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

Deliverable D2.2a

Starter-kit for smart irrigation system – v1

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Document revision history

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V1.1	May 31st, 2022	Public release
V1.0	May 30th, 2022	First draft version for internal approval
V0.1	May 23rd, 2022	First release for review

EXECUTIVE SUMMARY

Deliverable D2.2a describes the INTEL-IRRIS starter-kit for smart irrigation systems – v1. 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.

The first official demo of the starter kit will be scheduled for the INTEL-IRRIS General Meeting, June 7-10, 2022 in Rabat, Morocco.

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1. Introduction

1.1. Context

The usage of smart technologies and especially sensor systems is not new in agriculture and so-called Smart Farming Technologies (SFT) cover a wide range of data-oriented technologies targeting optimization of agricultural processes, including the optimization of irrigation. Regardless of the irrigation technique, monitoring of environmental characteristics – for instance soil water content or matric potential sensors – are promising in providing data that can be used to limit and optimise the usage of water ("more crop per drop"). In addition to field monitoring, it is also possible to take into account a larger variety of parameters (soil texture, crop type, salinity of the irrigation water, satellite data, weather forecast, etc.) and include agricultural models/knowledge with corrective & predictive analytic. And finally, with disruptive AI techniques integrating all these information, it will be possible to provide better decision-making feedbacks.

Despite all these possibilities and promising results offered by SFT, the smallholder community usually still rely on traditional agricultural practices learned on the field mostly from indigenous knowledge and are reluctant to step into technology-based systems mainly because commercial solutions for smart farming easily cost several thousand euros, with most of these solutions relying on cloud servers and proprietary software platforms requiring SHFs to be bound to the infrastructure provider.

It is in that context that the PRIMA INTEL-IRRIS project (http://intel-irris.eu/) has the ambition to make digital and smart farming technologies attractive & more accessible to Smallholder Farmers (SHF). To address the needs of this community, the proposed solutions must be affordable, simple to use in the field and, most importantly, must be able to be integrated into existing farming practices. Therefore, by developing a low-cost, autonomous and smart irrigation control system INTEL-IRRIS seeks to change the perception SHFs usually have for what was until recently very high cost technologies. By implementing the **"intelligent irrigation in-the-box"** concept, INTEL-IRRIS wants to make smart irrigation systems as simple to install and use as a household appliance with very limited investment compared to their income. In addition, through a participatory piloting approach, INTEL-IRRIS will strongly involve SHFs into the innovation process itself to reach larger dissemination of this technology with a network of farmers able to support each other.

The "intelligent irrigation in-the-box" concept will be demonstrated by a starter-kit distributed to selected SHFs. The starter-kit will be ready to be deployed and consists of 1 **soil moisture sensor device** developed by UPPA (the low-cost sensor generic platform, initially presented in D1.2a on "Low-cost sensor generic platforms for connected irrigation system – v1" [1]) and **1 versatile IoT gateway** developed by WAZIUP (the edge-enabled gateway initially presented in D2.1a on "First report on specifications & functionalities of the edge-enabled sensor-gateway framework for smart irrigation system" [2]). Core to this "intelligent irrigation in-the-box" concept is the fully edge-enabled IoT gateway that will receive, store, process and display sensor data in a user-friendly manner. Here, a "fully edge-enabled IoT gateway" means that, by default, the operating mode of the gateway is without Internet access: all processing and advanced features are embedded on various

containerized applications running on the gateway. Then, when targeting SHFs, the gateway should be able to display simple irrigation notifications on a small embedded OLED screen as well as on an intuitive embedded web dashboard interface with more functionalities, locally accessible through a smartphone or a tablet by connecting to the gateway's WiFi access point.

1.2. Contributions

As indicated previously, INTEL-IRRIS has the ambition to make digital and smart farming technologies attractive & more accessible to SHFs. Therefore, a trade-off will be made to meet the main objective which is to provide a low-cost irrigation system that can be deployed by SHFs in an out-of-the-box manner. While the soil moisture sensing part adopts a simple yet robust and efficient low-cost design largely inspired by many do-it-yourself initiatives and previous contributions. Unlike those low cost sensors that too often provide non-reliable data, INTEL-IRRIS will contribute in greatly improving the quality of the collected data with (i) advanced calibration of the different sensors and (ii) allowing more plant and soil parameters to be pre-configured into the control system. **Two versions of the starter-kit** will be provided, using different soil moisture sensors.

Version 1 will use a low-cost (less than 12 euro) capacitive soil moisture sensor (the waterproof Gravity SEN0308 from DFRobots) where the soil bulk density has to be known in order to provide the required level of accuracy. Calibration procedures on various soil types are currently developed in the laboratory by IRD.

Version 2 will use a medium-cost (less than 40 euro) Watermark soil moisture sensor which measures the electrical resistance inside of a granular matrix to determine soil water tension. For simplicity, we will use the term “tensiometer” for the Watermark. The tensiometer approach is to measure directly the force holding water in the soil (thus avoiding the need of measuring the soil bulk density). The Watermark is a widely used tensiometer due to its high efficiency vs cost ratio and numerous documentations and tutorials describing its installation can easily be found.

In addition to providing calibrated sensors at low cost, another major contribution of INTEL-IRRIS will be to provide the "out-of-the-box" feature, i.e. the control part making the irrigation recommendation is embedded in the IoT gateway which consequently does not require any internet connection. Here, with soil specialists and agriculture experts, the complex soil-water-plant-atmosphere interaction model will be integrated into the gateway itself to provide increased accuracy on recommended actions. T**he ultimate objective of INTEL-IRRIS is to include agricultural models/knowledge with corrective & predictive analytic** – from simple computer-based decision models to more advanced AI-based processing – to adapt the applied control to local conditions & practices (dry region, open field or greenhouse) and crop/plant varieties that usually have different water need profile at their various stage of development. To work towards this objective, INTEL-IRRIS is developing a versatile and full edge-IoT/AI system.

The "intelligent irrigation in-the-box" concept and the developed starter-kit are illustrated below.

Figure 1 – Intelligent irrigation in the box concept

Figure 2 – Starter-kit with Version 1 of soil sensor device

In this deliverable D2.2a, we are presenting the work conducted on preparing the starter-kit by integrating the low-cost sensor generic platform and the edge-enabled gateway. **Version 1 with the capacitive sensor is the target solution for the first deployment phase of the starter-kit while version 2 with the tensiometer will be under test by INTEL-IRRIS partners.**

2. Preparation of the starter-kit for testing

2.1. List of hardware

A list of sensor hardware components [3] has been provided by UPPA with example links to suppliers. The document will be used by local partners in Algeria and Morocco to seek and investigate on how these hardware could be provided by local suppliers.

2.1.1. Soil device

The various components to build the low-cost soil sensor device of the starter-kit are illustrated below.

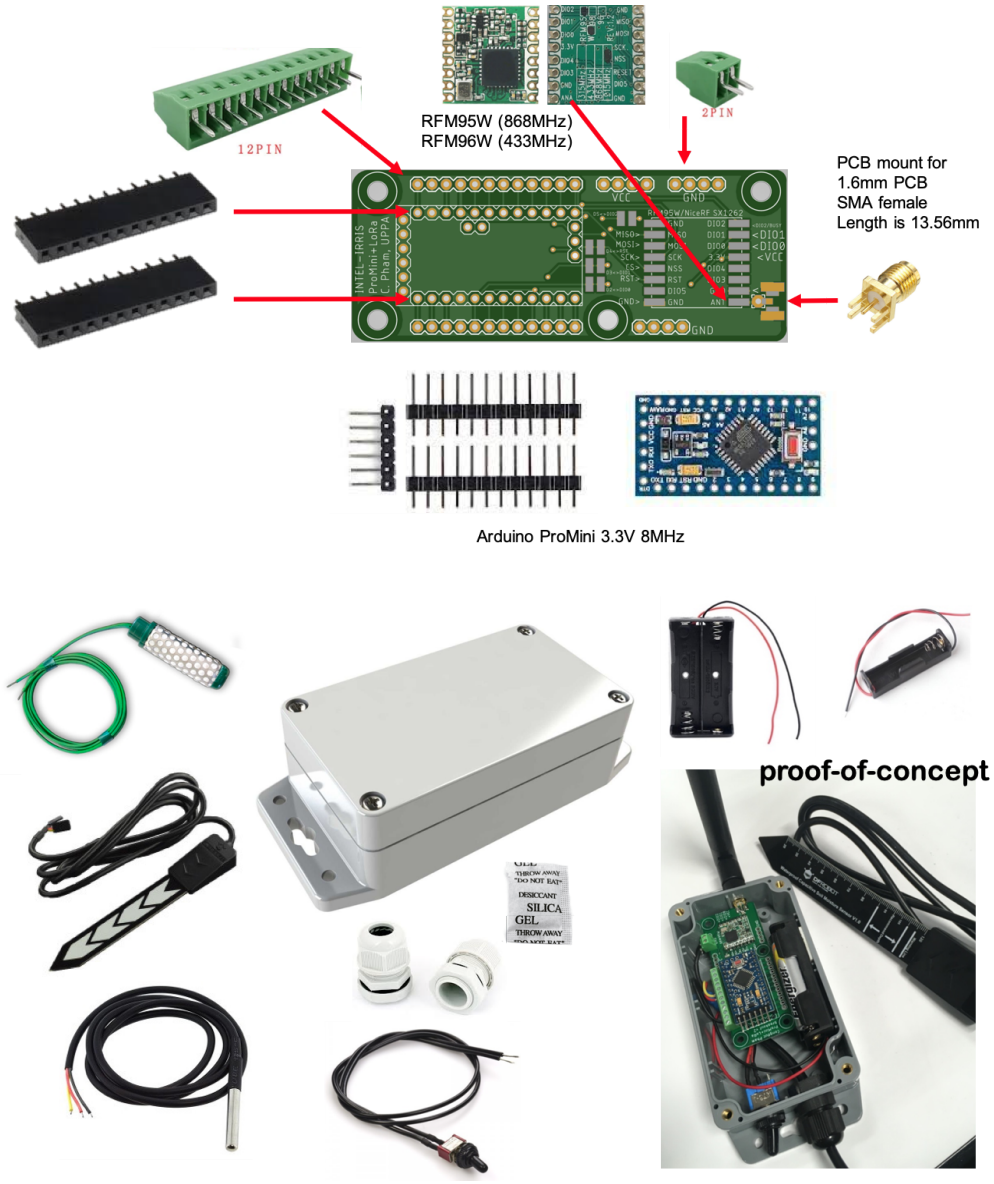


Figure 3 – All the parts of the soil sensor device

INTEL-IRRIS D1.2a on “Low-cost sensor generic platforms for connected irrigation system – v1” [1] and updated by D1.2b for “Low-cost sensor generic platforms for connected irrigation system – v2” presented the technological components of the low-cost soil sensor device in more detail.

2.1.2. IoT Gateway

Regarding the IoT gateway part, the main hardware component is the versatile single-board-computer Raspberry Pi. A LoRa radio module would be attached to the Raspberry to receive data from the soils sensor device as illustrated below. It is based on the WaziGate framework developed by WAZIUP [4]. The LoRa WaziHat is shown in Figure 4.

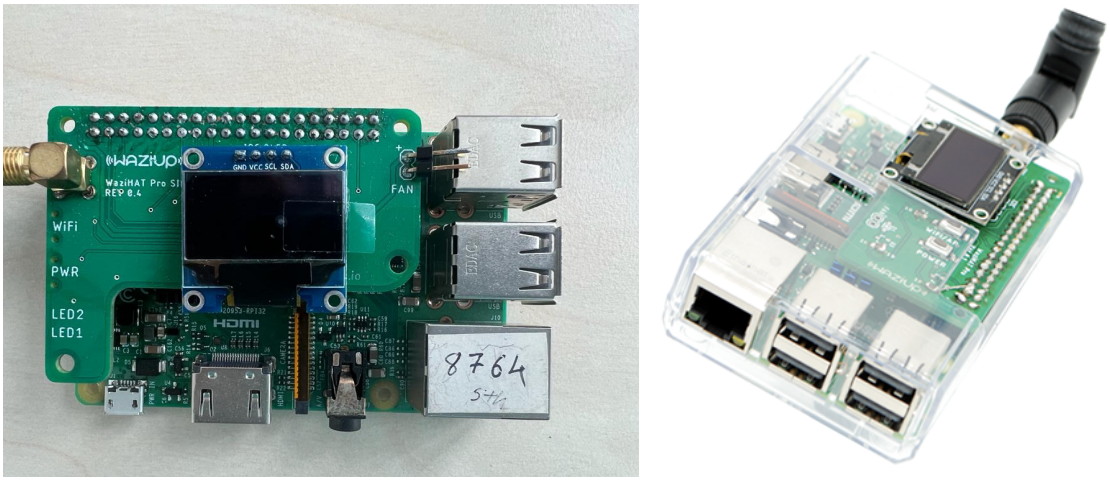


Figure 4 – The Raspberry Pi with the LoRa WaziHat

WAZIUP developed a number of embedded software to turn the Raspberry into a versatile edge-enabled IoT gateway to fit the INTEL-IRRIS’s objectives of simple deployment and usage by smallholders. The proposed user interface includes a small OLED screen and an embedded web-based dashboard that can be accessed through a smartphone as illustrated below.

Figure 5 – The OLED and web-based user interface of the WaziGate

2.2. Preparing starter-kit for test by local partners

Prior to large-scale distribution of the starter-kit, a small number of starter-kit will be distributed to technological Algerian (UORAN1) and Moroccan (ENSA Safi) partners as well as to French agriculture partner IRD. They will test a fully assembled kit and also assemble themselves a number of starter-kits. UPPA prepared the packages that have been shipped to local partners.

Figure 6 – Preparing the components of the starter-kit

A non-technical video has been produced to show the preparation of the starter-kit for technological partners. INTEL-IRRIS video showing production of the starter-kit

https://youtu.be/5nznRcloe40

The LoRa WaziHat are under manufacturing and could not be including in this first version of the starter-kit. A simpler LoRa module breakout is used instead and shown in Figure 7. When available, the WaziHat will provide easy access to user-defined functionalities through push buttons embedded on the WaziHat itself.

Figure 7 – Preparing components of the starter kit for shipping

2.3. Configuration of the starter kit

2.3.1. INTEL-IRRIS Soil sensor device

The code for the soil sensor device is developed by UPPA and is available on the INTEL-IRRIS GitHub [5] in the Arduino folder.

For version 1 of the starter-kit, the code is pre-configured for a capacitive sensor (SEN0308) with a pre-defined device id and encryption keys for LoRaWAN transmission to the IoT gateway.

2.3.2. INTEL-IRRIS WaziGate

The generic WaziGate framework [4] developed by WAZIUP has been further customized by UPPA for the INTEL-IRRIS starter-kit with the following additional features:

- an INTEL-IRRIS Soil device is defined and pre-configured as SOIL-AREA-1 device
- a Soil Humidity Sensor with "Raw value from SEN0408" label is defined on the dashboard for the SEN0308 capacitive sensor
- an OLED screen status manager will show visual soil status information for the end-user

A ready-to-use SD card image has been created from the INTEL-IRRIS WaziGate specific configuration and is available on the INTEL-IRRIS project web site for download [6].

The WaziGate dashboard, which can be accessed from a smartphone connected to the WaziGate's WiFi network, showing the device and the configured sensor is illustrated below.

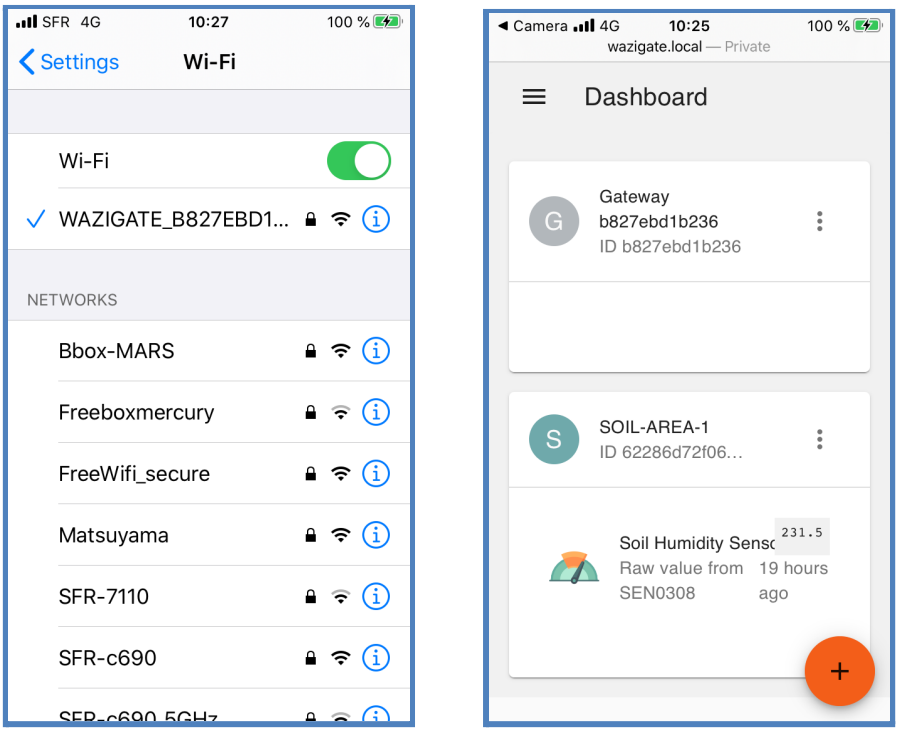


Figure 8 – The INTEL-IRRIS WaziGate dashboard

The INTEL-IRRIS WaziGate distribution provides a specific OLED display when a small OLED screen is attached to the gateway.

With a small .96" OLED screen, information summary can be easily displayed for the end-user: the sensor type, the sensor raw value, the time of last received data and the soil condition, both with graphic bars and with a soil condition text: 5 bars: very wet, 4 bars: wet, 3 bars: wet-dry, 2 bars: dry-wet, 1 bar: dry, 0 bar: very dry.

With only 1 device, a main screen is displayed for 6s every 30s where a screen saver display will show a shorter version of those information. If there are several devices (here SOIL-AREA-1 and SOIL-AREA-2), then the main screen will be displayed for 5s and the screen saver display with shorter information for each device will be displayed for 12s. All devices will be displayed this way in a cyclic manner.

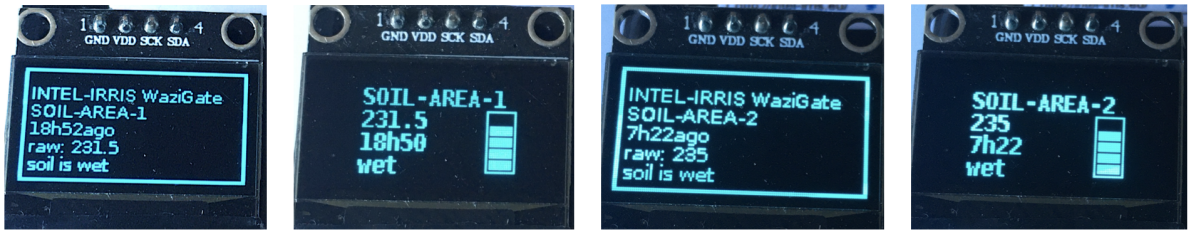


Figure 9 – The OLED interface of the INTEL-IRRIS WaziGate

2.3.3. Frequency version

The starter kit is available in 2 frequency band versions:

- EU868 for 863-870 MHz frequency band: France & EU, Morocco
- EU433 for 433.05-434.79 MHz frequency band: France & EU, Algeria and Morocco

We decided to use EU433 for both Algeria and Morocco.

2.3.4. Default configuration

The default configuration for the starter kit is shown below.

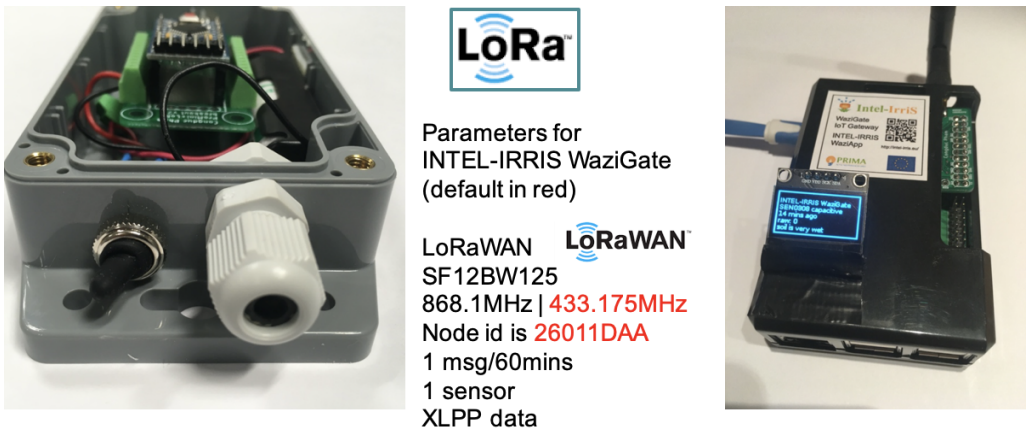


Figure 10 – Default configuration of the starter-kit

2.3.5. Simplifying connection to the WaziGate

In order to access the WaziGate dashboard, the user has to first connect to the WaziGate WiFi. The WiFi network starts with “WAZIGATE_” appended with a unique ID string which is different for each WaziGate. For instance, the following figure shows the WiFi network “WAZIGATE_B827EBD1B236” listed on a smartphone.

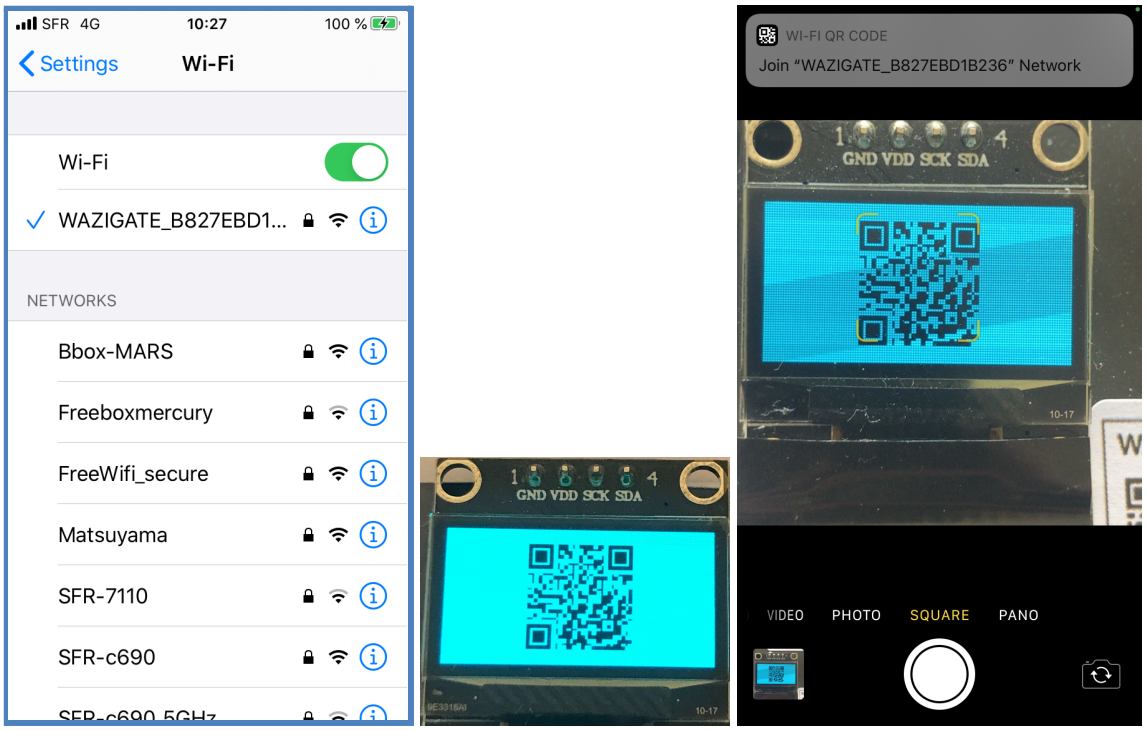


Figure 11 – Automatic joining of WiFi network with QR code

It is not difficult to select a WiFi network which starts with “WAZIGATE_” and enter the default WiFi password (“loragateway”). However, we also try to simplify this procedure for end-users, especially when targeting smallholders, and use QR code instead. As the WiFi network name changes from one WaziGate from another, it is not possible to print it on a tag. Therefore, the INTEL-IRRIS WaziGate has a software add-on that displays the WiFi connection QR code on the OLED screen that can then be scanned from a smartphone for the connection process.

Then, once connected to the WaziGate’s WiFi, the manual procedure would be to open a web browser and connect a static URL which is either http://wazigate.local or http://10.42.0.1. Therefore, automatization of the connection procedure to the dashboard can be realized with a sticker QR code placed on each WaziGate of the starter kit.

http://10.42.0.1

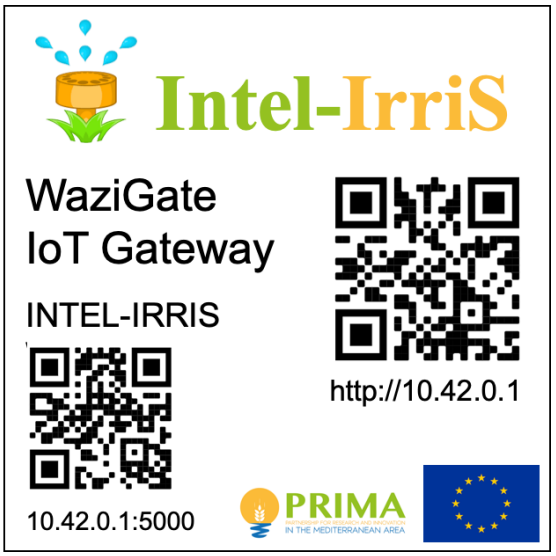


Figure 12 – QR code for fast connection to the WaziGate's dashboard

With the dynamic QR code displayed on the OLED screen and the static QR code stick on the WaziGate, end-users can actually get access to the WaziGate's dashboard without typing anything.

3. PACKAGING OF THE STARTER-KIT FOR DISTRIBUTION

3.1. Stickers for visual identity

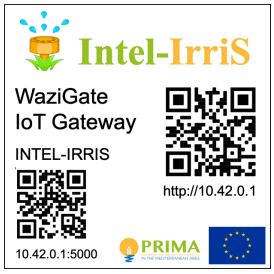
Waterproof stickers in various formats have been designed for visual identity of the starter-kit components. A QR code linking to the INTEL-IRRIS web site http://intel-irris.eu is included.

- 8cm x 3cm: for device

- 6cm x 4cm: for device

- 4.5cm x 6cm: for device, with identification tag

- 3.5 cm x 3.5 cm: for WaziGate



Here are some pictures in a deployment scenario.

Figure 13 – Devices with stickers

3.2. Packaging in a nice box

The whole starter-kit will be packaged in a nice box along with basic installation instructions. The booklet for those basic installation instructions is currently under design and development.

Figure 14 – The box for the starter-kit

Figure 15 – The content of the starter-kit

3.3. Starter-kit quickstart video

We produced a quickstart video for the starter-kit.

- **Video n°6. YouTube video showcasing the starter-kit for the Smallholder Piloting Program**: https://youtu.be/TBeyGvqpbxk

.

A shorter teaser video has also been “tweeted” on Twitter.

- **Video n°7. YouTube teaser video of the starter-kit for the Smallholder Piloting Program**: https://youtu.be/s3PvkzUOYZY

4. Development of the INTEL-IRRIS WaziApp

The INTEL-IRRIS Irrigation WaziApp (IIWA) is a dedicated embedded application running on the WaziGate IoT gateway that is developed by WAZIUP in collaboration with all other partners regarding specifications and desirable functionalities. It will allow much more parametrization features, as illustrated in the application's general architecture depicted below, to provide more accurate irrigation recommendations, going much further than the simple soil status indication from the OLED.

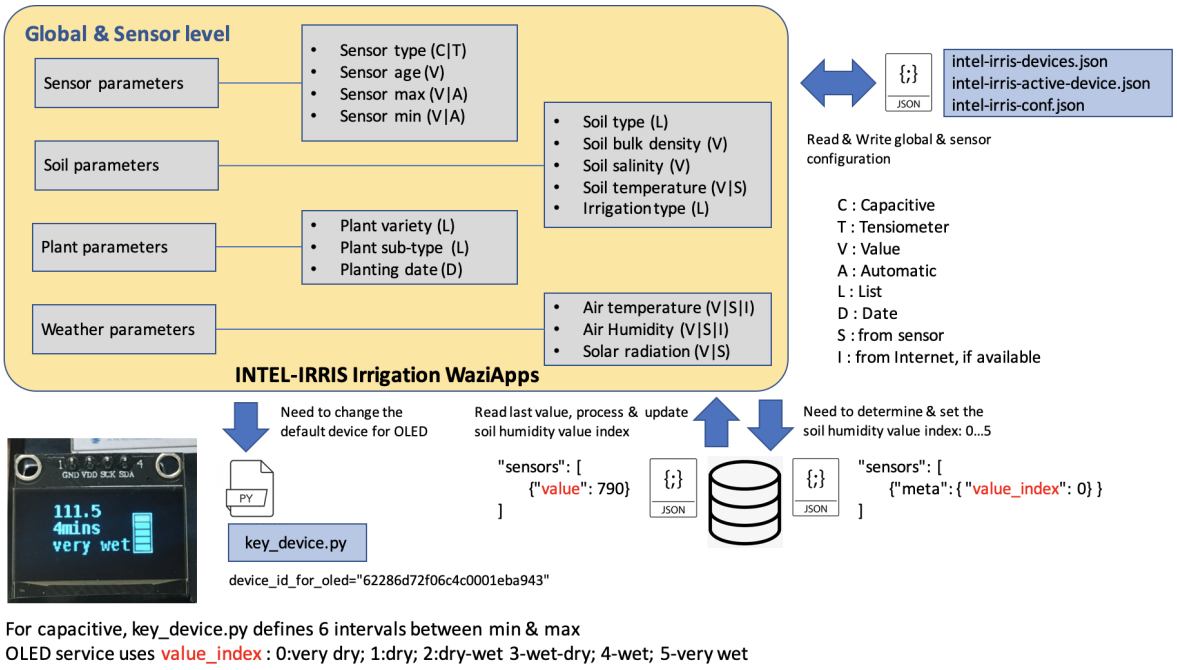


Figure 16 – INTEL-IRRIS Irrigation WaziApp architecture

A proof-of-concept of IIWA running on the WaziGate has been prototyped by WAZIUP and integrated into the WaziGate for validation of the approach.

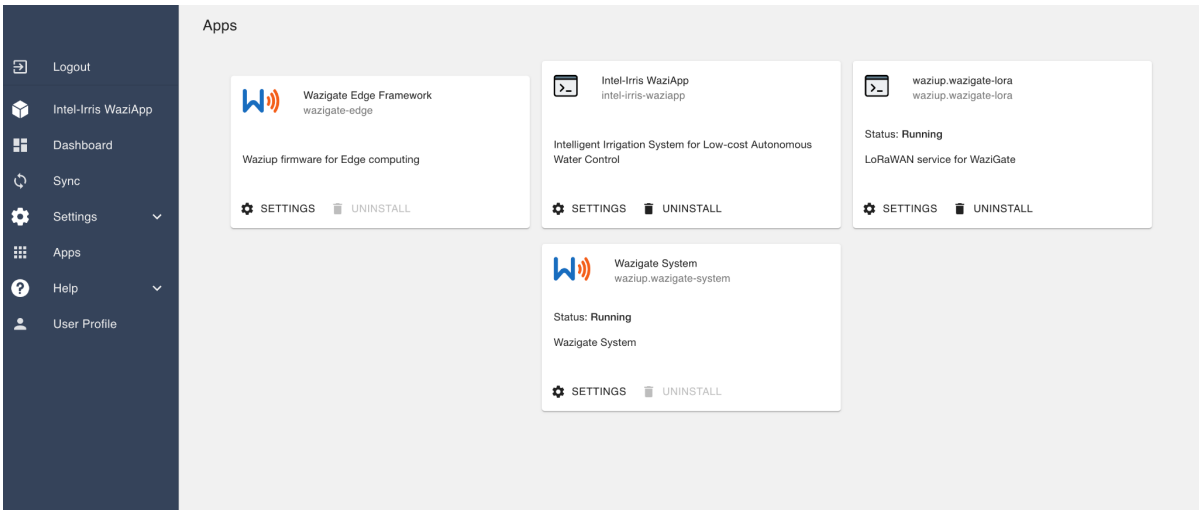


Figure 17 – Integration of embedded irrigation app into dashboard

The IIWA application is dedicated to be accessed from a smartphone through the WaziGate's embedded web interface as illustrated below.

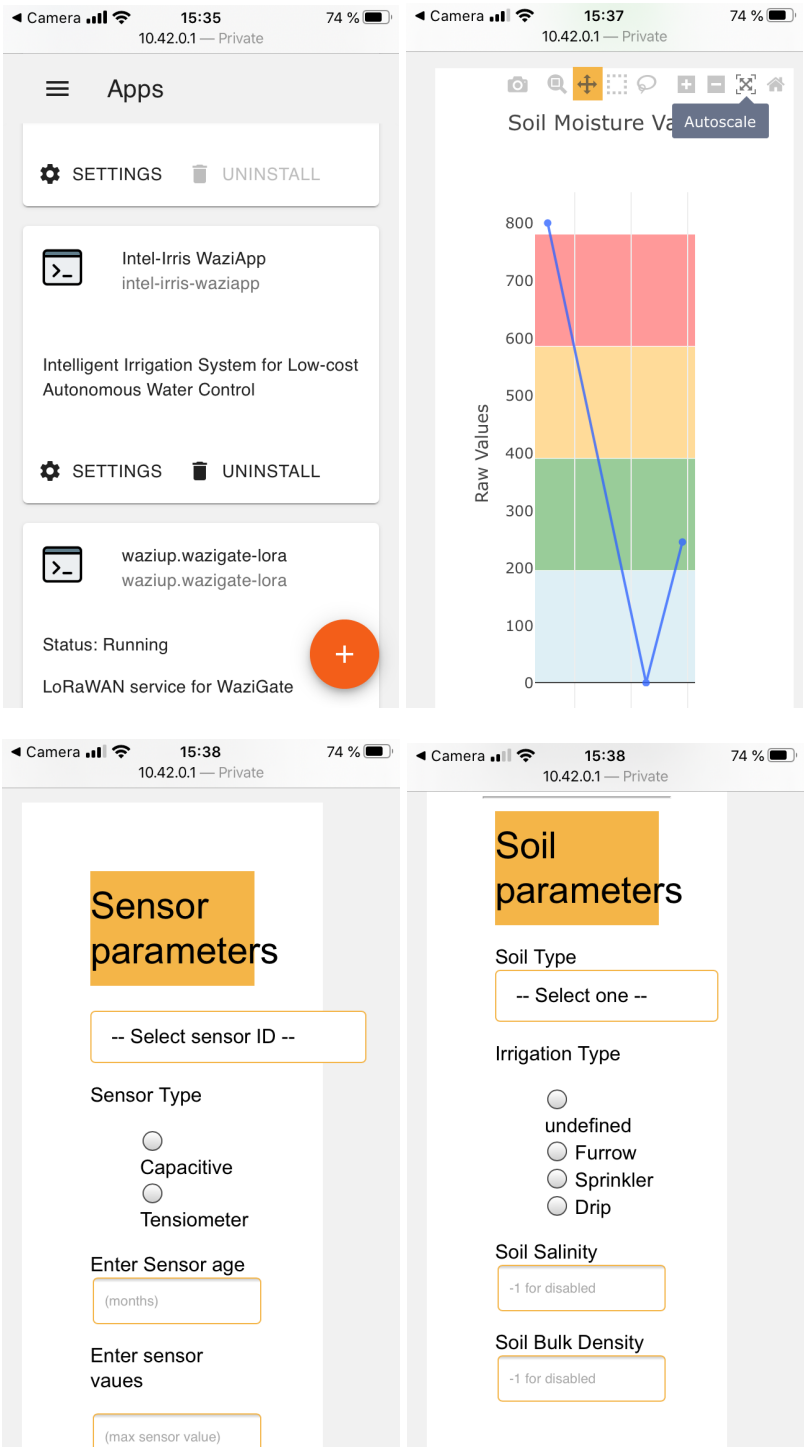


Figure 18 – INTEL-IRRIS Irrigation WaziApp user interface

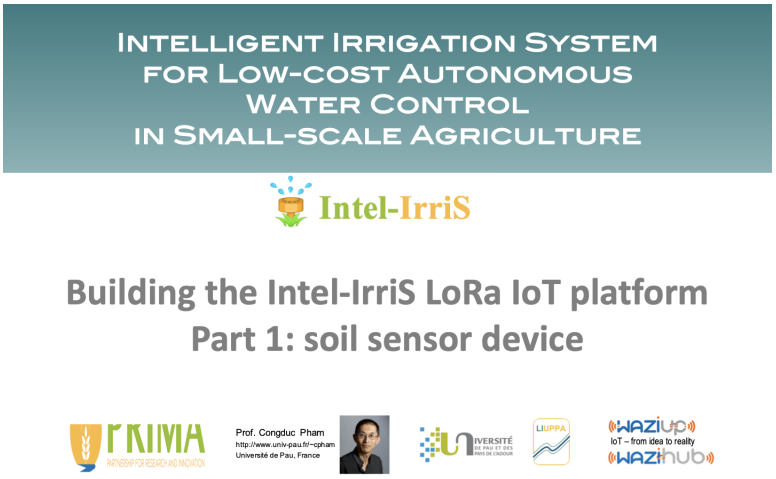
The development of IIWA is in its early stage and will continue, targeting inclusion into the INTEL-IRRIS starter-kit v2 for the Smallholder Piloting Program.

5. Documentation and tutorial materials

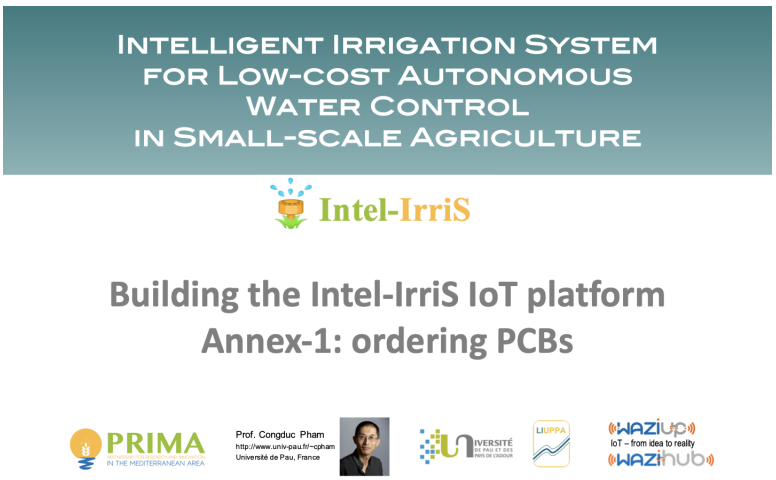
Several tutorial slides and tutorial videos have been produced to show in a didactic manner all the steps to assemble, program and deploy the various components of the starter-kit.

These tutorial materials are listed on the project web site, in the Document → Tutorials/Videos/Slides section. http://intel-irris.eu/tutorials-slides.

- **Tutorial slides on Building the INTEL-IRRIS LoRa IoT platform. Part 1: soil sensor device**. Related videos are Video n°1, Video n°2 and Video n°3. https://github.com/CongducPham/PRIMA-Intel-IrriS/blob/main/Tutorials/Intel-Irris-IOT-platform.pdf

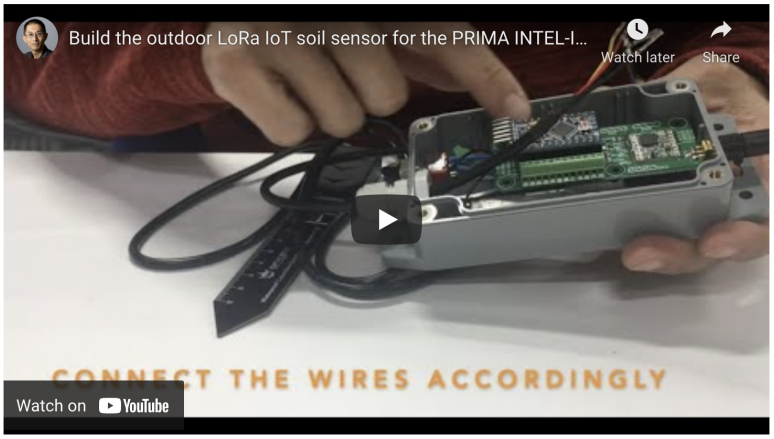


- **Tutorial slides on Building the INTEL-IRRIS LoRa IoT platform. Annex 1: ordering PCBs.** The tutorial shows how to order and get the INTEL-IRRIS PCBs to build the IoT microcontroller platform manufactured by PCB suppliers.. https://github.com/CongducPham/PRIMA-Intel-IrriS/blob/main/Tutorials/Intel-Irris-PCB.pdf



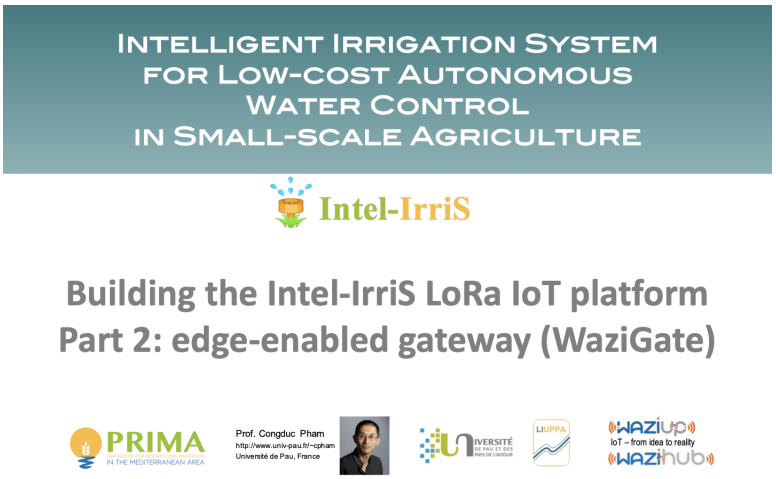
- **Video n°1. YouTube tutorial video showing how to build the IoT microcontroller platform for the LoRa IoT soil sensor device**. https://youtu.be/3jdQ0Uo0phQ

- **Video n°2. YouTube tutorial video showing how to build the outdoor LoRa IoT soil sensor device**. https://youtu.be/zcazzDbXvHk

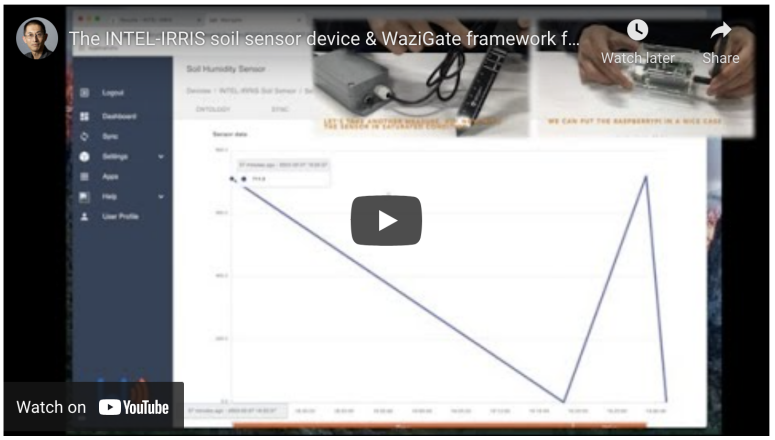


- **Video n°3. YouTube tutorial video showing how to wire the SEN0308 capacitive sensor and test LoRa data transmission on the Edge IoT gateway**. https://youtu.be/n0YGan7_vUc

- **Tutorial slides on Building the INTEL-IRRIS LoRa IoT platform. Part 2: the edge-enabled gateway (WaziGate)** which shows how to prepare the INTEL-IRRIS WaziGate IoT gateway. Related video is Video n°4. https://github.com/CongducPham/PRIMA-Intel-IrriS/blob/main/Tutorials/Intel-Irris-edge-gateway.pdf



- **Video n°4. YouTube tutorial video demonstrating the INTEL-IRRIS soil sensor device & WaziGate framework for intelligent irrigation in-the-box**. https://youtu.be/j-1Nk0tv0xM.



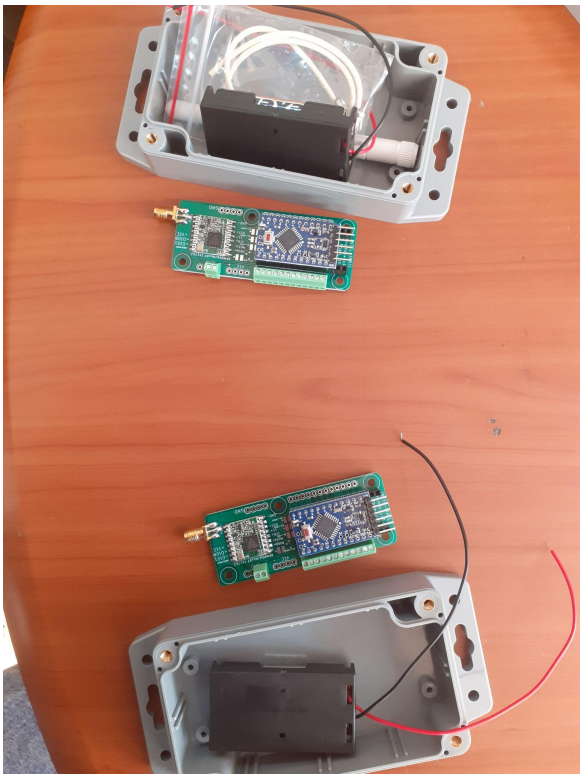
6. Assembling & test of starter-kit by partners

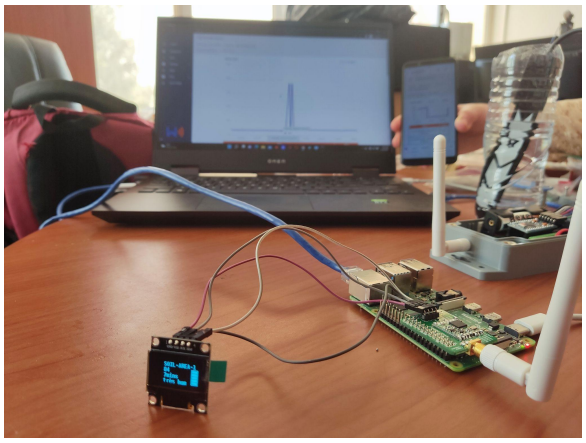
In March 2022, 5 starter-kit to be assembled have been sent to UORAN (Algeria). 4 starter-kit to be assembled have been provided to IRD (France) and 15 starter-kit to be assembled have been provided to ENSA (Morocco) during a technical meeting on soil sensor at IRD on March 28th, 2022. Assembly by partners will verify that all the above-mentioned tutorial resources can allow our technical partners to build and configure the starter kit.

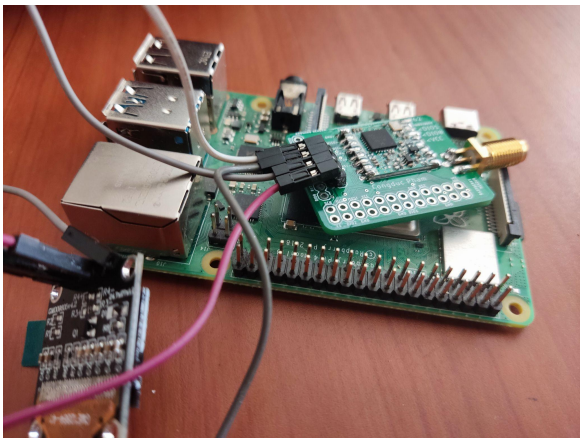
A dedicated tutorial slide on the assembly of the starter-kit is available.

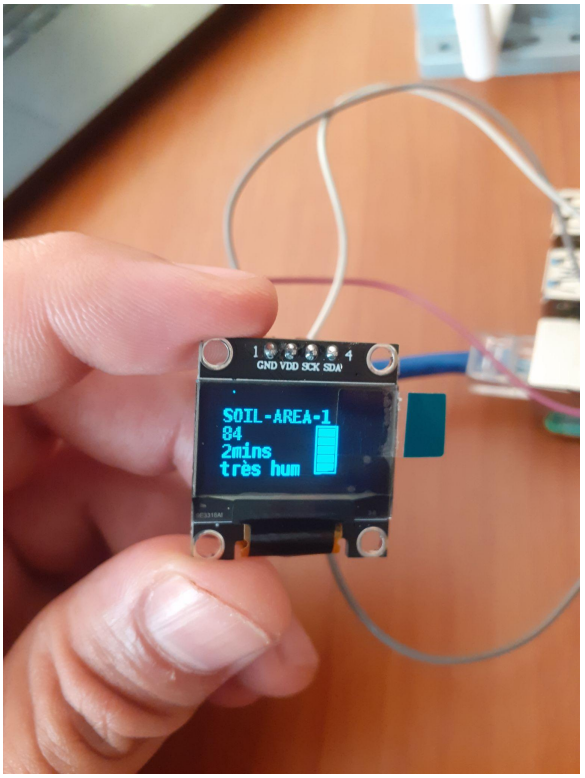
- **Tutorial slides on Building the INTEL-IRRIS LoRa IoT platform. Part 3: the INTEL-IRRIS starter-kit**. https://github.com/CongducPham/PRIMA-Intel-IrriS/blob/main/Tutorials/Intel-Irris-starter-kit.pdf

6.1. Assembly by UORAN1









Pr. Bouabdellah Kechar (UORAN1, Algeria) and Pr. Mohammed Benkhelifa (UMAB, Algeria) visited Pr. C. Pham (UPPA, France) in May 24-25, 2022, for a technical meeting on the Smallholder Piloting Program and, at this occasion, 10 additional starter-kit have been provided to UORAN1 for deployment in Algeria. In total, Algerian partners have been provided with 15 starter-kit.

6.2. Assembly by ENSA Safi

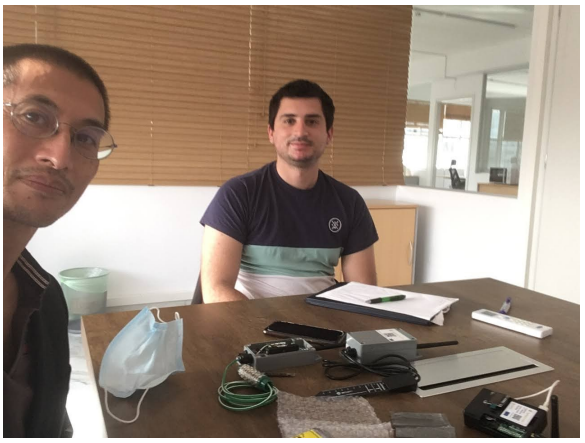
6.3. Assembly & test by IRD

After assembling the starter-kit, IRD also conducted early deployment tests of the starter-kit in various out-door conditions for the enclosure and resistance to sun/heat.

6.4. Test by AUA

A starter-kit has been provided to AUA during a technical meeting in AUA (April 5-6, 2022).



7. Conclusions

D2.2a presented the INTEL-IRRIS starter-kit that will be used for the first phase of deployment in the Smallholder Piloting Program. This version of the starter-kit will consist in the capacitive version 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.

The starter-kit has been extensively tested by INTEL-IRRIS partners to ensure that all desirable features are in place.

The first official demo of the starter kit will be scheduled for the INTEL-IRRIS General Meeting, June 7-10, 2022 in Rabat, Morocco.

REFERENCES

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Acronyms List

Acronym	Explanation
SFT	Smart Farming Technologies
SHF	Smallholder Farmers
IIWA	INTEL-IRRIS Irrigation WaziApp

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