SWAMP

SMART WATER MANAGEMENT PLATFORM

Project nº: 777112

WP2

D2.7 Virtual Entity Extensions for Smart Water Management

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Abbreviations

SWAMP	Smart Water Management Platform
ICT	Information and Communication Technologies
IOT	Internet of Things
SEPA	SPARQL Event Processing Architecture
VE	Virtual Entity
PE	Physical Entity
DE	Digital Entity
VPE	Virtualised Physical Entity
WDN	Water Distribution Network

Executive Summary

This document is part of deliverable D2.7 virtual entity extensions for smart water management. The deliverable is a result from Task 2.3 Virtual entity and service extensions.

The objective of the task is to extend the FIWARE and SEPA IoT baseline used in the project with new type of sensing and actuation capabilities to make them more feasible for rapid prototyping in smart water management domain. The task has created entity representations for the SWAMP specific IoT Resources such as sensors for soil moisture and water levels, elements for irrigation and distribution systems, and drones and their sensors such as multispectral camera. In addition, the project has created entity descriptions for the main physical entities that are not directly accessible IoT Resources, but that exist in project pilot such as farms, fields, management zones, crops, and canals for example. The project has developed reference implementations of IoT Services needed to support the use of the respective entities and IoT Resources.

The document specifies the entities, their purposes and data models, gives short descriptions of reference implementations of respective IoT Services and gives links to their open source implementations. In case of multispectral camera and drone-based reading of RFID sensors data will be sent according to equipment use and, in this case, the IoT services could be developed according to drone and camera specification. This document describes the basic structure about how to deal with basic drone and camera data.

The scope of this deliverable and document is to focus on run-time functionality of VEs. The services related to IoT and SWAMP system deployment management are described in deliverable 1.3. Domain-specific enablers and application services will be described in deliverable D1.4 Final SWAMP platform. Domain-specific enablers are for example field status monitoring, water need estimator, irrigation planning. Application services are for example UI visualisation, running irrigation, and various alert services.

1. Introduction

SWAMP platform is a collection of tools and design guidelines for the creation of SWAMP systems for precision irrigation and water distribution for agriculture.

The main idea in SWAMP project is to create models for the water distribution system, the farm, the crop, and the environment, to understand the situation in the water distribution network, the farms and the fields, and to analyse the water need of the crop, to plan how the crop is irrigated, and to irrigate the crop.

The IoT Service in SWAMP platform is defined as software service that is needed in accessing Virtual Entities in order to put their data in Virtual Entities to be manipulated by the IoT Platform. IoT Services that will be developed in SWAMP are defined in Chapter 4.2. It also includes the presentation of main FIWARE services that are used in pilots.

There are different ways to represent data in an information system. Cloud services, nowadays, tend to use data in JSON or XML in a non-relational database. Contextual data is also relevant to applications such as SWAMP. FIWARE platform, the basic structure of SWAMP platform represents data by NGSI and NGSI-LD structures, that may be represented by a JSON or JSON-LD document.

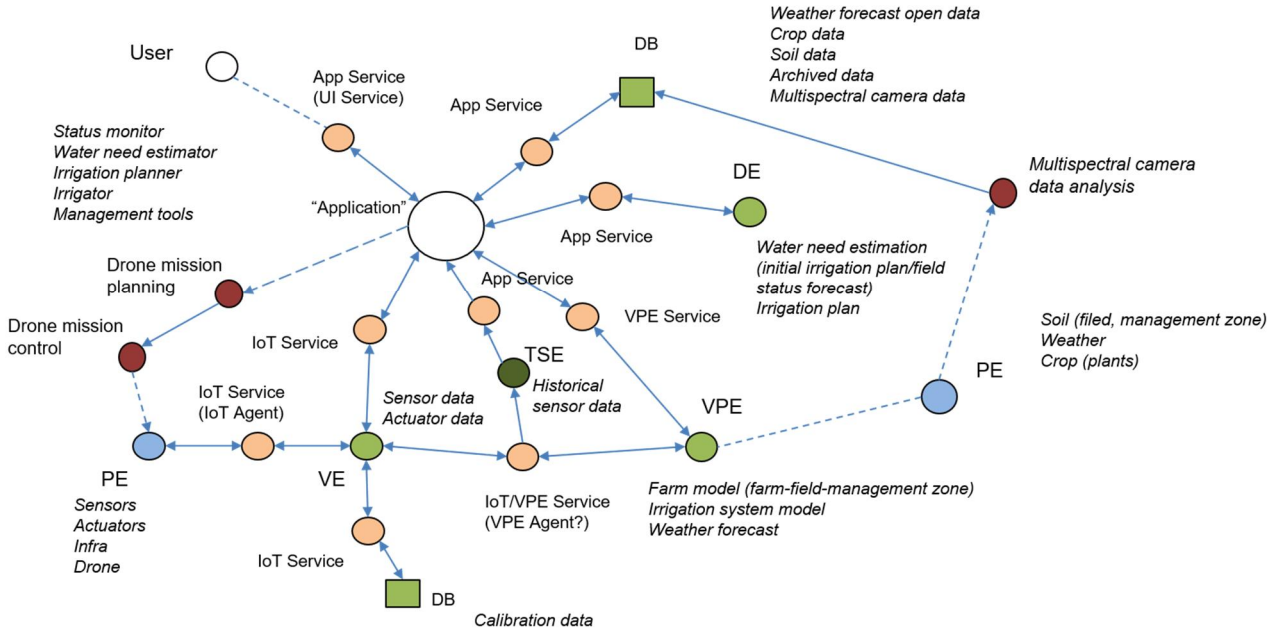
Considering the increasing amount of data, it becomes harder to query and analyse information without creating a relationship between them. For instance, one can argue that an irrigation system is composed by the pump, a valve and water reservoir. If such relationships are not modelled into the system, it is hard to know what pumps belong to each irrigation system.

With this in mind, new data representation models emerged in the last decade, such as JSON-LD (JSON Linked Data) and RDF/XML. These models are becoming the current standards in Cloud Systems in order to enable interoperability. Ontology is also important to make data be understandable in a context. In SWAMP project ontology follows models and recommendations used in agriculture.

Although there are several data representation models, there is no consent in the literature on how to document entities of a system. However, one can divide the IoT data representation documentation into three layers: Data Model, Entity Model and Ontology Model.

The Data Model describes the data from implementation point of view. The Entity Model describes the data in a higher level of abstraction through the data flow between entities. Finally, the ontology Model describes the data from a query perspective, so that interoperability is reached.

The purpose of this document is to specify the virtual entities (VE) that are needed in creations of the models. The Virtual Entity is the digital representation of physical world entity that SWAMP platform directly interacts with such physical entity, such as soil probe or drone. Entities from physical world can be connected to digital platform (e.g. sensors and actuators) or they can be just physical entities whose can be modelled in the SWAMP platform in order to organising data about the farm (e.g. fields, canals), but the platform does not control such physical entities directly, i.e. such entities exist and be part of the SWAMP platform, but the platform does not directly interact with such entities. In the latter case we talk about virtualised physical entities (VPEs). Digital Entities (DEs) are data elements presented in the platform that relevant to control data in the platform but is not directly connected with physical world. Digital representations are defined as SWAMP Ontology models given in Chapter 4.1. The SWAMP platform implements the Virtual Entities using collections of Context Entities of FIWARE or RDF-Graphs used in Linked Data. These models are interchangeable with each other.



PE = Physical element that is needed in SWAMP system
VE = Virtual Element that represents any PE that has connection to SWAMP platform
VPE = Virtualised Physical Element, Virtual Element of PE that does not have connection to SWAMP platform
DE = Digital Entity
TSE = Time-Series Entity (collected data series from VE, VPE) – special case of DE
IoT Service = Functionality that accesses VE's
VPE Service = Functionality that accesses VPE's
App Sevice = Functionality that connects application to SWAMP platform
DB = external DB

FIGURE 1 - RELATIONSHIP BETWEEN VES, VPES, DES AND OTHER ELEMENTS

SWAMP platform is based on FIWARE IoT platform and SEPA dynamic Linked Data approach. The main idea has been to use FIWARE IoT platform in data collection and storage and to use SEPA for linking the SWAMP platform with Linked Data and Semantic Web ecosystems. FIWARE gives robustness and scalability needed in IoT interaction and SEPA gives the flexibility and interoperability of semantic data. The following chapters describe the key features of FIWARE and SEPA that are needed for understanding our design decisions related to Virtual Entity and IoT Service models and extensions. The development of the entities described in this document are depicted in deliverable D2.1

2. SWAMP Entities

SWAMP entities belong to three categories (i.e., virtual entity, digital entity and virtual physical entity) and can be logically grouped as depicted by the following figure 2.

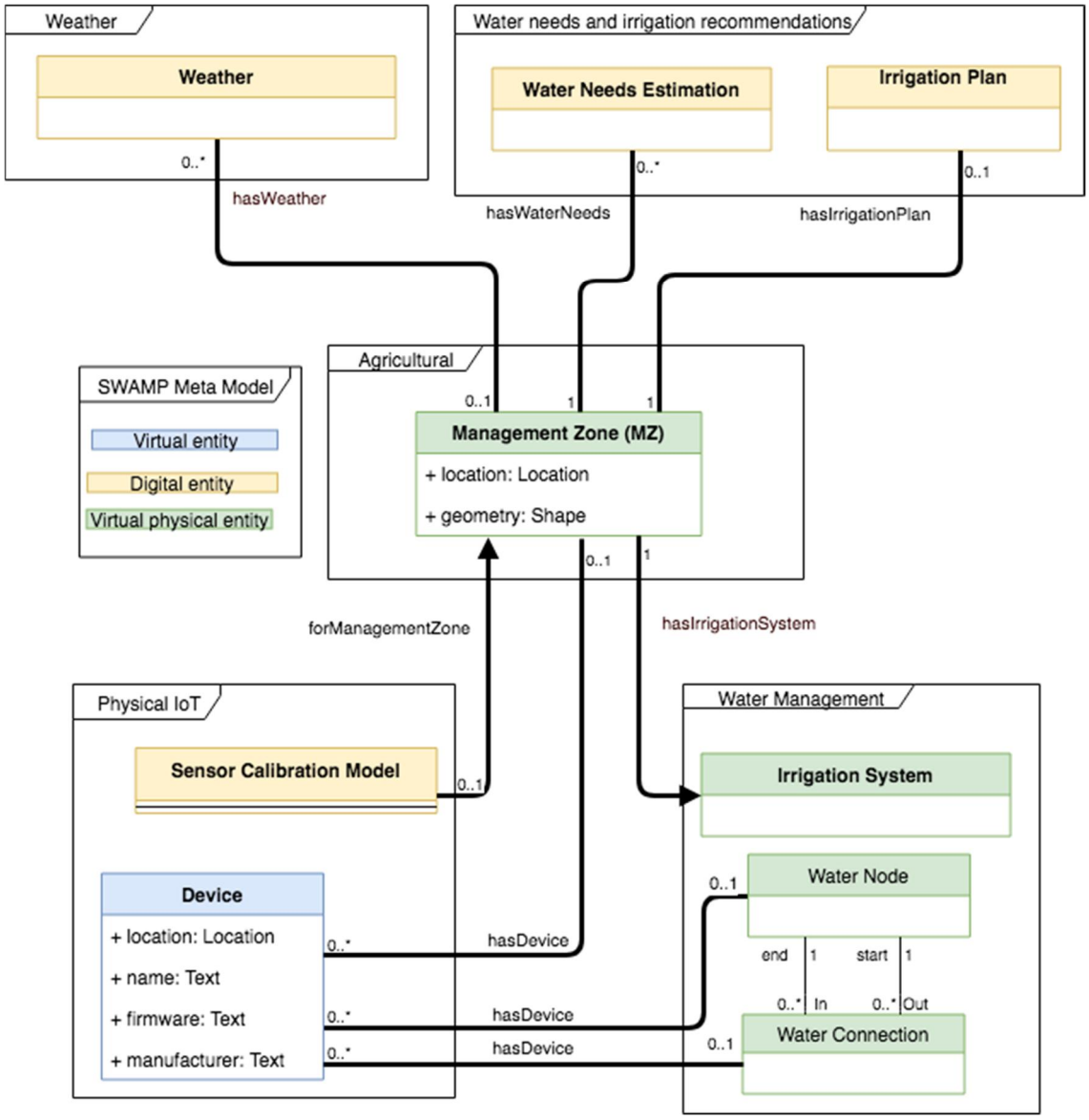


FIGURE 2 - SWAMP ENTITIES GROUPS

SWAMP entities can be classified in five different domains:

- Agricultural: it includes all the entities related to crop management;
- Water Management: it includes all the entities which form the water distribution and irrigation systems;
- IoT: it includes all the entities that refer to physical devices like boards or sensors;
- Weather: it includes the entities related to live weather information and weather forecasts;
- Water needs and irrigation recommendations: it includes the entities which represent the output of the water needs estimation and irrigation recommendation services.

Entities within a domain can be related to entities in other domains thanks to a set of relationships. For example, a Device can be placed inside a Management Zone (MZ) or associated with a Water Node through the hasDevice property. Other relevant extra-group relationships are:

- hasIrrigationSystem: relates a MZ and the Irrigation System employed there.
- hasWeather: connects a MZ with a Weather entity that exports data about the current weather in that zone.
- hasWaterNeeds: is used to link to a MZ the result of the water need estimation.
- hasIrrigationPlan: allows to specify the optimal irrigation plan for a specific MZ.
- forManagementZone: relates a Sensor Calibration model to a MZ.

The following figures are extended views of the above-mentioned groups of entities. For each entity is provided a list of attributes and the intra-relationships with others. While the list of relationships can be assumed as completed, the list of attributes is a summary of the most relevant ones. Details on the attributes of each single entity are reported in Section 3.

2.1. Agricultural entities

The agricultural group contains several entities which are essential to a correct water need estimation for a crop. In the SWAMP platform, every Field is logically composed by one or more Management Zone (MZ). Each Management Zone has a geo-referenced shape and unique soil properties. Consequently, a MZ is related to exactly one Soil entity where soil physical and chemical characteristics are stored.

Furthermore, a Field is also related to its crop information which is saved inside the Crop entity. This entity contains data about the development of a crop while its general static properties are contained inside a Crop Type entity.

Finally, the agriculture domain contains the Farmer entity which is related to a Farm by the Owns relationship.

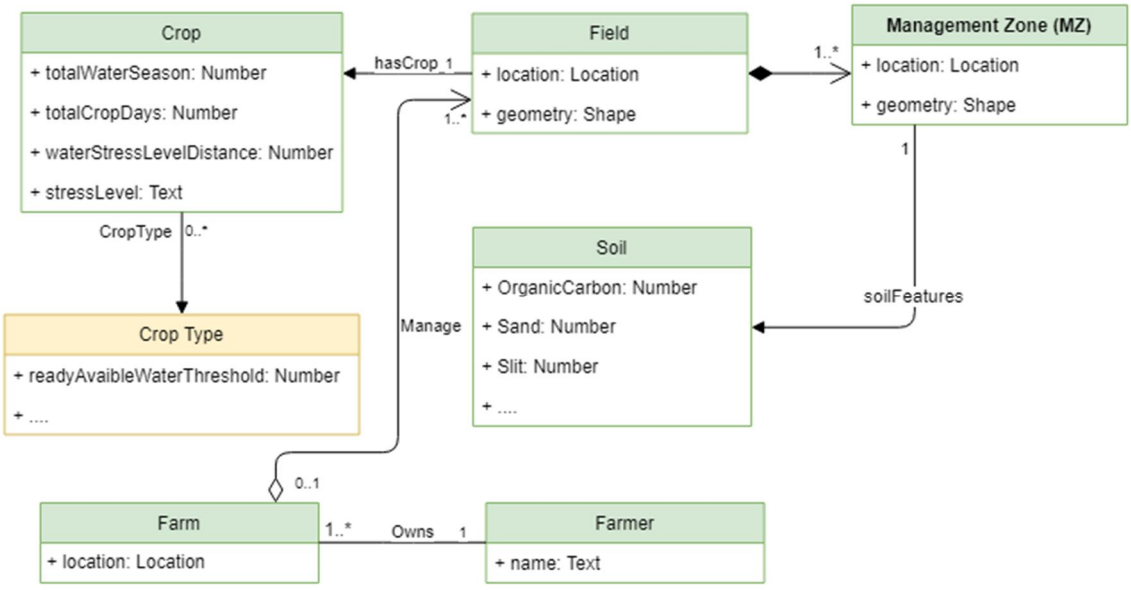


FIGURE 3 - AGRICULTURAL ENTITIES AND THEIR RELATIONSHIPS

2.2. Physical IoT entities

Within IoT group the most relevant concept is the Device. A device is a physical electronic component which could host zero or more Actuators or Sensors. Moreover, each sensor can be characterized by Sensor Calibration Model which allows to transform raw sensor data into a significant physical measure (e.g., temperature, humidity, soil moisture). Finally, a device can be powered by various supply systems, in Fig 4 Battery Supply and mixed Solar and Battery system are shown.

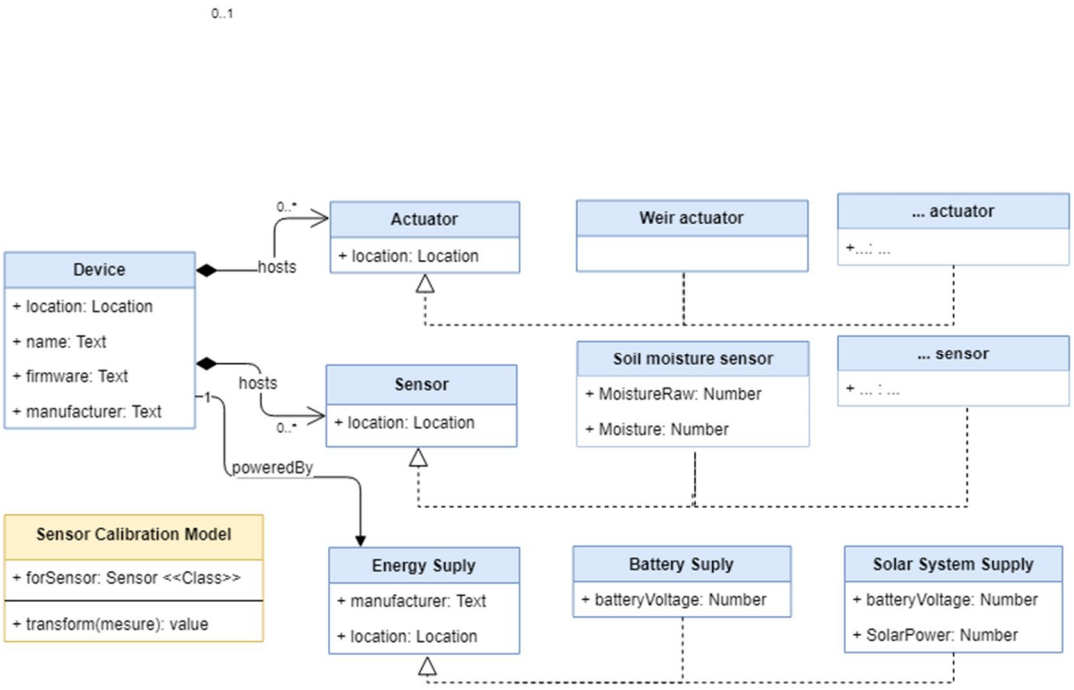


FIGURE 4 - PHYSICAL IOT ENTITIES AND THEIR RELATIONSHIPS

Consider for example the most common sensor employed within the pilots: the soil probe. A soil probe contains different sensors deployed at different depth levels. Using the model proposed above an instance of soil probe can be describe as depicted in Figure 5. The soil probe is an instance of Device and hosts three sensors, which have different depth values in their location field.

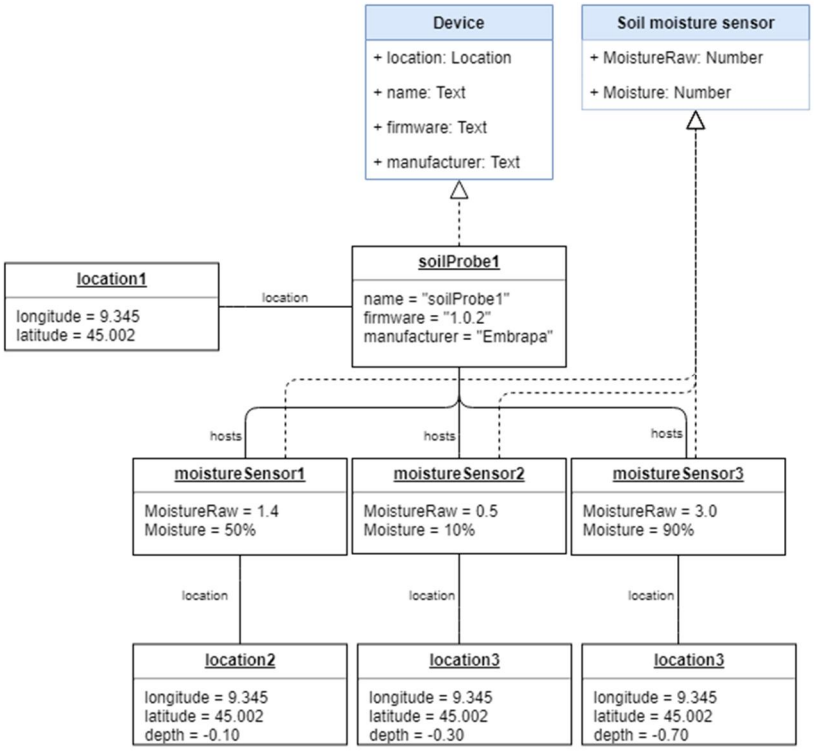


FIGURE 5 - MODEL FO SOIL PROBE DEVICE WHICH INCLUDES TREE SOIL MOISTURE SENSORS

This model has the advantage to be very flexible while giving a general data structure, which can be used to infer features or capabilities of a device.

2.3. Water management entities

The entry point for the Water Management group is the Irrigation System. It is related to exactly one Management Zone and it is a specialization of a Water Distribution Network (WDN). This generalization is crucial to homogenously describe also the requirements of the Italian pilot, where Irrigation Systems and a Water Distribution Network coexist. A WDN is composed of one or more Water Nodes, which can be connected by a Water Connection.

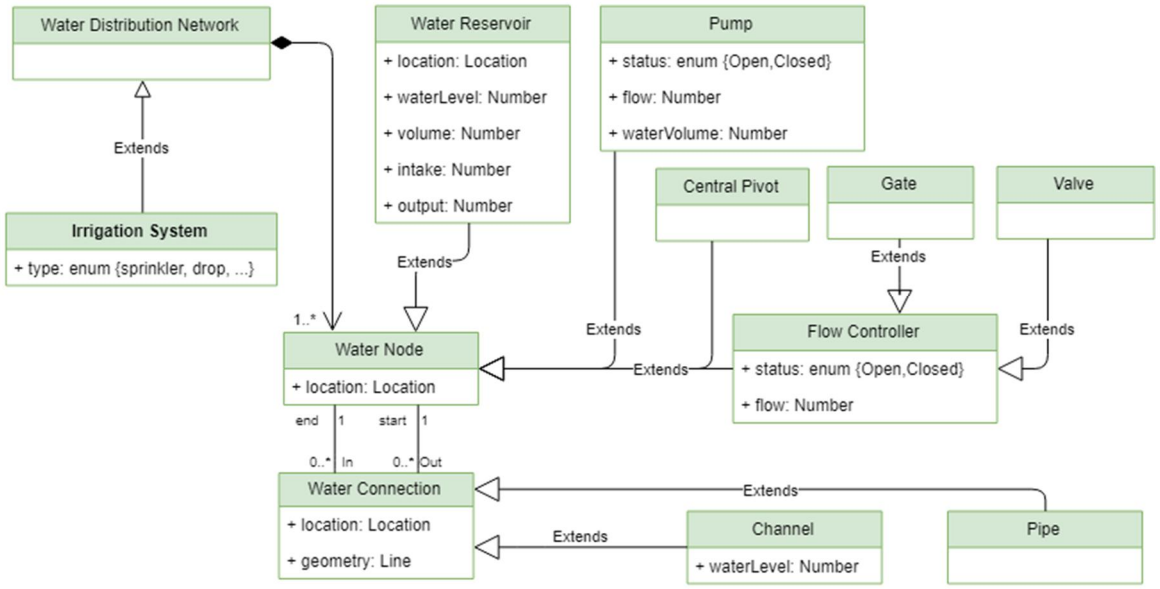


FIGURE 6 - WATER MANAGEMENT IOT ENTITIES AND THEIR RELATIONSHIPS

In general, this model describes a labelled graph as illustrated in Figure 7. Usually the starting Water Nodes are Water Reservoir entities, which stores information about the current usage of a water source. On the other hand, an example of a water connection could be a Channel or a Pipe.

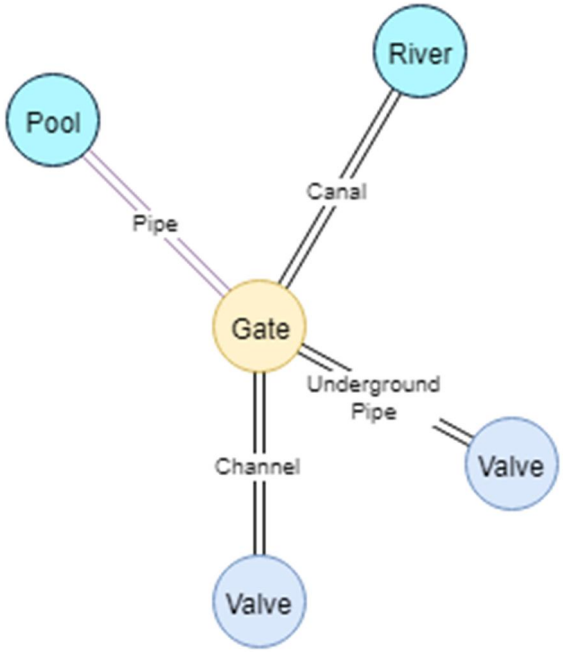


FIGURE 7 - AN EXAMPLE OF A WDN WHERE A POND AND RIVER SERVE AS A WATER RESERVOAIR

2.4. Weather entities

Weather conditions play a crucial role in the water needs estimation process. The Weather group is mainly composed by the Weather entity. This data is essential for the correct estimation of a crop development stage. Furthermore, Weather Forecast contains logically the same information represented in Weather entity but in a future period (start from “validFrom” to “validTo”). Finally, weather data can be produced by in-situ Weather Station which is employed to consider micro-climate effects of the field. The station is related with zero or more Device entities instances which describe the weather station equipment (i.e. deployed sensors). Moreover, it can be used for validating and "correcting" weather forecast data if there are systematic errors.

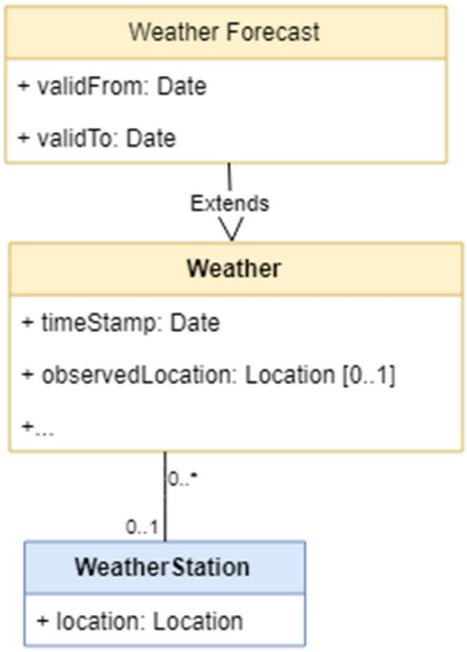


FIGURE 8 - WEATHER ENTITIES

2.5. Water needs and irrigation recommendations entities

The Water needs domain groups all the virtual entities related to the SWAMP recommendation system. The entry point is the Irrigation Plan, which is related with exactly one MZ and is composed by one Irrigation Recommendations. An Irrigation Recommendation contains data about the quantity of water that should be supplied and when to start/stop the irrigation procedure. Each Irrigation Recommendation satisfies 1 or more Water Need Estimation. A Water Need Estimation entity is associated exactly one MZ and it describes the output of an estimation computed by the SWAMP platform.

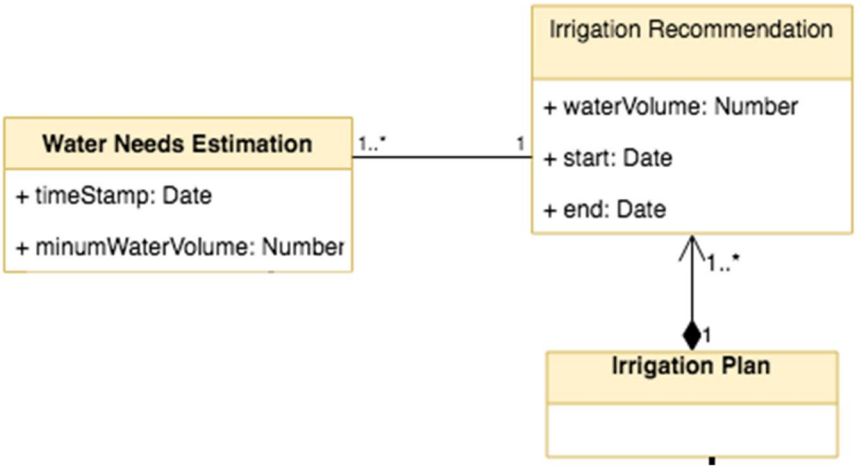


Fig. 9 Water needs and recommendations

3. SWAMP Entity descriptions

This chapter contains the definition to all entities needed for a generic farm. This description is separated first by the common properties applied to all entities in the SWAMP platform, later the entities are divided into its categories (Virtual entities, virtualized physical entities and digital entities). In original FIWARE structure this distinction do not happen and it calls them all just entities.

There is firstly a brief description of what that entity represents than each entity is represented by a table with the attribute name, attribute type, the description of each attribute and if that attribute is mandatory or optional. Following the tables, a description of the entity in the JSON-LD format is given as well as the SWAMP ontology description.

In this chapter specification of all Entities must contain the purpose of VE, the data/information model (with syntax and semantics), and how entities are presented in Orion.

3.1. Common properties/attributes of all entities

Being based on the NGSI-LD information model [6], Virtual Entities share a set of common properties summarized as follows:

TABLE 1 - COMMON PROPERTIES FOR ALL ENTITIES

Attribute Name	Attribute Type	Description	Constraint
id	@id	The URI which identifies the entity instance. NGSI-LD specification recommends to use URN [URN].	Mandatory
type	@type	The URI which identifies the class of the entity.	Mandatory
dataProvider	URL	Specifies the URL to information about the provider of Virtual Entity	Optional
dateModified	DateTime	Last update timestamp of this entity	Read-Only. Automatically generated

dateCreated	DateTime	Entity's creation timestamp	Read-Only. Automatically generated
name	Normative References: https://schema.org/name	Name given to the entity	optional
context	string	Explains what exactly the context for each attribute in the entity by a description or a URL where the description is.	optional

It is important to notice that the properties dateModified and dateCreated are automatically generated by Fiware/Orion and that some of these properties are optional since its use might be or not necessary in order to better describe the entities inside SWAMP.

The attributes refFarm and refFarmer are used as a main source to define all the entities and the relationship for a given farm. These attributes should not be used in their own entities (farm and farmer) since it is not necessary that an entity have a relationship to another entity of the same type for the purpose presented above.

TABLE 2 - COMMOM PROPERTIES FOR MOST ENTITIES

Attribute Name	Attribute Type	Description	Constraint
refFarm	Relationship	Relationship to the farm ID	Mandatory
refFarmer	Relationship	Relationship to the farmer ID	Mandatory

3.2. Virtual entities in SWAMP

As described in section 1 a Virtual Entity is a digital representation of a real physical entity that SWAMP platform directly interacts with, such as soil probe or drone. This section presents the Virtual Entities that SWAMP is going to use inside FIWARE. It is important to notice that some of those entities are different from the UML diagram in section 2 since for FIWARE and the concept of Internet of Things the most important component is the “Thing” that is going to be managed by people, so for example in this section a soil probe is a “thing” that has multiple properties for each sensor associated with it whereas in section 2 a soil probe is described as a device with multiple sensors entities associated with it.

3.2.1. Soil Probe

This entity contains a description of the Soil Probe. This entity is primarily associated with the vertical segments of the environment and agriculture but can be used in many different applications. It represents the values monitored from the Soil Probe system. As an example, in this entity it is presented a soil probe with 3 as the number of sensors since 3 depths of measurement is commonly going to be used in SWAMP. However, one could change this entity by updating the property number of sensors as well as the depths associated with them, in this way it is possible to create a soil probe entity with N number of sensors and N number of depths.

The soil probe system may have a calibration model associated with it that may convert the value of the sensor in a humidity rate. The raw value measured from sensor is mandatory. The percentage rate of water may be registered in this entity whether data would be calibrated by the soil probe system but will be mandatory after processing data (calibration).

TABLE 3 - SOIL PROBE ENTITY

Attribute Name	Attribute Type	Description	Constraint
location	geo:json	Location of the soil probe (farm location) Representation by a GeoJSON geometry. (https://tools.ietf.org/html/rfc7946)	Mandatory
dateRetrieved	DateTime	The date and time the data was retrieved by the soil probe system	Mandatory
Firmware	Text	Version of software release	Optional
Manufacturer	Text	What company develops such probe	Optional
numberOfSensors	Number	Indicates the number of sensors in this soil probe	Mandatory
soilMoistureRawDepth1	Number	Soil moisture raw measured from the field at depth 1	Mandatory
soilMoistureRawDepth2	Number	Soil moisture raw measured from the field at depth 2	Mandatory
soilMoistureRawDepth3	Number	Soil moisture raw measured from the field at depth 3	Mandatory
soilMoistureCalibratedDepth1	Number	Soil moisture calibrated measured from the field at depth 1	Optional
soilMoistureCalibratedDepth2	Number	Soil moisture calibrated measured from the field at depth2	Optional
soilMoistureCalibratedDepth3	Number	Soil moisture calibrated measured from the field at depth 3	Optional
soilTemperatureDepth1	Number	Temperature of the soil measured from the field at depth 1	Optional
soilTemperatureDepth2	Number	Temperature of the soil measured from the field at depth 2	Optional
soilTemperatureDepth3	Number	Temperature of the soil measured from the field at depth 3	Optional
SoilConductivityDepth1	Number	conductivity of the soil measured from the field at depth 1	Optional
SoilConductivityDepth2	Number	conductivity of the soil measured from the field at depth 2	Optional
SoilConductivityDepth3	Number	conductivity of the soil measured from the field at depth 3	Optional

RefManagmentZone	Relationship	Relationship between probe and management zone	Mandatory

3.2.2. Weather Station

This is a sample of the information proposed in FIWARE for the entity Weather Observe [13]. It is important to notice that the properties described in this entity might not be the same as the ones that could be used for a weather station sold in the industry.

TABLE 4 - WEATHER STATION ENTITY

Attribute Name	Attribute Type	Description	Constraint
location	geo:json	Location of the weather station. Representation by a GeoJSON geometry. (https://tools.ietf.org/html/rfc7946)	Mandatory if address is not presented
Address	String	Civic address of the weather station	Mandatory if location is not presented
refPointOfInterest	PointOfInterest	A reference to a point of interest associated to this Weather Station	Optional
dateRetrieved	DateTime	The date and time that the weather information was retrieved in ISO8601 UTC format.	Mandatory
source	Text or URL	A sequence of characters giving the source of the entity data	Optional
weatherType	Text + Allowed values	The observed weather type. It is represented by a comma separated list of weather statuses. Allowed values: A combination of (clearNight,sunnyDay, slightlyCloudy, partlyCloudy, mist, fog, highClouds, cloudy, veryCloudy, overcast, lightRainShower, drizzle, lightRain, heavyRainShower, heavyRain, sleetShower, sleet, hailShower, hail, shower, lightSnow, snow, heavySnowShower, heavySnow, thunderShower, thunder).	Optional
dewPoint	Number	The dew point encoded as a number. Default unit degree centigrade	Optional
visibility	Text	One of (VeryPoor, poor, moderate, good, veryGood, excellent)	Optional
temperature	Number	Air's temperature observed	Optional
relativeHumidity	Number	Air's relative humidity observed (percentage expressed in parts per one)	Optional
precipitation	Number	Precipitation level observed in litter per square meter	Optional

windDirection	Number	The wind direction expressed in decimal degrees compared to geographic North (measured clockwise), encoded as a Number.	Optional
wind Speed	Number	The observed wind speed in m/s, encoded as a Number.	Optional
atmosphericPressure	Number	The atmospheric pressure observed measured in Hecto Pascals.	Optional
pressureTendency	Text or Number	Is the pressure rising or falling? It can be expressed in quantitative terms or qualitative terms.	Optional
solarRadiation	Number	The solar radiation observed measured in Watts per square meter.	Optional
illuminance	Number	the illuminance observed measured in lux (lx) or lumens per square meter (cd-sr-m-2)	Optional
streamGauge	Number	The water level surface elevation observed by Hydrometric measurement sensors, namely a Stream Gauge, expressed in centimeters.	Optional
snowHeight	Number	The snow height observed by generic snow depth measurement sensors, expressed in centimeters.	Optional
refWaterEstimate	Relationship	Relationship to the Water Estimate ID	Mandatory

3.2.3. Water Flow Meter

Water flow meter used in pipe system provides water meter counter tick. With this entity it is possible to measure the water usage for the irrigation system by using flow meters attached to some position in the irrigation system in order to better understand water usage in the field. To interpret values, they must be compared against the time period of the measurement. Counter value can be used as multiplier to get total water use over the period.

TABLE 5 - WATER FLOW METER ENTITY

Attribute Name	Attribute Type	Description	Constraint
waterMeter	Number	Counter of 10 litre increments of water flow since start of the meter	Mandatory
refIrrigationSystem	Relationship	Relationship to the Irrigation System ID	Mandatory

3.2.4. Water Level Meter

This entity is used for measuring canal water level or water reservoir water level.

TABLE 6 - WATER LEVEL METER ENTITY

Attribute Name	Attribute Type	Description	Constraint
location	geo:json	Location of the water meter (farm location) Representation by a GeoJSON geometry. (https://tools.ietf.org/html/rfc7946)	Mandatory
waterLevel	Number	indicates the water level in cm	Mandatory
refIrrigationSystem	Relationship	Relationship to the irrigation system ID	Mandatory

3.2.5. Central Pivot

This entity contains information to describe the central pivot position inside the farm as well as the relationships to the irrigation system that it belongs to. It is important to notice that the sprinklers are attached to each part of the central pivot arm and as such it might be necessary to indicate the relationship for each sprinkler to the central pivot or irrigation system.

TABLE 7 - CENTRAL PIVOT ENTITY

Attribute Name	Attribute Type	Description	Constraint
location	geo:json	Location of the central pivot (farm location) Representation by a GeoJSON geometry. (https://tools.ietf.org/html/rfc7946)	Mandatory
angle	Number	Shows the angle from the north position	Mandatory
AngularVelocity	Number	Angular velocity in radians per second.	Mandatory
state	Number	Indicates if the equipment is on or off	Mandatory
refIrrigationSystem	Relationship	Indicates a relationship with the irrigation system	Mandatory

3.2.6. Water pump

A pump has a curve associated to it that shows the performance for the given pump by the metrics head and flow. The head means the pressure in the pump's exit while the flow indicates the flowrate in the pump's exit. These values cannot be directly measured in the pump but can be measured in the exit pipeline and entrance pipeline as well the rotation speed of the rotor. It is interesting to measure the power consumption for the pumps since for some farms this is an important factor into the decision to irrigate (for example in MATOPIBA).

TABLE 8 - WATER PUMP ENTITY

Attribute Name	Attribute Type	Description	Constraint
location	geo:json	Location of the pump (farm location) Representation by a GeoJSON geometry. (https://tools.ietf.org/html/rfc7946)	Mandatory
state	Number	Indicates if the pump is on or off	Mandatory
pressure	Number	Indicates the pressure in the pump's exit in bar, psi or Pa	Mandatory

flowRate	Number	Indicates the flow rate in m³/h in the pump's exit	Mandatory
powerConsumption	Number	Indicates how much kwh is been used	Mandatory
refIrrigationSystem	Relationship	Indicates a relationship with the irrigation system	Mandatory

3.2.7. Valve

Valves are common devices used in hydraulic systems and are capable control or measure the fluid that flows thought them. This entity is used to model different kinds of valves such as gate, globe, butterfly, ball, plug, pitch, needle, check valves etc.

Most valves only control the fluid that flows thought than however sensors could be associated with the valves to further define fluid flow. One example could be a globe valve that controls the flow rate in the pipes and this valve could be associated with a flow rate sensor in order to know the flow rate in the valve.

This entity is them used to define different kinds of valves and as such should have the attributes accordingly to the properties associated with the valves (for a globe valve can be position and flow rate while for a pressure control valve can be position and pressure).

TABLE 9 - VALVE ENTITY

Attribute Name	Attribute Type	Description	Constraint
location	geo:json	Location of the valves (farm location) Representation by a GeoJSON geometry. (https://tools.ietf.org/html/rfc7946)	Mandatory
state	Number	Indicates if the valve is open or closed	Optional
position	Number/string	indicates its positon by a number or string	Optional
flowRate	Number	Indicates the flow meter in m³/h	Optional
pressure	Number	Indicates the current pressure in psi, bar Pa	Optional
refIrrigationSystem	Relationship	Relationship to the Irrigation system ID	Optional

3.2.8. Solar Energy System

Solar energy system provides information about status of the power system of off-grid communication infrastructure (probes and gateways). Energy system provide information about production and consumption of energy. An example of solar energy system is Victron Energy solar charge controller that is providing information about the connected photovoltaic solar panel attached battery and voltage regulated load that is connected to the charge controller

TABLE 10 - SOLAR ENERGY SYSTEM ENTITY

Attribute Name	Attribute Type	Description	Content
solarPower	Float	Solar panel power measured in Watts	Mandatory
solarVoltage	Float	Solar panel voltage measured in Volts	Mandatory
batteryCurrent	Float	Battery current and direction (negative values drawing from the battery and positive values charging battery) measured in Volts	Mandatory

loadCurrent	Float	Measured load current drawn from the power system in Amperes	Mandatory
batteryVoltage	Float	Battery voltage in Volts	Mandatory

.

3.2.9. Drone

This entity contains the information about drone status. This will be used to present to the farmer information about the drone that might be in its interest such as location, if it is flying or not, the manufactures name etc.

TABLE 11 - DRONE ENTITY

Attribute Name	Attribute Type	Description	Constraint
Name	Normative References: https://schema.org/name	Name given to the Drone	Optional
location	geo:json	Position of the drone in WGS-84 coordinate system	Mandatory
status	String	Status of the drone: off, on, armed, active, disarmed	Mandatory
horVelocity	Number	Horizontal velocity of the drone in meters per second	Mandatory
homeLocation	geo:json	Coordinates of home location of the drone.	Mandatory
batteryCapacity	Number	Indicates drone's battery level in percentage	Mandatory
firmware	string/number	Indicates the firmware version	Mandatory
manufacturer	String	Indicates drone's manufacturer	Mandatory
flightmission	String	Indicates if the drone is in a flight mission and the number for that flight mission	Mandatory
camera	string	Indicates what the camera type is (mulstisprectral or another possible)	Mandatory

3.3. Virtualised Physical Entity descriptions

As described in section 1 a Virtualized Physical Entity is an entity whose presentation SWAMP platform needs for organising and modelling the farm (e.g. fields, canals), but the platform does not control such physical entities directly.

3.3.1. Farmer

A farmer is an entity that is important in order to give access to information in the platform and to better control who has access to the SWAMP platform. It is used to define who is the responsible for the farm and this person could be the farmer, manager, pilot responsible or anyone else who is responsible for the given farm

TABLE 12 - FARMER ENTITY

Attribute Name	Attribute Type	Description	Constraint
name	Normative References: https://schema.org/name	Name given to the farmer	Mandatory
email	string	Farmer's email	Mandatory
phone	string	Farmer's phone number	Mandatory

3.3.2. Farm

The farm entity is used to instantiate each pilot in SWAMP and as a main point for queries. Every other entity inside SWAMP has a relationship to this entity. This can be used in order to easily query every component that belongs to a farm.

TABLE 13 - FARM ENTITY

Attribute Name	Attribute Type	Description	Constraint
location	Geo:json	Location of the farm represented by a GeoJSON geometry. (https://tools.ietf.org/html/rfc7946)	Mandatory
area	Number	Farm area	Mandatory

3.3.3. Field

The field entity is used to separate each farm in multiple fields since for example in MATOPIBA there are multiple central pivots, so the field entity is used to declare each portion of the farm.

TABLE 14 - FIELD ENTITY

Attribute Name	Attribute Type	Description	Constraint
location	Geo:json	Location of the field represented by a GeoJSON geometry. (https://tools.ietf.org/html/rfc7946)	Mandatory
area	Number	Field area	Mandatory

3.3.4. Management Zone

The management zone represents the portions of a plot in which some crop will be developed. Each management zone has its physical-chemical properties and geo-reference parameters that may change between difference seasons. The Management Zone Virtual Entity correlates the soil properties with soil probes. It also stores the georeferenced information related to the area represented by this management zone.

TABLE 15 - MANAGEMENT ZONE ENTITY

Attribute Name	Attribute Type	Description	Constraint
location	geo:json	Location of the MGMT Zone (farm location) Representation by a GeoJSON geometry. (https://tools.ietf.org/html/rfc7946)	Optional

refField	Relationship	Relationship to the Field ID	Mandatory
refWaterEstimate	Relationship	Relationship to the water estimate ID	mandatory

3.3.5. Soil

Soil is a complex entity which comprises a set of features that influence the development of a crop and how much water should be applied in the irrigation. The soil parameters are for example:

- Organic carbon
- Total nitrogen
- Soil reaction (pH2O)
- Cation exchange capacity (CEC_{soil})
- Cation exchange capacity of clay size fraction (CEC_{clay})[a]
- Base saturation (as % of CEC_{soil})
- Effective cation exchange capacity (ECEC)[b]
- Aluminium saturation (as % of ECEC)
- $CaCO_3$ content
- Gypsum content
- Exchangeable sodium percentage (ESP)
- Electrical conductivity of saturated paste (ECe)
- Bulk density
- Coarse fragments (vol.%)
- Sand (mass%)
- Silt (mass%)
- Clay (mass%)
- Available water capacity (AWC; cm to specified depth, from −33 to −1500 kPa; % v/v)

Data related to soil could be found in the following references and may be used to populate the SWAMP database defined according to the data model presented in this item.

- SOTER - programme that mapped soil in the world [16].
- Dataset SOTER that includes Brazil [17].

The data model to represent the soil in SWAMP is

TABLE 16 - SOIL ENTITY

Attribute Name	Attribute Type	Description	Constraint
source	Text or URL	A sequence of characters giving the source of the entity data	Optional
orgCarbon	Number	Organic carbon	Optional
totNitrogen	Number	Total Nitrogen	Optional
soilRetation	Number	Soil Retantion (pH2O)	Optional
soilCatExcCap	Number	Cation exchange capacity (CECsoil)	Optional
soilCatExcCapClay	Number	Cation exchange capacity of clay size fraction (CECclay)	Optional
soilBaseSat	Number	Base saturation	Optional
soilEffecCatExcCap	Number	Effective cation exchange capacity	Optional

soilAluSat	Number	Aluminium saturation	Optional
soilCaCO3	Number	CaCO3 content	Optional
soilGyp	Number	Gypsum content	Optional
soilExcSod	Number	Exchangeable sodium percentage	Optional
soilEleCondSatPas	Number	Electrical conductivity of saturated paste	Optional
soilBulDen	Number	Bulk density	Optional
soilCoarseFrag	Number	Coarse fragments (vol.%)	Optional
soilSandMass	Number	Sand (mass%)	Optional
soilSiltMass	Number	Silt (mass%)	Optional
soilClayMass	Number	Clay (mass%)	Optional
refmanagementZone	Relationship	Relationship to the Management zone ID	Mandatory

3.3.6. Crop Instance

Crops will develop in several areas, for several times. Crop Instance is related to crop type, and each time it will be updated with data about that instance that is expect for the SWAMP to be applied in the field. This entity correlates data related to a certain instance of the crop type during a season which is growing in a management zone.

TABLE 17 - CROP INSTANCE ENTITY

Attribute Name	Attribute Type	Description	Constraint
Name	Normative References: https://schema.org/name	Name given to the crop with variety	Optional
refManagmentZone	Relationship	Relationship to the the management zone Zone ID	Mandatory
totalWaterSeason	Number	how much water SWAMP delivered during the whole season. Default unit: mililitters (mm)	Mandatory
totalCropDays	Number	Total crop days in the season	Mandatory
devDays	Number	how may days since seeding. Default unit: days – see https://schema.org/durationOfWarranty - number is feasible to use for quantitative values.	Mandatory
H2ORequiredMin	Number	Minimum amount of water that SWAMP has to provide for this crop instance	Mandatory
H2ORequiredMax	Number	Maximum amount of water that SWAMP has to provide for this crop instance	Mandatory

3.3.7. Water Distribution Network

A water distribution network entity is used in order to be a main source to the relationships to the elements that compose the irrigation system.

TABLE 18 - WATER DISTRIBUITION NETWORK

Attribute Name	Attribute Type	Description	Constraint
location	geo:json	Location of the irrigation system (farm location) Representation by a GeoJSON geometry. (https://tools.ietf.org/html/rfc7946)	Mandatory

3.3.8. Irrigation system

An irrigation system entity is used in order to define the irrigation system type and its components by been a central entity to the relationships for each element that can have a relationship to this entity.

TABLE 19 - IRRIGATION SYSTEM ENTITY

Attribute Name	Attribute Type	Description	Constraint
refManagementZone	Relationship	A reference to the management zones irrigated by this Irrigation system	Mandatory
irrigationType	Text	The type of this system can be sprinkler, drop, central pivot...	Mandatory
MaxFlowRate	Number	Indicates the maximum flow rate to the whole irrigation system	Mandatory

3.3.9. Water Node

A water node is the core element of a Water Distribution Network. It could be the source of water, an output or an element of conjunction between different Water Connections.

TABLE 20 - WATER NODE ENTITY

Attribute Name	Attribute Type	Description	Constraint
location	geo:json	Location of the water node. (https://tools.ietf.org/html/rfc7946)	Mandatory
in	Relationship	Input water connections	Mandatory
out	Relationship	Output water connections	Mandatory
refWaterDistribuitionNetwrok	Relationship	Relationship to the Water Distribuition network ID	Mandatory

3.3.10. Gate

A door, valve, or other device for controlling the passage especially of a fluid

TABLE 21 - GATE ENTITY

Attribute Name	Attribute Type	Description	Constraint
location	geo:json	Location of the water node. (https://tools.ietf.org/html/rfc7946)	Mandatory
position	Number	Indicates the gate position between open and close	Mandatory
in	Relationship	Input water connections	Mandatory
out	Relationship	Output water connections	Mandatory
refWaterDistribuitionNetwrok	Relationship	Relationship to the Water Distribuition network ID	Mandatory

3.3.11. Water Connection

A water connection is a physical connection between water nodes.

TABLE 22 - WATER CONNECTION ENTITY

Attribute Name	Attribute Type	Description	Constraint
location	geo:json	Location and the shape of this water connection. (https://tools.ietf.org/html/rfc7946)	Mandatory
start	Relationship	A reference of the water node where this connection starts	Mandatory
end	Relationship	A reference of the water node where this connection ends.	Optional
refWaterDistribuitionNetwrok	Relationship	Relationship to the Water Distribution network ID	Mandatory

3.3.12. Pipe

A pipe is a water connection between valves, and it is used in order to create a better understanding of the irrigation system.

TABLE 23 - PIPE ENTITY

Attribute Name	Attribute Type	Description	Constraint
location	geo:json	Location and the shape of this water connection. (https://tools.ietf.org/html/rfc7946)	Mandatory
start	Relationship	A reference of the water node where this connection starts	Mandatory
end	Relationship	A reference of the water node where this connection ends.	Optional

refWaterDistribuitionNetwrok	Relationship	Relationship to the Water Distribution network ID	Mandatory

3.3.13. Channel

A channel is a water connection between water nodes, and it is used in order to better describe the water distribution network.

TABLE 24 - CHANNEL ENTITY

Attribute Name	Attribute Type	Description	Constraint
location	geo:json	Location and the shape of this water connection. (https://tools.ietf.org/html/rfc7946)	Mandatory
start	Relationship	A reference of the water node where this connection starts	Mandatory
end	Relationship	A reference of the water node where this connection ends.	Optional
refWaterDistribuitionNetwrok	Relationship	Relationship to the Water Distribution network ID	Mandatory

3.4. Digital entities in SWAMP

3.4.1. Weather Forecast

The SWAMP will use the weather forecast data model available in the GSMA Mobile Alliance website. This data model was already adopted by FIWARE community. Such data model will be used by both Weather Forecast Services and Local Weather Station data, since some pilots have their own weather station.

The data model below is a copy of Weather forecast data model defined in FIWARE data model website [12]. There is an ID from the place we have the weather forecast. This ID in the entity itself, and there is no other entity to correlate weather with farm. Such ID (first parameter) must be related to the farm – ID from FARM.

TABLE 25 - WATHER FORECAST ENTITY

Attribute Name	Attribute Type	Description	Constraint
location	geo:json	Location of the weather station .Representation by a GeoJSON geometry. (https://tools.ietf.org/html/rfc7946)	Mandatory
Address	String	Civic address of the weather station	Mandatory if location is not presented
refPointOfInterest	PointOfInterest	A reference to a point of interest associated to this Weather Station	Optional
dateRetrieved	DateTime	The date and time the forecast was retrieved in ISO8601 UTC format.	Mandatory

dateIssued	DateTime	The date and time the forecast was issued by the meteorological bureau in ISO8601 UTC	Mandatory
Validity		Includes the validity period for this forecast as a ISO8601 time interval. As a workaround for the lack of support of Orion Context Broker for datetime intervals, it can be used two separate attributes: validTo and validFrom	Mandatory
validFrom	DateTime	Validity period start date and time	Optional
validTo	DateTime	Validity period end date and time	Optional
source	Text or URL	A sequence of characters giving the source of the entity data	Optional
weatherType	Text + Allowed values	T The forecasted weather type. Allowed values: A combination of (clearNight,sunnyDay, slightlyCloudy, partlyCloudy, mist, fog, highClouds, cloudy, veryCloudy, overcast, lightRainShower, drizzle, lightRain, heavyRainShower, heavyRain, sleetShower, sleet, hailShower, hail, shower, lightSnow, snow, heavySnowShower, heavySnow, thunderShower, thunder).	Optional
visibility	Text	One of (VeryPoor, poor, moderate, good, veryGood, excellent)	Optional
temperature	Number	Air's temperature forecasted	Optional
feelsLikeTemperature	Number	Feels like temperature forecasted	Optional
relativeHumidity	Number	Air's relative humidity observed (percentage expressed in parts per one)	Optional
precipitationProbability	Number	The probability of precipitation, expressed as a number between 0 and 1	Optional
windDirection	Number	The wind direction expressed in decimal degrees compared to geographic North (measured clockwise), encoded as a Number.	Optional
windSpeed	Number	The observed wind speed in m/s, encoded as a Number.	Optional
atmosphericPressure	Number	The atmospheric pressure observed measured in Hecto Pascals.	Optional
solarRadiation	Number	The solar radiation observed measured in Watts per square meter.	Optional
illuminance	Number	the illuminance observed measured in lux (lx) or lumens per square meter (cd-sr-m-2)	Optional

dayMinimum	StructuredValue	Minimum values forecasted fo the reported period	Optional
dayMaximum	StructuredValue	Maximum values for the reported period	Optional
uvIndexMax	Number	The Maximum UV index for the period, based in the World Health Organization's UV index measure.	Optional

GSMA IoT Big Data harmonized data model 5.0, June 2018 – Weather Forecast model, Weather observed.

3.4.2. Water need estimate

Water need estimate is an entity used in order to store information about the water estimate based on algorithms that are better described in WP3.

TABLE 26 - WATER NEED ESTIMATE ENTITY

Attribute Name	Attribute Type	Description	Constraint
dateRetrieved	DateTime	The date and time the data was retrieved by the water estimation application	Mandatory
dateIssued	DateTime	The date and time water need estimation was issued by the in ISO8601 UTC format	Mandatory
validFrom	DateTime	Includes the validity period for this estimation as an ISO8601 time interval.	Optional
validTo	DateTime	Includes the validity period for this estimation as an ISO8601 time interval.	Optional
source	Text	A sequence of characters giving the source of the entity data	Optional
dayMinimum	Structured Value	Values for the minimum amount of water used in irrigation for a day	Optional
dayMaximum	Structured Value	Values for the maximum amount of water used in irrigation for a day	Optional
generateIrrigationRec	Relationship	Relationship to the Irrigation Recommendation ID	Mandatory

3.4.3. Irrigation plan

The irrigation plan is generated considering water availability and irrigation constrains. In top of water recommendations that are ideal scenarios for each management zone.

TABLE 27 - ENTITY PLAN ENTITY

Attribute Name	Attribute Type	Description	Constraint
validFrom	DateTime	Indicates the start time to the irrigation plan	Mandatory
validTo	DateTime	Indicates the end time to the irrigation plan	Mandatory
refManagmentZone	Relationship	Relationship to the management zone related to this plan.	Mandatory

refIrrigationSystem	Relationship	Relationship to the Irrigation system that is going to execute this plan	Mandatory

3.4.4. Irrigation Recommendation

The recommendation is generated by the Water Need models and represent the ideal irrigation, without consideration of water availability and irrigation system constrains.

TABLE 28 - IRRIGATION RECOMENDATION ENTITY

Attribute Name	Attribute Type	Description	Constraint
validFrom	DateTime	Indicates the start time of this irrigation	Mandatory
validTo	DateTime	Indicates the end time of this irrigation	Mandatory
waterVolume	Number	The amount of water which should be supplied to the management zone	Mandatory
refIrrigationPlan	Relationship	Relationship to the irrigation plan ID	Mandatory

3.4.5. Crop Type

The crop type entity contains information for the development stages of the particular crop in the farms. Since in the beginning the SWAMP platform will use development stage of each kind of crop according to FAO[11] definition.

There are several kind of crop types, development stages, water needs and evapotranspiration. The information to populate datasets could be found in this FAO's website as well, but, in the future, SWAMP model will take into consideration the seed variety, which may be different from FAO's website. Model could be completed with information about nutrients, colours, aspect of the plant, etc. that are not defined at this point but could be extended in this entity.

TABLE 29 - CROP TYPE ENTITY

Attribute Name	Attribute Type	Description	Constraint
Name	Normative References: https://schema.org/name	Name given to the crop with variety	Optional
dateRetrieved	DateTime	The date and time the forecast was retrieved in ISO8601 UTC format	Mandatory
dateIssued	DateTime	The date and time the forecast was issued by the meteorological bureau in ISO8601 UTC format	Mandatory
totalWaterSeasonMin	Number	how much water (min.) will be needed to the whole season. Default unit: millilitres (ml)	Mandatory
totalWaterSeasonMax	Number	how much water (max.) will be needed to the whole season. Default unit: millilitres (ml).	Mandatory
totalDays	Number	To crop development according to the region	Mandatory

CropGrowPeriods	ImageObject	picture to recognize the crop development. http://www.fao.org/land-water/databases-and-software/crop-information/cotton/en/) for example	Optional
devInitialDays	Number	how many days since seeding	Mandatory
devInitialDaysH2OMin	Number	how much water is needed min. It changes according to the region	Mandatory
devInitialDaysH2OMax	Number	how much water is needed in the beginning of the crop max. It changes according to the region	Mandatory
devInitialRootDepth	Number	Depth of the roots (area to be monitored) in the beginning of the crop development	Optional
devInitialKc	Number	Kc in the beginning of the crop. It changes according to the region	Optional
devInitialKy	Number	Ky in the beginning of the crop. It changes according to the region	Optional
devCropDevDays	Number	how many days since the end of initial dev. stage. Default unit: days – see https://schema.org/durationOfWarranty - number is feasible to use for quantitative values	Mandatory
devCropDevH2OMin	Number	how much water is needed min. It changes according to the region	Mandatory
devCropDevH2OMax	Number	how much water is needed max. It changes according to the region	Mandatory
devCropDevRootDepth	Number	Depth of the roots (area to be monitored) in the dev. of the crop development	Optional
devCropDevKc	Number	Kc in the dev of the crop. It changes according to the region	Optional
devCropDevKy	Number	Ky in the dev of the crop. It changes according to the region	Optional
devMidSeaDays	Number	how many days since end of Crop Development stage	Mandatory
devMidSeaH2OMin	Number	how much water is needed min. It changes according to the region	Mandatory
devMidSeaH2OMax	Number	how much water is needed max. It changes according to the region	Mandatory
devMidSeaRootDepth	Number	Depth of the roots (area to be monitored) in the mid-season of the crop development	Optional
devMidSeaKc	Number	Kc in the mid-season of the crop. It changes according to the region	Optional
devMidSeaKy	Number	Ky in the mid-season of the crop. It changes according to the region	Optional

devLateDays	Number	how many days after the end of MidSeason stage	Mandatory
devLateH2OMin	Number	how much water is needed min. It changes according to the re	Mandatory
devLateH2OMax	Number	how much water is needed max. It changes according to the region	Mandatory
devLateRootDepth	Number	Depth of the roots (area to be monitored) in the late season of the crop development	Optional
devLateKc	Number	Kc in the late season of the crop. It changes according to the region	Optional
devLateKy	Number	Ky in the late season of the crop. It changes according to the region	Optional

3.4.6. Multispectral camera

it is important to have a way to easily locate the images collected by the drone and the data that correspond to the analysis of this images. In the Italian pilot, images are acquired by a multispectral camera RedEdge (https://www.micasense.com/rededge-mx) and the processed by the Pix4d software (https://www.pix4d.com/) to calculate the Leaf Area Index (LAI). The image format is 16 bits RAW TIFF and meta-data includes day and time, geo-location (latitude, longitude and height over the ground) and heading.

TABLE 30 - MULTISPECTRAL CAMERA ENTITY

Attribute Name	Attribute Type	Description	Constraint
Name	Normative References: https://schema.org/name	Name given to the Multispectral camera	Optional
image	URL	Indicates the URL to the images capture by the camera	Mandatory
ndvi	URL	Indicates the result image with the NDVI colour scheme	Mandatory
lai	number	Indicates the leaf area index by a number	Mandatory
RefManagementZone	Relationship	Relationship to the management zone entity ID	Mandatory

4. SWAMP ontology

The SWAMP IoT baseline includes FIWARE (see Section 2.1) and thus it inherits the FIWARE data model that is going to be aligned with the ETSI NGSI-LD specifications [6] which allows to represent and retrieve context data according to a meta-model grounded on RDF/RDFS. Moreover, the SWAMP platform includes SEPA (see Section 2.2) to create a data bridge with the Linked Open Data cloud [2]. This solution makes it possible the integration of FIWARE and Linked Data ecosystems, granting the Linked Data agents and services to interact with FIWARE using the Linked Data standard protocols and formats provided by SEPA (e.g., SPARQL 1.1 protocol [3], SPARQL 1.1 Query language [4] and SPARQL 1.1 Update language [5]). On the other hand, FIWARE benefits from the interoperable data sources made available through the Linked Open Data cloud.

Because of that, the SWAMP ontology has been framed within the ontology proposed by NGSI-LD [6]. Figure 9 gives an overview of the ontologies and vocabularies used for the development of the SWAMP ontology.

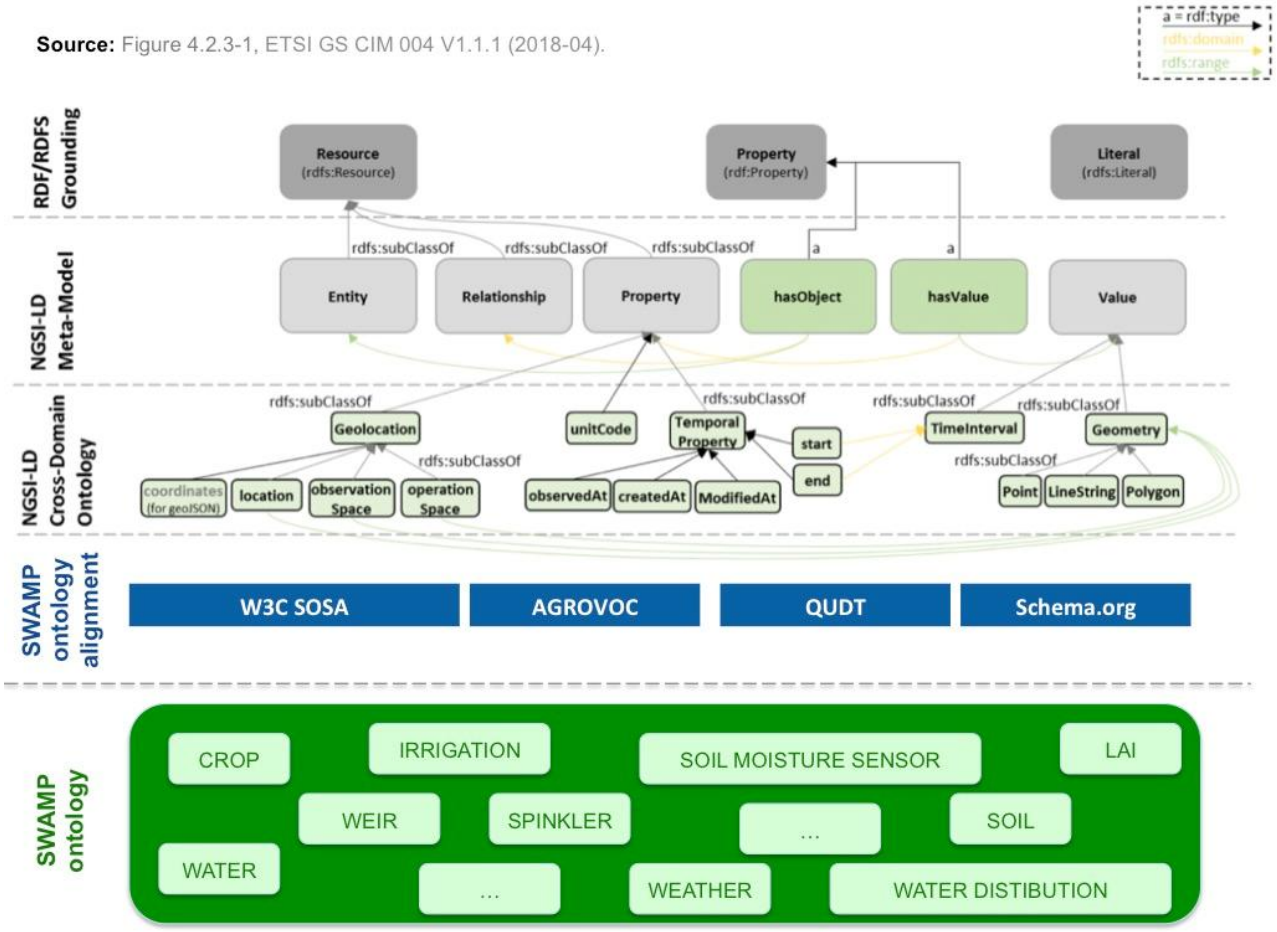


FIGURE 9 - SWAMP ONTOLOGY IS ALIGNED WITH THE NGSI-LD, SOSA, AGROVOC, QUDT AND SCHEMA.ORG ONTOLOGIES AND VOCABULARIES

In particular, the ontology is based on the following ontologies and vocabularies:

- NGSI-LD [6]: the ontology is layered in two parts: a meta-model and a cross-domain ontology (see Figure 3). The meta-model includes the following concepts: Entity, Relationship, Property and Value. The NGSI-LD meta-model representation reflects and extends the Entity-Relationship model (i.e., a relationship can be linked to another relationship, relationships may have properties). The NGSI-LD meta-model takes the form of a property graph [19], in contrast with the RDF graph model grounding Linked Data.

- QUDT [18]: it provides semantic specifications for units of measure, quantity kind, dimensions and data types. QUDT can be adopted to represent physical data values (i.e., which require a unit of measure) as an alternative to the NGSI-LD unitCode. In fact, NGSI-LD suggests the use of Recommendation No. 20 - Codes for Units of Measure Used in International Trade [18] by UNECE which defines a string code for each unit of measure. If, on the one hand, this approach could simplify the application development, on the other hand it could limit the interoperability of data values. Because of that, all the data values that should be shared as Linked Open Data are suggested to be represented using the QUDT ontology.

- SSN/SOSA [19]: the W3C Semantic Sensor Network (SSN) ontology has been adopted to represent all the typical concepts of an IoT application which are independent from the specific agricultural domain. SSN includes a lightweight and self-contained core ontology named SOSA (Sensor, Observation, Sample, Actuator) which includes a set of common classes (e.g., Sensor, Actuator, Observation, Sample, Platform, Procedure, Result) and properties (e.g.,hasResult, hasSample, observes, hosts).

- AGROVOC [9]: it is the reference vocabulary developed by FAO for all the agriculture related terms and it provides also a Linked Data interface . All the URIs of entities and properties which refer to agricultural specific concepts (e.g., Leaf Area Index) have been aligned by means of the rdfs:isDefinedBy property with the corresponding URI of AGROVOC (e.g., http://aims.fao.org/aos/agrovoc/c_35196).

- Schema.org [10]: for all the concepts that are not specific to the agricultural and IoT domains, the SWAMP ontology refers to Schema.org (e.g., Person, Place, Organization).

5. Examples

This section presents some examples about how to develop virtual entities in SWAMP platform and how a virtual entity is described in the SWAMP ontology.

5.1. Soil Probe Example

Virtual entity of Soil Probe that provides soil and atmospheric measurements from three layers of soil as well as ground level atmosphere. Entity has tributes that it provides.

TABLE 31 - SOIL PROBE ENTITY EXAMPLE

Attribute Name	Attribute Type	Description	Constraint
Layer1 Humidity	Float	Provides pre-calibrated soil volumetric water content measurement (VWC) as floating point percentage from 5cm depth	Mandatory
Layer1 Raw Humidity	Integer	Raw ADC reading of the soil moisture sensor. Provides raw 16-bit reading to facilitate post measurement calibration from 5cm depth	Mandatory
Layer2 Humidity	Float	Provides pre-calibrated soil volumetric water content measurement (VWC) as floating point percentage	Mandatory
Layer2 Raw Humidity	Integer	Raw ADC reading of the soil moisture sensor. Provides raw 16-bit reading to facilitate post measurement calibration from 10cm depth	Mandatory
Layer3 Humidity	Float	Provides pre-calibrated soil volumetric water content measurement (VWC) as floating point percentage from 15cm depth	Mandatory
Layer3 Raw Humidity	Integer	Raw ADC reading of the soil moisture sensor. Provides raw 16-bit reading to facilitate post measurement calibration from 15cm depth	Mandatory

Layer1 Temperature	Float	Temperature of soil at 5cm depth in Celsius degrees	Mandatory
Layer2 Temperature	Float	Temperature of soil at 10cm depth in Celsius degrees	Mandatory
Layer3 Temperature	Float	Temperature of soil at 15cm depth in Celsius degrees	Mandatory
Soil Resistance	Float	Resistance of the soil in 10cm depth measured as Ohms measured with 3.3V	Mandatory
Air Temperature	Float	Temperature of ambient air at surface inside the sensor casing as Celsius degreed	Mandatory
Air Pressure	Float	Air pressure as kilo Pascal	Mandatory
Battery Voltage	Float	Battery voltage of the sensor as Volts	Mandatory

5.2. Weather station example

Libellium [15] commercial agriculture sensors provide number of measurements that measure soils and atmospheric parameters. Libelium sensor is defined as set of devices which send data irregularly to each other

TABLE 32 - WEATHER STATION ENTITY EXAMPLE

Attribute Name	Attribute Type	Description	Constraint
Waspmote Battery	Integer	Libelium Waspmotes have set of sensors attached to aggregator device that has independent battery and solar panel. Battery level is provided as percentage	Mandatory
Waspmote Soil Temperature	Float	Soil temperature measurement from soil temperature probes as Celsius degrees	Mandatory
Waspmote Soil Moisture	Float	Soil moisture as hydrostatic tension measured as millibars	Mandatory
Waspmote Wind Direction	String	Libelium weather station observed wind direction with 16 direction scale (N,NNE, NE, ENE, E, ESE, SES, S, SWS, SW, WSW, W, WNW, NW, NNW)	Mandatory
Waspmote Wind Speed	Float	Libelium weather station wind speed as meters per second	Mandatory
Waspmote Rain Gauge 1	Float	Liblium weather station pluviometer current sum of the mm of rain during the interval period (15min)	Mandatory
Waspmote Rain Gauge 2	Float	Liblium weather station pluviometer current sum of the mm of rain during the last hour	Mandatory

Waspmote Rain Gauge 3	Float	Liblium weather station pluviometer current sum of the mm of rain during the last 24 hours	Mandatory
Waspmote Air Humidity	Float	Libelium air humidity measurement as relative humidity in percentage	Mandatory
Waspmote Air Pressure	Float	Libelium barometric pressure in kilo pascals	Mandatory
Waspmote Air Temperature	Float	Air temperature in Celsius degrees	Mandatory

Entity has an extensive large number of attributes that are measured simultaneously. Even if value of some attribute is not sent because it has not changed, same timestamp that applies for the updated attribute applies also for the not updated ones.

5.3. JSON-LD description of the observation made by a soil sensor according to the SWAMP ontology

The vocabulary presented in Section 4 can be used to describe in a more formal language the entities presented in Section 3. The following example describes a soil moisture measurement (i.e.,75%) of a field (i.e., urn:ngsi-ld:Field:030885) made by a sensor (i.e., urn:ngsi-ld:MoistureSensor:131074). According to SOSA, the central element is an Observation (i.e., urn:ngsi-ld:Observation:458923) which links the feature of interest (i.e., the field), the observed property (i.e. the moisture) and the sensor that made the Observation (i.e. urn:ngsi-ld:MoistureSensor:131074). In the example, an instance of Observation (i.e. urn:ngsi-ld:Observation:458923) is linked with a sensor instance using the property sosa:madeBySensor, while the object of the observation is expressed using sosa:observedProperty. From the value of this property (i.e. swampSoilMoisture) it can be inferred that the instance is a measurement of the soil moisture. Finally, the property sosa:FeatureOfInterest relates the observation with the object that has been observed (i.e. the field urn:ngsi-ld:Field:030885).

```
{
    "@context": {
        "swamp": "http://swamp-project.org/ontology/swamp#",
            "ngsi-ld": "http://uri.etsi.org/ngsi-ld/",
                "qudt": "http://qudt.org/schema/qudt#",
                    "qudt-unit": "http://qudt.org/vocab/unit#",
                        "rdfs": "http://www.w3.org/2000/01/rdf-schema#",
                            "sosa": "http://www.w3.org/ns/sosa/"
    },
    "@graph": [{
        "@id": "swamp:Field",
        "rdfs:subClassOf": ["ngsi-ld:Entity", "sosa:FeatureOfInterest"]
    }, {
        "@id": "swamp:Measure",
        "rdfs:subClassOf": ["ngsi-ld:Value", "qudt:QuantityValue"]
    },
    {
        "@id": "swamp:SoilMoisture",
        "@type": "sosa:ObservableProperty"
    }, {
        "@id": "urn:ngsi-ld:Field:030885",
        "@type": "swamp:Field"
    },
    {
        "@id": "urn:ngsi-ld:MoistureSensor:131074",
        "@type": ["ngsi-ld:Entity", "sosa:Sensor"]
    },
    {
        "@id": "urn:ngsi-ld:Observation:458923",
        "@type": ["ngsi-ld:Entity", "sosa:Observation"],
        "sosa:hasFeatureOfInterest": {
            "@type": "ngsi-ld:Relationship",
            "nsgi-ld:hasObject": "urn:ngsi-ld:Field:030885"
        },
        "sosa:observedProperty": {
            "@type": "ngsi-ld:Property",
            "nsgi-ld:hasValue": "swamp:SoilMoisture"
        },
        "sosa:madeBySensor": {
            "@type": "ngsi-ld:Relationship",
            "nsgi-ld:hasObject": "urn:ngsi-ld:SoilProbe:131074"
        },
        "sosa:hasResult": {
            "@type": "ngsi-ld:Property",
            "nsgi-ld:hasValue": {
                "@id": "swamp:Measure:673412",
                "@type": "swamp:Measure",
                "qudt:numericValue": 75,
                "qudt:unit": {
                    "@id": "qudt-unit:Percent",
                    "@type": "qudt:CoutingUnit"
                }
            }
        }
    }
```

FIGURE 10 - SOIL SENSOR JSON-LD EXAMPLE

6. Summary

This report describes the virtual entities and data structures that compose the SWAMP platform data storage specification. In this document it is proposed entity representations for the SWAMP specific IoT Resources such as sensors for soil moisture and water levels, elements for irrigation and distribution systems, and drones and their sensors such as multispectral camera. The document also specifies the entities, their purposes and data model, gives short descriptions of reference implementations of respective IoT Services and gives links to their open source implementations.

The parameters depicted in each virtual entity were defined according to literature and evaluation of sensors, drone data; and at the same time parameters were organized to fit what it will be necessary to be used in artificial intelligence algorithms from WP3. All parameters and ontology are defined in open standards in order to be used by any SWAMP platform component.

The virtual entity definitions are the basis of the development of deliverable 2.1 in which scripts and definitions about how to implement them in SWAMP platform are depicted.

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