RAINBO

Comune di Bologna

lepida spa

arpae emilia-romagna

NIER INGEGNERIA

MEEO Meteorological Environmental Earth Observation

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Document Summary

The present document summarizes the results of the RainBO project concerning the task "RainBO Platform Architecture" of the Action C3.
The purpose of the Action C3 is the study, design and implementation of the prototype of RainBO software platform starting from the requirements resulted as outcome of the Action C1 and provided in the deliverables "Collection of user needs and review of the state of the art" and "RainBO specification of requirements".
In particular, the Task1 of the Action C3 aims at designing the architecture of RainBO platform in terms of:

- Databases: Monitoring DB, Territorial DB, Historical DB

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- Conventional monitoring systems: rain gauges, water level gauges, radar
- Non conventional monitoring systems: Rainlink4EMR module, App Crowd Source
- Forecast data: hydrological response for medium and large (Random Forest) basins, meteorological modeling Cosmo-Lami
- Water balance data: WHC
- Sensornet WebServices
- Business software modules: vulnerability, data mining, scenarios analysis
- GUI: ON-LINE and OFF-LINE capability

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1. Introduction

The RainBO platform consists of the following key elements:

1. database containing monitoring, territorial and historical data
2. software modules, which are the platform intelligence
3. graphic interface, which is the platform output

One of the most important element of the platform is the database containing the monitoring data, whose functionality is to integrate data collected from different monitoring infrastructures, both conventional and unconventional, as well as forecast data, hydrological and meteorological models, and estimated ones. Moreover, the territorial database hosts data from the processing of the application modules, which constitute the output used by the graphic interface.

The RainBO platform architecture has been designed according to the following attributes:

- open: each module will expose standard interfaces (web services) in order to ensure system generality and replicability as well as interoperability and integration with other platforms.
- centralized: each DB will be centralized and will enable sharing of data, managed and updated by different users.
- scalable: each module will be developed so as to be implemented on different machines.
- modular: the platform will be formed by individual modules ensuring more flexibility, maintainability over time, as well as platform evolution, since each module can evolve or be replaced independently from each other.
- configurable: each module will be configurable, i.e. the operating parameters must be read from the table and not written in code.

The purpose of this document is the description of the RainBo platform architecture, understood as a description of the various components and especially of their mutual interactions, while its functionality is described in detail in the deliverable "RainBO-Specification_of_requirements_002nier.pdf"

2. RainBO Architecture

The architecture on which the RainBO platform consists of the following main components:

1. **Databases**: RainBO platform allows the integrated use of different data, including data acquired from the monitoring infrastructures, territorial data, data related to past occurrences and data coming from hydrological simulation models. The integrated use of data is an innovative issue in the architecture.
   - **Monitoring DB:** RainBO Monitoring DB matches with the Sensornet platform database and the Emilia-Romagna region IoT platform database, made up of thousands items over all the territory.
     The platform collects real-time sensor measurements and it dispatches automatic alerts in case of critical conditions such as thresholds overpassing or rapidly evolving phenomena.
   - **Territorial DB:** the Territorial DB contains basic regional maps (such as river basins), hazard maps from the Floods Directive (2007/60/EC), and territorial data at the municipality level (like hospitals, schools, emergency areas etc.). The Territorial DB also contains the maps resulted from the business modules elaborations of RainBo platform (like vulnerability maps and risk maps). The maps are in both vector and base raster format.
   - **Historical DB:** the data of the historical events are one of the source for the data mining module. This database contains significant variables of past events, such as hydrometric levels, precipitation and, where available, related damages.

2. **Conventional monitoring systems**: one of the basic components of the RainBO platform monitoring infrastructure is the conventional monitoring systems module. Among others, it hosts Arpae hydro-pluviometric stations and radar. The upgrade of the monitoring infrastructure for the Ravone creek test case will consist of a new rain gauge in the catchment and a new water level gauge in addition to the existing one.
   - **Rain gauges**
   - **Water level gauges**
   - **Radar**

3. **Non-conventional monitoring systems**: in addition to traditional systems, the RainBO platform monitoring infrastructure hosts an innovative technology based on commercial cellphone communication microwaves links and also in a crowd-sourcing application:
   - **Rainlink4EMR module**: a rainfall monitoring system based on microwave links data provided by telecommunication operators.
   - **Crowdsource Application**: a crowdsource application collecting and visualizing information regarding the observed present weather from citizens, in a smart and intuitive manner. The app was created thanks to a strong networking activity with the RMAP project..

4. **Forecast data:** the management of extreme rain events cannot rely only on real time monitoring systems, whether conventional or non-conventional, but it must also include forecasting systems:
   - **Forecast hydrological response of basins to heavy-rains**:
     i. **for small basins**: the algorithm is calibrated on historical and scenarios data computed by means of **Criteria 3D model** and produces a distribution of forecast of the maximum level of the creek at the water level measure point (typically the entry of the culvert). Input are: current condition of soil moisture (WHC), observed and forecast precipitation.
     ii. **for medium and large basins: Random Forest**, hydrological statistical model able to forecast the probability of exceeding the three alert thresholds fixed for the main rivers of

Emilia-Romagna: Warning (threshold 1), Pre-alarm (threshold 2), Alarm (threshold 3) at the water level measure point, in the next 6-8 hours.

- **Meteorological Modeling Cosmo-Lami**: the data, provided in grid format, GRIB, with a spatial resolution at 7 km and 2.8 km and temporal validity of three and two days, respectively, contain forecast for various meteorological parameters, including one hour or three-hour precipitation forecast.

5. **Water balance data**
    - **WHC (Water Holding Capacity):** the WHC index provides the maximum amount of water the soil can hold, given the current conditions of soil moisture. It is one of the input parameters to identify the hydrological scenario for small basins. The WHC index for the Ravone creek test case is daily estimated through a mono-dimensional restriction of the Criteria3D water balance model and it is calculated on the first 35 cm of soil. It becomes zero when the soil is above the field capacity and is no longer able to retain water. To compute this index, the model uses as input soil, crop and weather data (temperature and precipitation) that Arpae collects for all the Emilia-Romagna region. The use of one estimated value instead of the measured ones of soil moisture has the advantage that it can be estimated on all the similar catchments of the region and it is not affected by sensor lacking or failures and local peculiarity.

6. **Sensornet WebServices:** all issues related to sensor configuration, data acquisition, and standardization are resolved within the Sensornet platform, which exposes the data from sensors, real and virtual, punctual and gridded, through standard webservices:
    - WMS by Open Geospatial Consortium, for grilled data
    - SensornetAPI by RainBO project, for punctual data

7. **Business software modules:**
    - **vulnerability:** the vulnerability module calculates the degree of vulnerability of exposed items (schools, hospitals, stations, etc.) over flood events. Vulnerability is a component used for the risk scenarios calculation and it can be defined as the possibility of a territory to be affected by emergencial scenarios related to the entity of damages. Vulnerability will take into account the presence of sensible targets in the territory, such as:
        - population (considering different ages ranges and the percentage of disabled people);
        - public and private places such as as schools, hospitals, commercial centers, cinemas, theatres, etc. (considering their opening times: day, night, weekend, etc.)
        - governments and legal Institutions such as institutional offices, cultural heritages, civil protection areas, etc.
        - targets that could develop a domino effects (NAT-TECH) such as establishments that could be affected after a major accident, thermoelectric power plants, incinerators, purifiers, electricity networks, etc.

    Concerning the correlations between historical series, real-time and forecasting data, data mining module will be defined in order to manage these information and, with a statistic analysis, in order to produce the probability of reaching a certain river threshold level. Data mining algorithm will be developed by MEEO with the support of ARPAE.

The output of Data mining module will be used as input in Scenarios Analysis module in order to combine the threshold level to the flood areas. By overlapping these flood areas with the vulnerability maps, the user can be visualized the risk referring scenarios.

- **data mining:** the data mining module has the primary task of identifying possible correlations between historical series, real-time and forward-looking monitoring data and supporting the identification of more likely scenarios.
- **scenarios analysis:** the scenario analysis module provides the most likely expected scenarios to historical events collected in HistoricalDB.

8. **GUI:** the GUI allows graphic interaction between users and implemented databases and software modules, through an integrated Geographic Information System, able to visualize geographic maps e spatial information, and interfaces to insert and update data stored in the Data Bases.
    - **Early-warning module - ON-LINE capability**: the early warning module is able to recognize and to report in advance a critical scenario.
    - **Planning support module - OFF-LINE capability:** it is the support module for territorial planning through visualization and consultation of spatial data, vulnerability, hazard and risk maps.

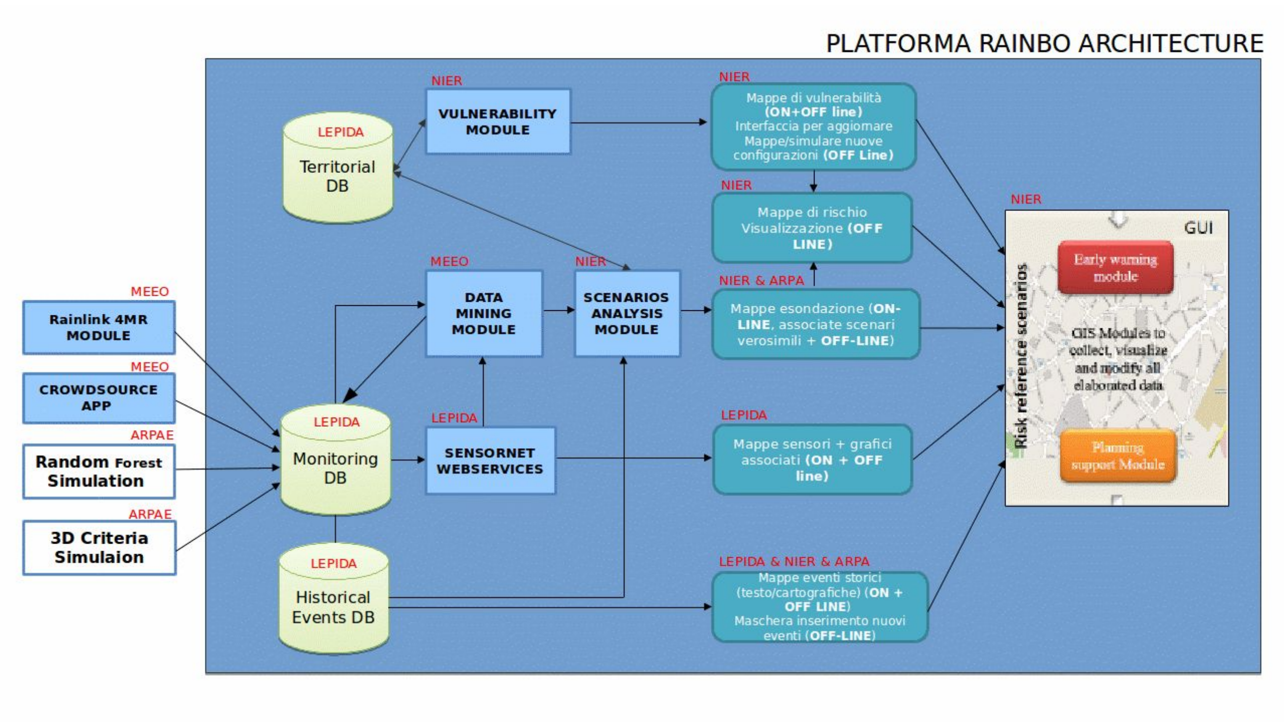

Figure A: RainBO Platform Architecture

2.1. Databases

2.1.1. Monitoring DB

Sensornet platform DB forms the Monitoring DB of RainBO Platform.

Sensornet integrates different types of monitoring data coming from different monitoring infrastructures and systems:

1. Conventional monitoring infrastructures
   - rain gauges
   - water level gauges
   - radar
2. Non - conventional monitoring infrastructures
   - Rainlink4EMR module
   - Crowdsource Application
3. Forecast data:
   - hydrological statistical model for medium and large rivers (Random Forest)
   - precipitations from meteorological modeling (LAMI)
4. Estimated data
   - WHC (Water Holding Capacity)

Sensors integrated in Sensornet platform are usually physical sensors (such as rain gauges and water level gauges) installed on the regional area and transmitting accurate measurements of physical variables sampled at a predetermined rate. There are many, however, “virtual sensors” introduced to manage data not related to physical measures, such as rivers level or amount of rainfall, but to their estimated values or their forecast. The objective “virtual” clarifies that they are not real, while the name “sensor” enables to borrow the descriptive data model of the real ones, constituted by the geographic coordinates, the typology and the data, which do not derive from physical measures, but from mathematical and/or statistical models and are not in real time, but forecast (Nanni, S and Mazzini, G, 2018, February. Sensornet Early-Warning System Integration, Sensornets 2018: 6th International Conference on Sensor Networks).

There are other kinds of grid-type measurements as well, such as radar measurements. They do not refer to a precise geographic point but rather to a set of cells covering the regional territory overall, or part of it as in the case of the microwaves module maps.

Spot measurements are displayed as a two-dimensional value / time chart. Grid measurements can also be displayed in the same way, by representing every cell of the grid as a "virtual" sensor located on the "centroid" of each cell. From the physical point of view, grid measurements considered as “virtual” sensors located in the centre of the grid itself makes sense in case of monitoring high hydro-geological risk areas, as in the case of the Ravone cell. More generally, the grid size display is made with a color-coded map showing the levels of variable of interest on all grid cells that form the territory map.

Spot measurements are configured within Sensornet through geo-referred sensors at the measuring point and through tables describing the type and the associated measurements. Grid measurements are also configured by sensors, but in this case the coordinate value does not match with a geographic point of view, but with the top leftmost point of the map. Maps are associated with a classified "map" table, which is different from those used for the configuration of point sensors. It contains all relevant information to describe the maps themselves (see Annex 1 - MonitoringDB Data Model).

The integration of data coming from different monitoring systems in Sensornet is realized through a federated approach that preserves the investments made on already existing systems and protects the technical, technological and organizational autonomy of the individual systems and of their owners. The architecture implemented in Sensornet platform provides an interconnection middleware between different data sources and central system, acting as a data collector from different sources and a data normalizer towards the central system, as shown in Figure 1.

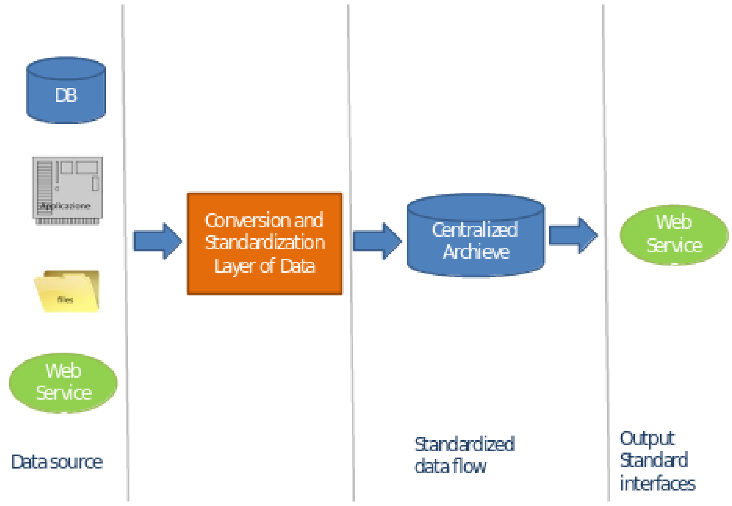

Figure 1: data flow within Sensornet: collection, standardization and storage and access of the data

The middleware consists of a series of atomic modules for data retrieval from individual sources and of their manager, which oversees their activation and coordination. Each module contains the access rules and the required commands for retrieving data from a specific source or database and to store them in a standard format on the centralized database. A standardization process has to be carried out to acquire data from heterogeneous sources and to use them in a contextual and correlated mode. The creation of a standardized data stream is one of the added values of the Sensornet platform, as it transforms data from different sources into a single standard format, regardless of the technologies, the interfaces, formats and data type of the sources.

Sensornet publishes the interface between the monitoring system, RainBO platform and possible third party platforms as a web service (see Annex 4 - SensornetAPI).

2.1.2. Territorial DB

The model of the territorial data was defined starting from the existing national and regional guidelines for the planning of Civil Protection and it requires the mapping of all exposed items, flood maps, river hydrography and territory maps (see Annex 2 - Territorial Data Model).
The basic regional maps contained in the the Territorial DB are the following ones:

- Regional technical cartography (CTR) updated in 2013 with the topographic database (TIFF format in regional extension, WGS84 UTM32)
- Ortho-photo Agea2014 ((TIFF format in regional extension, WGS84 UTM32)
- DSM Agea2008 (TIFF format in regional extension, WGS84 UTM32)
- DTM Agea2008 (TIFF format in regional extension, WGS84 UTM32)
- River basins from numerical data 1:10.000 (shapefile format in regional extension, WGS84 UTM32)
- Toponymy from DbTopo - layer TOP_GPG (shapefile format in regional extension, WGS84 UTM32)

Starting from these data, the RainBO platform provides the following maps:

- vulnerability maps
- hazard maps
- risk maps
- sensors maps
- historical events maps

2.1.3. Historical DB

(see Annex 3 - HistoricalDB Data Model).

2.2. Conventional monitoring systems

2.2.1. Arpae hydro-pluviometric monitoring system (rain gauges, water level gauges)

The Arpae hydro-pluviometric system, consisting of 242 water level gauges and 282 rain gauges, has already been integrated into the Sensornet platform over the past years. In order to make it suitable to RainBO purposes, some new rain gauges were added. They are similar to the ones installed in the basins located in the Parma provincial area after the flood occurred in October 2014:

- Rain gauge- Fugazzolo (PR)
- Rain gauge- Ravarino (PR)

The integration of these new sensors simply resulted in their configuration within predefined tables and without the need of additional code.

The data coming from the hydro-pluviometric monitoring system are available on Arpae ftp server ("ftp.smr.arpa.emr”).

Arpae hydro-pluviometric monitoring system data are available from Sensornet to RainBO platform through a web service (see Annex 4 - SensornetAPI (beta)) .

2.2.2. Ravone creek monitoring enhancement

Within the RainBO project the monitoring infrastructure for the Ravone creek test case will be extended with a new rain gauge in the catchment, a new new soil moisture sensor and a new water level gauge. The measured data are spread by Arpae through the RMAP project's AMQP protocol.

All the new sensors planned for the Ravone creek monitoring enhancement have been already installed and the data are being operationally recording through the Rmap protocol into the RainBo database.

As all the non-institutional monitoring networks, the integration of data coming from the new rain gauge and the new water level gauge inside Sensornet requires:

1. the development of a new data acquisition module for the RMAP project's AMQP protocol.
2. the configuration of a new rain gauge bound, unlike all others, to the new AMQP acquisition module.
3. the configuration of a new water level gauge tied, unlike all others, to the new AMQP acquisition module.

The AMQP acquisition module is also required for integrating Crowd Source Application data, whose distribution is expected through the same protocol (see Crowdsource Application).

Data provided by the new sensors are spread by Sensornet to RainBO platform through a web service (see Annex 4 - SensornetAPI).

2.2.3. Radar

The territory of the Emilia-Romagna region is covered by two weather radar located in Gattatico (RE) and in San Pietro Capofiume (BO). Reflectance data are spread in a specific format on the open data platform of Arpae, while the hourly precipitation data is spread through an *ad hoc* procedure.

An *ad hoc* stream was triggered for the automatic and periodic distribution of both reflectivity maps and hourly precipitation maps on the ftp server provided by LepidaSpa (ftp2.lepida.it), according to the RainBO project goals.

Images sent are a merge of the two systems (reflectivity radar maps and accumulated hourly precipitation). Every new capture of the reflectivity (the frequency of observations is related to the meteo conditions at the time) generates a merge image, which is then sent to the Lepida ftp server.

Maps show the estimate rainfall in the last 60 minutes as well and they are updated every 15 minutes.

Radar maps are integrated into Sensornet platform through a single virtual sensor to which two distinct measurements are associated: reflection and time accumulated.

Radar maps are made available from Sensornet to RainBO platform through a web service (see Annex 4 - SensornetAPI (beta)) .

2.3. Non-conventional monitoring systems

The RainBO project envisages the integration and use of different non-conventional monitoring infrastructures. As well as the capability to provide rainfall data coming from Microwave data, the RainBO platform improves the RainBO Monitoring DataBase with other qualitative information on the present weather and its impact provided by citizens.

Conventional and-non conventional monitoring systems are merged because of two main aspects:

1. they are both are georeferenced with respect to a same reference system (WGS84)
2. their data is synchronized temporally

For that reasons conventional and-non conventional monitoring systems they can be overlapped and comparable

2.3.1. Rainlink4EMR module

The microwave rainfall monitoring system is one of the main outputs on the RainBO project. The system exploits the microwave links used in commercial cellular communication networks worldwide. Application and implementation details of the corresponding new module are described in the deliverable RainBo_C2_2_Deliverable_RainfallDataMicrowaveLinks.pdf.
The microwave links data used in the project come both from Lepida telecommunication network and from Vodafone commercial infrastructure. The first ones mainly cover the Appenine area of the Emilia Romagna, the second ones focus on Bologna and Parma metropolitan areas.
In this document we want to highlight the way of integrating rainfall measurement data from the new Rainlink4EMR module inside Sensornet, which is expected both at the map and at spot level.
The georeferred continuous precipitation maps are obtained by merging Vodafone and Lepida data, mainly referred to the Bologna area, and on Parma. The precipitation maps are obtained by applying RainLink algorithm on a regular grid with spatial resolution of 5km x 5km.
Real time punctual data are generated by the rainfall measurements (distribution of punctual values of rainfall) provided by virtual sensors and "simulated" by the intermediate point of each of the available Lepida microwave links. It has not been possible to provide analogue real time punctual data with Vodafone data.
Rainlink4EMR data are available from Sensornet to RainBO platform through two web services (see WMS and Annex 4 - SensornetAPI) .

2.3.2. Crowdsource Application

As described in the deliverable RainBo_C2_4_deliverable_CrowdSourcing.pdf, the RainBO crowd sourcing application (Rmap4RainBO) improves the Rmap project promoted since several years by Arpae-SIMC Emilia Romagna within the Participative Environmental Monitoring Network (*https://www.arpae.it/sim/*). For all the details of the Rmap objectives, standard, methods, protocols please refer to the deliverables of previous project.

In the present deliverable we will explain in detail how the Crowd Sourcing Application integrates in the Sensornet platform and how acquisition, storage and visualization of data on the platform have been solved and implemented (see Figure 2: Architecture integration between Rmap4RainBO and Sensornet).

https://partecipa.rainbolife.eu/

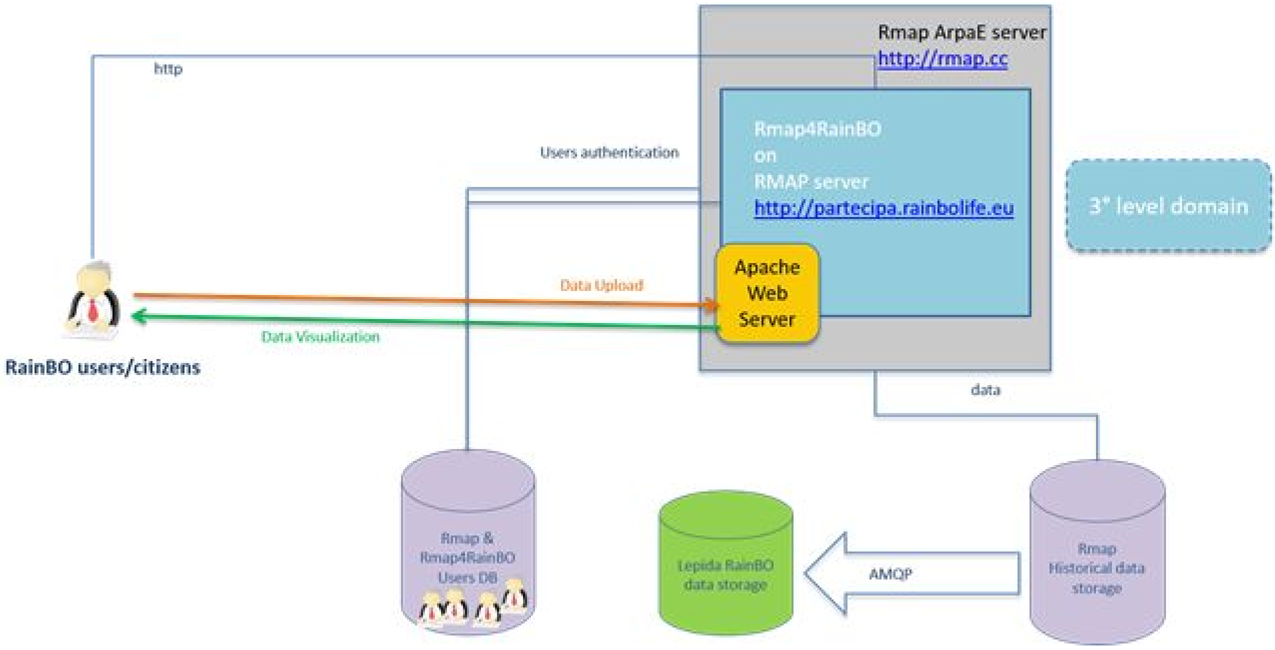

Figure 2: Architecture integration between Rmap4RainBO and Sensornet

As shown in Figure 2, data from Rmap4Rainbo (or crowdsourcing app) is distributed on RMAP data flow, through the AMQP protocol.

Data coming from Rmap4Rainbo are described and stored in a specific table (crowsourcing) of the MonitoringDB of Sensornet Platform. This table has been kept separate from the table containing all the other maps (radar, etc.) because of the unpredictability of data geolocation and number from crowdsourcing, and the reliability of the information therein (see Annex 1 - MonitoringDB Data Model).

Data from the crowdsourcing application are displayed through maps available from Sensornet to RainBO platform through the Web Map Service (WMS).

2.4. Forecast data

The integration in Sensornet of forecasts from hydrological and meteorological modeling data was achieved through the definition of "virtual" sensors, that, unlike the real ones, are not associated to physically observed data but to the forecasted ones provided by the models. This kind of solution allowed to integrate these new types of "virtual" sensors with the real ones completely, while maintaining the consistency of data and their modeling within the Sensornet platform.

2.4.1. Hydrological forecast for small basins

The forecast for small basins is based on a statistical approach calibrated on historical and scenarios data computed by means of Criteria3D model on the Ravone creek. it produces a distribution of forecast of the maximum level of the creek at the water level measure point. Input are: current condition of soil moisture (WHC) estimated by the mono-dimensional restriction of Criteria3D, observed and forecast precipitation.
The computation of the forecast is performed inside the platform in the Data Mining module. Therefore, the integration of the forecast needs the transfer from Monitoring DB to Data Mining of aggregated observed and forecast data.
The output of the forecast is associated to a “virtual sensor”, at the entry of the culvert for the Ravone case.
Further details are provided in Deliverable C4.1 - Test Cases Specification.

2.4.2. Hydrological forecast for medium and large basins

Random Forest is an hydrological statistical model able to forecast the probability of exceeding the three alert thresholds set for the main rivers of Emilia-Romagna region. The integration of the Random Forest virtual sensors inside the Sensornet platform requires:

1. The implementation of a new data acquisition module (randomforest module) of the .csv files, provided by ArpaE every 10 minutes on a ftpServer hosted by LepidaSpa.
2. The definition of a new type of Random Forest sensor associated to the four probabilities of exceeding the three alert thresholds described above.
3. The configuration of two new Random Forest type sensors alongside the Parma and Baganza river sections.

The integration of hydrological modeling for other medium and large basins simply requires the configuration of other Random Forest virtual sensors through the right compilation of the related tables of the MonitoringDB.

The forecast hydrological response of basins to heavy rains is available from Sensornet to RainBO platform by a web service (see Annex 4 - SensornetAPI).

It’s important to highlight that these two hydrological modeling are applied in different cases: Random Forest in applied for medium size rivers, whereas Criteria 3D is applied on creeks, so they cannot be compared.

2.4.3. Meteorological Modeling Cosmo-Lami

The GRIB data relating to the Cosmo-Lami weather model are provided by ArpaE in open data format (https://drive.google.com/drive/folders/0B7KLnPu6vjdPamtMWmxyQTJrWms).

They consist of "data packs" containing a picture of the value of a variable within the reference cell. The number of cells and their positioning are encoded inside the pack and allow the geo-localization of the forecast variables.
In the GRIB files the territory of Emilia-Romagna is divided into a matrix of 45 * 27 points, corresponding to cells of size 7x7 km.
Among the various predictive parameters provided within the GRIB files, only the one related to rainfall is integrated in Sensornet.

Data relating to the meteorological modeling can be used both as maps to get i.e. an overview of the precipitation forecast, but also as spots (in numerical format) to get i.e. hourly precipitation provided on a selected grid cell (as in the case of Ravone creek). The numerical format is key information for the prediction of the water level peak for small catchment.

Lami maps in Sensornet are integrated through four separate virtual sensors, each one corresponding to a different range of forecast rainfall aggregation periods: 3h, 6h, 12h, 24h.
In the Sensornet platform a new "virtual" Lami sensor was defined to allow the integration of Lami data (in GRIB format) related to precipitation forecast, which were needed to identify the hydrologic scenario for the Ravone creek (Criteria 3D).
In the case of the Ravone creek, as in almost all small streams, a single cell in the reference grid covers the whole extension of the basin. Cell-related data can be represented through a virtual sensor placed on the center of the cell itself.

GRIB data relating to Lami previsional data provide the accumulated rainfall value, allowing the calculation of the equal precipitation value per hour. A precipitation threshold (2 mm) is set in order to predict the rainfall beginning and end, and to infer both the duration, the maximum rainfall intensity and the accumulated rainfall.

The integration of the new type of "virtual" Lami sensor inside the Sensornet platform, indeed, has required:
1. The implementation of a new GRIB data acquisition and processing module (modelloLAMI module).
2. The definition of a new type of Lami sensor, which the four measures previously described are associated.
3. The configuration of a new Lami type sensor at the Ravone creek, identified by the coordinates of the corresponding grid cell.

The integration of other sensors, related to the meteorological forecasts for another creek, requires only the configuration of another Lami type virtual sensor associated with the coordinates of the corresponding grid cell.
Meteorological Modeling Cosmo-Lami data are available from Sensornet to RainBO platform through two web services (see WMS and Annex 4 - SensornetAPI) .

2.5. Water balance data

2.5.1. WHC

The new "virtual" WHC sensor defined in Sensornet platform integrates the estimated value of the soil Water Holding Capacity. WHC index can be produced for every cell of the meteorological analysis grid of Emilia-Romagna region (ERG5). In the Ravone case study, data refer to the cell that contains the prevailing area of the catchment and data can be represented by a sensor placed within the cell itself.

The integration of the new type of "virtual" WHC sensor inside the Sensornet platform required:

- The implementation of a new data acquisition and processing module (WHC module) of the .csv files, provided by Arpae Bologna every day, on a ftpServer hosted by Lepida Spa.
- The definition of a new type of WHC sensor.
- The configuration of a new WHC type sensor at the Ravone creek, identified by the coordinates of the corresponding grid cell.

The integration of other WHC sensors, related to water balance simulation for another creek, requires only the configuration of another WHC type virtual sensor associated with the coordinates of the corresponding grid cell.
WHC data are available from Sensornet to RainBO platform through a web service (see Annex 4 - SensornetAPI).

2.6. Sensornet Webservices

The interface between the Sensornet and RainBO platforms consists of two webservices, one for maps related to grilled data (WMS http://www.opengeospatial.org/standards/wms) and one for the punctual sensor, (see Annex 5 - SensornetAPI).

2.7. Business software modules

2.7.1. Vulnerability module

The Vulnerability module is a standard web service that provides vulnerability maps of all exposed items depending on the type of building, use, resident population, and specific parameters as hours or periods of use.

The module input consists of a vulnerability map, which collects vulnerable elements in a municipal area. Elements are stored in the Territorial Database together with the vulnerability algorithm attributes. The output consists of the corresponding vulnerability maps, stored in the RainBO database (see Figure A).

- ON-LINE: the module provides the vulnerabilities maps related the reference scenarios (hazards maps according to the level of the river evaluated), on the basis of specific parameter as hours, seasons, etc.
- OFF-LINE: simulates new configurations and new scenarios.

2.7.2. Data mining module

The data mining module is a web service that provides support for identifying the most likely scenarios, such as expected river levels, not only from real-time and forward-looking monitoring data, but also through the correlation with past events.

Data mining module implements the relationships between the values of the significant parameters of the expected rain event and the corresponding river level at the monitored point, resulted from the 3D hydrological simulation model for small basins.

The module inputs consists of real-time monitoring data, forecast data, and mapped historical event data. Output is made up of the most likely scenarios, referred to as expected levels of rivers (see Figure A).

- ON-LINE: Provides the most likely scenarios, known as the expected level of rivers, from real-time monitoring data, forecast data, and mapped historical events.
- OFF-LINE: Simulates scenarios that correspond to selected monitoring, forecast and historical events. It can also temporal analysis on a set of historical data for recall pattern detection.

In the following figure the scheme of the Data Mining to be implemented in RainBO project.

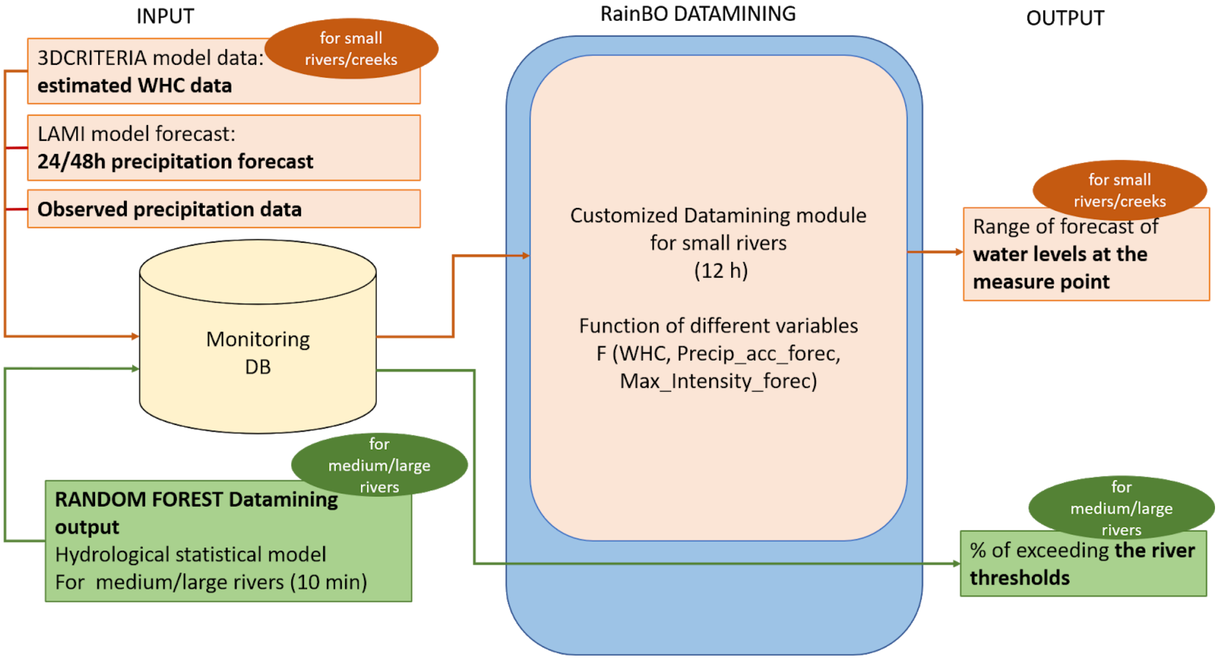

Figure 3: RainBO Data Mining architecture

The RainBO data mining module is composed by two main components:

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1. The Random Forest Data mining component, already implemented for the monitoring of medium/large rivers, especially used in the Parma province and integrated in the RainBO project. The Random Forest data are not affected by the RainBO data mining module. Its output consists in forecasting a probability of flood alert threshold exceedance for each of the three alert levels defined by the Civil Protection Authority.
2. A custom data mining for the monitoring of the small rivers or creeks, based on a function of different variables collected by the Monitoring DB coming from model and forecast data. The site-specific function is developed by the study of the historical data series and the simulation of a wide range of possible scenarios through the water balance model Criteria3D. The involved variables are the following ones:
    a. Forecast accumulated precipitation
    b. Forecast maximum hourly precipitation intensity
    c. Water Holding Capacity (WHC index)

The data mining implementation is developed by MEEO in collaboration with ArpaE, that provides the functions and algorithms to be implemented.

In Figure. 3 the red color was used for the small rivers and the green for the large ones.
The datamining module implemented for RainBO includes only a component for the small rivers monitoring. The Random forest model was not customized as the project is focused on the small rivers, so its output are kept as outcomes of the RainBO datamining.
The monitoring DB collects observed data, forecasted weather data (LAMI), estimated data (WHC) from Criteria model and hydrological forecast from Random Forest model, as in the figure 3.

2.7.3. Scenarios analysis module

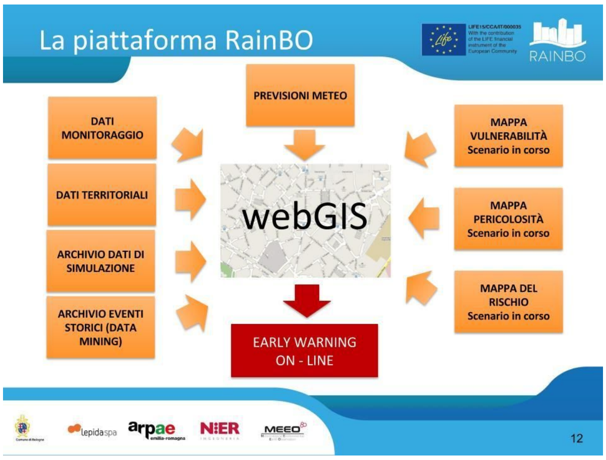
The Scenario Analysis Module consists of a web service providing flood maps matching with the most probable scenarios expected for river levels as a result of Data mining (input). The outputs are the corresponding flood maps (see Figure A) and/or information about the current event (as for example: sensor measuring or similar historical event).

2.8. GUI

The RainBO interface provides two main modes of operation: ON-LINE (Alert functionality) and OFF-LINE (territorial planning functionality) (see GUI_RainBO_Mockup deliverable).

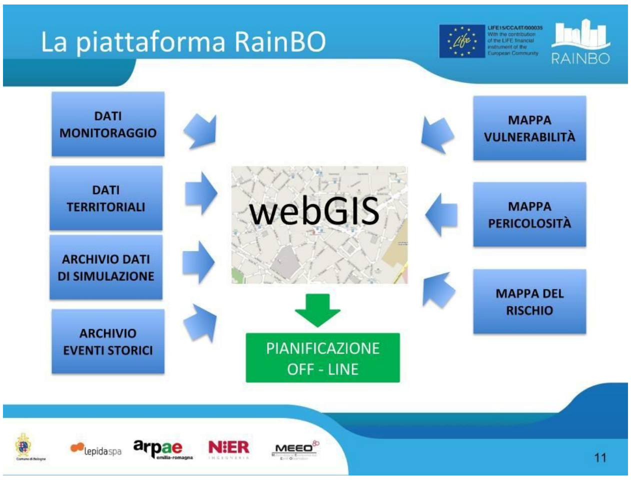
2.8.1. Early-warning module - ON-LINE capability

In the ON-LINE mode, the RainBO platform is able to continuously monitor the phenomenon and its evolution, and to generate early warning when critical thresholds are reached, with an alert forecast up to 12/24 hours, depending on lead time of forecast.



2.8.2. Planning support module - OFF-LINE capability

In OFFLINE mode, the RainBOW Platform is a planning tool by simulating the phenomenon and its possible impacts on the territory.



2.9. Internally and externally Communication of RainBO project

Even though the platform is targeted to local administrations and public authorities in civil protection, it will be communicated internally and externally

The communication action describes the main tasks to be carried out to enhance the communication of the project results. Regarding the internal communication, all partners are spreading the project state of the art and results on their sites. As far as concerns the external communication, all partners are spreading the project through their networks such as public, private and research institutions, municipalities, civil protection (both at a municipal and a regional level).

The stakeholder engagement process, to be started on 13th February 2018, involves many actors (municipalities, public institutions, universities) that can be interested in the RAINBO project as they deal/dealt with similar projects and topics.

This meetings aims to spread the project results and to find synergies between the projects and to improve the integration of information provided by the projects. Other meeting with public institutions, citizens and citizen association will follow.

The project results are spread also through the participation and invitation to meetings (other project meetings, network meetings, etc.) and through the web site, web articles and social networks.

Annex 1 - MonitoringDB Data Model

Annex 2 - Territorial Data Model

Annex 3 - HistoricalDB Data Model

Annex 4 - SensornetAPI