Sensor Network for Smart Agriculture

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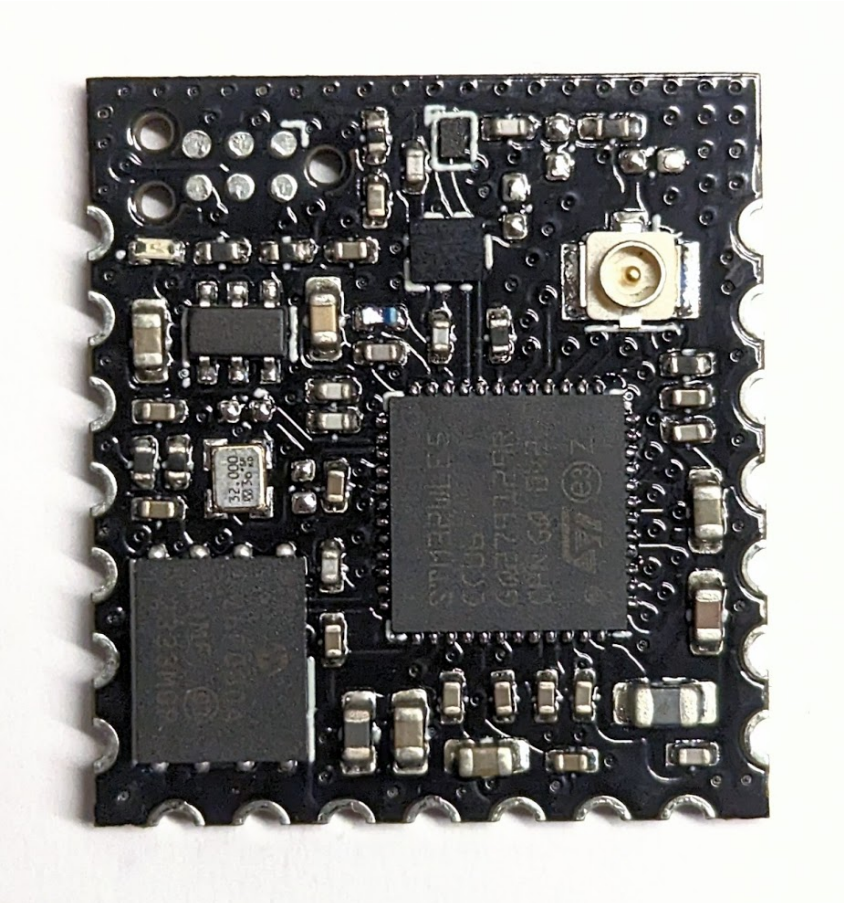
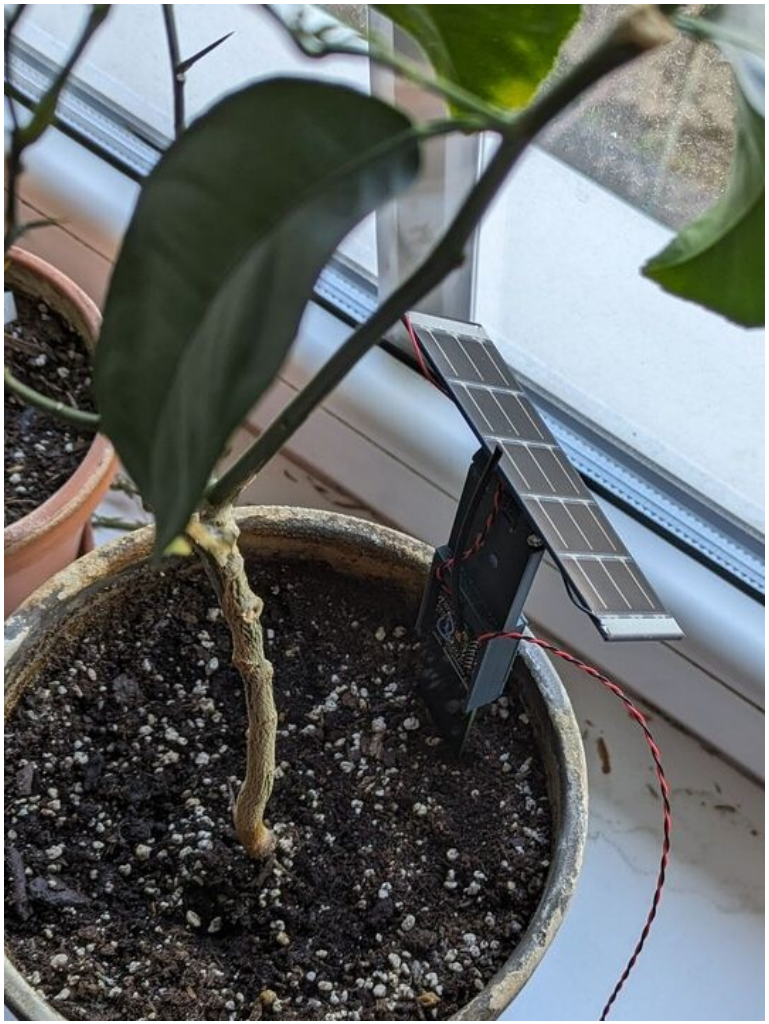
Goals

1. Create a universal platform: LoRa Module and Firmware



2. Demonstrate its capabilities: Wireless soil moisture sensor



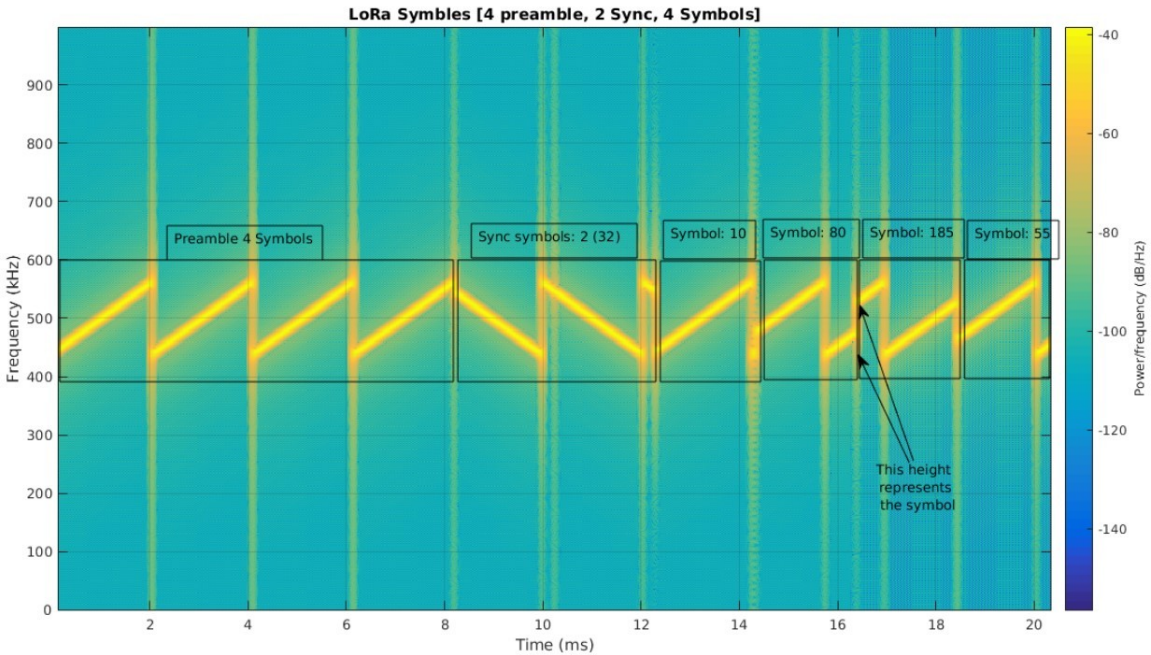
Goals

1. Low–power LoRa Module
- A platform for rapid application development

2. Custom soil moisture sensor network
- Able to cover large–enough area (kilometers)
- Zero–maintenance
- No external dependency on commercial networks
- Potentially extensible with more sensor types

Cover large–enough area with no external dependency

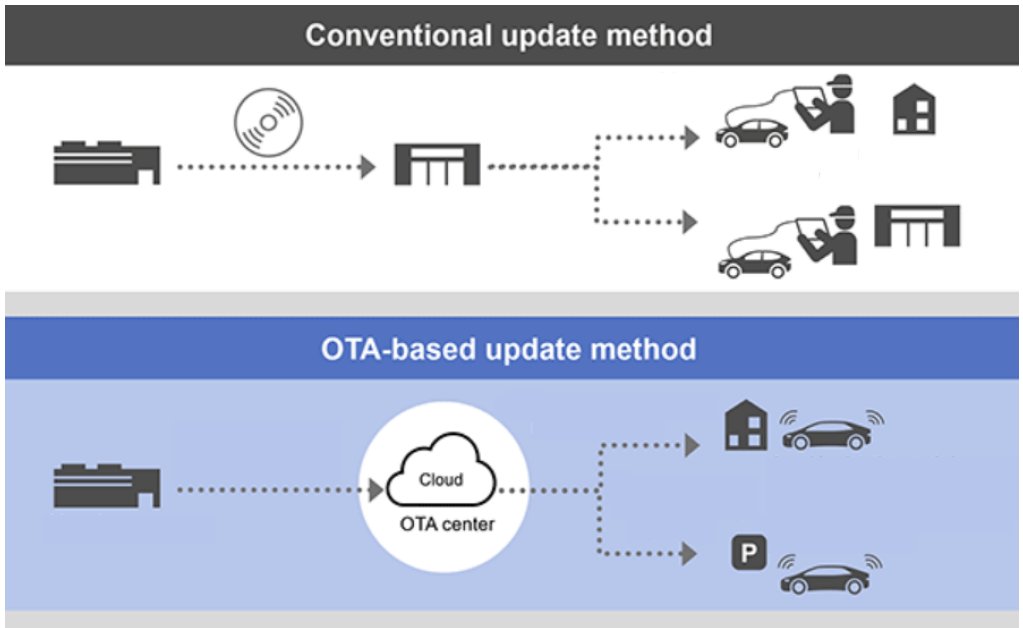
- LoRa
  - Long range (kilometers)
  - Low power (5 mA receive)
- Custom protocol
  - Low duty–cycle
  - Not reliant on LoRaWAN
  - Efficient



LoRa signal - Frequency/Time, [1]

Zero–maintenance and extensible

- Solar power
  - No infrastructure required
  - Self–sufficient
- Over–the–Air updates
  - New features and improvements
  - Long–term support



Conventional × OTA update, [2]

Soil Moisture Sensor

Absolute soil water content measurement is impractical

- High power draw
- Bulky
- Expensive

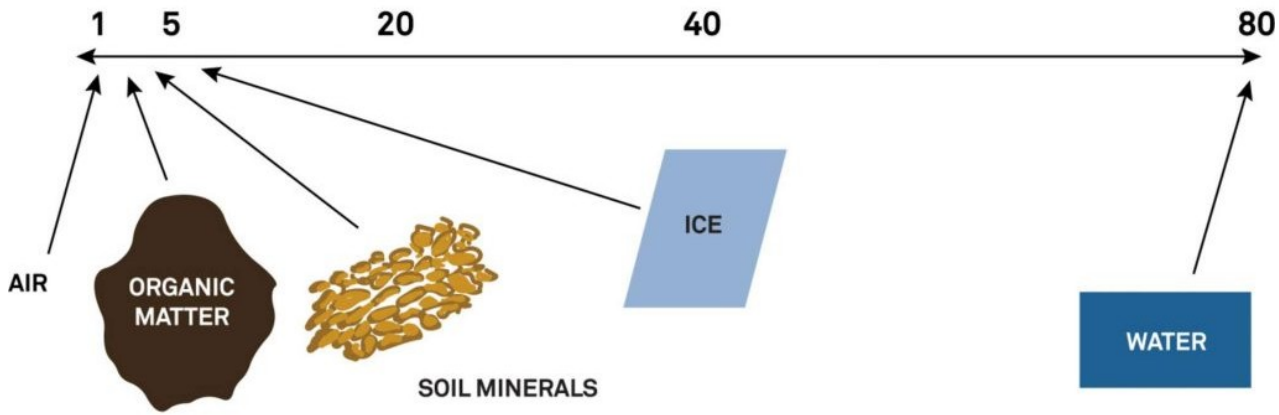
Properly calibrated relative measurement is sufficient for monitoring purposes

$\rightarrow$ Capacitive soil moisture sensor

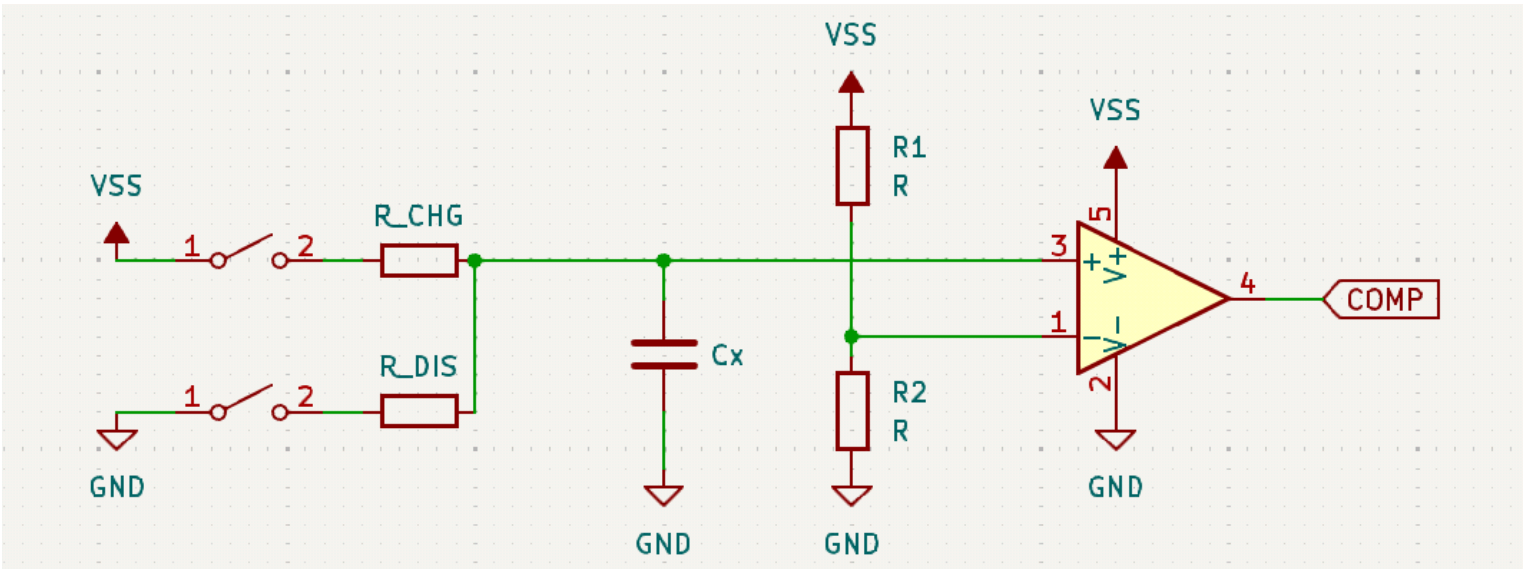
Soil Moisture Sensor

$$C = \frac{\epsilon_r \epsilon_0 S}{d} \quad [\mathrm{F}]$$

$$\tau = RC \quad [\mathrm{s}]$$

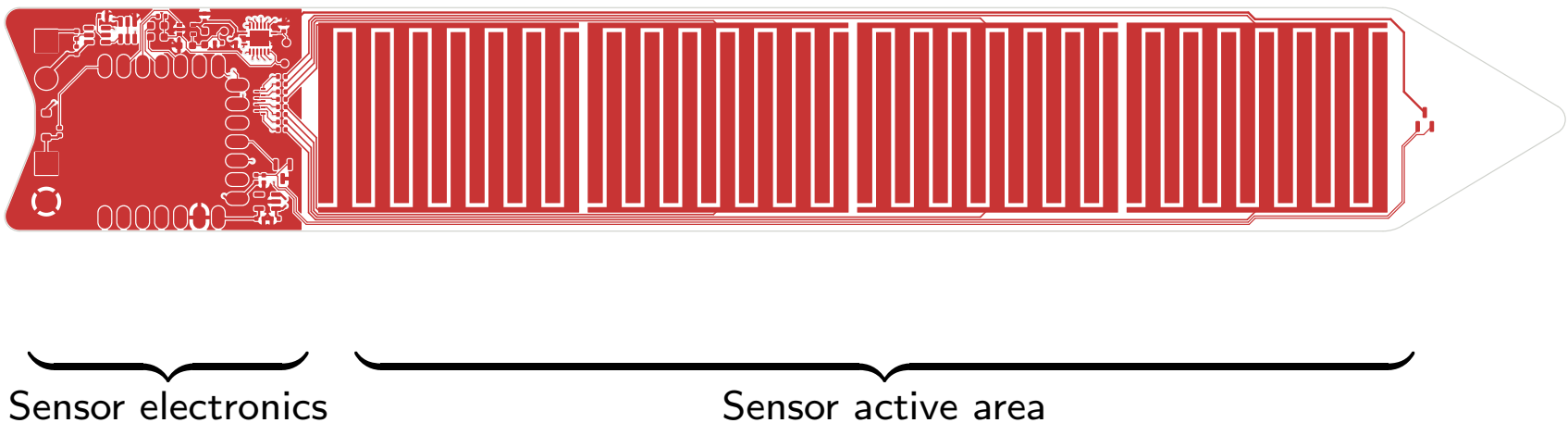


Dielectric constant ϵ_r of materials found in soil, [3]

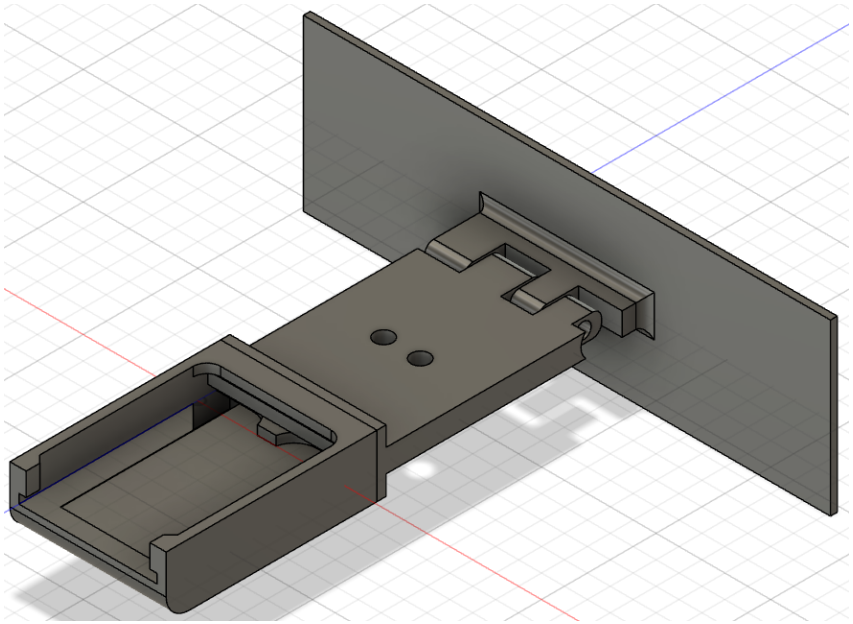


Soil Moisture Sensor

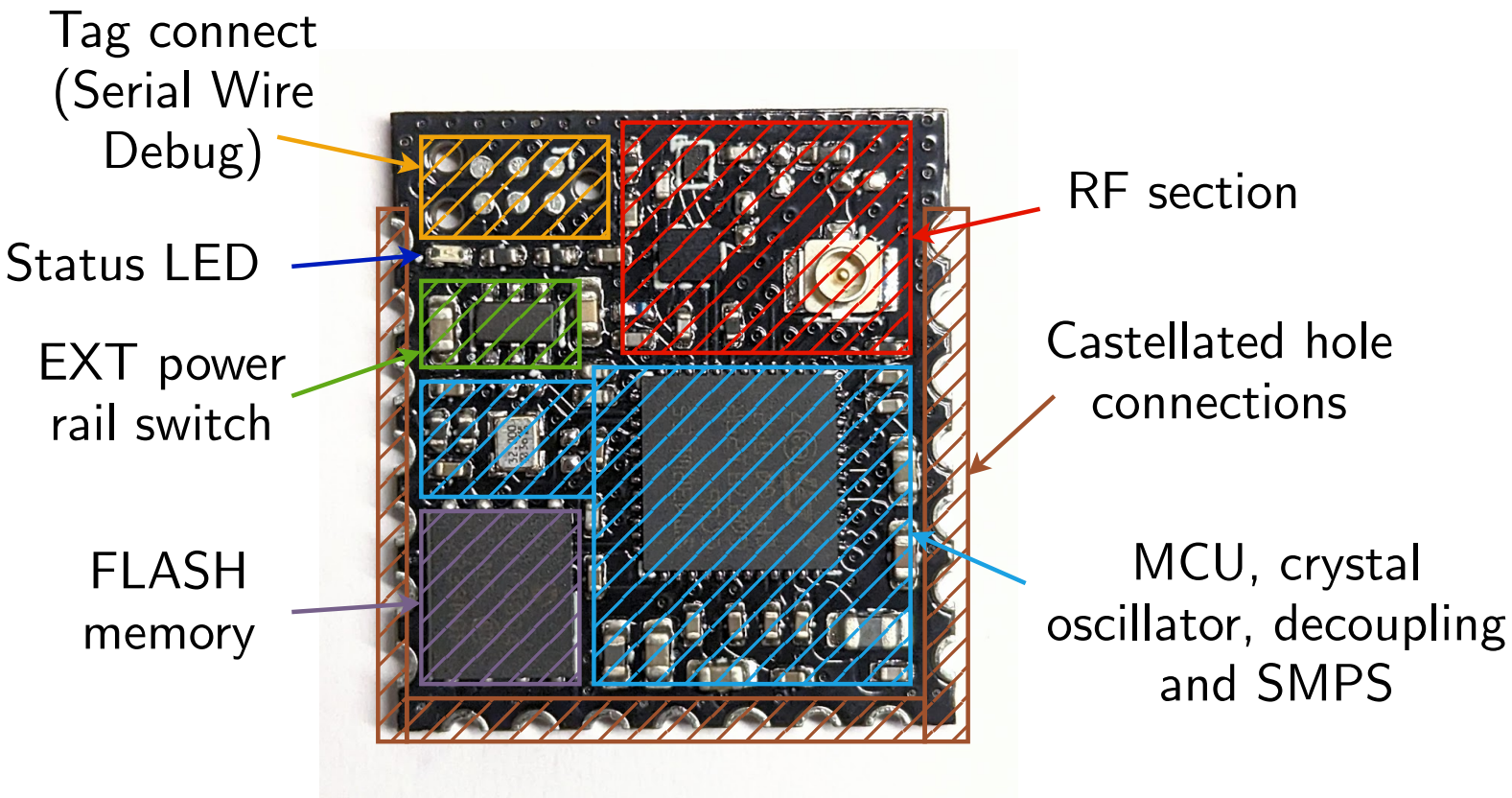
- PCB construction
- 4 capacitive zones (15 cm total depth)
- 330 mAh lithium cell, 150 mWp solar panel



Soil Moisture Sensor

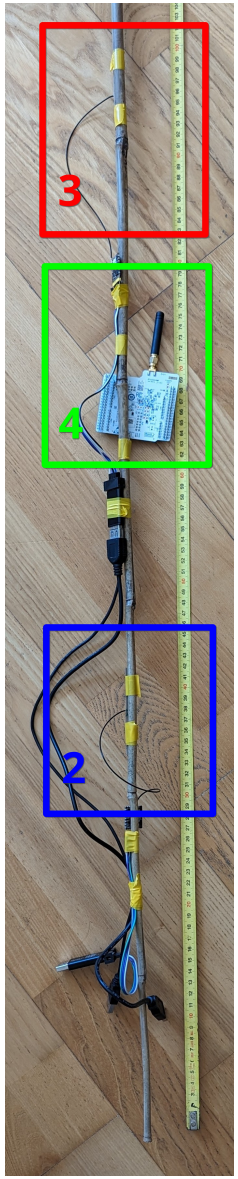


LoRa Module



- **STM32WLE5CC**
- 868 MHz, 15 dBm
- **20.32×22.48 mm**
- 1 MB FLASH
- 2.3–3.5 V
- 16 IO pins

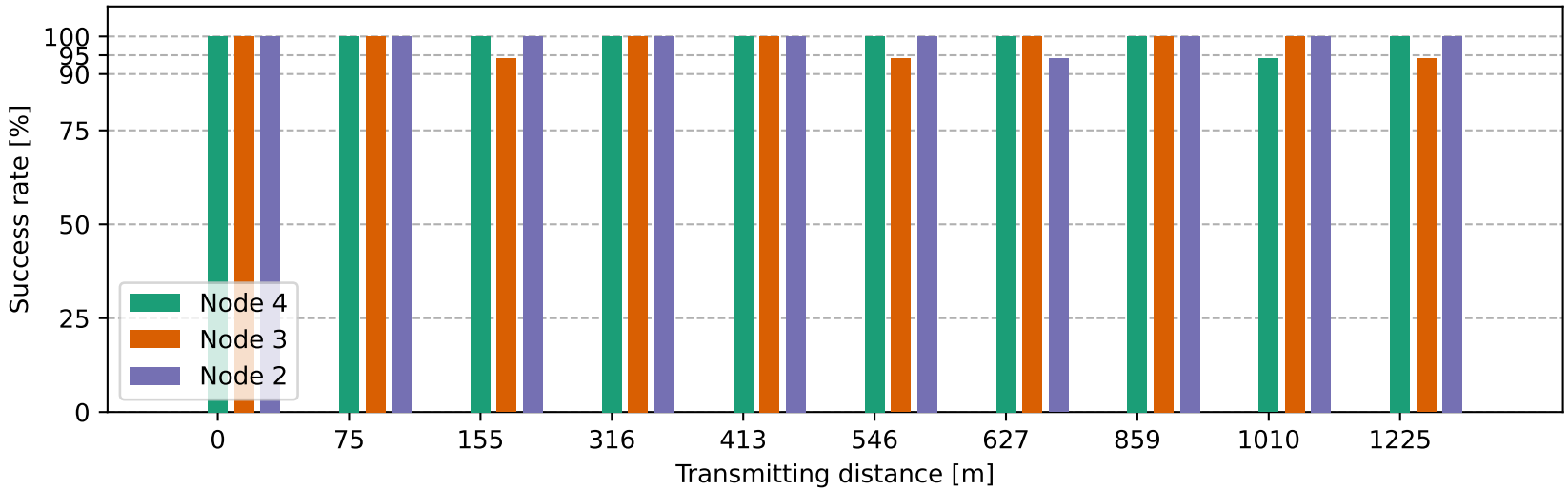
LoRa Module Range Test

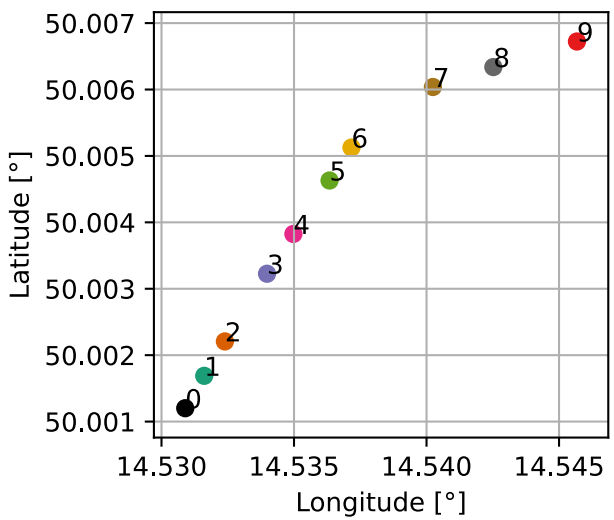


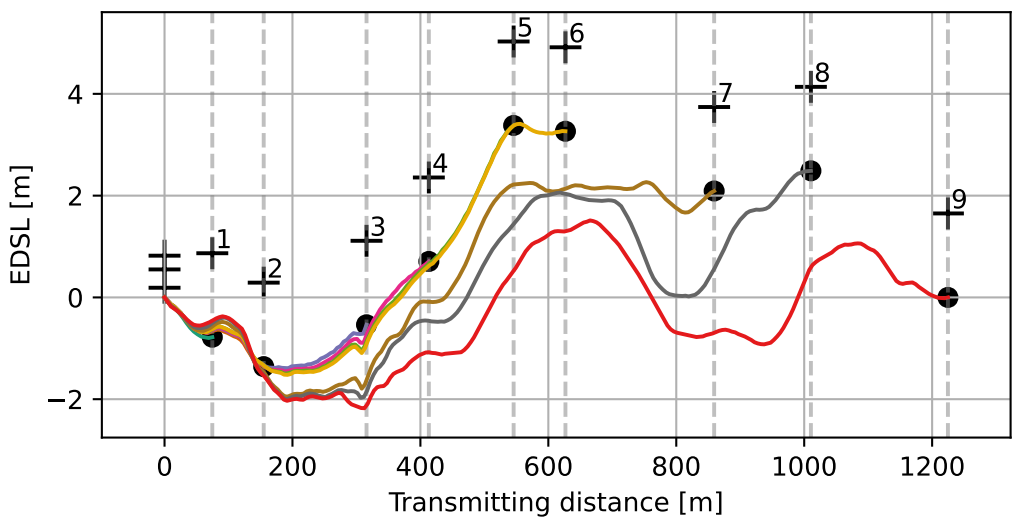
Node 2

Node 3

LoRa Module Range Test - SF11

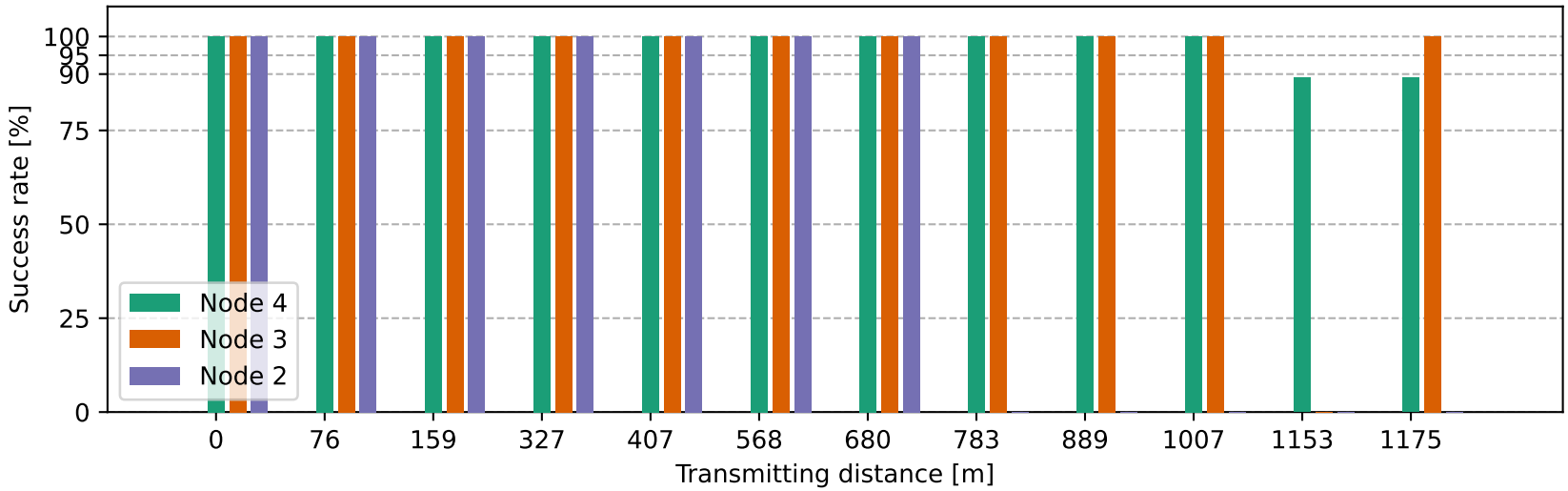


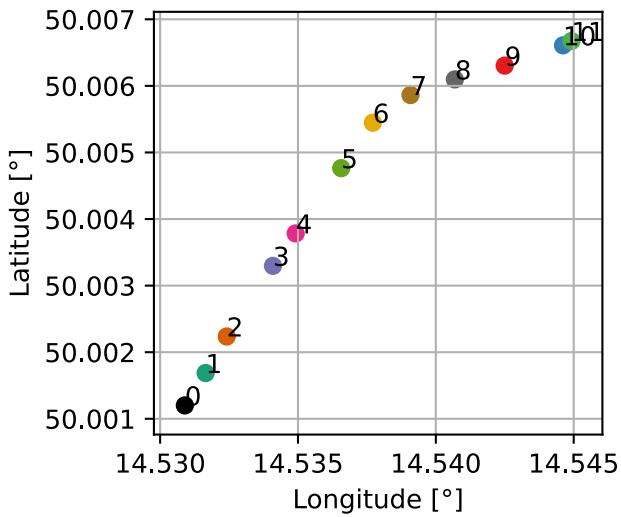


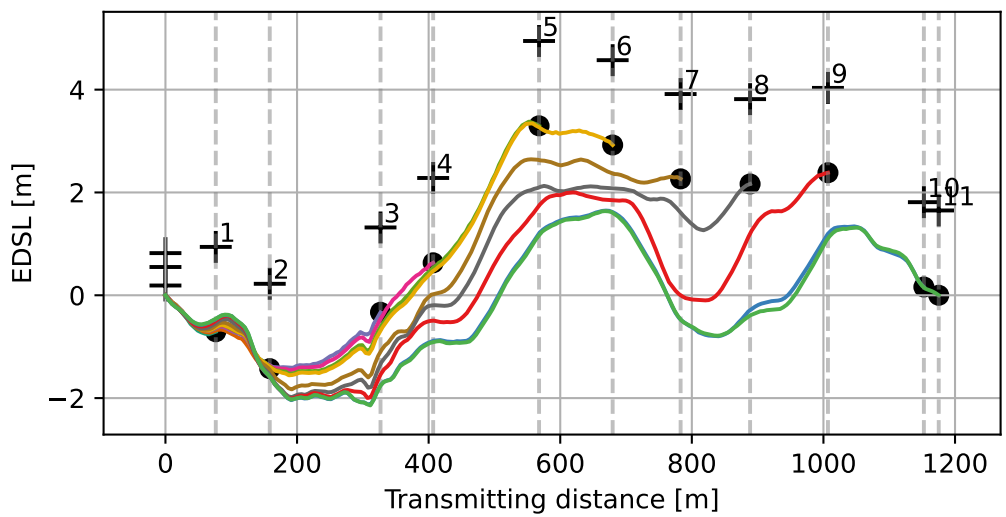


Node 2 - 20 cm, Node 3 - 80 cm, Node 4 (Nucleo) - 50 cm, 1.125 s round-trip, 300 bps, Page 41, Section 4.4.4

LoRa Module Range Test - SF5

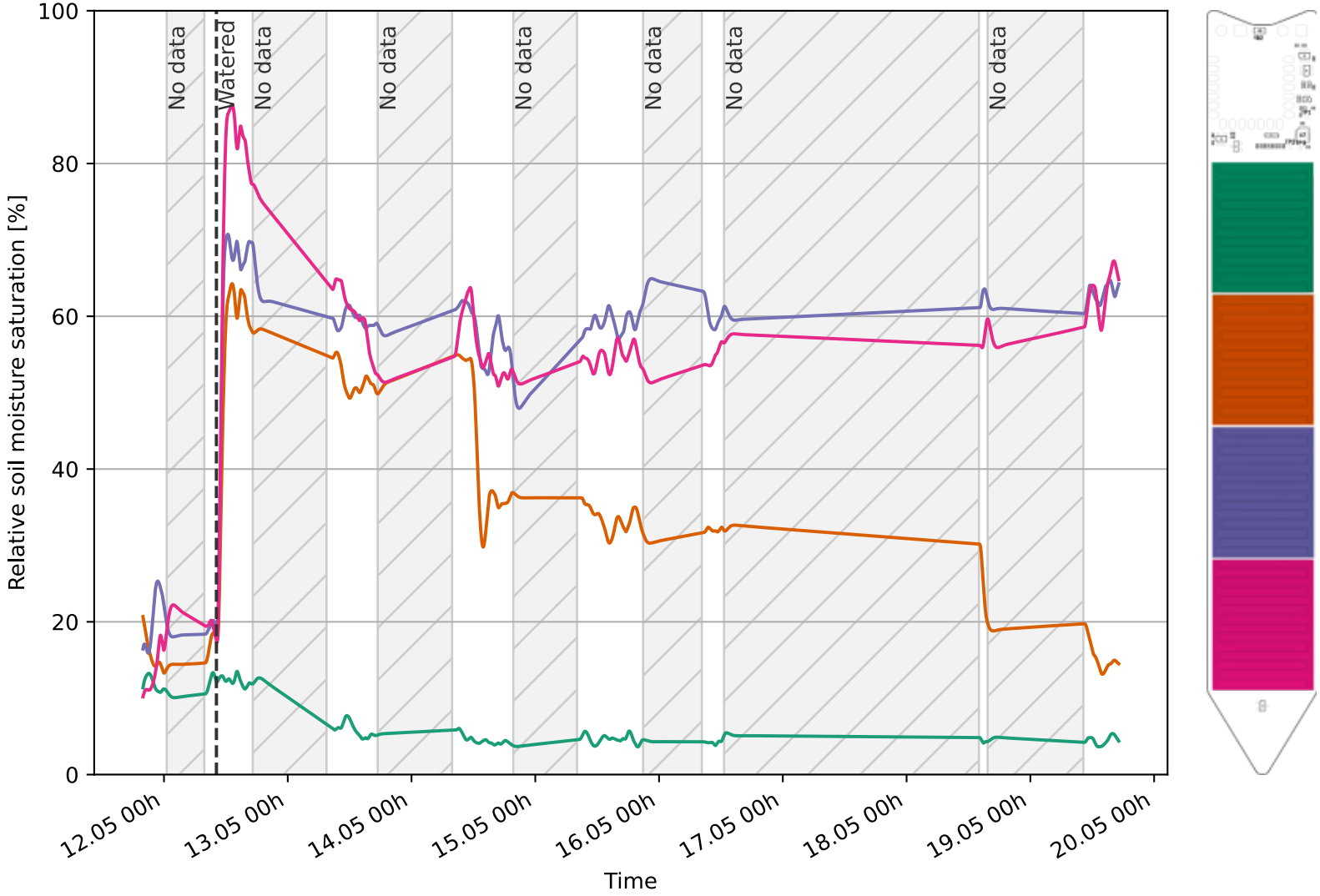






Node 2 - 20 cm, Node 3 - 80 cm, Node 4 (Nucleo) - 50 cm, 0.125 s round-trip, 3 kbps, Page 41, Section 4.4.4

Soil Moisture Sensor Validation



Live Demo

(or visit the link)

Conclusion

This thesis brought

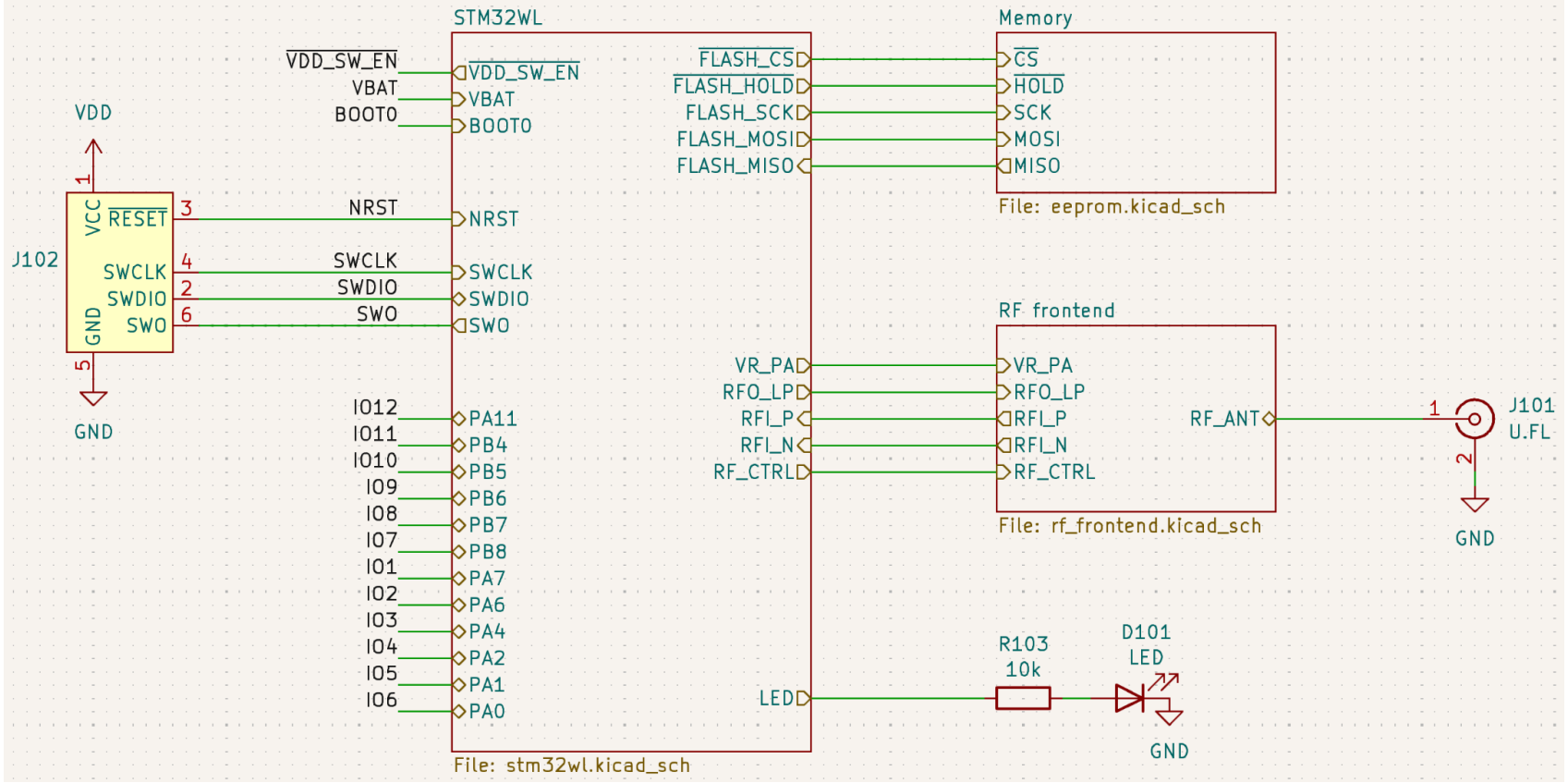
- **STM32 LoRa Module - a low–power platform for connected sensors**
  - `module-runtime` Rust package - HAL, protocol, async executor; enabling rapid application development with emphasis on reliability
  - Optimized for low duty–cycle operation
  - Over–the–Air update capability with rollback
- **Soil moisture sensor - an application of the module**
- Backend service combining soil moisture sensor data with weather forecast to optimize watering schedule

All publicly available at `https://github.com/manakjiri`

References I

- Giuseppe Panza, "What LoRaWAN and "Chirp Spread Spectrum" (CSS) technology have in common? Part III | LinkedIn." [Online]. Available: https://www.linkedin.com/pulse/what-lorawan-chirp-spread-spectrum-css-technology-have-giuseppe-panza-hz5dc/
- Mobility Connected, "What are OTA Updates?" Jan. 2024. [Online]. Available: https://www.hitachi.com/products/it/lumada/global/en/spcon/uc_00866s/
- METER Group, "Soil moisture sensors—How they work. Why some are not research grade - METER Group," May 2023, section: Measurement Insights. [Online]. Available: https://metergroup.com/measurement-insights/soil-moisture-sensors-how-they-work-why-some-are-not-research-grade/

LoRa Module


STM32WL
Memory
VDD_SW_EN
VBAT
BOOT0
VDD
J102
VCC
RESET
SWCLK
SWDIO
GND
SWO
NRST
SWCLK
SWDIO
SWO
GND
IO12
IO11
IO10
IO9
IO8
IO7
IO1
IO2
IO3
IO4
IO5
IO6
PA11
PB4
PB5
PB6
PB7
PB8
PA7
PA6
PA4
PA2
PA1
PA0
FLASH_CS
FLASH_HOLD
FLASH_SCK
FLASH_MOSI
FLASH_MISO
CS
HOLD
SCK
MOSI
MISO
File: eeprom.kicad_sch
RF frontend
VR_PA
RFO_LP
RFI_P
RFI_N
RF_CTRL
RF_ANT
J101
U.FL
GND
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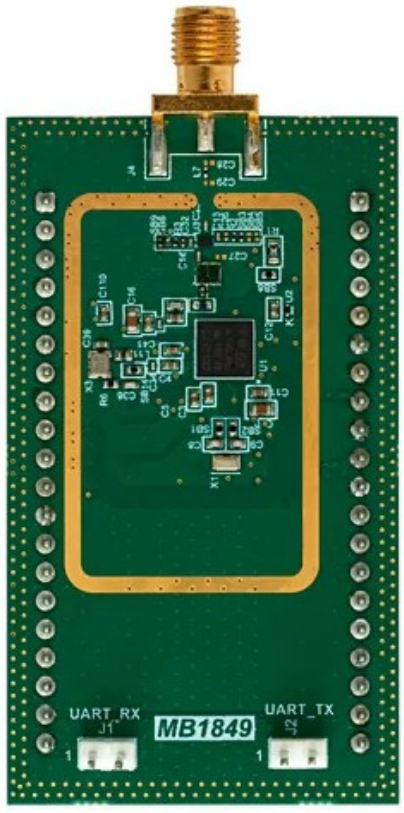
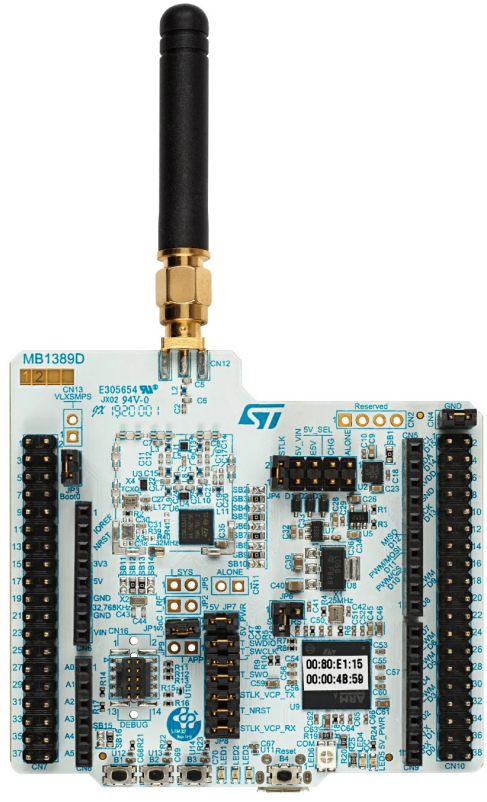
R103
10k
D101
LED
GND
File: stm32wl.kicad_sch

LoRa Module

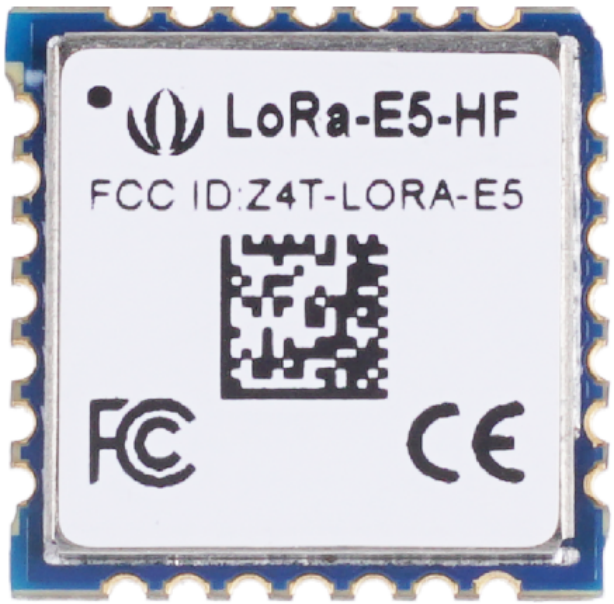


STDES-WL5U4ILH



Nucleo-WL55JC

Existing solution?



Seeed Studio Wio-E5

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?

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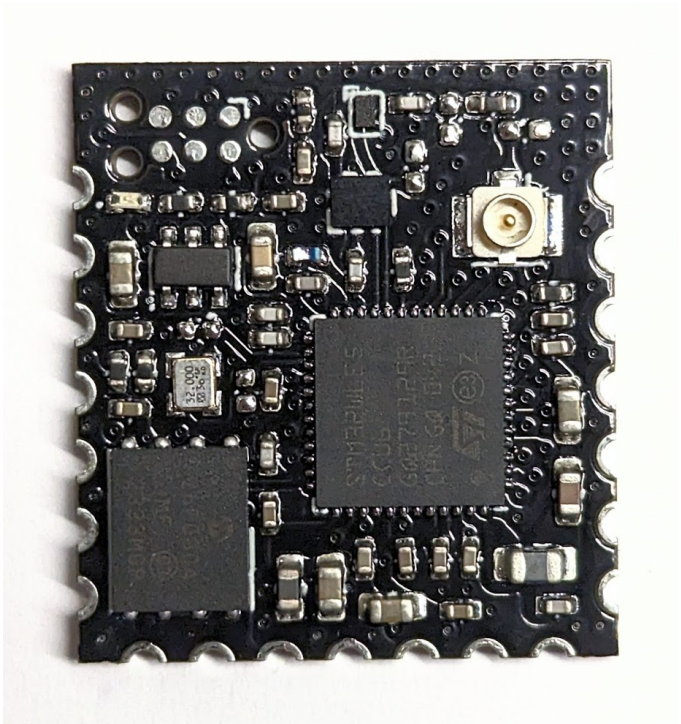
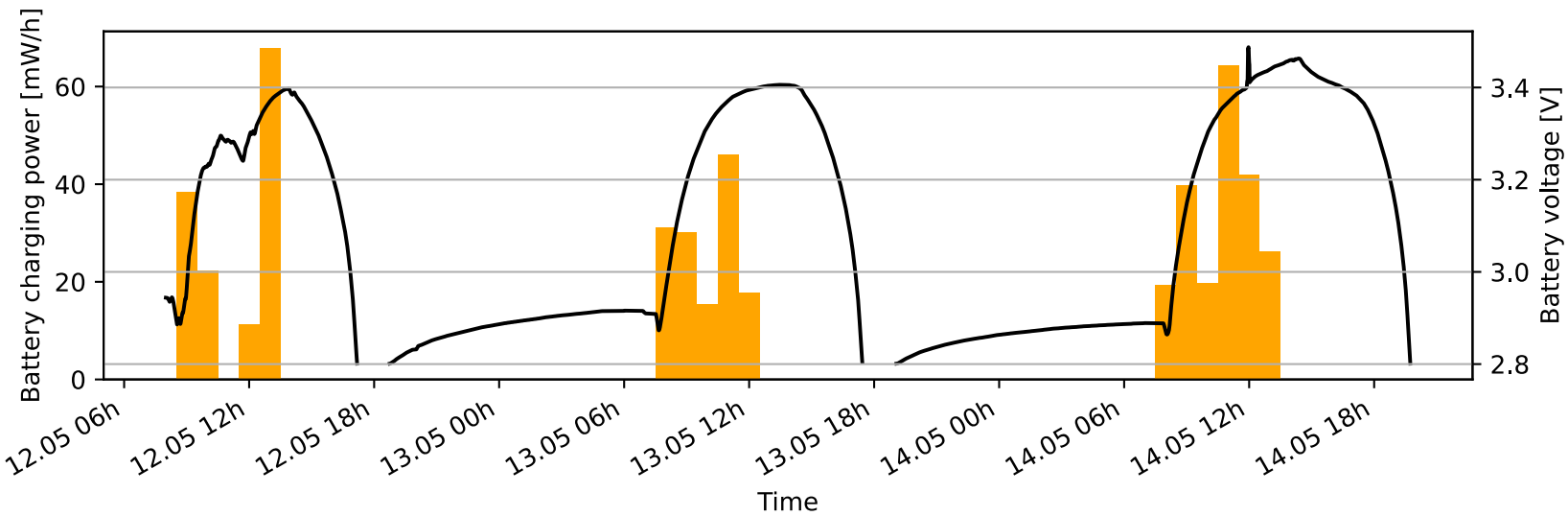
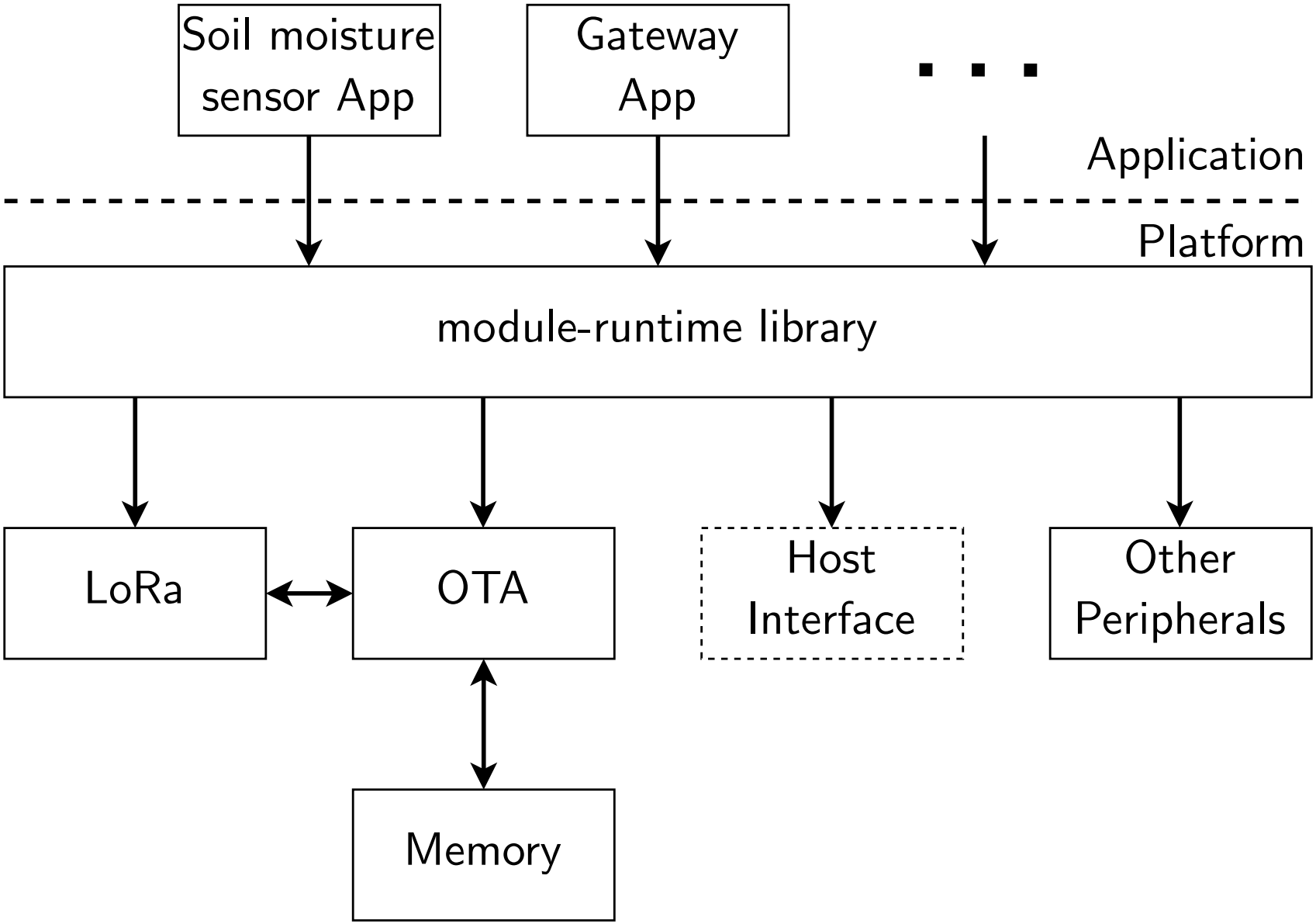


My LoRa Module

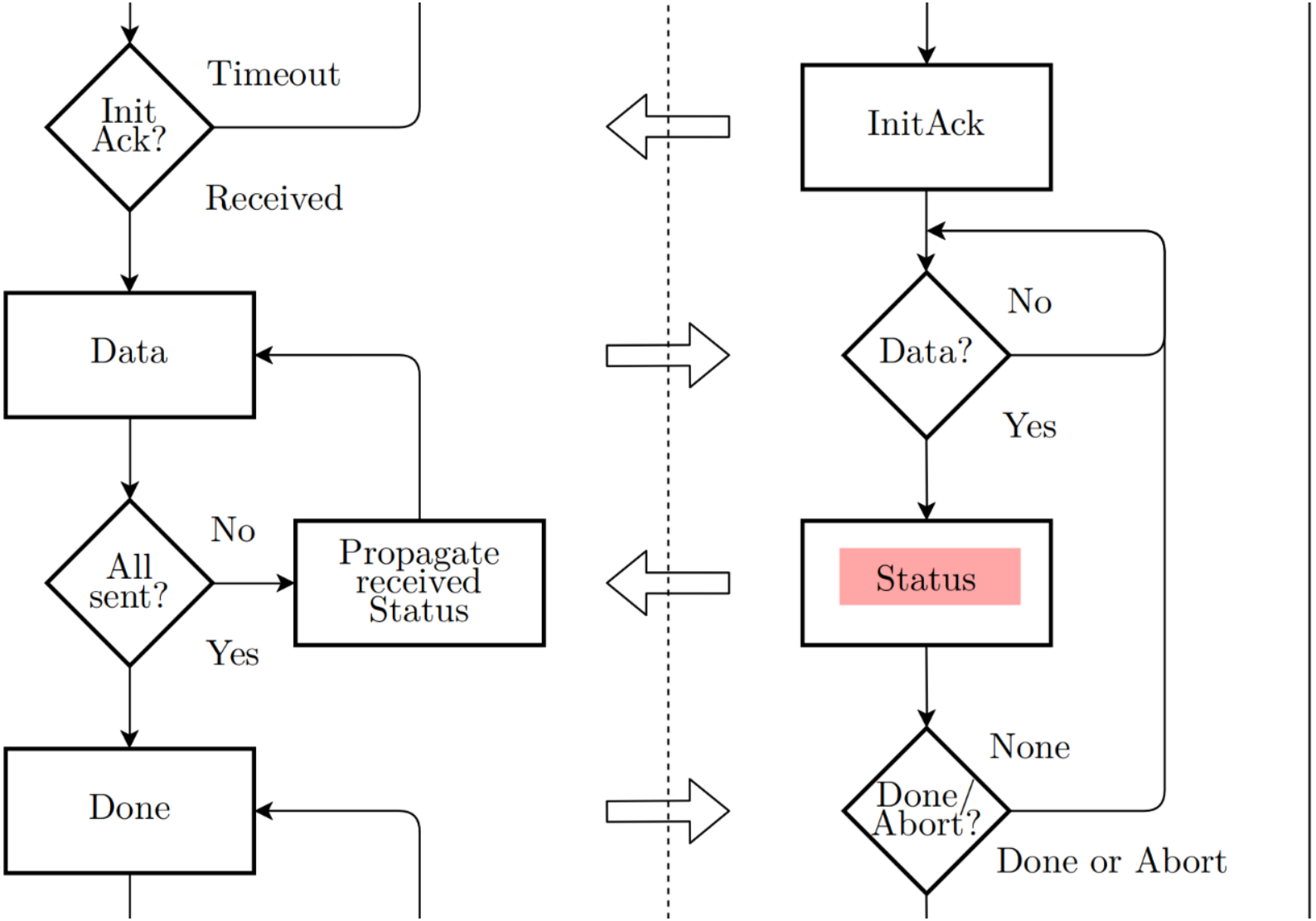
Solar Power


Battery charging power [mW/h]
0
20
40
60
Battery voltage [V]
2.8
3.0
3.2
3.4
12.05 06h
12.05 12h
12.05 18h
13.05 00h
13.05 06h
13.05 12h
13.05 18h
14.05 00h
14.05 06h
14.05 12h
14.05 18h
Time

Firmware


Soil moisture sensor App
Gateway App
Application
Platform
module-runtime library
LoRa
OTA
Host Interface
Other Peripherals
Memory

Over The Air Update



Page 36, Figure 4.9

LoRa Module

- 2.8–3.3 V nominal voltage range,
- low power design - support for switchable power rails,
- target the EU868,
- wide temperature range
- minimize the amount of specialized hardware,
- support for OTA updates,
- integrated RF,
- host communication interface,
- minimal footprint,
- low cost.

Page 15, Section 3.2.3