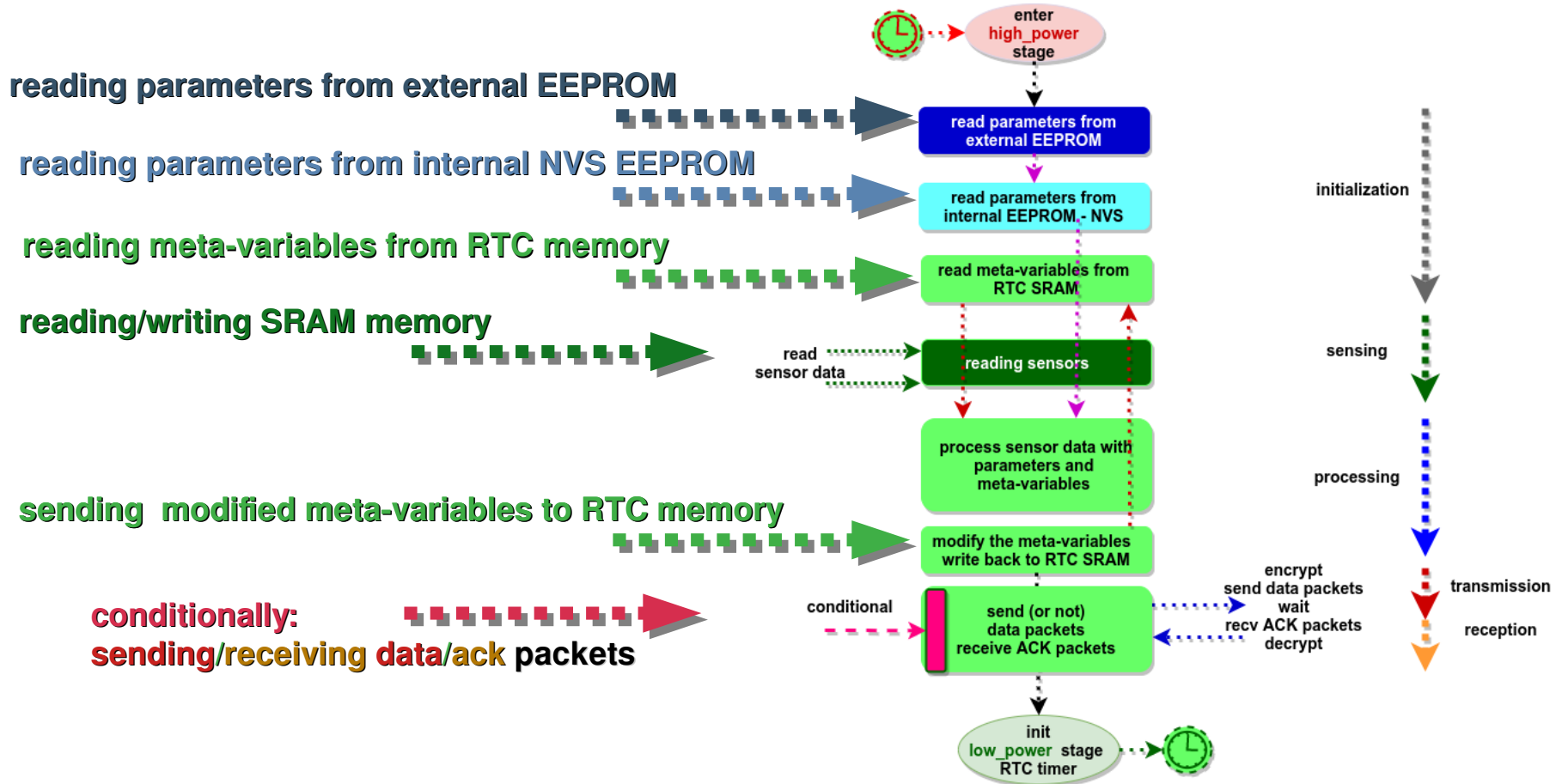
internal permanent values
meta-parameters
base_cycle, max_cycle, min_delta,
max_delta, thresholds, ...

low_power stage
parameters
sensors states, cycle factor, delta factor,...

high_power stage: program
static/dynamic data
sensor values, transmission buffers, ...

interpreter
predefined modules - tools,
application modules

high_power stage : SRAM & EEPROM



Adaptive Low-Power IoT Protocol

(principle: cycles, stages, phases)

testing thresholds
for urgent data



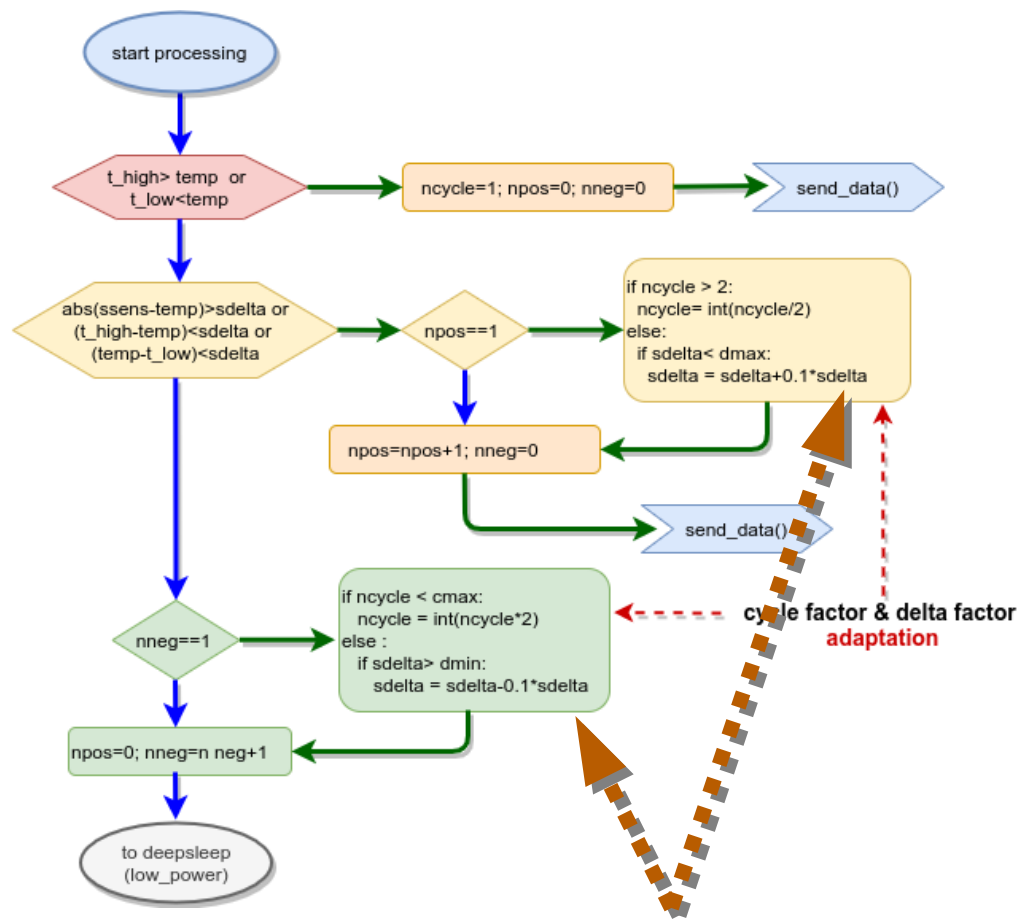
threshold
condition

testing delta for
"normal" data



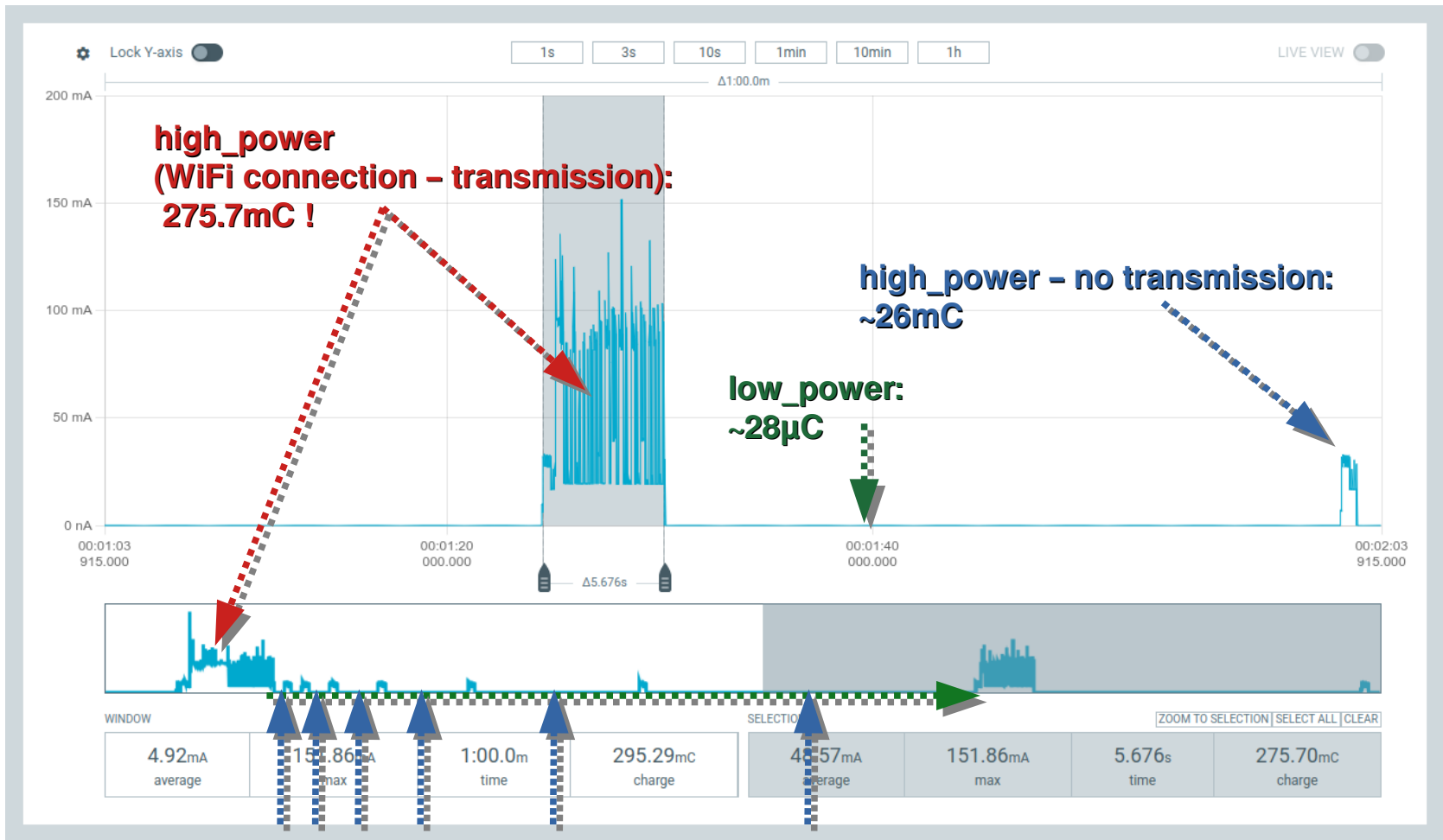
delta
condition

no data sent



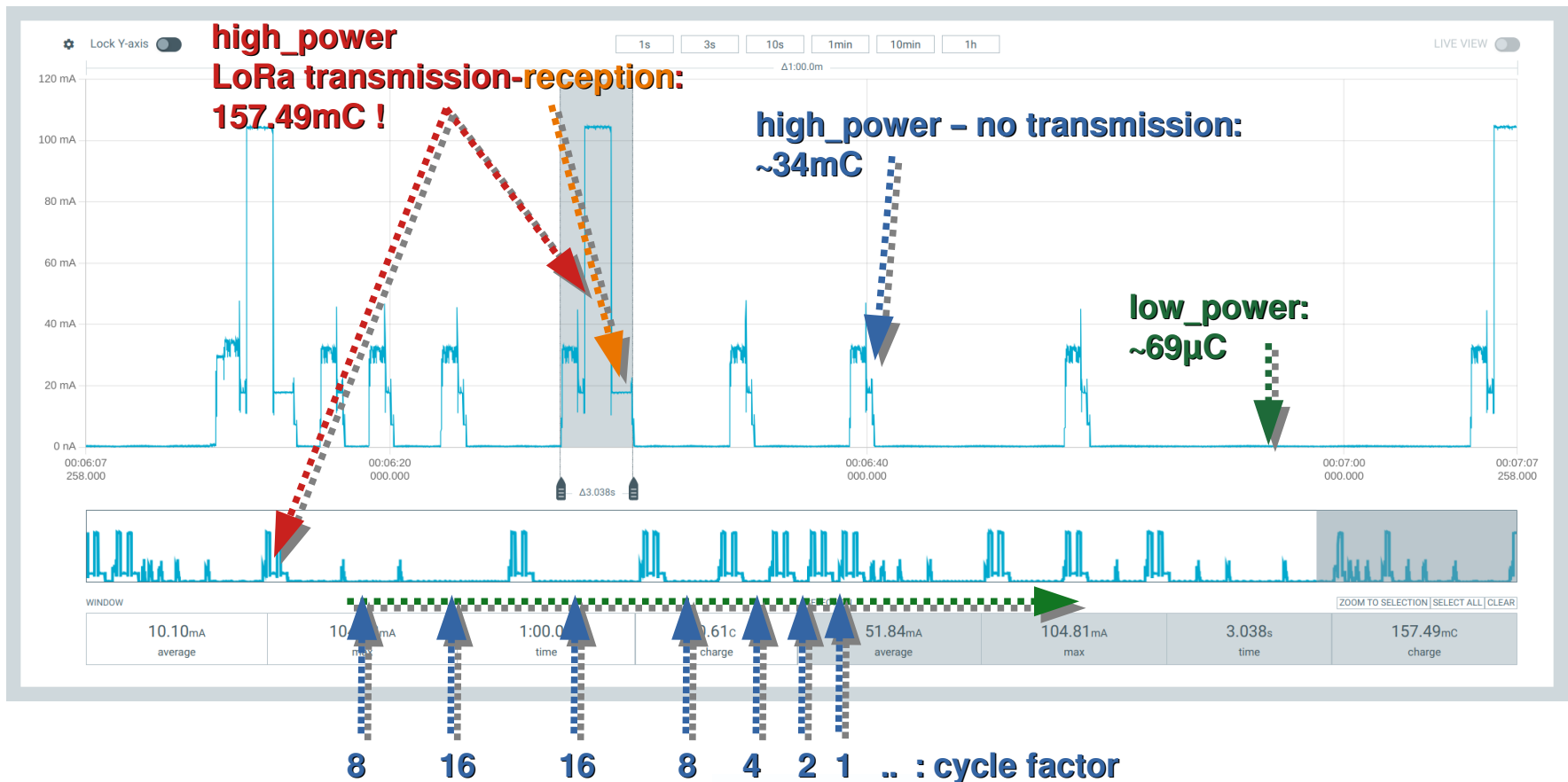
loading-processing-storing meta-variables

DT (WiFi) - power consumption analysis



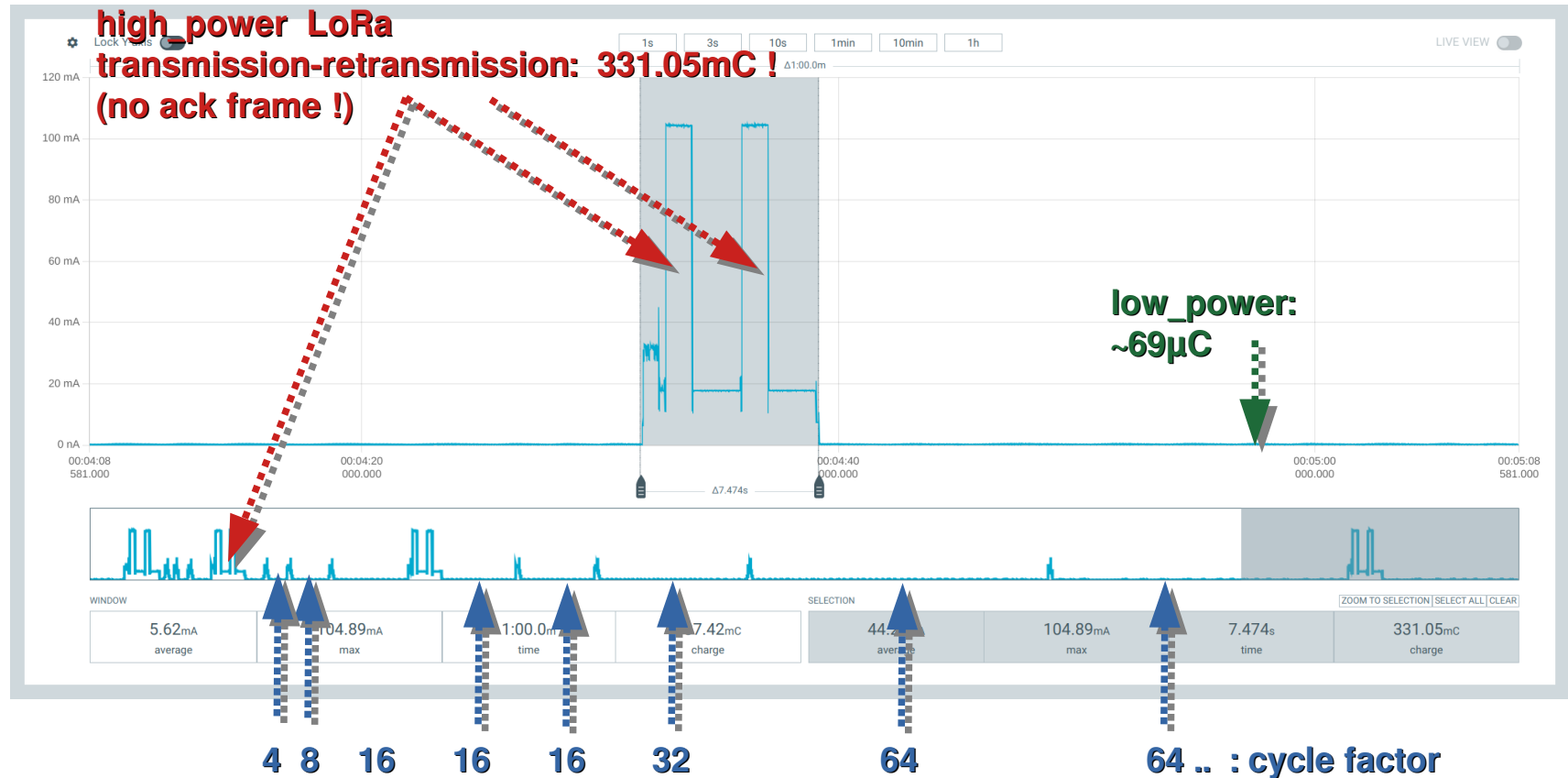
RT (LoRa) - power consumption analysis

LoRa radio parameters: SF=11, SB=125KHz, CR=8 (32-bytes – “long” frames)



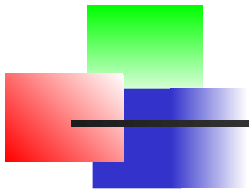
RT (LoRa) - power consumption analysis

LoRa radio parameters: SF=11, SB=125KHz, CR=8 (32-bytes – “long” frames)



cycle factor is meta-variable in RTC-memory

64 is **max_cycle** parameter in NVS



Summary

Direct Terminal: WiFi

Essential feature of the protocol is avoidance of **very-high cost of WiFi** (connection-transmission) : average current $< 500\mu\text{A}$;
no Router/Gateway required

Close Terminal: MAC-WiFi

Important feature is avoidance of **low-cost WiFi** (transmission only) :
average current $< 400\mu\text{A}$;
need of MAC-WiFi Router

Remote Terminal: LoRa

Avoidance of relatively-low cost of LoRa transmission (**depending on the radio parameters**) cost of transmission: average current $< 300\mu\text{A}$;
need of LoRa-WiFi Gateway