Intelligent Irrigation System for Low-cost Autonomous Water Control in Small-scale Agriculture

Deliverable D2.2c

Starter-kit for smart irrigation system – v3

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DOCUMENT REVISION HISTORY

Version	Date	Changes
V1.1	Feb 23th, 2024	PUBLIC RELEASE
V1.0	Feb 1st, 2024	FIRST DRAFT VERSION FOR INTERNAL APPROVAL
V0.1	Dec 7th, 2023	FIRST RELEASE FOR REVIEW

Executive Summary

Deliverable D2.2c describes the INTEL-IRRIS starter-kit for smart irrigation systems – v3. The starter-kit consists of the low-cost soil sensor device and the versatile edge-enabled IoT gateway with all packaged configuration and add-on software for out-of-the-box deployment.

Table of Contents

1. Introduction

The "intelligent irrigation in-the-box" concept will be demonstrated by a starter-kit that consists of 1 **soil moisture sensor device** (either capacitive or tensiometer) developed by UPPA and **1 versatile IoT gateway** based on the WaziGate distribution developed by WAZIUP and further customized for INTEL-IRRIS by UPPA. On the gateway, a dedicated application to enhanced irrigation notification and parameters is part of the starter-kit

Refer to D2.2a “Starter-kit for smart irrigation system – v1” and D2.2b “Starter-kit for smart irrigation system – v2” for a more detailed description of the evolution of the starter-kit. This deliverable D2.2c “Starter-kit for smart irrigation system – v3” only addresses the new development to the starter-kit.

Readers can also refer to D1.2c “Low-cost sensor generic platforms for connected irrigation system – v3” for more information on low-cost sensor hardware platform.

2. Sensor device part

2.1. IRD PCB v4.1

We present here the last version of this PCB. Since it is the last deliverable on the hardware, we include here some parts that were presented in D1.2c and we add what has been changed for this last version. All the features introduced into the previous version are retained.

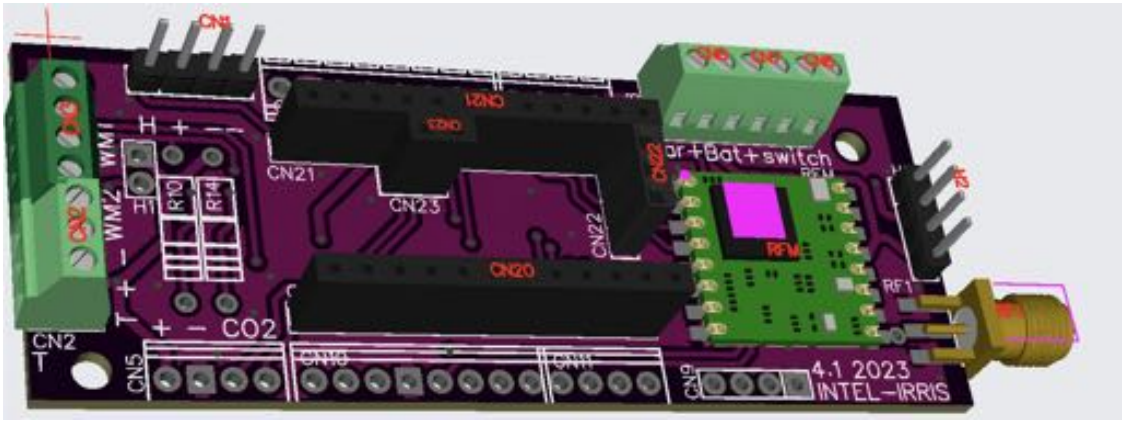
The v4.1 of the PCB is an optimizing version of the previous versions for:

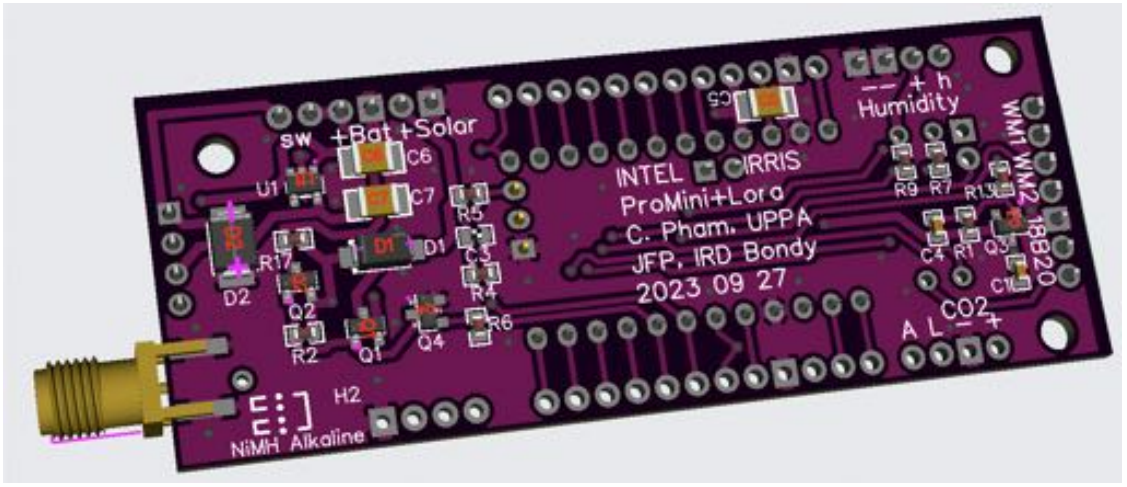
- Facilitating the use of the raw PCB without CMS
- Facilitating the use of standard no-rechargeable battery (i.e. alkaline)
- Allowing simple addition of a small solar panel and NiMH rechargeable battery
- Facilitating switching between these options with a dedicated connector
- Providing a PCB where all components can be assembly by a manufacturer

The 2-Watermark sensor version has an optimized wiring with only the usage of one resistor with less reserved GPIO pins. Soil insulation between the 2 sensors is conserved.

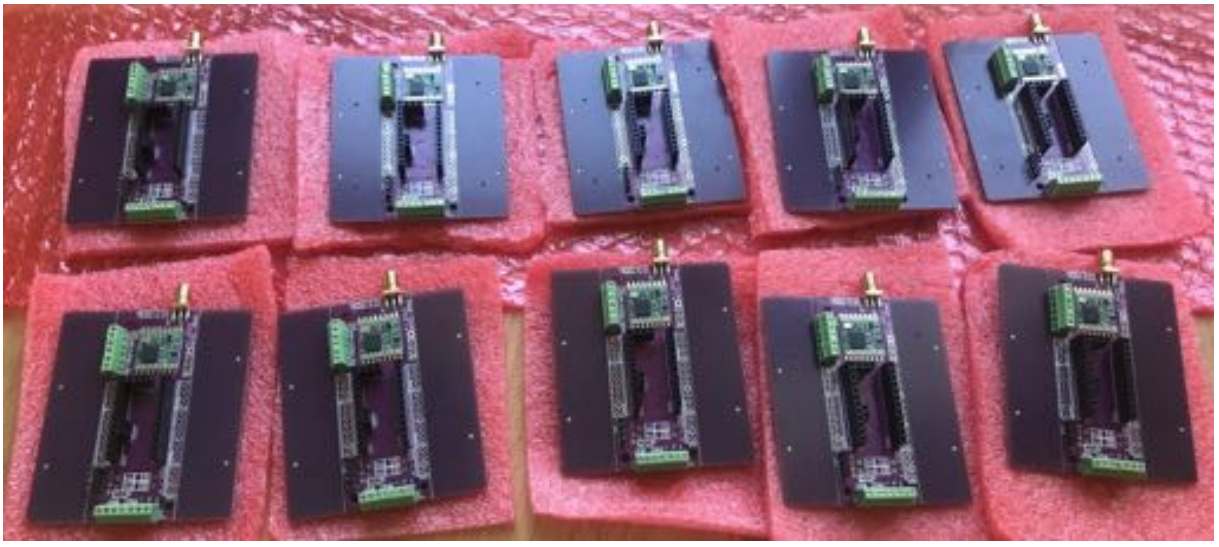
2.1.1. Manufacturing & assembly of the PCB

The first batch for test of the fully assembled boards based on the new IRD PCB with low-cost solar charging capabilities has been ordered for manufacturing on October 6th,2023 (https://intel-irris.eu/first-batch-of-intel-irris-fully-assembled-boards-based-on-the-new-ird-pcb.



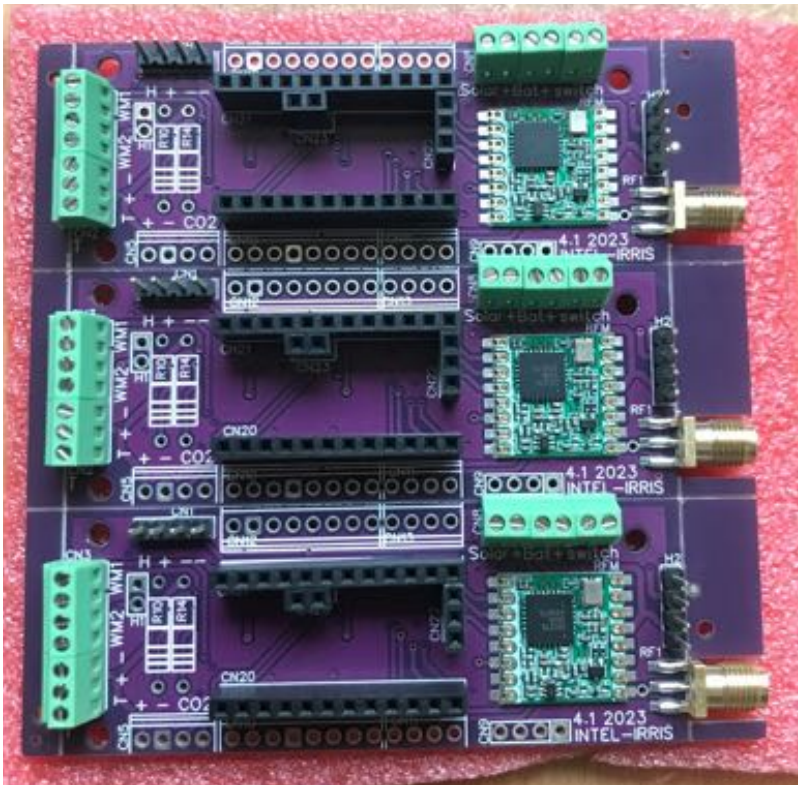


The 10 pieces arrived on October 13th, 2023!

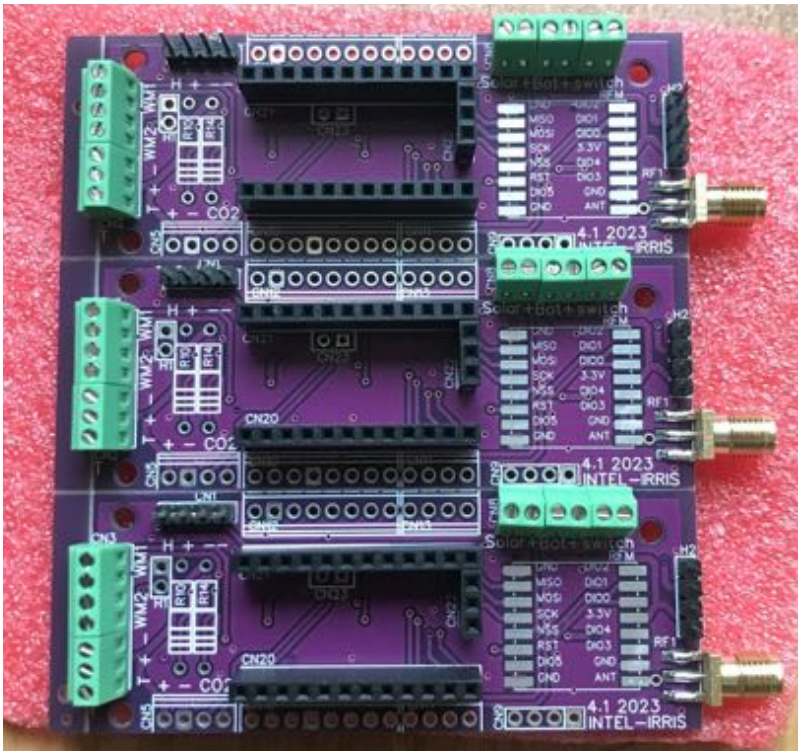


After having successfully passed the final tests that validated the design of the board and the manufacturing process from the manufacturer, a larger order was placed on October 27th, 2023.

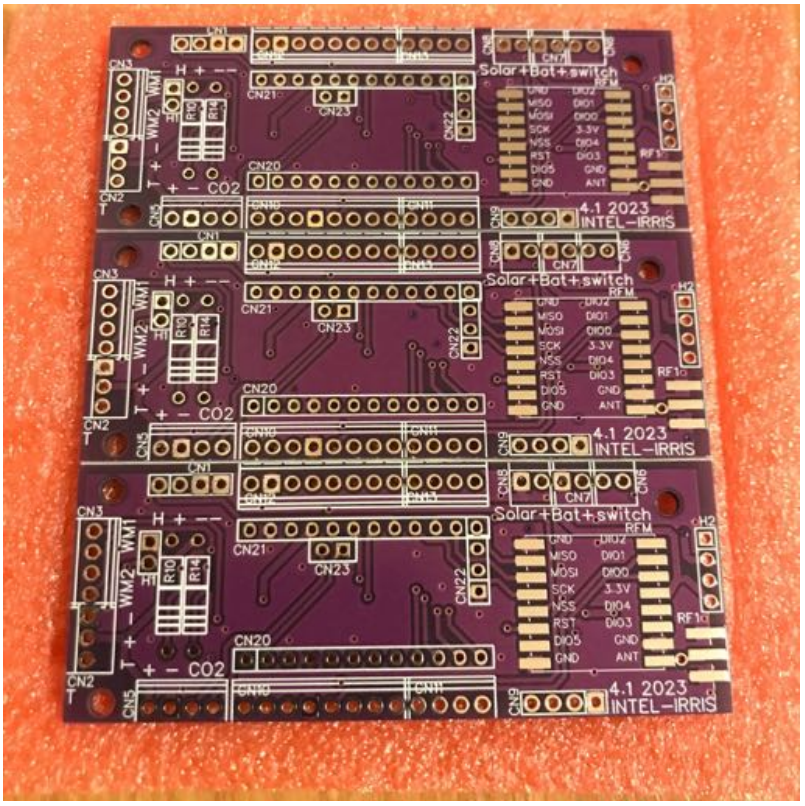
- 60 pieces of PCBA with RFM95W radio module for 868MHz, panelized in 3 pieces



- 45 pieces of PCBA without any radio module (the radio module, either RFM95W or RFM96W for 433MHz can then be soldered afterwards), panelized in 3 pieces



- 45 pieces of the raw PCB, panelized in 3 pieces

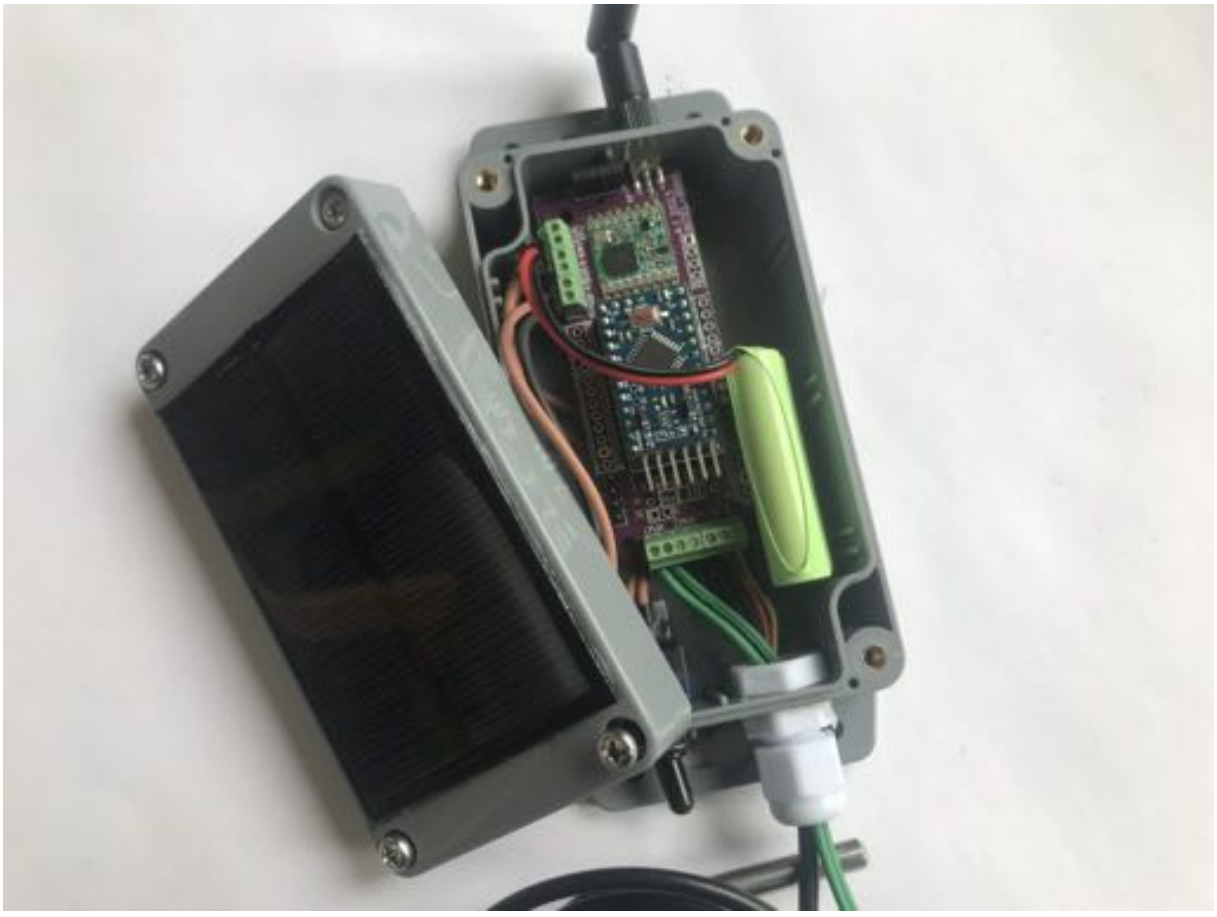


Cost per piece of the fully assembled PCBA is about 9€. The Arduino Pro Mini microcontroller can then just be plugged on the board. Total cost with the external Pro Mini microcontroller is about 12€.

A new video has been produced to show how partners or third parties can order the fully assembled PCBA directly from a PCB manufacturer.

- NEW! OCT-23. Video n°9. YouTube tutorial video showing how to order the fully assembled INTEL-IRRIS PCBA

2.1.2. Assembling the soil sensor device with new PCBA



Associated tutorials have been updated and a new tutorial has been produced to especially focus on the new IRD PCB v4.1:

- Tutorial slides building the INTEL-IRRIS IoT platform. Part 1: soil sensor device. Covers all versions of PCBs. Related videos are Video n°1, Video n°2 and Video n°3. See below. The tutorial has been updated to include the latest PCBs.

- **NEW! OCT-23.** Tutorial slides building the INTEL-IRRIS IoT platform. Part 1: soil sensor device. Focus on the latest IRD PCBv4.1 (recommended). The tutorial has been updated to focus on the latest IRD PCBv4.1.

2.1.3. First distribution of the PCBA v4.1

On October 29th, 2023, 6 PCBA of the first batch were distributed by UPPA to our UORAN1 partner in Paris (left photo). The new PCBA's features have been presented and Pr B. Kechar will use them with his UORAN1 team for next deployments for the Smallholder Piloting Program. 2 INTEL-IRRIS gateways have also been provided, with change in frequency band as Algeria has recently adopted the EU868 frequency band for LPWAN.

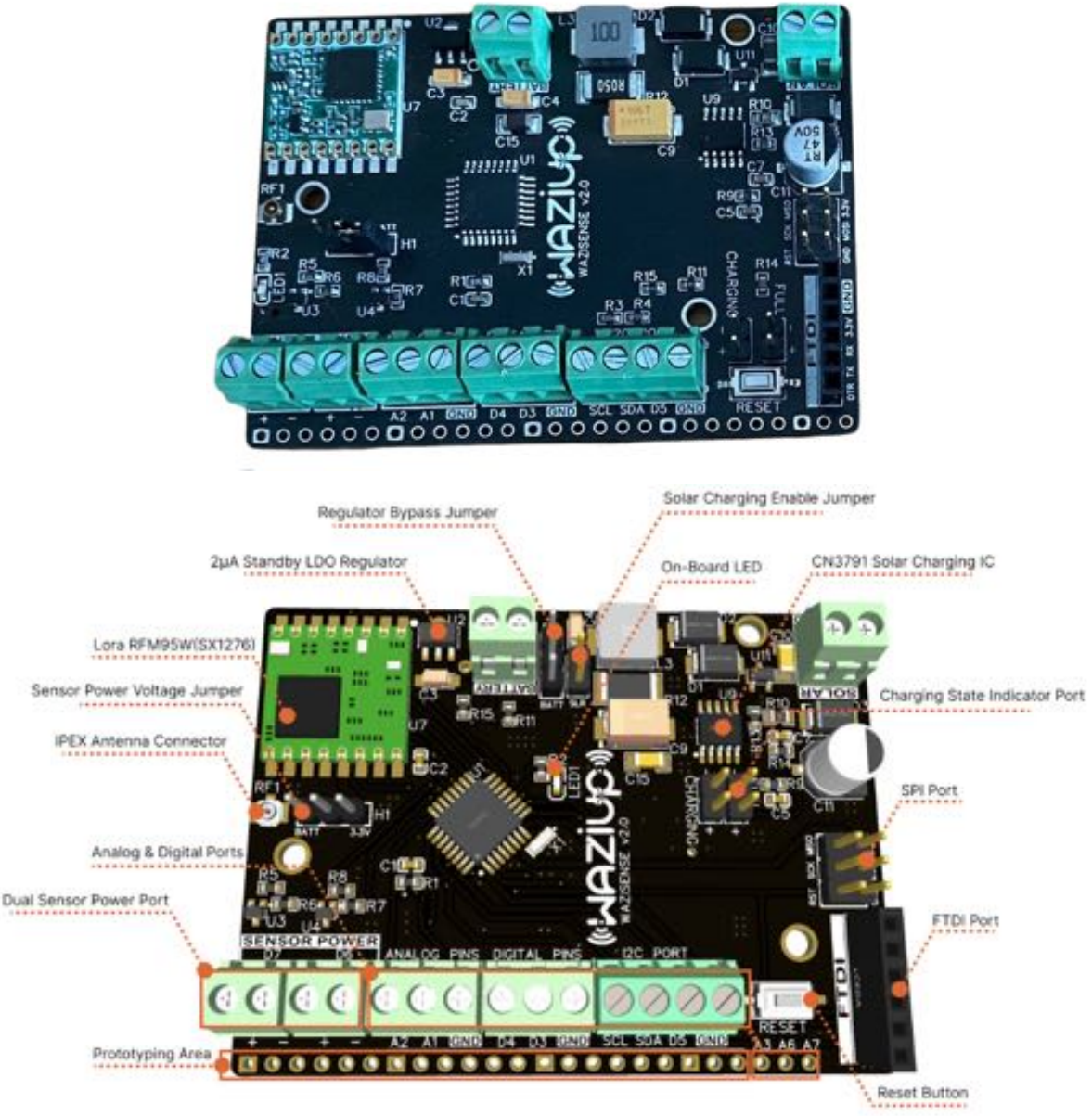
On January 18th (Paris, right photo) and 19th (IRD, Bondy, photos below), 2024, Jean-François Printanier from IRD organized technical assembling training sessions for the new PCBA to increase capacity-building of UORAN1 team for next deployments of the kits for the Smallholder Piloting Program.

2.2. WaziSense v2

We present here the last version of this PCB. Since it is the last deliverable on the hardware, we include here some parts that were presented in D1.2c (https://intel-irris.eu/wp-content/uploads/2023/07/D1.2c.pdf) and we add what has been changed for this last version.

The WaziSense v2 is a low-power development board specifically designed to address the unique challenges of agricultural and environmental monitoring applications in harsh outdoor deployment conditions.

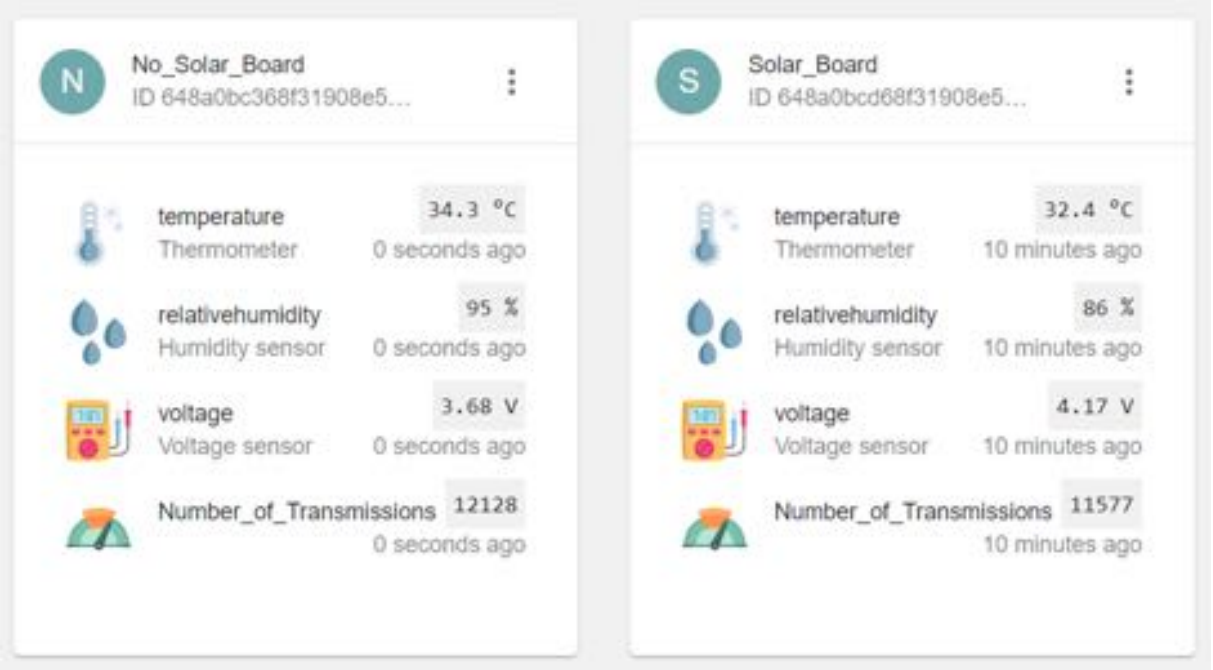
Equipped with solar battery charging capacity, low power long range communication and several ports for easy connection to a wide range of digital and analog sensors, the WaziSense v2 empowers farmers, researchers, agricultural experts and hobbyists with a versatile platform to monitor, control, and optimize their operations seamlessly.



2.2.1. Testing and deployment results

After designing and producing the first test batches of this board, there were various tests done by a number of people. These tests checked the power systems, microcontroller functionality, GPIO functionality, LoRa transmission and comprehensive power consumption tests. The WaziSense v2 passed all the tests and on 13th June 2023 an outdoor deployment was then done to test the board in a real-world environment. The deployment test has been described in D1.2c (https://intel-irris.eu/wp-content/uploads/2023/07/D1.2c.pdf).

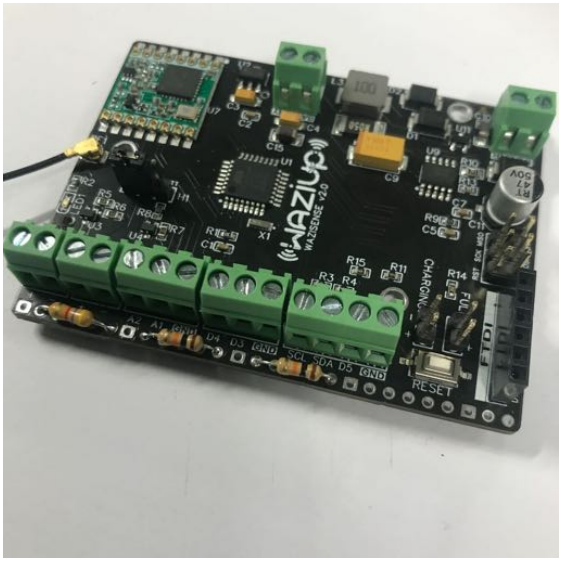
After approximately 5 days of deployment since 13th June 2023, the no solar board and no solar board had made 709 and 135 posts respectively to the WaziGate dashboard. Later, after more than 90 days since the deployment, the board with a solar panel had remained fully charged while the other board without a solar panel had approximately 57% battery power left. At this rate, if it took 90 days to consume 43% of the battery power, then it would take approximately 209 Days or 6.8 Months to consume 100% of the battery power.

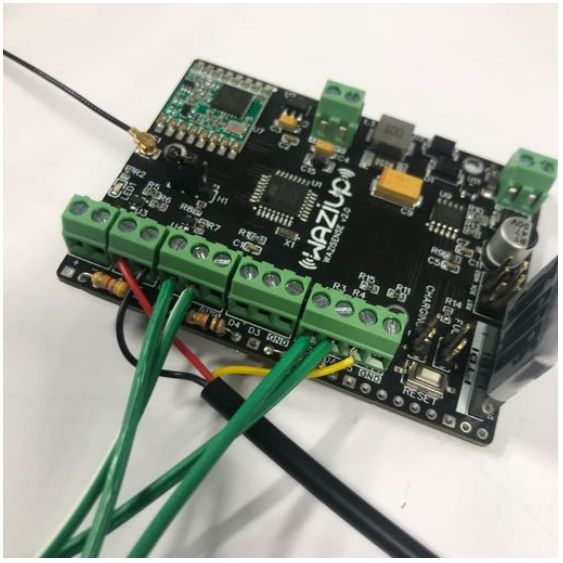


On 3rd November 2023, a larger batch of the WaziSense v2 was subsequently ordered from a PCB manufacturer once the test and deployment results were considered acceptable. INTEL-IRRIS will now be able to support numerous deployments with this production.

2.2.2. Using WaziSense v2 for INTEL-IRRIS device

UPPA tested and integrated the WaziSense v2 for the INTEL-IRRIS soil device. The software code has been updated to support the dedicated GPIO assignment for wiring the physical sensors. The INTEL-IRRIS tutorial in building the low-cost soil humidity sensor platform has been updated with assembly information for the WaziSense v2.



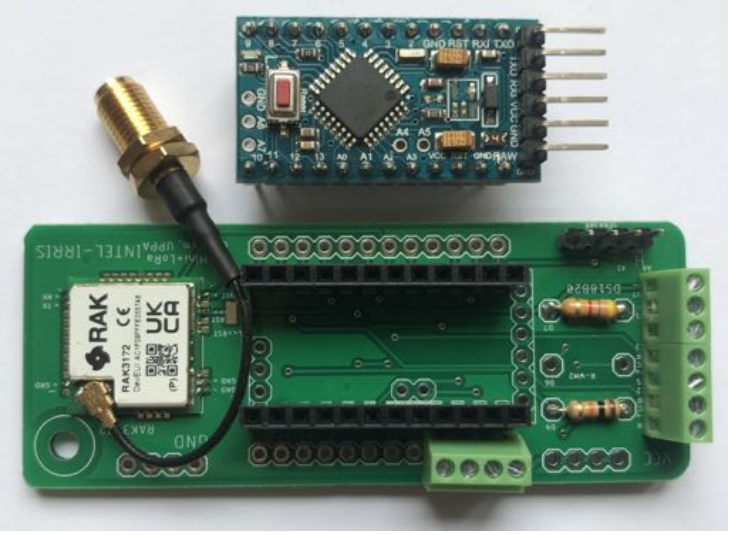


2.2.3. Launching larger production of WaziSense v2

On 3rd November 2023, a larger batch of the WaziSense v2 was subsequently ordered from a PCB manufacturer once the test and deployment results were considered acceptable. INTEL-IRRIS will now be able to support numerous deployments with this production.

2.3. RAK3172 LoRaWAN PCB

UPPA designed an improved PCB which integrates the LoRaWAN RAK3172 radio chip to provide full LoRaWAN connectivity including Over-The-Air-Activation to avoid static devices addresses to be configured manually as it is the case for the starter-kit. It also provides simpler wiring of sensors, similarly to the IRD's PCB. There is no solar circuit however, as the main objective is to support full LoRaWAN connectivity for large-scale and worldwide deployment scenarios.



The energy consumption in deep sleep mode is still below 5uA, allowing an autonomy of more than 2 years with 2 regular AA alkaline batteries.

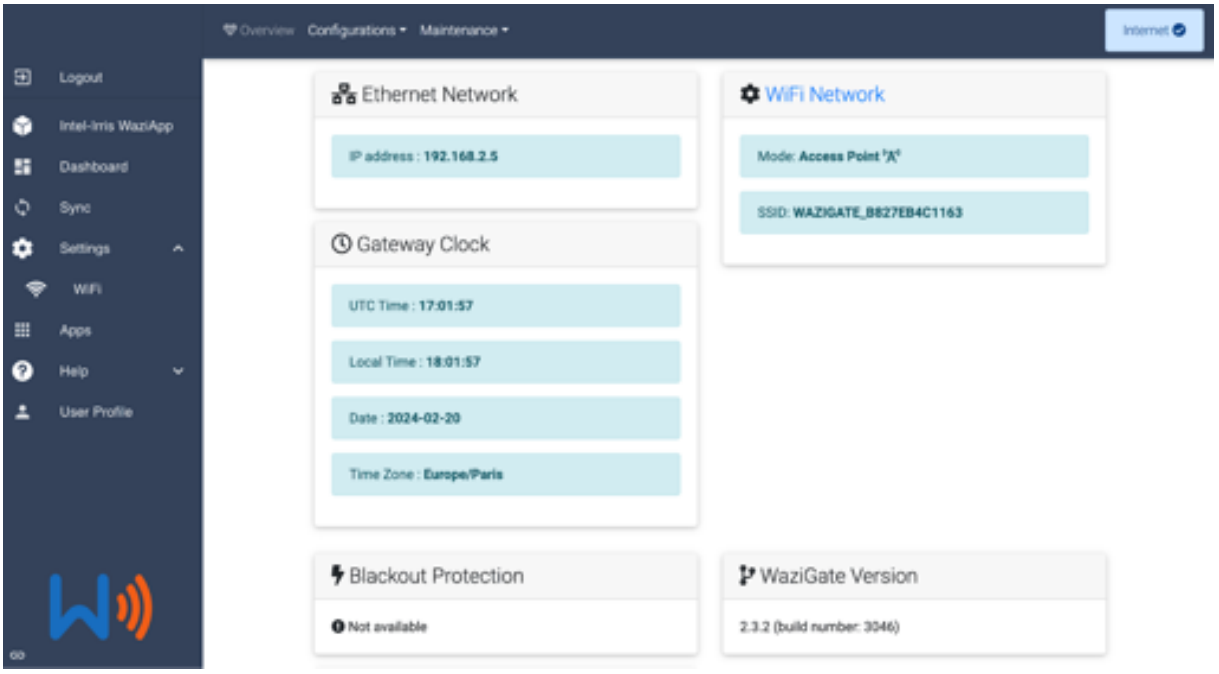
The Gerber files for this RAK-based PCB is available on INTEL-IRRIS's GitHub. The INTEL-IRRIS tutorial in building the low-cost soil humidity sensor platform has been updated with assembly information for the RAK-based PCBs.

3. GATEWAY PART

3.1. Software

3.1.1. Generic WaziGate framework

The INTEL-IRRIS gateway is based on the generic WaziGate framework (https://www.waziup.org/iot-edge-platform/#wazigate) available from https://github.com/Waziup/WaziGate. For the starter-kit v3, it is using WaziGate v2.3.2 build number 3046. WaziGate v2 has been improved for more stability and less I/O operation on the SD card. It has been extensively tested for INTEL-IRRIS and has been selected.



3.1.2. INTEL-IRRIS specific WaziGate distribution

On top of the generic WaziGate distribution, INTEL-IRRIS has developed specific software layers and modules to add all the INTEL-IRRIS functionalities. These addition are available on the INTEL-IRRIS GitHub (https://github.com/CongducPham/PRIMA-Intel-IrriS) and have been documented in the previous deliverables.

- D2.2a "Starter-kit for smart irrigation system – v1" https://intel-irris.eu/wp-content/uploads/2022/06/D2.2a.pdf
- D2.2b "Starter-kit for smart irrigation system – v2" https://intel-irris.eu/wp-content/uploads/2023/07/D2.2b.pdf

A summary of the main contributions of the INTEL-IRRIS WaziGate framework is below to provide simple deployment of the INTEL-IRRIS starter-kit:

- Definition of INTEL-IRRIS starter-kit sensor configuration
- Scripts to automatize the creation of sensor devices
- OLED screen for quick visualization of sensor data
- Simplifying WiFi connection to the WaziGate with a smartphone/tablet
- Real-Time Clock support
- Auto-configuration features
- Integration of Home Assistant
- Backup/Recovery procedures
- Advanced scripts for dataset support
- Embedded IIWA application dedicated to irrigation management

3.2. Hardware

3.2.1. New LoRa hat with on-board RTC

The WaziHat sits on top of a Raspberry Pi to provide radio communication capability with sensor nodes using LoRa rado technologies. For the Raspberry Pi boards before the Raspberry Pi 5, there is no onboard Real Time Clock (RTC) that can enable the Raspberry Pi to keep track of the current time, especially when there is no internet connectivity or after a restart. This knowledge of the current time is important since sensor values are saved with a timestamp of when they were received by a WaziGate. To address this issue, the new WaziHat has an onboard Real Time Clock that is powered by a single rechargeable coin cell battery. Even when a WaziGate is powered off, the RTC will always be keeping track of time and the Raspberry Pi can get the current time from it.

Other specifications of the new WaziHat are:

- LoRa support
- Connector for an OLED screen
- Connector for a CPU fan
- Multifunction buttons
- Indicator LEDs
- External antenna connector for LoRa

- Extended header pins to make the Raspberry Pi General Purpose Input Output (GPIO) pins available to a user

On September 13, 2023, the first made batch of this board was received. Testing was then conducted to determine the performance of the power system, multifunction buttons, LEDs, Real Time Clock, OLED, LoRa, and whether it would fit within the custom WaziGate casing also designed by Waziup e.V.

3.2.2. New WaziGate casing

Custom cases are being designed for the WaziGate to meet various requirements such as accommodating various Raspberry Pi boards, fitting the WaziHat and adopting its components like the antenna slot, OLED, multifunctional buttons, exposing the Raspberry Pi I/O, among others. There are different deployments that the cases are designed to cover:

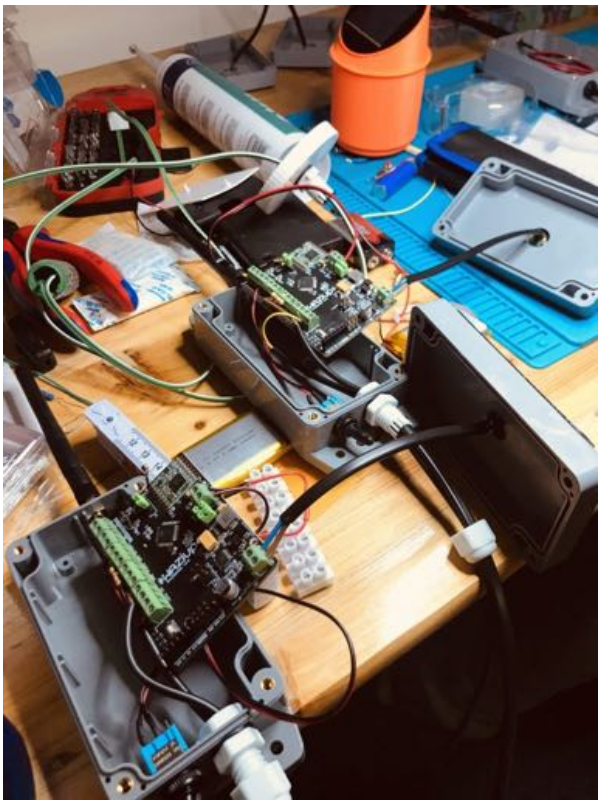
- Indoor: the WaziGate is mounted in a protected environment, such as a technical cabinet. The antenna needs to be mounted on the roof.
- Outdoor: the WaziGate is deployed outside, e.g. directly on a pole on the roof. The antennas can stay connected to the gateway. The outdoor gateway case should resist environmental factors, such as direct sunlight, dust and water, such as IP65 or more.

Currently, the indoor WaziGate case has been designed, tested and a number of 3D prints done as its specifications are being met. The first design for this case has been open-sourced and published on Thingiverse. The case can be produced by 3D printing the design files.

At the time of this writing, Raspberry Pi 5 has been released and this indoor case has been updated to also accommodate the new RPI5.

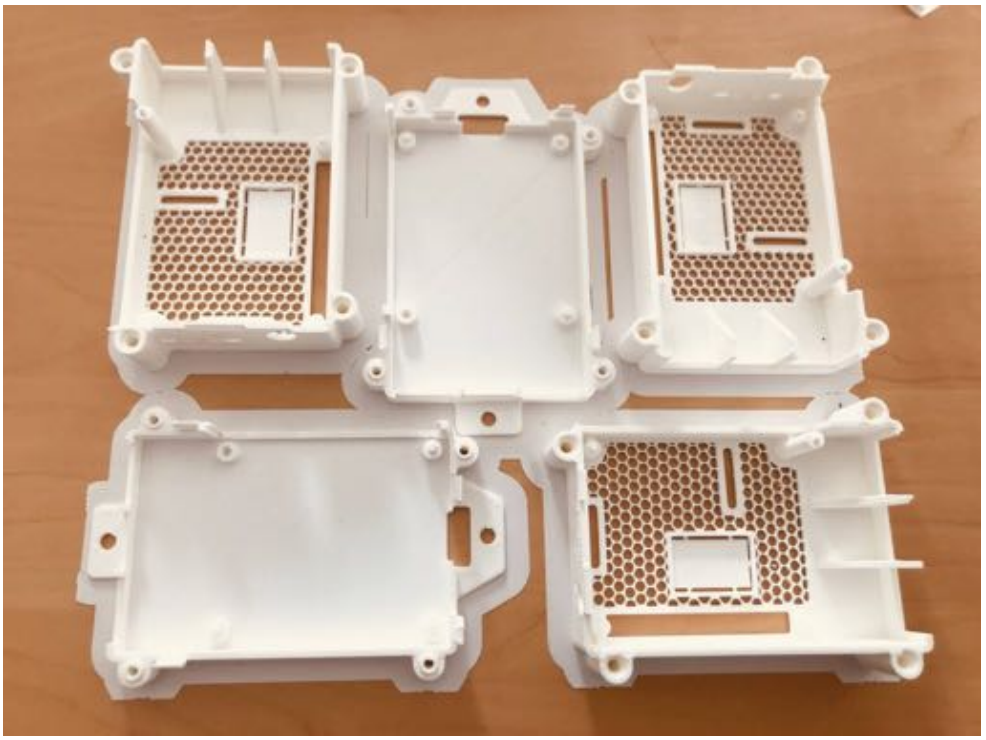
4. Putting it all together

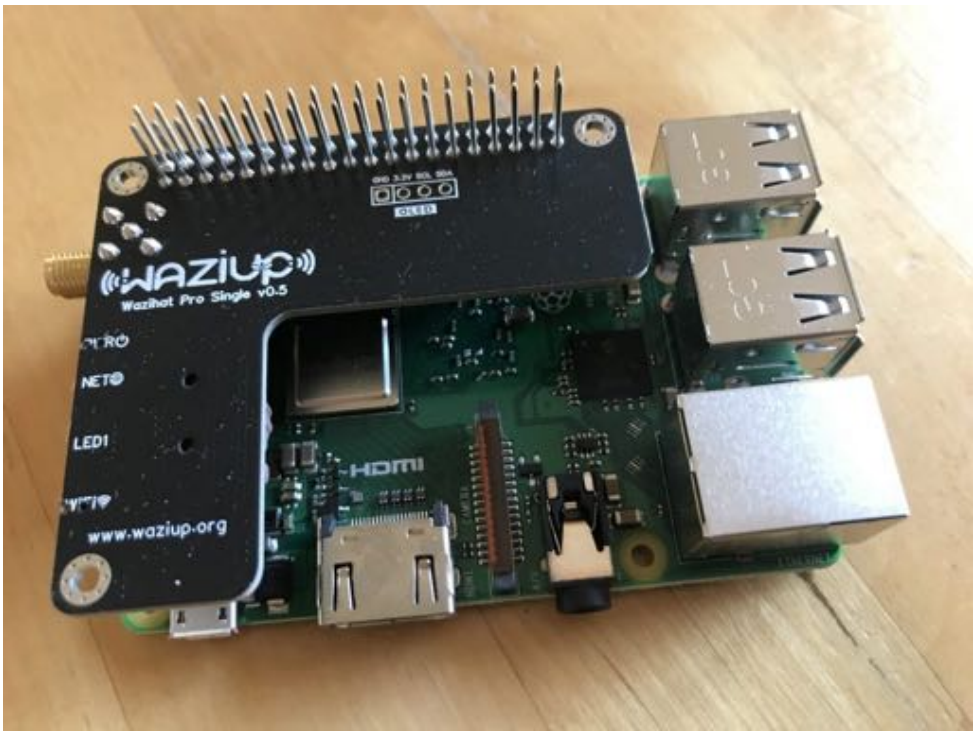
After the General Meeting of Dec. 12-13, 2024 at WAZIUP e.V. office, the whole WAZIUP e.V., UPPA and IRD team worked hard to make the INTEL-IRRIS starter-kit v3 ready for Algerian partner UMAB to take them back to Algeria!



Following the soil humidity device design proposed by UPPA, the starter-kit v3 includes the design based on the new WaziSense from WAZIUP e.V. and the design based on the dedicated PCBA v4.1 from IRD. Both have on-board solar panel charging capabilities, allowing almost unlimited power autonomy!

The starter-kit v3 also features the new gateway 3D-printed casing and the WaziHat radio hat where an OLED screen can be directly soldered.





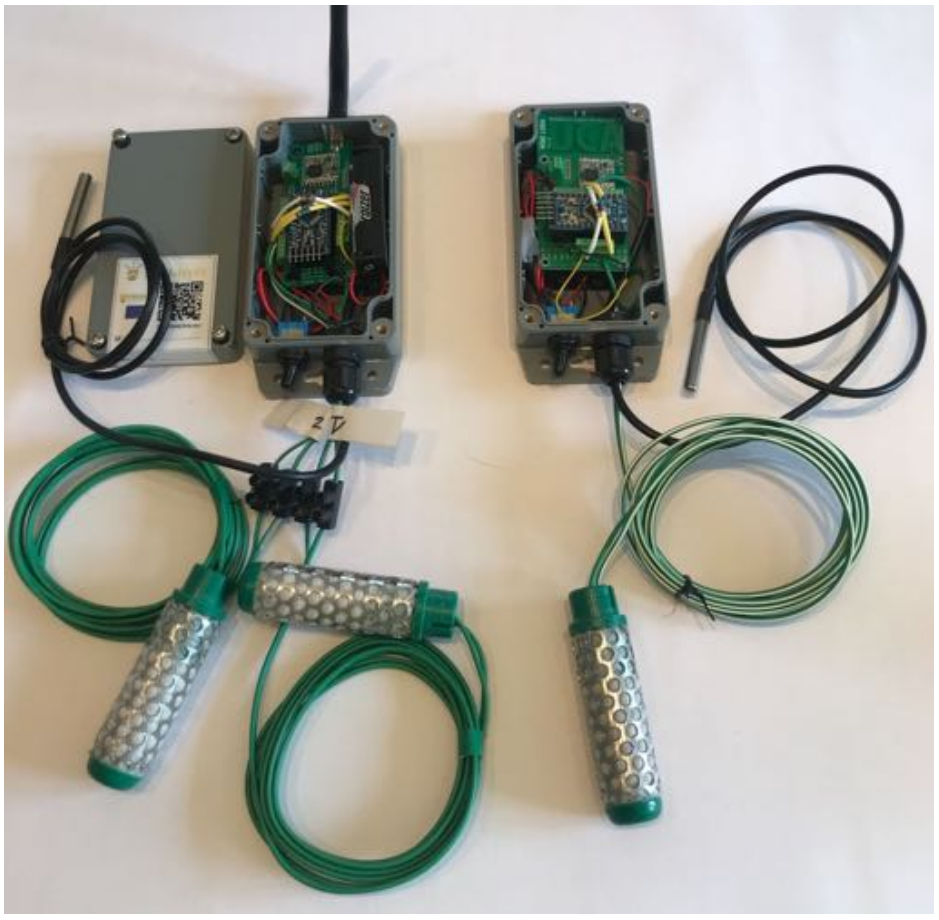
We were also lucky to receive all the ordered WaziHat from Chinese manufacturer one day before all partners had to travel back! The whole team was then able to assemble 16 INTEL-IRRIS gateways for the Smallholder Piloting Program in Algeria and Morocco!

5. CUSTOMIZATION EXAMPLES

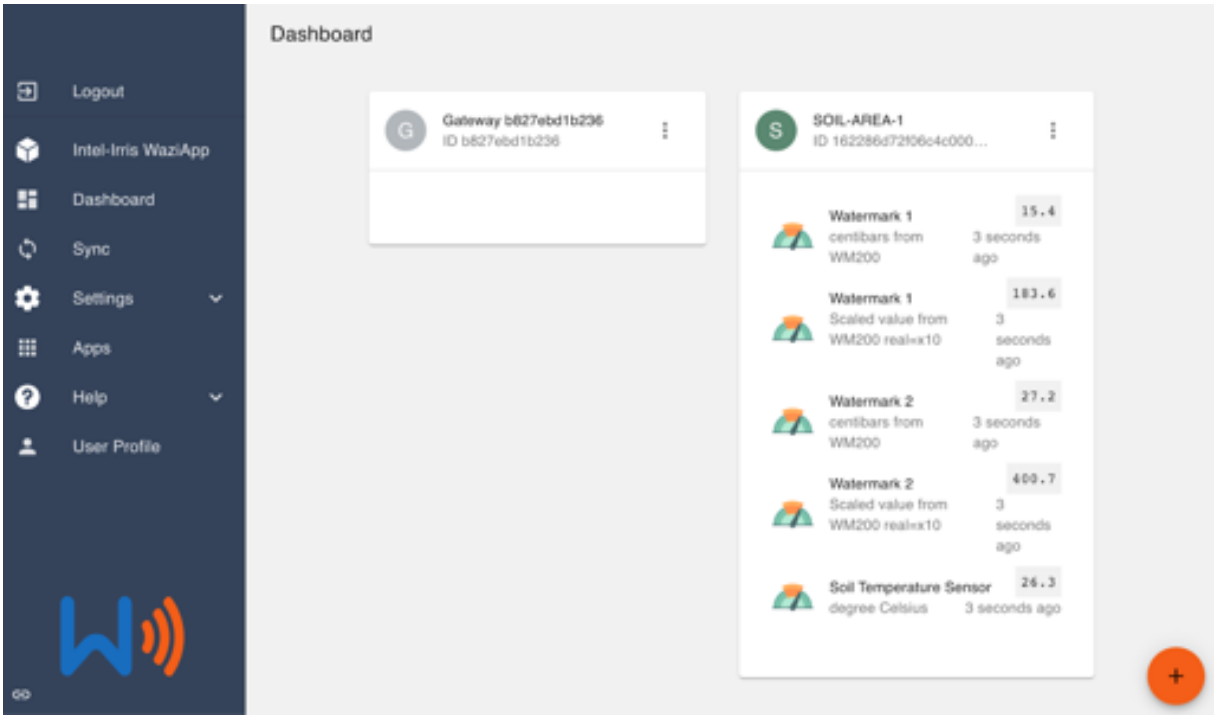
5.1. 2-watermark soil sensor

Discussions with our agriculture partners highlighted the benefit of a 2-Watermark device version that would enable accurate detection of water movement between the 2 soil humidity sensors that would be buried at different depths. The visit of a citrus farm in the Mostaganem area in March 2023 confirmed the need for such a version, despite the increased cost of the device which would be close to 90€. However, discussions with farmers showed that even a small number of these devices could advantageously replace the traditional “analog” vacuum-based water tension system, especially as the lifetime of the watermark sensors can span several years which is not the case for the vacuum-based water tension system.

Traditional water tension sensors at 2 depths (30cm & 60cm)



The 2-Watermark version (left) compared to the 1-Watermark version (right)

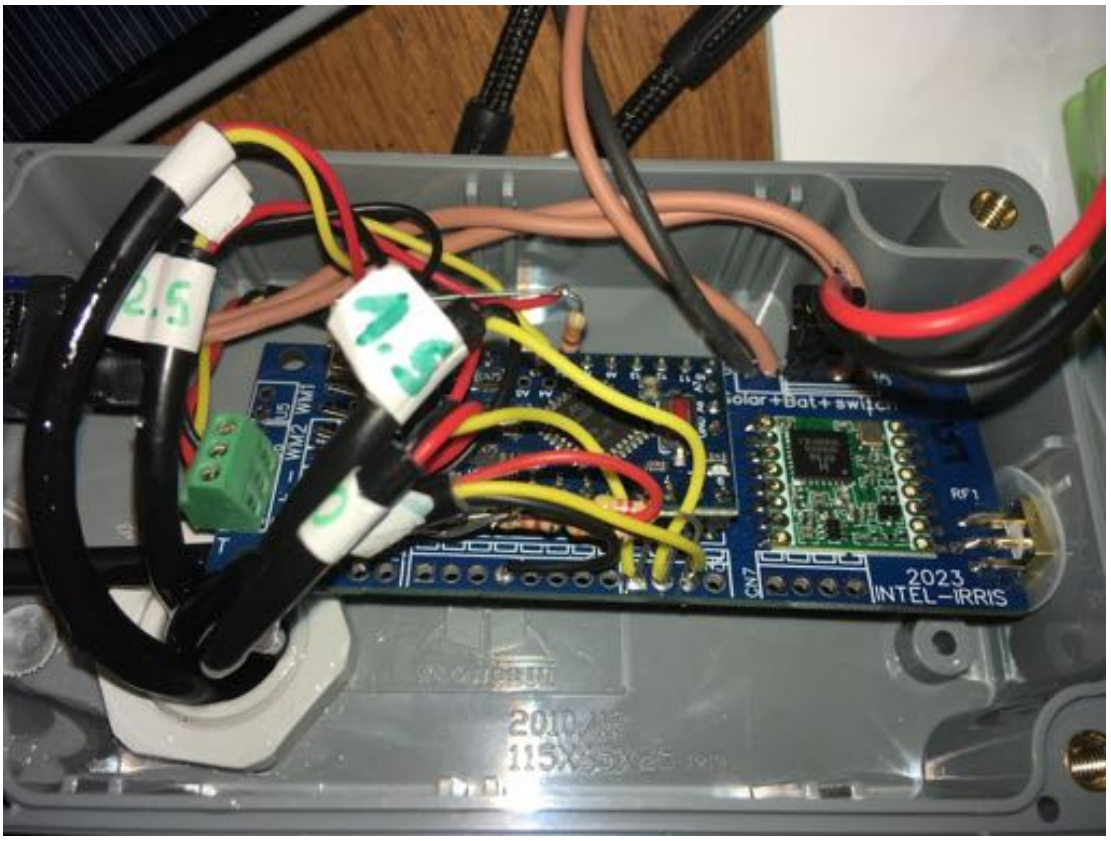


The 2-Watermark device in WaziGate dashboard

5.2. Depth temperatures soil sensor

To measure the temperature into the soil at different depths, IRD has developed a specific version of sol sensor with 6 temperature soil sensors.

Measured deep are 2.0 m, 1.5 m, 1.0, m, 0.5 m and 0.05 m near the surface. Air temperature can also be measured with the regular sensor. Cable length is 3 meter and 18B20 pull up resistor is decreased to 3.3 kOhm. For more than 5 meters this pull up resistor could be decreased to 1 kOhm. Silicone is added into the multiple hole cables for waterproofing.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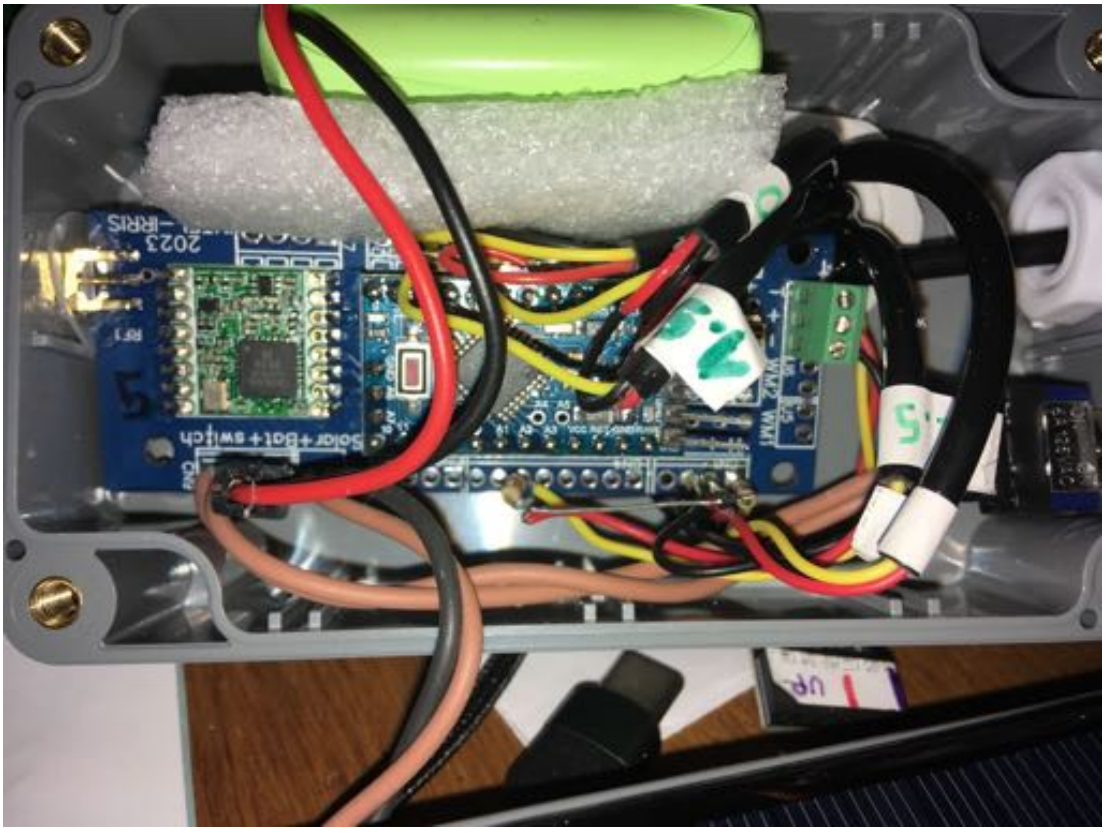
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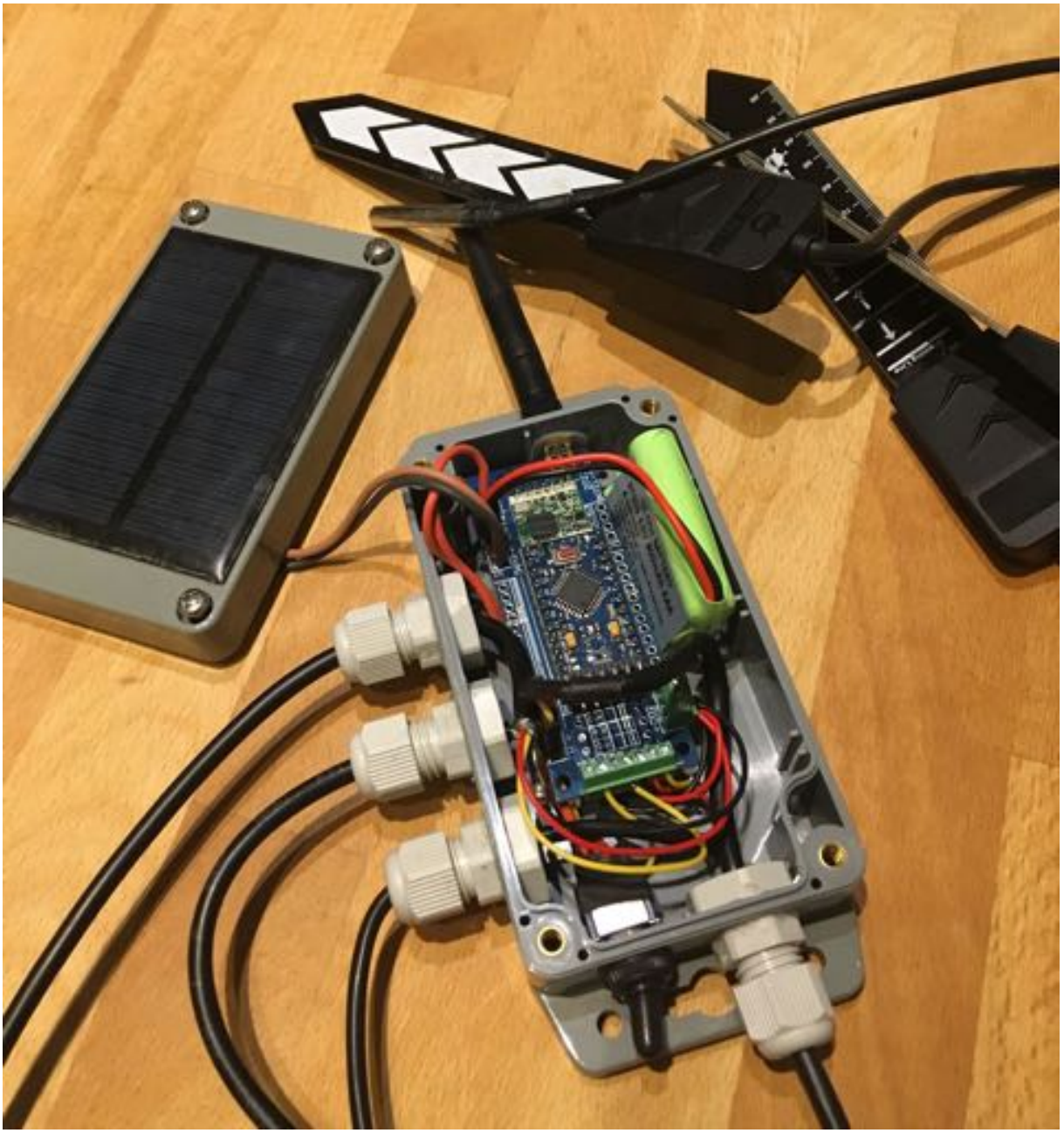
5.3. More humidity sensors for repeatability test

We need to have at least 3 identical sensors to validate scientific results. The 2 additional SEN0308 capacitive sensors are connected on the Watermark connector. Power lines are both connected to the CO2 connector.



6. Conclusions

D2.2c presented the INTEL-IRRIS starter-kit v3. The main new contributions consist in the PCBs and hardware platform for the soil sensor device and the IoT gateway. Customized devices have been designed for various tests and deployment with specific needs. These customized devices show the genericity of the proposed hardware and software framework.

REFERENCES

[1] D1.2a “Low-cost sensor generic platforms for connected irrigation system” http://intel-irris.eu/wp-content/uploads/2022/01/D1.2a.pdf

[2] D2.1a “First report on specifications & functionalities of the edge-enabled sensor-gateway framework for smart irrigation system” http://intel-irris.eu/wp-content/uploads/2022/03/D2.1a.pdf

[3] List of hardware parts. Technical Annex for D1.2a. https://github.com/CongducPham/PRIMA-Intel-IrriS/blob/main/Tutorials/Intel-IrriS-low-cost-sensor-hardware-parts.pdf

[4] WaziGate framework from WAZIUP https://www.waziup.io/documentation/wazigate/

[5] INTEL-IRRIS GitHub https://github.com/CongducPham/PRIMA-Intel-IrriS

[6] INTEL-IRRIS WaziGate SD card image on INTEL-IRRIS web site http://intel-irris.eu/results

Acronyms List

Acronym	Explanation
AI	Artificial Intelligence
API	Application Programing Interface
CSV	Comma-Separated Values
FTP	File Transfer Protocol
GPIO	General Purpose Input Output
HA	Home Assistant
IIWA	INTEL-IRRIS Irrigation WaziApp
JSON	JavaScript Object Notation
PCB	Printed Circuit Board
REST API	REpresentational State Transfer API
RTC	Real Time Clock
SCP	Secure Copy
SFTP	Secure FTP
SSH	Secure Shell
UI	User Interface
USB	Universal Serial Bus

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