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Integrated Open Service Platform for Enhanced Risk and Emergency Management: the PHAROS Solution

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ABSTRACT:

The deployment of new methods and tools for the provision of emergency management services to cover the whole disaster management cycle is a key success factor to increase the efficiency of emergency management processes, enhancing resilience of the population. Due to the evolving nature of current threads where concatenation of different hazards has become common, it is necessary to consider systems providing multi-hazard assets and allowing interoperability and coordination of the involved organizations. In this regard, satellite-based technologies, namely earth observation systems, satellite communication and satellite navigation systems, can provide robust solutions when integrated with terrestrial systems. The PHAROS system presents a multi-hazard open platform intended to integrate different data sources and tools for the provision of emergency management services, benefitting from the synergies between the available tools. The provided services not only focus on the response phase, but support operators during the preparedness, mitigation and recovery phases. These are intended to support the complete process ranging from the monitoring and detection of a possible risk and its assessment until the provision of suitable operational proposals and the dissemination of alert information to the population at risk. The modular web-based architecture allows a flexible and scalable system deployment which can be tailored to the needs of the different responders. Moreover, interoperability with already existing systems together with the provision of data exchange mechanisms will allow different organizations involved in emergency management to benefit from the use of the PHAROS assets while easing cooperation and coordination among them. The paper presents the PHAROS approach, both from an operational and architectural perspective, focusing on the short term approach for the management of wildfires. The document describes the overall system architecture and the integrated assets, highlighting the enhanced synergies and the increased added value towards the provision of efficient emergency management.

KEYWORDS:

Alert message, communications protocol, GNSS, earth observation, in-situ sensor, decision support

1. INTRODUCTION

In the past several decades there has been a sharp increase in extreme emergency events worldwide due to natural hazards or human interaction. Public authorities and private initiatives are working every year on thousands of crisis episodes which cause important human, economic and ecological losses. Both, private sector and public authorities are aware of how crucial it is to improve the management, the decision processes and the containment during the complete emergency management cycle. Therefore, several national and European initiatives focusing on the use of satellite technologies applied to the areas of Earth Observation (EO), communication and navigation, are being developed. In the EO field, two major categories of products can be found: rapid mapping based on Copernicus services and sensor data (Copernicus website, 2015) and enhanced situational awareness by combining data processing with simulation and modelling techniques (PREFER website, 2015; LAMPRE website, 2015; InCREO website, 2015; SAFER website, 2015; SENSUM website, 2015; FAST website, 2015; RASOR website, 2015). Regarding communication, several solutions have been developed and deployed, mainly to cover two specific areas: communication with first responders on the field, generally based on the integration of terrestrial and satellite systems (Berioli et. al., 2011; Globalstar website, 2015; Iridium website, 2015) and the use of multi-channel approaches to allow authorities to communicate with the citizens at risk (Mulero Chaves et. al., 2014). Finally, satellite navigation assets can be exploited to provide location-based services (LBS) for first responders on the field as well as for dissemination of alerts and information from authorities to citizens (De Cola et. al., 2012). The described current solutions generally provide non-integrated tools which tackle single aspects focusing on specific phases of the emergency management cycle. This lack of a holistic approach triggers data interoperability issues when several authorities using different tools are simultaneously involved, leading to a sub-optimal use of the existing synergies between them. This is particularly relevant for the management of intra-state emergencies and cross-border operations.

In order to overcome the aforementioned shortcomings, PHAROS designs and implements an innovative multi-hazard open service platform which integrates space-based observation, satellite communications and navigation assets with terrestrial technologies to provide sustainable services for a wide variety of users in multi-application domains, such as prediction/early detection of emergencies, population alerting, environmental monitoring, crisis and risk management and decision support, targeting several users, such as crisis managers, operators of critical infrastructures, insurance companies and academic/research. The system has been designed in cooperation with an end users community formed by first responders covering different operational areas, like Firefighters and Civil protection authorities, Police, and traffic regulation agents. Thanks to this close interaction, the project design has been focused on the critical demands of the end users group to provide them with robust solutions to be used for wildfire management at the present time but without forgetting the multi-hazard approach in the long term perspective.

The present work introduces the service approach defined by PHAROS in order to overcome the existing limitations, presents the overall system architecture and describes short term perspective, focused on wildfire management. The paper is structured as follows: an overview of the service concept is provided in Section 2; Section 3 describes the reference system used to derive the short term approach (detailed in Section 4). Finally, Section 5 presents the conclusions.

2. THE PHAROS SERVICE CONCEPT

The PHAROS service concept is intended to satisfy the requirements of a wide range of users during the complete emergency management cycle. As a first classification we can distinguish between (i) system users and (ii) recipients, being the former the ones actively accessing the provided services and the latter, the citizens passively receiving information and alerts published by the system. Thereafter, system users can be further categorized in primary and secondary users. Primary users are responsible authorities formally assumed to confront a particular incident which access and use the system for institutional purposes and include the first responders located on the affected area. Secondary users are third-party entities (i.e. research institutions or private companies) which exploit any service or product provided by the system. Unlike primary users, secondary users do not have direct access to the system but only to a limited set of available products.

The PHAROS service concept considers two main categories of services and products to be provided: (i) data products and services and (ii) advanced products and services. Data products and services are based on the gathering of information from different sources (EO, data sensors and data provided by first responders on the field) and its proper presentation to the user, both for visualisation and download. The amount and type of data to be gathered and presented will depend on the availability of the information sources, which could be added or removed according to the situation. Advanced services, mainly conceived for primary users, make use of data processing and fusion techniques applied to the available input data. The general advanced products and services are classified in the following categories: monitoring and detection, data fusion and decision support, simulation services, alert and information services and provision of a Common Operation Picture (COP). Advanced services are intended to interact with each other, meaning that the outcome of a service, if available, can be used as input by another service (service chaining). This increases the added value of the complete service chain by benefitting from the existing synergies among the different services.

3. THE PHAROS REFERENCE ARCHITECTURE

The PHAROS platform is based on a modular architecture allowing a flexible integration of the different assets. Therefore, each asset is considered as an independent module that can be interconnected to the overall system by means of the service platform, which is the core element acting as a mediator between the involved modules. The main assets that are considered are: data sources (EO systems, in-situ sensor networks and external systems), simulation tools, situation assessment and decision support services and alerting tools (see Figure 1).

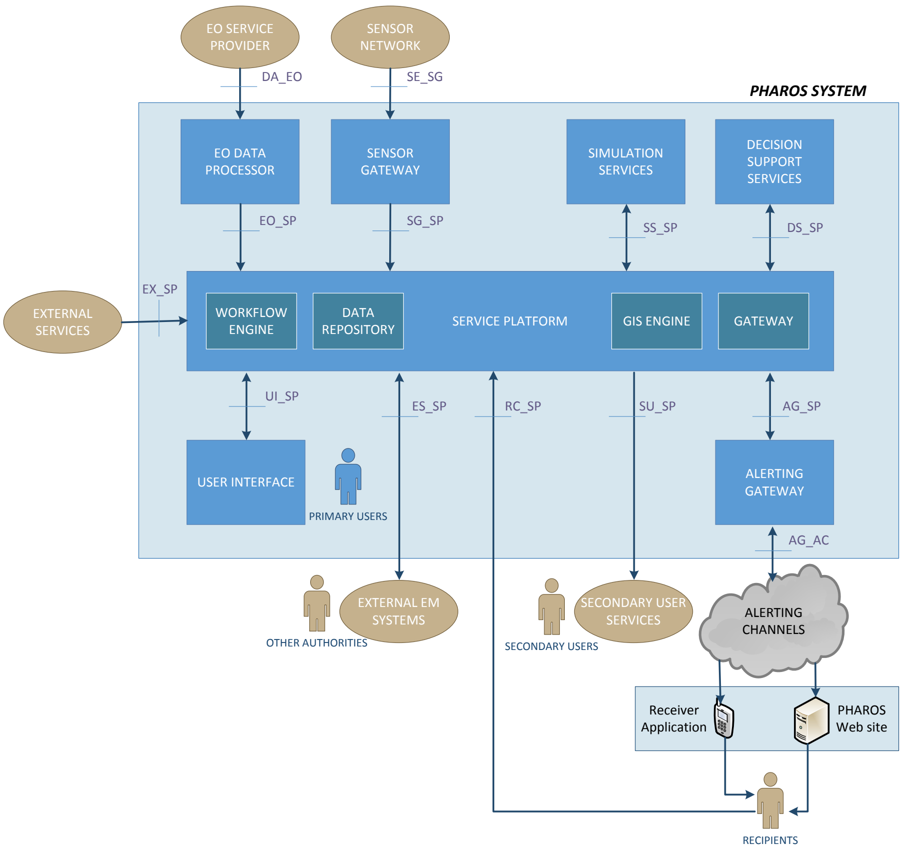

Figure 1 PHAROS Long Term Reference Architecture

The PHAROS modular architecture is intended to provide flexibility and scalability at two different levels: functional and operational scalability. The term “functional scalability” must be understood as the capability that the system shall provide in order to allow addition or removal of functionalities (modules) according to the situation, the hazards to be addressed and the corresponding operational domains. “Operational scalability” refers to the capability of the system deployment to allow its use in the widest range of organisational structures, at local, regional, national and international level. These structures vary depending on the different political and organisational/administrative structures, as well as on the type of hazard, its scope and evolution. This means that on one hand, the authority in charge may vary depending on the hazard type (for instance, firemen might be the responsible authority in forest fire cases while civil protection might be in charge of other types of hazards).

On the other hand, a higher-level authority might get involved in the management of the crisis, depending on its scope and how the crisis evolves. Generally, the higher levels of the command hierarchy are involved if the crisis escalates though several jurisdictions at the same level (for instance, national authorities may get involved if the crisis exceeds the borders of the region where the crisis was originated). Operational scalability allows seamless communication among PHAROS instances operated at different levels of a given hierarchy. Furthermore, the system uses a dedicated data structure intended to allow the exchange of information with other external systems being used by additional authorities involved.

4. THE PHAROS SHORT TERM APPROACH

This section introduces the PHAROS short term approach, which is focused on the provision of services for the wildfire scenario. Therefore, the generic modules presented in Section 3 are replaced in the short term by the particular tools tailored to the mentioned use case.

3.1. The Service Platform

The Service Platform (SP) is the central entity in the PHAROS architecture (see Figure 1), which has been designed and implemented in a generic and application-agnostic manner. The main motivation behind the generic multi-mission software SP, as opposed to application-specific solutions, is the observation that most disaster management platforms share some common aspects such as acquisition and processing of EO data, leveraging information from in-situ sensors using data fusion algorithms, using GIS for information management/representation and using workflows for incident management. In this context, the SP aims to constitute a generic application-agnostic core system to which all peripheral application-specific components will interface. The functional capabilities of the SP are geospatial data storage, workflow handling and execution, access control, user management, configuration, access to historical data and platform monitoring.

In order to implement these capabilities, the SP integrates the following basic components, as also shown in the high-level architectural diagram in Figure 2:

- a Data repository, for geospatial, sensor and generic data, allowing the SP to act as information hub for all interconnected modules. Communication of data is achieved via open standardized services (OGC WMS/WFS/WCS/SOS).
- an Enterprise Service Bus for message routing, forwarding and adaptation, allowing the SP to act as mediator, facilitating communication in a unified way.
- a Workflow Engine (WFE) for component orchestration, enabling the SP to run specific processes in order to pool data from sources, adapt them, invoke processing modules and integrate the final product. This process is application-domain specific, yet it is easily reconfigurable and can be edited even via graphical editors.
- Last, the SP implements Management-related services, which allow the supervision of its operation and the configuration of the individual components.

The Service Platform is implemented under the .NET framework, using a customized version of Geoserver (Geoserver, 2015) for storing and manipulating geospatial data and Apache ODE (Apache, 2015) for workflow execution. The components for access control, service mediation and management/configuration are custom built. Overall, the technical approach adopted for the PHAROS SP exploits well-established contemporary paradigms in software engineering and relies on widely adopted standards and technologies. SP interfaces mostly comply with global open standards (including the OGC specifications for geospatial and sensor data), thus promoting the applicability and future commercial adoption of the platform.

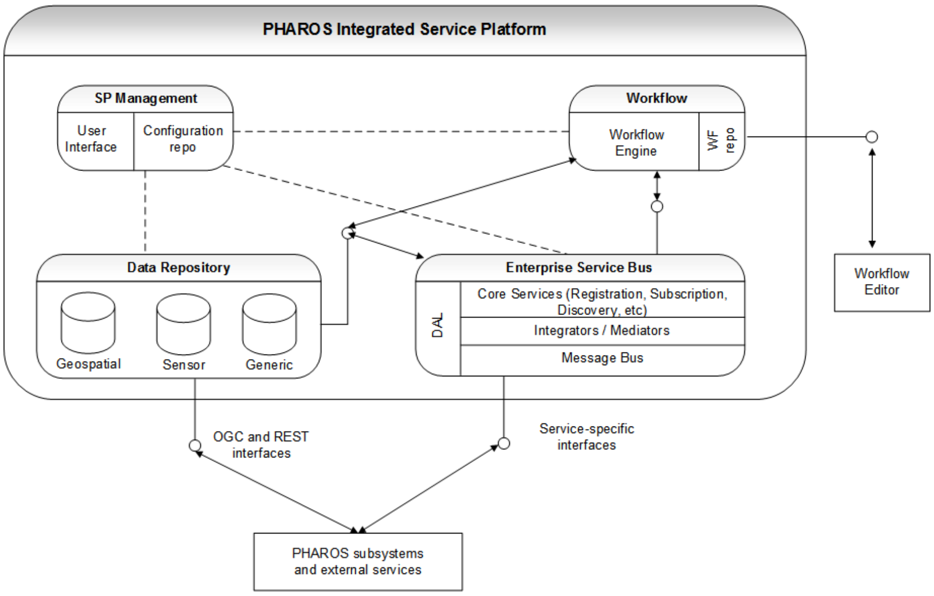

Figure 2 Functional Architecture of the PHAROS Service Platform

3.2. Earth Observation Assets and Fire Service

The Fire Service is intended to detect thermal anomalies based on EO data in order to support the different phases of the disaster management cycle. Firstly, fire hotspots (thermal anomalies) are used during the detection and immediate response phase as input for the PHAROS Simulation Service. These hotspots are derived automatically and in near real time (NRT) from MODIS and MSG data. The MODIS data are available in a high (1d) temporal and in a medium (250m – 1000m) spatial resolution. The MSG data are available in a very high (1h) temporal and in a low (<1000m) spatial resolution. These EO data services are running as external services and are available via OGC service interfaces. Secondly, EO (high spatial resolution) images, thematic products (burnt scars) and maps are used during the recovery, mitigation and preparedness phases. The data are available in a high (<30m) to very high spatial resolution (<2.5m) and in a medium to low temporal resolution (> 1d). Products and maps based on these data must be generally manually created and require high expert knowledge. For the implemented short term approach of the project, a limited implementation will be provided for demonstration purposes. On the long term run these products will be created on demand (in the case of a fire emergency activation or for pre- and post-operational purposes, e.g. forest inventory regarding fuel capacity, change detection, seasonal variations).

For the MODIS based detection of high temperature events (HTE) the MOD14 algorithm is used. The algorithm is based on the shift of radiances to shorter wavelengths (middle infrared) with an increasing surface temperature. MOD14 is well documented and tested in operational services and guarantees comparability and reproducibility as well as a standardized international acknowledged product (Morisette et. al., 2005; Fuchs et. al., 2015). The thermal information is collected at 1000 m spatial resolution twice daily by each sensor (Terra and Aqua) providing up to four thermal observations daily. The MODIS images used for fire detection are acquired from two direct broadcast receiving stations from DLR located in Oberpfaffenhofen and Neustrelitz.

The hotspot detection service will be enhanced with the integration of other satellite missions. The most advantages can be achieved by using a geostationary satellite. On the one hand, the service will provide hotspots in a high temporal resolution (up to 15 minutes) and on the other hand, fires during the night will be detected as well. The SEVIRI Sensor (Spinning Enhanced Visible and Infrared Imager), for instance, installed on MSG-1 and 2 (Meteosat Second Generation satellite) platforms and covering Europe and northern Africa, provides data in 12 different wavelengths within the visible to infra-red spectrum and with a pixel size of 1 km for the high resolution visible channels, and up to 3 km for the infrared channels. The EO and derived data products will be provided with INSPIRE/OGC compliant services (WMS/WFS/WCS/CSW) through the EOC Geoservice of the

Earth Observation Center (EOC) of DLR.

3.3. In-situ Sensor Assets

In order to complement the EO-based crisis detection assets, PHAROS integrates in-situ sensor networks as an additional monitoring and detection tool. In the short term approach, the FireWatch system has been considered for the particular wildfire case. Based on high resolution optical sensors, FireWatch enables an automated early recognition of smoke as a first indicator of an incipient wildfire. This way, the system can cover and protect any area as long as there is line of sight between at least one sensor and the spot of a potential fire break-out. Since the fire recognition is based on visual smoke detection, the system also recognizes emerging fires in hidden areas near the ground, as long as the smoke above the fire is visible. Smoke Detection is an important basis for the early detection of fires with a long range (>15km). In natural surroundings (depending on weather, type of flammable substances etc.) smoke has a special kind of dynamic, which is only recognizable on an automated basis by means of modern identification technology, computer science and image processing software.

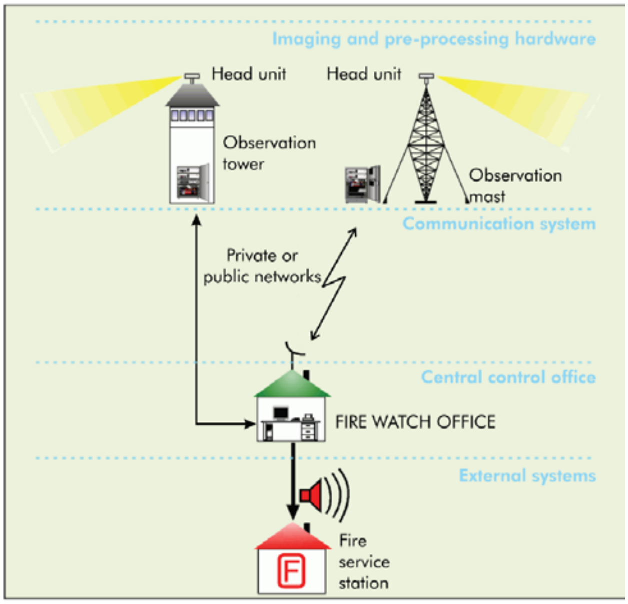

Figure 3 FireWatch Architecture

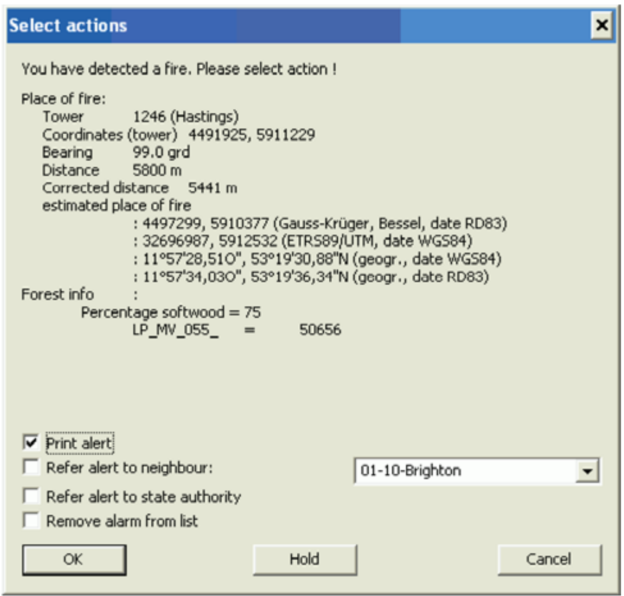

Figure 4 FireWatch Alert Message

The FireWatch system consists of three main elements: (i) imaging hardware including the optical sensor at the observation tower; (ii) the FireWatch Central control office and (iii) the communication network (see Figure 3). The imaging hardware consists of a sensor head (camera) with the optical sensor, a pan and tilt mounting unit, and the housing. The camera is installed on top of an elevated structure such as a tower or a mast. Each unit covers a radius of 10 to 15 km depending on the visibility and the local elevation profile. The optical sensor contains a high resolution CCD chip with a resolution of 1360 x 1024 pixels. The extremely high grey scale resolution of 14 bit enables the application of special image-processing software. The CCD sensor is sensitive to light with wavelengths from the near infrared to the visible ranges. An interference rejection filter and a low pass filter are installed to limit the detected wavelength to visible or near infrared light, which allows the FireWatch system to switch to night vision. A local computer is installed at each tower to control the sensor movements and pre-process the acquired images. During the image pre-processing phase, the algorithm compares the current frame with previous frames and determines if there have been changes. The pre-processing step handles not only the automatic detection of smoke within the observed area, but also the transmission of the corresponding alerts to the central office via e.g. radio links, whenever a smoke cloud is detected. A central control office is typically located in the forest department headquarters. This central control office plays the role of the sensor gateway described in the PHAROS system architecture (see Figure 1). It includes a central operator control panel computer, which receives signals from all detectors of the area to be surveyed and displays the received data (alerts, images, information management, etc.). The central control office computer displays a map of the forest department, the positions of the sensors and coordinates of the events detected through the analysis of the panoramic images transmitted by the sensors.

If smoke is detected, an alert is generated and transmitted immediately to the FireWatch office software at the central control office (see Figure 4). This FireWatch office software processes the alert and displays it to the operator. The operator must approve or reject the alert through a visual assessment of the image sequences which have been previously identified as a possible smoke alert (defined also as event). Once the alert has been verified and confirmed, it may be forwarded by the operator as an alarm to the fire service control centre as well as to the SP. Besides providing real time alert messaging, FireWatch also provides other relevant data about the identified wildfires (e.g. geographical location of ignition points, current fire perimeter, timestamp, images, live video sequences) which are useful for the situation assessment performed by the PHAROS users and rescue personnel on the field and are used as real-time input data for the Simulator module.

3.4. Energy-Efficient Satellite Uplink

The use of satellite communications for interconnecting the available sensor networks to the SP allows increasing network reliability, ubiquity of service and high levels of security in support of mission-critical requirements. Whenever there is a requirement for collecting data from remote "white" areas where no type of communication is provided due to lack of terrestrial infrastructures (no base stations for GSM/UMTS coverage, no cables for wired connection), the satellite represents the unique solution to provide connectivity. Additionally, when dealing with hazardous events, it may happen that a terrestrial infrastructure was initially available and used to connect the remote sensors, but suddenly it becomes not available as a consequence of the event itself. For very sensible communications, the satellite is used as a secondary link, in order to back-up (whole or part of) the functionalities of the terrestrial primary link when it is not operating. Many are the existing and well established solutions to connect remote areas to service headquarters via satellite: from the traditional VSAT (Very Small Aperture Terminal) in C-band or Ku-band, to the MSS (Mobile Satellite Services) at lower frequencies, typically in L-band or S-band, and operated by geostationary and non-geostationary satellites. In PHAROS, a new technology that combines the benefits of more recent High-Throughput Satellites (HTS) in Ka-band with an innovative transmission protocol for bursts of messages, identified as F-SIM (Fixed Satellite Interactive Messaging), is used. The architecture of this satellite solution is an IP network composed of a hub, a satellite segment, and several remote terminals connected to the in-situ sensor networks, as shown in Figure 5.

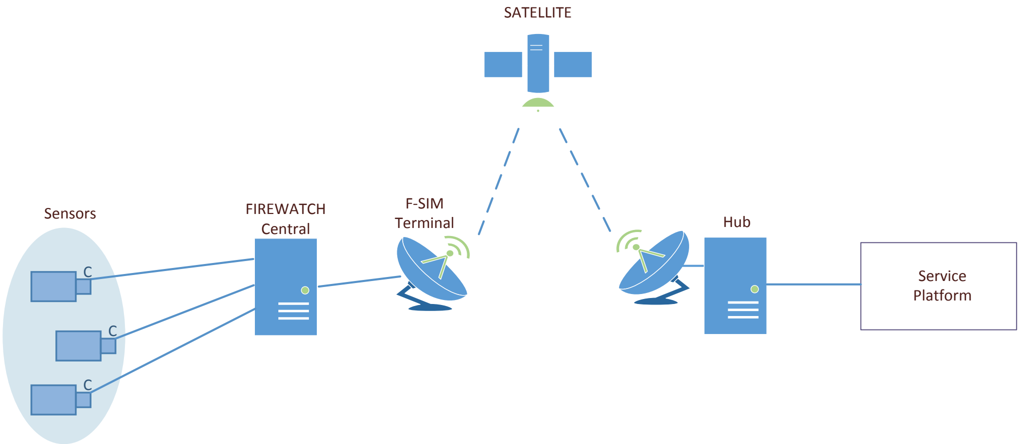

Figure 5 Satellite Uplink Architecture

The remote terminals consist at this stage of a common satellite dish of 70-80 cm of diameter as those used for satellite TV reception, however equipped with a more complex feed that embeds all the functionalities related to the transmission of messages; thanks to the gain of such antenna, the use of a powerful satellite, and the very few data to transmit, the terminal results very energy-thrifty. Thanks to this low power consumption, it is conceivable to deploy the F-SIM terminal in a stand-alone fashion, powered by solar panels, and therefore totally independent from the terrestrial infrastructures. The satellite used is EUTELSAT KA-SAT, in geostationary orbit at 9º East, launched in 2009 and providing broadband services over all Europe and the Mediterranean sea with its 82 spotbeams in Ka-band, for a total aggregate throughput of 90 Gbps. The hub is where the remote terminals and the communication are managed: the messages sent from the remote terminals are received and decoded at the hub, and then dispatched to the PHAROS SP via the internet backbone.

The interactions between the remote terminals and the hub are specified by the F-SIM protocol, derived from the ETSI TS 102 721 standard defining the S-MIM (S-band Mobile Interactive Multimedia) protocol (ETSI, 2012). Both S-MIM and F-SIM are based on the Enhanced Spread Spectrum Aloha (E-SSA) (De Gaudenzi et. al., 2008), an optimized air-interface for the return link over satellite in which the remote terminals transmit in a fully asynchronous mode and share the return channel over satellite with spread spectrum techniques. The result is a simplified access scheme where the terminals do not need to coordinate to use the space segment, therefore reducing the signaling overhead on the forward link; at the hub, the simultaneous random transmissions are perfectly decoded with a specific technique for Successive Interference Cancellation (SIC) that resolves the packet collisions with very low Packet Loss Ratio (PLR) even at high access load. Compared to its predecessor S-MIM defined for mobile terminals in S-band, the F-SIM protocol in Ka-band proposes a higher flexibility on the physical layer through the combination of options for channel bandwidth (2.5, 5 or 10 MHz), spreading factor (16 to 256) and message burst size (38 to 1513 bytes); at link layer, the protocol provides innovative procedures to remotely control the active terminals and dynamically adapt their transmission mode to the kind of service (e.g. data to be sent) and the link margin (e.g. in case of rain attenuation). The F-SIM protocol also includes a Power Control mechanism at link layer to control the distribution of the power at which the packets are received, therefore improving the interference cancellation at the hub and increasing the whole system capacity (number of simultaneous terminals) and increase the efficiency of the interference cancellation at the hub. The whole system has been designed to minimize the implementation complexity of the terminal (and therefore its cost), however reaching a spectral efficiency higher than 2 bits/second/Hertz) never reached before in asynchronous satellite access mode schemes.

3.5. Risk Modelling and Simulation

In the short term approach, the aim of the risk and modeling services provided by the Simulation module is, on one hand, to provide operational services that create outputs to support first responders during the management of a forest fire incident, and on the other hand, to provide non-operational services that create periodical outputs to support forest fire mitigation and planning purposes. Hence, the aim of the provided services is fourfold: (i) to forecast the behavior of forest fire in an operational timeframe in a certain area and to allow the adjustment of the obtained simulations to reflect the real conditions of the fire; (ii) to calculate the evacuation time to a certain point (i.e. time the fire starting at a given location takes to reach certain evacuation trigger points); (iii) to make the assessment of the forest fire growth potential with basis on electric supply networks as well as of the potential impact of forest fire on these infrastructures and (iv) to make an assessment of the forest fire structural hazard for a certain area.

The Simulation module includes the following components presented in Figure 6: (i) the Simulation Engine hosting the Simulation Engine Core that carries out the forest fire behavior and risk calculations and the Live fuel moisture processor that takes care of the calculation of the vegetation fuel moisture to be used by the Simulation Engine Core; (ii) the Data Repository that stores both the inputs and outputs of the previously mentioned sub-components of the Simulation Engine.

The Simulation module is invoked and provided with input parameters through the SP (e.g. weather, ignition point(s) parameters, evacuation trigger points…) to run the corresponding simulations or to adjust them in case new data about the location of the fire is entered in the system. The simulation results are provided to the SP data repository. The provided services have been categorized into several simulation modes, classified into operational and non-operational, according to their purpose, i.e. for their operational use (operational) or for fire planning and mitigation tasks (non-operational).

Operational simulation modes are triggered on demand by the user through the GUI or by the PHAROS Decision Support System (DSS).

- Fire spread: Provides a set of raster and vectorial outputs that represent the forecast of the behaviour of the fire for wildfire incidents with the capability of calibration of the results. This mode is triggered manually by the user through the GUI, through ignition points identified by FireWatch sensors (in-situ) or by ignition points identified through EO sensors.
- Evacuation time: Provides a set of raster and vectorial outputs that forecasts the time the fire would take to reach a certain critical point when starting at a certain location.

Non-operational simulation modes run periodically, providing users with the latest fire risk assessment.
- Forest fire structural hazard: In general terms it can be explained as representing the risk of fire for a certain area i.e. the easiness that a fire has to spread for each cell of the considered area based on several fire behaviour variables.
- Forest fire growth potential based on critical infrastructures: Provides the assessment of fire spread potential based on ignition points of critical infrastructures such as electric supply networks.
- Potential impact of forest fires on critical infrastructures: Provides a representation of the potential impact of the forest fire on critical infrastructures such as electric supply networks.

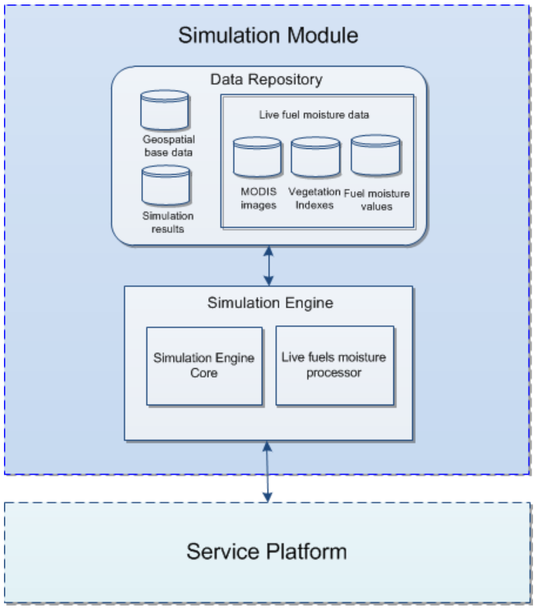

Figure 6 Simulation Module Architecture

3.6. Situation Assessment and Decision Support

The PHAROS Decision Support Services (DSS) aim at providing additional support to PHAROS users in the areas of situational awareness and decision making. Therefore, their objectives are, on the one hand, to generate a Common Operational Picture (COP) from all available sensor data (in-situ and EO), simulation and modeling results, and pre-compiled data and, on the other hand, to propose warning and information products which will be distributed using the PHAROS Alerting Gateway (AG). Hence, it comprises two main components: Situation Assessment Service (DSS-SA) and Decision Support Service (DSS-DS). Furthermore, the set of PHAROS DSS include the Incident Management Service (DSS-IM) which provides the necessary management and organizational capabilities to cope with more than one crisis simultaneously. The architecture of the Decision Support Services is generic and thus applicable in the multi-hazard context of PHAROS.

The Decision Support Services follow the Situation Awareness (SAW) Concept developed by Endsley focusing on the perception of elements in the environment within a volume of time and space, the comprehension of their meaning (Endsley et. al. 2003), and the projection of their status in the near future. The theoretical model consists of three stages, Perception, Comprehension and Projection to provide SAW, which can be followed by decision support (decision proposal, decision implementation) operating on the situation awareness generated in the previous step (see Figure 7). It must be noted that the process of generating Situation Awareness (SAW) is termed situation assessment (SA); thus, SAW can be considered a result of an SA process. The different services of the DSS (see Figure 8) are invoked by the SP either based on a set of workflows executed by the Workflow Engine or triggered by other PHAROS services, thus allowing event-driven as well as periodical execution. It is important to note that, unlike other information systems, PHAROS not only provides passive support (actions are triggered by the user only), but it can also act as an (pro-)active assistant to the user by performing background assessments, consistency checks and generating notifications and decision proposals.

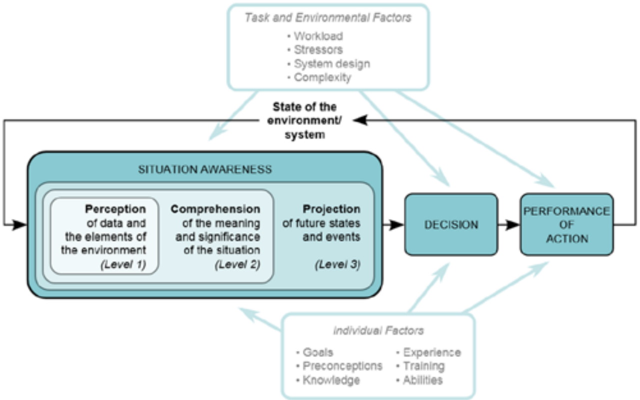

Figure 7 Situation Awareness Concept

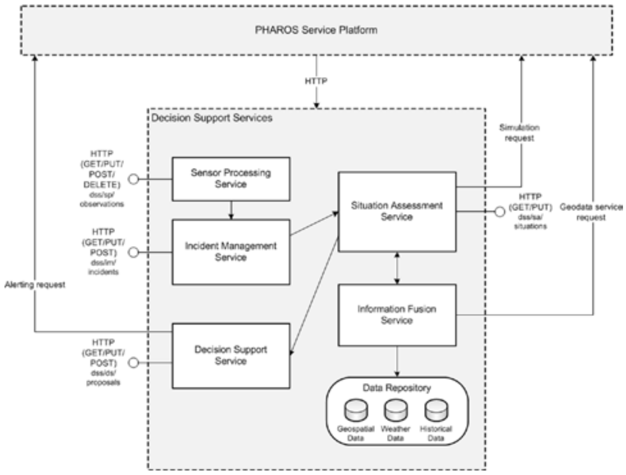

Figure 8 DSS Set of Services

The DSS Incident Management Service allows the creation and deactivation of incidents, the automatic or user-driven association of observations or simulation results to incidents. Expert domain knowledge is used to derive the rules for automatic incident management activities which enable the DSS to perform some initial assessment of incoming information; however, the user has the option to modify or overwrite the proposals of the DSS. The DSS mainly deals with situational awareness information generated on the basis of incoming sensor information, simulation results, background information and analysis results. Regarding the interoperable exchange of sensor data and (warning) products a number of suitable formats and standards exist, e.g. CAP, EDXL-DE, OGC SWE. For the interoperable exchange of situational awareness data only few approaches exist that do not fully cover the expressiveness required in PHAROS. As part of the PHAROS DSS development, a so-called shared Common Operational Picture (sCOP) format is specified that extends the existing Tactical Situation Object (TSO) standard. Two representations of the sCOP format with the same expressiveness are being developed for efficient internal communication between the DSS services and for interoperable exchange with external partners.

3.7. Advanced Features for Population Alerting

PHAROS also provides alerting features to allow authorities to inform and alert the population at risk by means of integrating an alerting gateway (AG) able to distribute alert and information messages towards targeted citizens through different communication channels. In the short term context of the project, the communication technologies to be integrated in the system are Cell Broadcast and satellite navigation services (GNSS, Global Navigation Satellite System), thus allowing citizens to receive the alert messages directly on their standard mobile devices, such as smartphones and tablets. These technologies enhance network resiliency and enable to target a large amount of citizens due to their large market penetration as well as benefitting from location-based features, the use of various communication links (i.e. GPRS, GNSS) and simple user interaction and configuration through the touch screen.

The alerting process can be manually triggered by primary users though the GUI or by the DSS, according to the situation. Primary users can either compose the message using already pre-defined options or manually enter the corresponding text fields. Regarding the transmission over the communication channels, the system is CAP-compatible (OASIS, 2010) and in case pre-defined options are used, advanced encoding of the message content can be applied to allow efficient transmission in terms of capacity and timely delivery over narrowband channels (De Cola et. al., 2012). The transmission of the encoded message allows primary users to create a unique message to be distributed over multiple channels while citizens can use a dedicated application to decode and present the message according to their preferences. This way, messages can be presented in multiple languages and multiple modes, such as text or speech, thus increasing social inclusion by addressing citizens with special needs. When a message has been received, citizens are notified by a distinctive audio signal as well as a vibration. The message is decoded by the application using a Message Composition Engine (MCE) and presented to the citizen in different modes, such as using text to speech technology or displayed on the screen, according to the citizen's configuration. The message, composed by a title, the hazard description and the recommended protective action, is displayed in the language pre-selected by the citizen. The citizen can also access additional information like the location of the hazard displayed on a map or attached pictures. In case free text is included in the message, the application will not be able to automatically decode and translate the message, but primary users are allowed to manually include multilingual versions of the message to be presented to the citizens, if needed (see Figure 9).

Figure 9 Screenshot of the mobile receiver application

6. CONCLUSIONS

Efficient risk and crisis management to enhance resilience of the population requires the provision of tools to tackle the requirements which arise along the complete emergency management cycle. Current tools cover different areas which are in many cases hazard-specific and not provided in an integrated manner.

The PHAROS system provides an open service platform which integrates a wide set of data sources and tools in a seamless manner in order to benefit from the existing synergies between the different modules. Services provided by PHAROS can be used during the whole emergency management cycle and cover a wide range of operational scenarios, from risk and crisis monitoring and detection, based on EO and in-situ sensors, decision support, risk modelling, situation assessment and alerting the population. The PHAROS architecture follows a modular approach, allowing a flexible system deployment which can be tailor to the user needs, providing functional and operational scalability. This allows the introduction of additional tools and data sources to address different types of hazards (multi-hazard approach) as well as the adaptation of the system to different organizational structures, enhancing cooperation among the involved authorities. In the short term, the PHAROS system is tailored to the wildfire use case scenario, while in the long term, the system can be gradually extended with additional assets focused on a wider set of hazards.

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