IOT-BASED PLATFORM WITH COST-EFFECTIVE GATEWAYS FOR OPTIMIZING IRRIGATION SCHEDULING

Manuel Mora González

Department of Software Development, Odin Solutions S.L, Calle Palma de Mallorca, 2 – 30009 Murcia (Spain). mmora@odins.es

Introduction

This document describes the IoT-data management platform developed for the PRECIMED project for optimized data driven fertilization and irrigation scheduling, by integrating the knowledge about fertilizers and irrigation water management with Information Communication Technologies (ICTs), a solution that is set in the frame of Precision Agriculture.

Precision Agriculture can be described as a way to "*apply the right treatment in the right place at the right time*" (Gebbers and Adamchuk, 2010).

Precise irrigation methods are being developed rapidly nowadays to respond to societal demands to save water while improving yields and crops quality. Irrigation strategies have been proven to successfully increase water use efficiency by reducing water use. But Precision Agriculture also includes the current trend of fertigation management, implying:

- precision crop irrigation and fertigation,
- use of crop-based information (crop indicators/descriptors),
- enhanced analysis, interpretation, and valorisation of the collected data,
- development of systems for growers' aid on efficient fertigation control.

Therefore, the aim of the PRECIMED platform has been to provide a solution for efficient and intelligent applications to aid not only irrigation but also fertigation control.

Fertigation and precision irrigation are technologically feasible using environmental sensors, probes, actuators, and decision support systems. Nowadays, there is a wide variety of possible solutions available on the market that range from the simplest ones based on hand sensing/actuation to the more complex using satellite multispectral imagery and A.I. In addition, the Internet of Things (IoT) is a highly promising family of technologies that offers many solutions towards the modernization of agriculture, allowing wireless and autonomous devices for monitoring and control without expensive routers or repeaters (gateways). Also, a new IoT paradigm called Cyber-Physical System (CPS), IoT gateways that enables the interaction of legacy sensors/actuators with crop facilities to perform precise data acquisition, and to enhanced remote actuations (i.e., over nutrition pumps, irrigation valves, greenhouse actuators, etc.).

This way, the PRECIMED platform has been developed based on open standards (i.e., FIWARE Community and the IETF IoT Consortium) to integrate Cyber-Physical Systems with their sensors and actuators deployed at the local crop premises, registering their information making it available for users via different Web services (Software as a Service, SaaS) and used by complex processes with Big Data technologies, predicting situations via mathematical and machine learning models, to improve decision support systems.

Development objectives

The main objectives of the development of the PRECIMED IoT platform can be summarized in the next ones:

- Use a layered architecture design to promote interoperability and scalability.
- Behave as a single management system with SaaS format, where users can have access to all their resources via Web in a unified system.
- Guarantee interoperability using open and standard interfaces (i.e., FIWARE and IETF).
- Be an open platform where users can register/unsubscribe devices, update their parameters, etc.
- Able to integrate other systems that may be already installed (i.e., using IoT agents).
- Be flexible and scalable to be able to deploy new modules and servers.
- Able to resolve the increase in the load of users or information by adequately sizing the hardware architecture.
- Offer maximum availability: maximize the availability of the systems (24/365) and offer an adequate policy for update procedures.
- Be able to be deployed in the cloud or "on-premise" in a simple way.
- Use wireless communications.
- Study, adapt, and implement lightweight communication protocols for constrained devices, taking advantage of Internet of Things and Services technologies.
- Improve water and nutrient use efficiency using intensive ICT solutions.
- Provide and register information at least about:
    - Current state of the deployed devices (i.e., battery, communication link, etc.).
    - Current state of irrigation/fertigation tasks (i.e., pending, completed, and stopped).
    - Water consumption.
    - Soil information (i.e., moisture, conductivity, and temperature).
    - Alerts.
    - Agronomic data of the crops and plots.
- Provide needed user control panels for map navigation, indicators, alarms, devices, etc.
- Provide an administrative tool for managing roles, users, and groups.
- Provide services to define alerts, rules, and programs for the irrigation management, also considering information from available weather stations.
- Develop a standards-based Decision Support System (DSS) for data-driven irrigation and fertilization management.
- Be able to integrate external services as external sources of information, like weather services, SCADA, GIS, etc.
- Facilitate the development and integration of predictive models, offered as external web services through REST API interfaces, giving them access to the data registered in the platform.

Architecture of the platform

The architecture of the platform is designed to cover the needs of a vertical solution for precise irrigation and fertigation management. It has a layered modular design, based on open and standard initiatives such as the one provided by the EU FIWARE Community, ranging from the deployment of sensors to the intelligent processing of data.

From the point of view of the hardware deployment that will manage the information, the platform comprises three main planes: the Crop Premises plane, the Edge Computing plane, and the Cloud plane. This layered structure view is shown in the next figure:

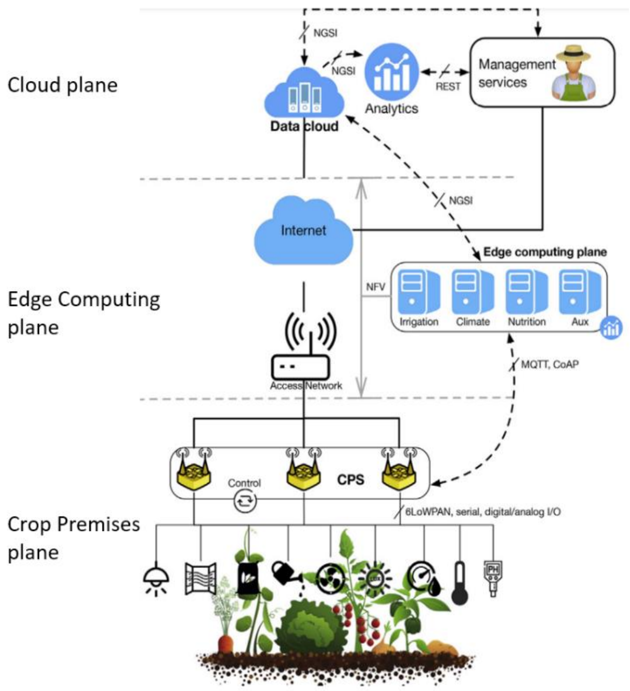

Figure 1 - Architecture layered view: Hardware deployment

The Crop Premises plane includes the sensors (e.g. soil moisture, temperature, CO2, conductivity, air pressure, counters, etc.) and actuators (e.g. pumps, valves, activation of devices for ventilation, etc.) needed for precision agriculture are deployed and connected with the cyber physical systems (CPS) nodes through wired and wireless communications channels using IoT lightweight protocols (e.g. NBIoT, LoRa, etc.) depending on the different scenarios. The CPS nodes can be interconnected with the Internet through an access network using also different technologies (e.g. wired links, microwave radio links, GPRS, etc.). Low level operations (atomic actions) that require minimum latency and high reliability in their communications can be executed in the CPS nodes (e.g. executing an irrigation planning, emergency reactive actions like closing a window due to climate conditions, etc.).

The Edge Computing plane includes a set of control modules virtualised to allow their instantiation at different levels in the network path. They orchestrate the CPS in the lower layer communicating with them using IoT lightweight communication protocols such as MQTT or CoAP.

Finally, the Cloud plane is where computer intensive tasks (cloud user services) like data analysis and smart management are undertaken. The elements deployed in this level have been also virtualized in high-end servers, working as the interface between users and the core platform, and storing (Context Broker) data and configuration parameters. Changes in those configuration parameters may trigger control actions that are managed by the lower edge subsystems.

Data acquisition

Let us focus now on how the information is introduced in the platform. From the point of view of data and services, the platform comprises three main layers: the Device & Data Acquisition layer, the Information Management layer, and the Service layer. This layered structure view is shown in the next figure:

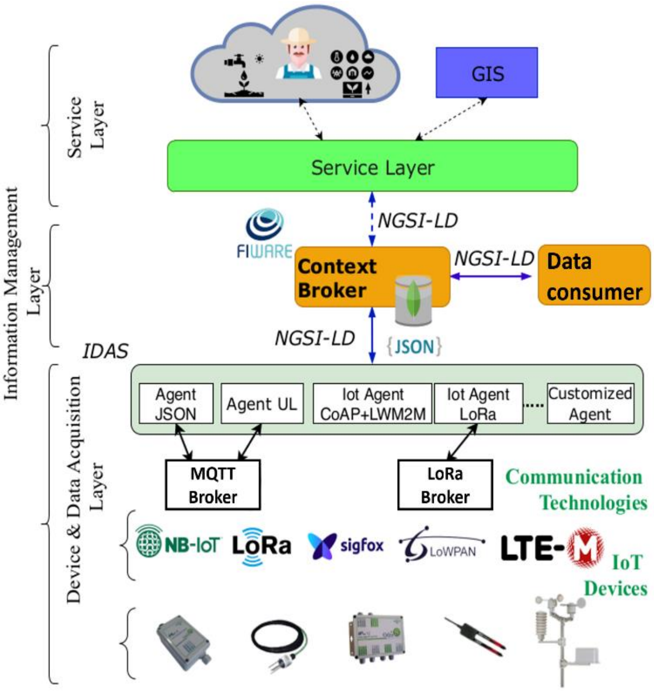

Figure 2 - Architecture layered view: Data & services

In the first layer (Device & Data Acquisition layer) we find the different sources of information that form the system, that include IoT devices (e.g. sensors, counters, actuators, IoT gateways), open data available on the Internet (e.g. weather services, etc.), and databases with any information of interest (e.g. Geographic Information System of Agricultural Parcels, satellite imagery, etc.).

Due to the restrictions imposed by the IoT devices (i.e., processing capacity, memory, power consumption, etc.) these constrained data sources use different communication technologies with lightweight protocols, instead of heavier ones used in the upper layers, and transmit their information to FIWARE IoT agents available in the special IoT Backend module of the platform.

This module acts as an intermediary with the upper layer (Information Management layer) by translating the information sent through the lightweight protocols to the FIWARE NGSI-LD data model, used by a Context Broker server where data is stored and later consumed for analysis and exploitation by external applications via standard API, and by services in the top Service layer.

IoT register and management services

In the platform there is a service to register and manage deployed IoT controllers equipped with multiple sensors and actuators. The service allows the user to list already registered IoT controllers, modify their configuration, delete them, and register new ones that communicate with the platform. The main functionalities available to help in these tasks are:

- Automatic detection of new IoT devices communicating information.
- Identification of well-known sensors and actuators.
- Automatic registration of single or batch of IoT devices.
- Manual registration for advanced IoT devices.

Available weather services integrated with the platform can also be added to the plots when no real weather stations are available for them in the field.

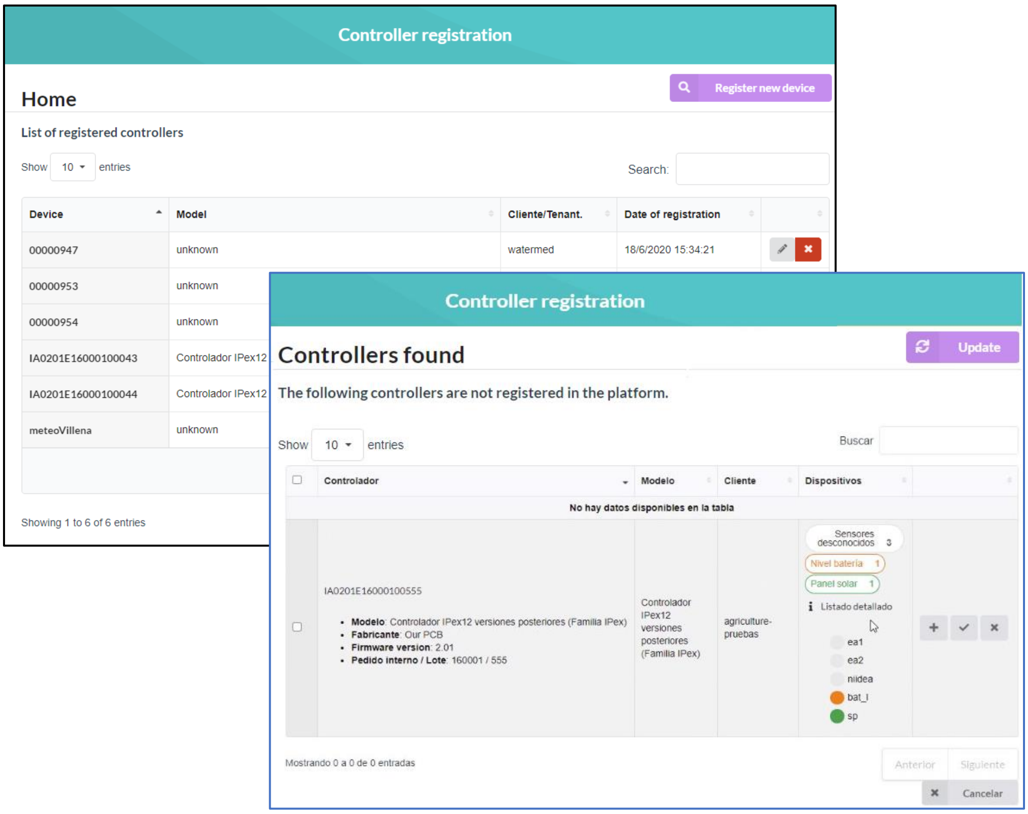

Figure 3 - IoT register service views

The platform offers a service to manage registered IoT controllers, allowing the user to locate them on a map view, assign them to a user or groups. Available weather services integrated with the platform can also be added with this service to the plots as *virtual weather stations* when no real weather stations are available for them in the field.

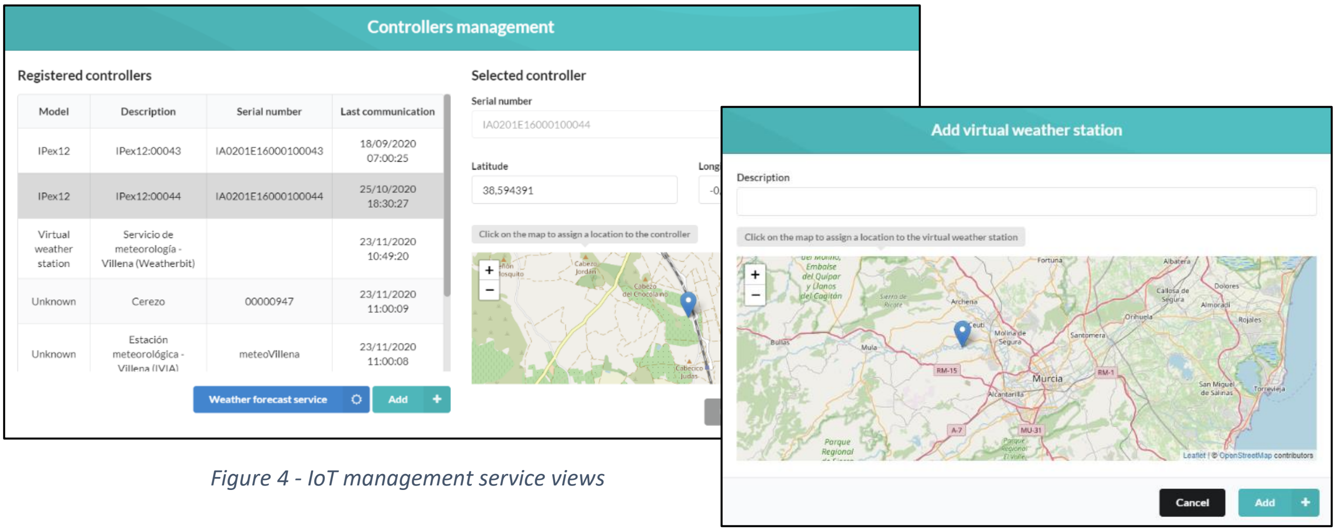

Figure 4 - IoT management service views

Agronomic management services

The platform offers a set of agronomic and administrative services:

- Multi-layered map view navigation: to access to all resources on a map view.
- Plots management: to register new plots, edit their geometry and location information, etc.
- Users and groups management: to register users, assign roles, create groups, etc.
- Rules management: to create rules to trigger alerts, control valves, etc.
- Irrigation schedule: to create and manage irrigation programs.
- Crops and plots agronomic information: to manage agronomic information along the seasons.
- Analysis registration of plants, soil, and irrigation water.
- Farmer Field Book: to register information about used fertilizers along the crop, etc.
- Graphs creator: to create complex graphs with historical data.

Next, it will be summarize the main services related with agronomic management.

<u>Crop information service</u>: to define crops and provide information about their agronomic properties, like the plant type (i.e., woody, herbaceous, cereal, etc.), plant specific properties (i.e. salinity tolerance, cold hours, etc.), the crop coefficient depending on its phenological state, etc.

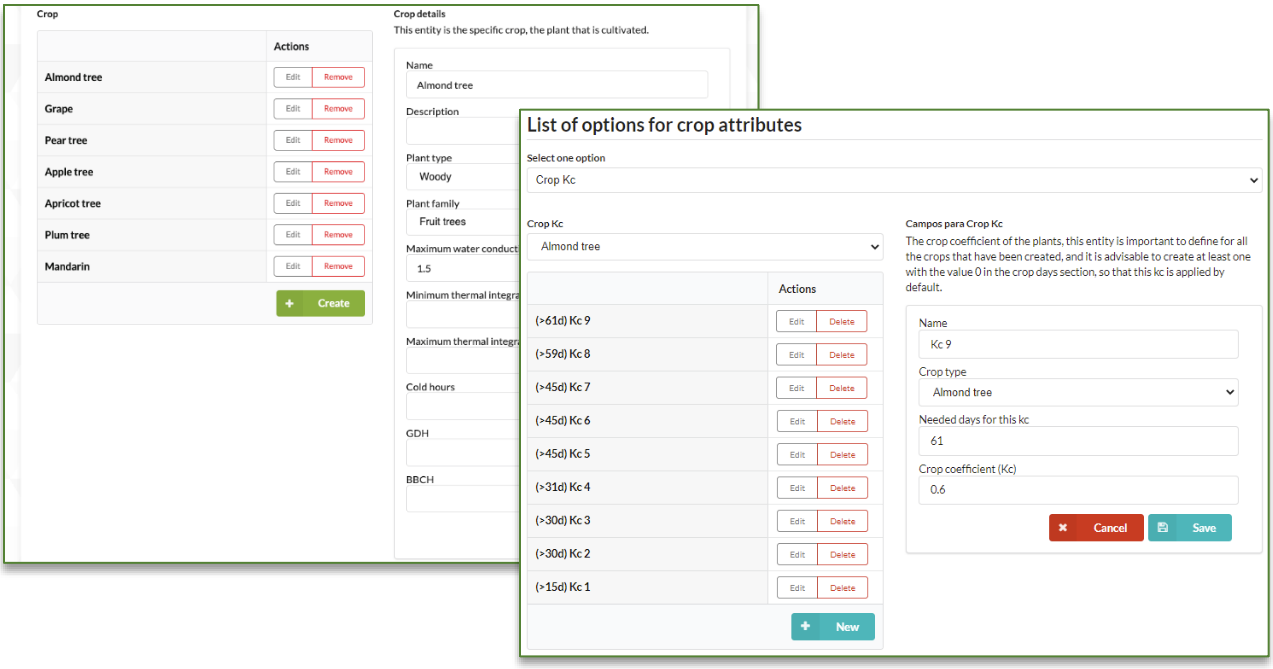

Figure 5 - Crop information service views

<u>Plot agronomic information service</u>: to register all the agronomic information relevant to the plots registered in the platform, like its crop (previously defined), the plantation frame, planting and harvesting dates, information about the plot soil, information about the irrigation system, etc. All the historical information will allow for comparing harvest's performance along the seasons.

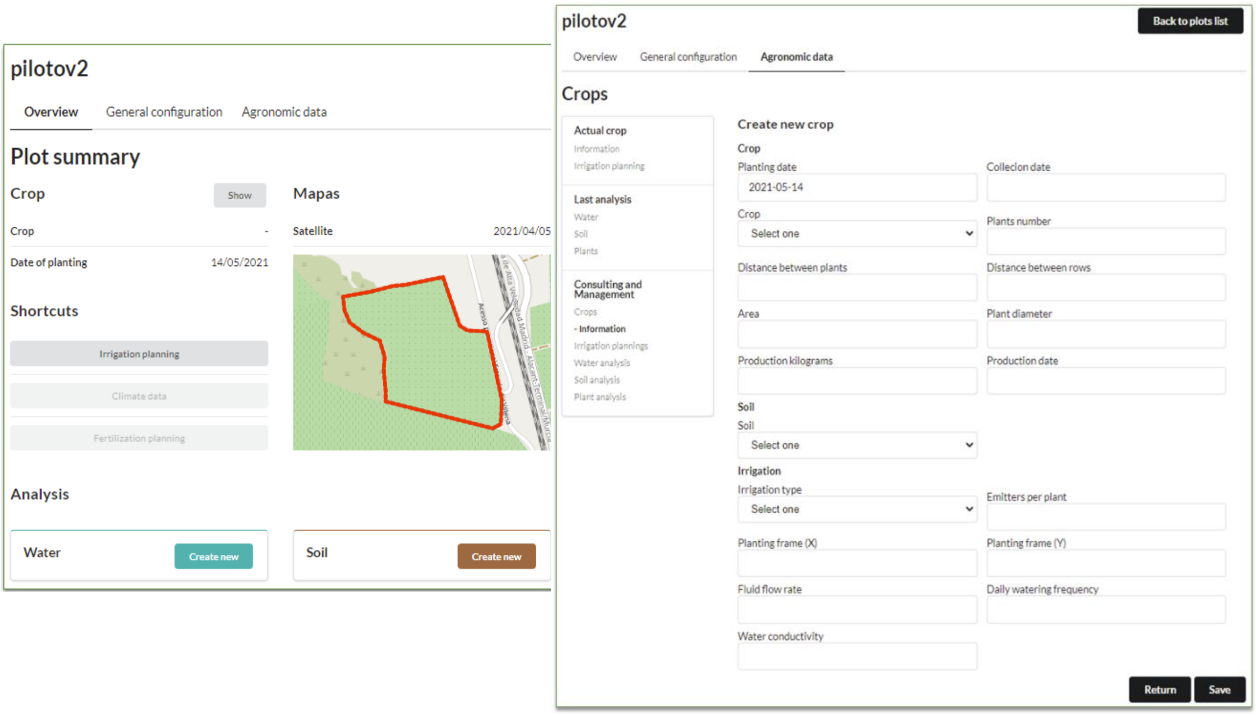

Figure 6 - Plot agronomic information service views

Analysis registration service: to register analysis data about the crop plant (macro, micro, etc.), soil (cic, macro, micro, anions, etc.), and irrigation water (chemicals, cations, anions, etc.) used along the season, to have a log along the production.

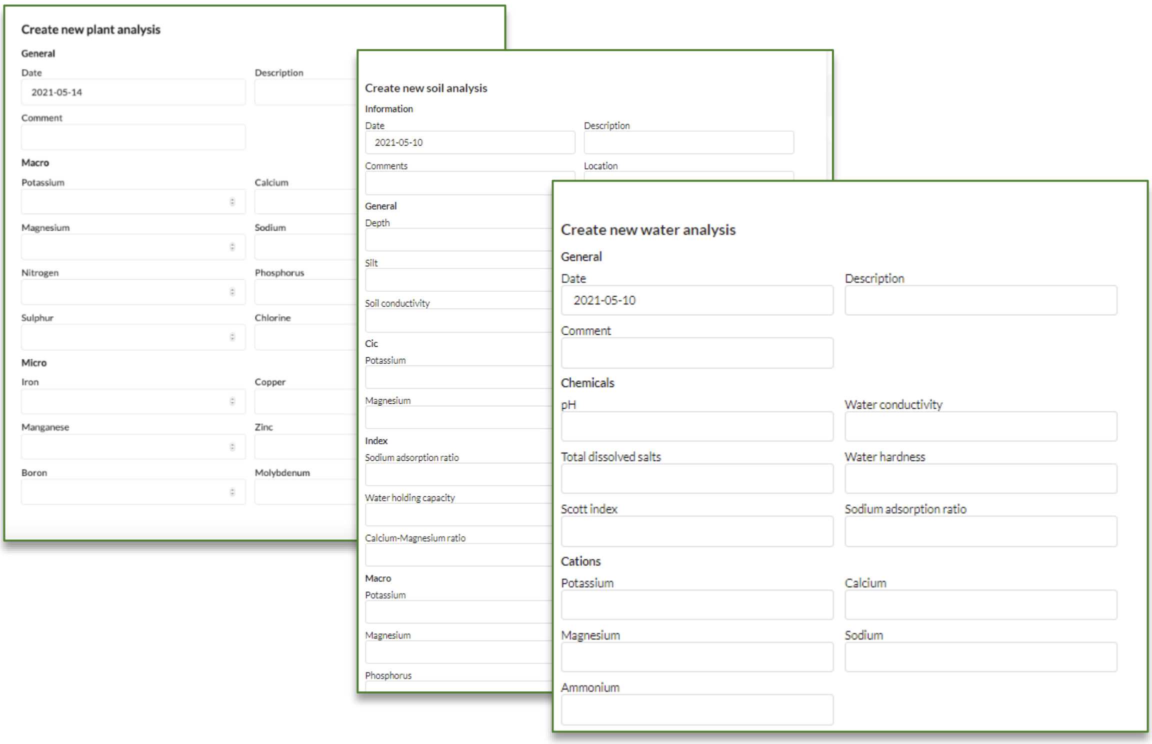

Figure 7 - Analysis registration service views

Irrigation scheduling service: to define and modify irrigation programs when the user has an irrigation controller device deployed in its plot. This service offers an advance mode to specify more elaborated programs and a mode to preview them in a timeline.

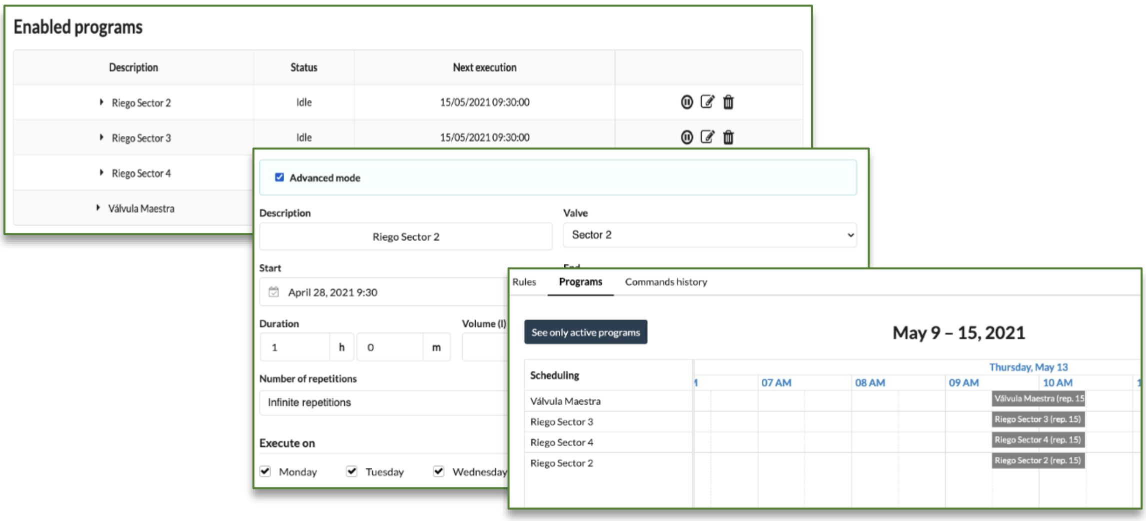

Figure 8 - Irrigation scheduling service views

Data exportation for exploitation

The platform offers different ways to access to the registered data for exploitation.

As it has been already mentioned before in the section for Data Acquisition, the registered data is stored in a FIWARE Context Broker server in the Information Management layer.

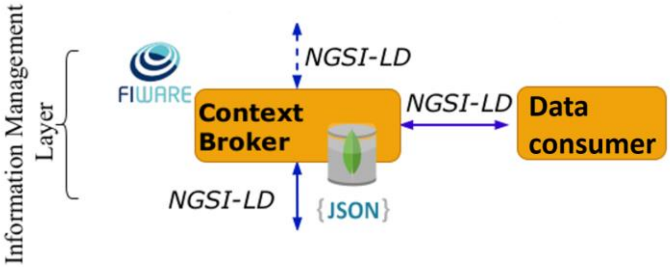

Figure 9 - Information Management layer

This data can be accessed by external services and by the platform ones via subscriptions to the Context Broker using its REST API retrieving data in FIWARE NGSI-LD data model format. This data can be accessed by external services to the platform also via another REST API provided by the platform using FIWARE NGSIv2 data model. For example, for some weather information you can get information with the next structures to be managed:


```
{
  "id": "urn:ngsi-ld:WeatherObserved:Spain-Valladolid",
  "type": "WeatherObserved",
  "dateObserved": {
    "type": "Property",
    "value": {
      "@type": "DateTime",
      "@value": "2016-11-30T07:00:00.00Z"
    }
  },
  "temperature": {
    "type": "Property",
    "value": 3.3
  },
  "precipitation": {
    "type": "Property",
    "value": 0
  },
  "location": {
    "type": "GeoProperty",
    "value": {
      "type": "Point",
      "coordinates": [-4.754444444, 41.640833333]
    }
  },
  "stationName": {
    "type": "Property",
    "value": "Valladolid"
  },
  "@context": [
    "https://schema.lab.fiware.org/ld/context",
    "https://uri.etsi.org/ngsi-ld/v1/ngsi-ld-core-context.jsonld"
  ]
}
```


NGSI-LD


```
{
  "id": "urn:ngsi-ld:WeatherObserved:Spain-WeatherObserved-Valladolid",
  "type": "Feature",
  "geometry": {
   "type": "Point",
   "coordinates": [
    -4.754444444,
    41.640833333
   ]
  },
  "properties": {
   "type": "WeatherObserved",
   "dateObserved": "2016-11-30T07:00:00.00Z",
   "temperature": 3.3,
   "precipitation": 0,
   "location": {
    "type": "Point",
    "coordinates": [
     -4.754444444,
     41.640833333
    ]
   },
   "stationName": "Valladolid",
   "address": {
    "addressLocality": "Valladolid",
    "addressCountry": "ES"
   },
   "@context": [
    "https://smartdatamodels.org/context.jsonld"
   ]
  }
}
```


NGSIv2

Figure 10 - NGSI data models examples

The platform also offers the possibility to download data to CVS files from the different user forms along the available services. In the next example, we can find the button to export to CVS available in a form for graph data representation, in this case of a multilevel soil moisture probe:

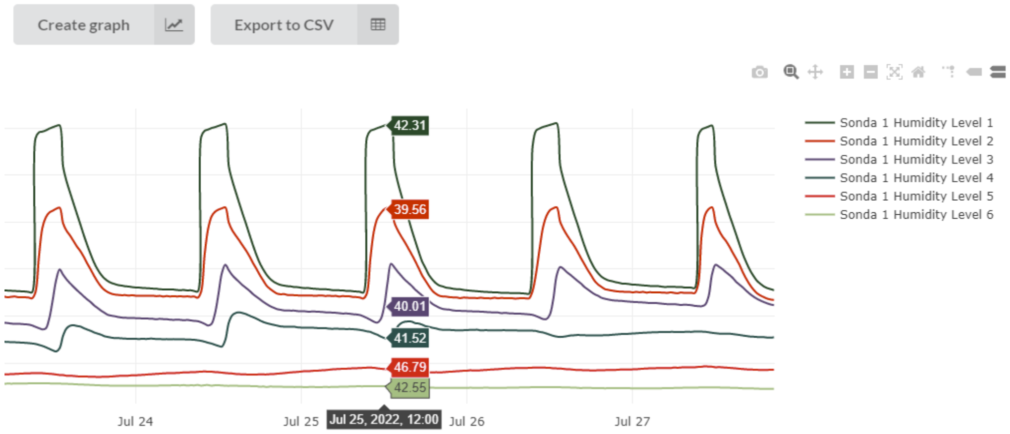

Figure 11 - Export to CVS in a graph

Conclusions

This document provides a summarized view of the design and development of the cost-effective IoT platform for PRECIMED.

The modularized architecture of the platform provides a decoupling in the different tasks, not only regarding the deployment perspective, but also from the performance and data management one.

The design of the platform and its architecture provide essential services at different levels to manage crops and their water resources efficiently. The platform has a high scalability and replicability, since it gives the possibility of obtaining data from as many different sensors as needed that continuously generate large amounts of information. It also gives a great heterogeneity, as it allows to obtain data from a high variety of sensors and heterogeneous sources of data. And finally, it also generates a high dynamism, due to the high speed of data generation and the need to create data models that allow better use and dissemination of the information to be exploited by new services.

The use of open standards in the communications of the deployed devices and in the used data models, has guaranteed the interoperability of the platform between software and hardware from different vendors, also making applications and services more functional and interoperable, highlighting the benefits in homogenising the information.

The use of open standards in the communications of the deployed devices and in the used data models to represent the information has highlighted its benefits, guaranteeing the interoperability of the platform between software and hardware from different vendors, and making developed applications and services more functional and interoperable.