An Open Service Platform for Multi-Hazard in Action - the PHAROS Pilot Demonstration

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Abstract: Natural and man-made disaster, whose impact has been increasing on the last years, present a series of common dynamics which can be exploited for a more efficient emergency management. Current disaster management systems focus on single types of emergencies and cannot be flexibly adapted to the respective situation. The presented approach developed during the PHAROS project describes an integrated service platform which offers tools for multi-hazard emergency management using a modular and flexible structure. The assets provided by PHAROS include:(i) data collecting and processing, (ii) communication and alerting means, (iii) risk and emergency detection and situation assessment, (iv) decision support. In addition to the system scope and description, the paper presents the PHAROS pilot demonstration used to validate the system. For this evaluation the system was developed for a forest fire scenario and tested in Solsona, Spain in March 2016 during a real operational prescribed burn.

Keywords: PHAROS, public alerting, forest fire, IT supported crisis management, risk assessment, earth observation, decision support

1 Introduction

The Earth trembles, rivers burst their banks, tsunamis destroy coastal regions. There is a higher concentration and impact of natural and man-made disasters, like floods, forest fires, nuclear accidents and earthquakes. Emergencies and disasters generally present some similarities with regard to their basic dynamics but at the same time pose particularities which must be tackled differently. Current disaster and emergency management tools are generally hazard-specific and cannot be easily adapted neither to support management

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of other types of emergencies nor to efficiently handle cascade events and inter-related crisis. Therefore, possible existing synergies between available tools are difficult to be exploited. Furthermore, the potential of space based technologies, such as satellite-based Earth observation (EO), satellite communications and satellite navigation, which are robust against disaster events, is not fully exploited for emergency management purposes. The PHAROS approach is to provide an integrated platform which offers a wide range of IT-based tools for multi-hazard emergency management during the complete emergency management cycle [Mu14a]. The system has a modular structure which is flexible and scalable, i.e. it allows easy tailoring to address different hazards (e.g. forest fires or floods) and needs. PHAROS assets include: (i) tools for data collection, processing and distribution, (ii) communication technologies with emphasis on public alerting, (iii) risk and emergency detection and forecast of the evolution and of the disaster itself, finally, (iv) decision support services.

Regarding the development of information and knowledge management systems in the context of disaster risk reduction, a list of issues which underline the need for a systematic approach have been identified, according to [Th16]. Among these issues, the following can be highlighted:

- Information is scattered among various agencies and institutions with limited coherence, coordination and sharing;
- Information about hazard events, exposure, vulnerability, and the impacts of disasters is often not systematically collected;
- Risk information is not systematically used for policy and decision making;
- There is little integration of knowledge systems at national, regional and community levels.

Therefore, there seems to be a need for tools that allow the gathering and integration of different information sources in a systematic way, making it possible to use the collected information for decision support purposes. Additionally, these tools shall enable information sharing among different jurisdictional and organisational levels, identifying the relevant information items and providing data formats supporting efficient data sharing. The modular PHAROS system approach is able to provide flexibility and scalability. On one hand, with respect to the functionalities that it is able to provide, thus allowing to add and remove system elements according to the hazard and scope to be addressed. On the other hand, scalability allows adapting the system deployment to the different organisational structures, at local, regional, national and international level.

Although keeping in mind a multi-hazard system approach, the design and implementation phases took into account forest fires as exemplary scenario. The system was validated and demonstrated in Solsona, Spain in March 2016 during a real operational situation in the context of a prescribed burn. The demonstration was done in cooperation with the Catalan Fire Brigades and the DLR VABENE++ project. Aerial real time image acquisition (optical and thermal) by means of a helicopter was included in the demonstration and the gathered data was presented to users for situation assessment.

This paper is organized as follows: section 2 describes the approach and applications of the system. Section 3 shows the structure of the system and the individual modules. Section 4 describes the pilot demonstration using a real forest fire and in section 5 the user evaluation is presented. Finally, section 6 concludes the paper.

2 The PHAROS Approach

The present document introduces the final version of the PHAROS system architecture with focus on the forest fire hazard. The description includes the identification of the different modules (sub-systems) that build the system, explaining their interaction with other modules and describing their functionalities. The developed system is in pre-operational state which integrates a number of modules, namely data systems (such as space-based and aerial EO data and terrestrial in-situ sensor data) together with tools for processing this data (such as simulators, alerting and decision support tools) as illustrated in figure 1. Each of these data systems and tools can be considered as an independent module to be integrated within the overall system, providing different features. The modules can be interconnected to the overall system by means of a service platform (SP), which acts as a mediator between them. It must be highlighted, for the sake of clarity, that even if the overall PHAROS system is described as a platform, the term service platform will be used to refer to the system mediating core module.

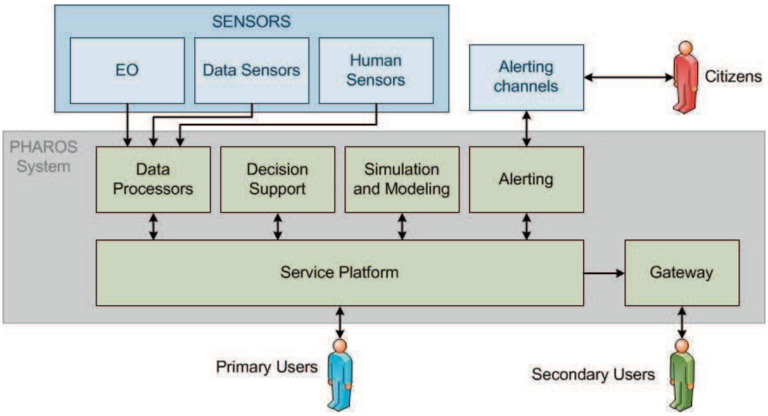

Fig. 1: PHAROS Functional Architecture

According to their purpose when using the system, users have been classified in three different categories: (i) primary users which are any responsible authority which uses the system to directly confront a particular situation and/or incident, (ii) secondary users, i.e. any third-party entity, for instance, research institutions or companies that exploit a service of the system and (iii) recipients like citizens that are provided with information that is sent/made available through the PHAROS system. Tackling these users, the PHAROS system combines the four applications described in the following.

Risk and threat assessment which is considered a key feature of the PHAROS platform. Primary users are interested in obtaining information that allows them to assess the existing risk or threat for different areas and hazards, taking into account the characteristics of the area, the current situation and the existence of critical infrastructures. Critical infrastructures must be understood as the assets, systems and networks, whether physical or virtual, so vital that their incapacitation or destruction would have a debilitating effect on security, national economic security, national public health or safety, or any combination thereof [Of16]. In risk assessment scenarios, not only the real but also the potential damages to the existing infrastructures play an important role together with the possibility that an event is initiated by the infrastructure itself. Together with the mentioned cases, users may interact with the system in order to get predictions of the evolution of the crisis, either during real crisis or for training, mitigation or preparedness purposes.

Furthermore, the system can be used for risk and disaster detection and monitoring scenarios. Automatic detection is important not only to timely detect hazards, which is a topic where already existing tools can offer satisfying solutions, but also to timely detect a high risk of any hazard likely to happen. This involve the use of different data inputs, such as EO data and in-situ sensor data, to be monitored together with the establishment of rules that will define the behaviour of the system for the different cases.

Another application area covered by the system is disaster management. This usually defines the interaction between the system and the different actors which need proposals on the suitable strategies to be carried out (for instance, sending an alert message, or fire fighting strategies), based on the input coming from the sensors and the data processing carried out by the system. Apart from primary users in the respective control centres, disaster management takes into account the involvement of first responders on the field, since many decisions are actually taken by them.

PHAROS is a composite system bringing together multiple and diverse actors, thus the efficient support of communications among the actors is also considered as a crucial aspect. The focus of communication is given to dissemination of alerting messages to alert recipients using a wide variety of communication technologies (alerting channels). Alerts are sent, for instance, to dedicated mobile applications for direct presentation in the users mobile terminals, data being transmitted over cell broadcast. Nevertheless, communication is not restricted to alerting; it also includes interconnection of the different elements of the system, as well as allowing sharing of data gathered and processed by PHAROS (e.g. simulation results, EO data) to third-party platforms in order to allow interoperability between different authorities in different areas or with different jurisdictional responsibilities.

3 System Description

The implemented PHAROS system architecture is depicted in figure 2. In the following, a detailed description of the implementation of each module focusing on the forest fire case is given. The arrows in the picture indicate the direction of the communication. Arrows in both directions indicate a bidirectional connection, for instance the simulation services and the service platform communicate with each other in a bidirectional way: the simulation services provide simulation results to the service platform and the last provides data that is used by the simulation services for the simulation.

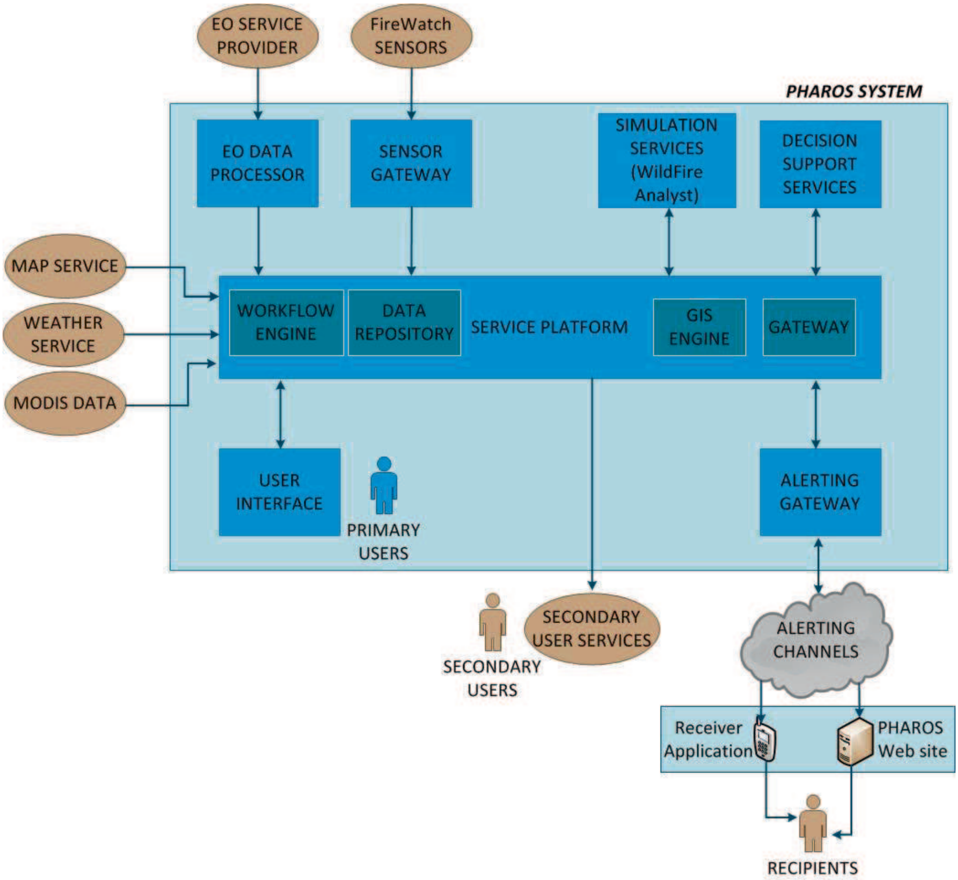

Fig. 2: PHAROS System Architecture

3.1 Service Platform

The Service Platform (SP) is the central component of the system. Its purpose is to interconnect the different modules and orchestrate the communication workflows between them. Its primary role is to act as a data mediator (information hub) between the different modules, so that they can exchange information in a transparent way, using common open APIs and interfaces. Furthermore, the SP is in charge of orchestrating the PHAROS system by implementing the rules established in the work-flow engine and invoking the appropriate modules according to pre-defined sequences. The SP exposes the services of the system via a graphical user interface (GUI) tailored for the primary users as well as via a gateway devised for secondary users to access the PHAROS services.

Most of the interfaces exposed by the SP are based on Web technologies and open standards, so that all modules can publish and acquire information in a uniform and coherent manner. The SP offers a data repository service for sensor and raster/vector geo-referenced data, where raw sensor information as well as processed data and simulation/assessment/ decision support data can be stored and acquired on-demand. A common information bus based on an enterprise service bus (ESB) architecture enables modules to asynchronously push and pull information also supporting publish/subscribe-based communication and allows the interconnection of a virtually unlimited number of heterogeneous sensors and processing modules, thus promoting the scalability and expandability of the system.

Finally, the SP provides connectivity with third-party services. It implements dedicated interfaces to external service providers as plug-ins, conforming to the providers API, in order to acquire information from sources external to the PHAROS platform. So far the SP interfaces two particular external service providers: a map and a weather service provider. Regarding the provision of services, it exposes an interface so that PHAROS-generated information can be consumed by third-party services, operated by secondary users.

3.2 User Interface

The user interface gives primary users access to the various functionalities of the system. It integrates together all the other sub-systems and offers multiple services to the users. It is also used by administrators to configure the system. It offers a login interface to identify users and their access rights. The interface intuitively makes sure that the user can find functionalities easily and quickly.

3.3 Earth Observation Systems and Processors

The EO data processor gives the possibility to use EO data (satellite and airborne based) and its derived products in the SP, making it available to other PHAROS components such as the simulation services and the decision support system). The SP and the EO Data Processor communicate using INSPIRE/OGC compliant services [Mu14b].

The primary use in the context of forest fire is the provision of an operational fire hot spot service, which is capable of detecting thermal anomalies in near-real time. For this purpose two independent EO platforms are used, the MODIS sensor from NASA [MO16] and the MSG Seviri Sensor [Me16] from EUMETSAT. Both of them are acting as a triggering input for the simulation services and the decision support services. The MODIS and MSG Seviri hotspot data does not need to be processed in the PHAROS system. Therefore these data can be considered as an additional data input, which is directly provided to the corresponding service through the SP.

3.4 Sensor System and Gateway

Sensor systems provide sensor data to be used for risk and emergency monitoring and management. In the particular forest fire case, the FireWatch system [IW16] is used as sensor network. The FireWatch in-situ sensor system performs a permanent and automatic surveillance of a predefined area regarding smoke as a first indicator of an incipient wildfire. In case that a smoke cloud is recognised, a detection message is generated, including further detection details (e.g. fire location, images) and transferred to the sensor gateway. The sensor gateway combines various sensor networks. Here, all messages are further processed and verified by human personnel. The sensor gateway controls the sensor network elements and provides the interface to the SP.

3.5 Simulation Services

The aim of the simulation services is twofold: (i) on the one hand, it enables the evaluation of the potential development of a detected crisis situation and on the other hand (ii), it enables to assess the risk of that situation related to the existence of critical areas or infrastructures. Concerning the first case, the simulation of the behaviour of the detected hazard can be manually triggered by the user or automatically by the operation of the decision support service. At the same time, the outcome of the simulation services can be used by the decision support service as described in the following paragraph. The simulation module is based on the WildFire Analyst capabilities [Te16]. This module provides, among others, the assessment of the forest fire potential based on critical infrastructures, the visualisation of fire evolution in an area and an estimation of the necessary evacuation time.

3.6 Decision Support Services

The Decision Support Services aggregate all available information about a situation (e.g. EO data, weather and mapping data provided by the external suppliers, data coming from the FireWatch system, the simulator outputs and any data manually introduced by the users) in order to provide tools for improving situational awareness by using a common operational picture (COP). A decision support system (DSS) has been developed which provides the user with notifications about important situation updates and alerting proposals based on the knowledge stored in the system by means of pre-defined alerting plans. The DSS can be extended to apply additional domain knowledge (work-flows, rules) provided by end users and domain experts to also cover additional proposal types and hazard types.

3.7 Alerting Services

Following a multi alerting channel approach for alerting services an alerting gateway (AG) has been developed. With the multi-channel approach the number of possible receivers is increased and with this the number of people reached, respectively. The objectives of the AG are: (i) to compose alert/information messages, either by combining options selected by the user through the GUI or by using the results of the operation of the DSS and (ii) to transmit the corresponding messages through selected available alerting channels. For transmitting the messages, the AG can use either the common alerting protocol (CAP) to ensure compatibility with already existing alerting systems as well as a new protocol for efficient transmission over narrow-band channels. An RSS-feed presented on a website and cell broadcast have been selected as alerting channels to evaluate the system. A receiver application for Android mobile phones has been implemented for the reception and presentation of the messages.

4 System Demonstration - Forest Fire in Solsona

The PHAROS system was validated and demonstrated in Solsona, Spain, March 2-4, 2016 in cooperation with the Catalan fire-brigades. Its main goal was twofold: (i) evaluating performance and viability of the integrated set of tools, services and products developed during the project, and (ii) testing, validating and gathering feedback from key stakeholder groups and end users (primary users) of the PHAROS platform in its pre-operational status. To achieve those objectives, the pilot demonstration was based on the forest fire scenario. A prescribed burn, a technique commonly used in forest management in order to minimise risks of fire in a region, was carried out during the demonstration. It was suitable to simulate a low-medium intensity forest fire [Co11],[RST13]. Some exercises to be carried out by the end users were prepared. In order to collect feedback a questionnaire was distributed among the end users and evaluated. The feedback gathered during the pilot demonstration revealed how the end users held a very positive opinion of the platform and the different components that they were able to test during the demo. For each of the components, recommendations and suggestions to improve the platform in possible future developments were collected.

The following different types of exercises were conducted: (i) Exercises using real-time sensor data and (ii) non-real-time exercises. When it was not possible to gather data from the field, manual input was used. Apart from real time data coming from the different sensors, the prepared setup allowed to manually configure the system parameters to see their effects during emergency management (e.g. higher wind speed in order to achieve larger fire perimeters).

4.1 Burning area and location

In figure 3 the selected area of the prescribed burn is shown. It includes virtual objects for the DSS which are described later on in the paper. The selection of the location depended essentially on three factors: weather conditions, type of vegetation and extension of the plot. However, there were additional objectives of the prescribed burn besides the PHAROS pilot which affected the area selection. These basically were forest fire prevention and forestry management [RST13],[ALM13],[Fe10]. The fire was used to reduce the fuel load, in particular the undergrowth vegetation was burned in order to reduce its amount for the fire season. The plot had a regular structure of Pinus nigra with undergrowth of Buxus sempervivens and Juniperus communis. Dominant Pinus nigra height is between 7 to 10 meters. The tree density was between 800 and 2700 trees/ha with complementary species such as Quercus ilex 200 to 500 tree/ha and regenerated of holm oak and pine.

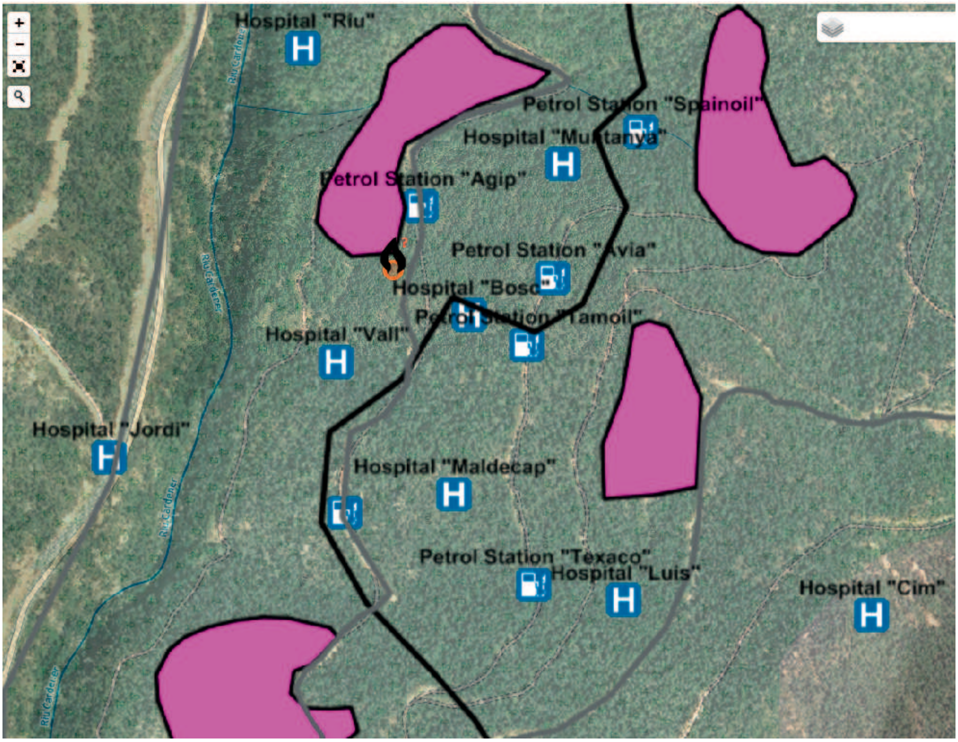

Fig. 3: Area of the prescribed burn with some exemplary virtual objects: hospitals (H), petrol stations, settlements (pink), power lines and streets

4.2 Description of the Prescribed Burn

Thanks to the support provided by the Forest Science Centre of Catalonia (CTFC), whose headquarters are located in Solsona, a control room was established in the CTFC premises. The fire could be monitored from the control room and a set of pre-defined exercises were carried out to test the PHAROS platform.

The execution of a prescribed burn (PB) was based on a prescribed burn plan, in which all detailed information of the PB is compiled. Before starting the PB, a briefing was carried out between all actors involved in the execution of the PB to clarify aspects related to the development of the PB and safety procedures for the staff:

- Review of PB objectives, as defined in a prescribed burn plan;
- Roles assignation, e.g. the head of burning, the head of ignition, the head of safety, the torches, the observers or watchers;

- Check of the radio communication;
- Definition of the smoke management;
- Recognition and tour of the plot, on foot or by car.

After this briefing, a test fire was carried out to evaluate if the fire behaviour was appropriate to achieve the PB objectives. Otherwise, the head of burning operations would reserve the right of postponing the PB by some hours or even cancelling it. If the tests were successful the exercises started.

Around 100 invited stakeholders from different organizations attended the PHAROS presentation and 25 of them could use and validate the platform. The demonstration involved the fire fighters experts that are commonly taking decisions during wildfires in the test region. Six experienced supporters, familiar with the PHAROS system, were distributed across four workstations in the control room. The supporters guided the end users through a forest fire exercise in order to explain them how the PHAROS platform worked; they simulated an emergency and recorded the participants feedback. Each workstation had a PHAROS platform running during the pilot demonstration. Groups of 2-4 end users gathered around each workstation while the main supporter explained the platform and performed the intervention on a simulated emergency.

The fire fighters performed the prescribed burnings during three days each with a duration of four to five hours. Thereby, the open fire line was around 80-100 meters. 12-20 fire fighters formed the team that carried out the burn. To give an idea of the fire some pictures of the fire can be seen in figure 4.

Fig. 4: Forest fire of the pilot demonstration

4.3 Fire Detection and Crisis Mapping

Besides the satellite data provided by the MODIS system a helicopter was used in cooperation with the project VABENE++ to provide the PHAROS system with real time data of the fire site. The BO 105 helicopter was equipped with two sensor systems: (i) AIR-

Sig sensors (thermal camera), (ii) a 4K camera. Different maps made from the helicopter during the burn are available at [Ze16].

For the fire detection the already mentioned FireWatch system was used. The FireWatch equipment was installed in a strategic location for fire surveillance. From there, the FireWatch cameras delivered smoke notifications to the PHAROS system at the start of every days exercises (figure 5, right side zoomed). In order to interconnect the FireWatch system with the SP a satellite link using F-SIM was selected. Satellites offer a robust connection in case of disasters and hazards. A 72 cm satellite dish for the F-SIM terminal was installed with line of sight to the geostationary satellite Ka-Sat at 9 degree East at same location hosting the FireWatch gateway.

Fig. 5: Forest fire detected by the FireWatch system

4.4 Decision Support with Virtual Objects

Considering that the chosen pilot area was in a remote area with few infrastructure and nearly no high-risk objects, in order to be able to test and show the features and capabilities of the PHAROS system during the pilot demonstration, the area and its surroundings needed to be filled with virtual objects. These virtual objects were fed to the PHAROS system (e.g. added to the geographic databases and the DSS configuration) in order to create a scenario of a populated (urban/rural) area with settlements, hospitals, petrol stations, streets and power lines. The placement of the virtual objects are shown in figure 3.

In order to assess the potential impact of wildfires assuming different environmental and weather conditions, a set of simulation runs were conducted and documented. An example where the prediction of the evolution of a fire is shown can be seen in figure 6 . The contours in the results show the evolution of the fire area on an hour basis, considering the wildfire to spread without control of the fire fighters. The results of the simulations were used by the DSS to assess the potential impact of the fire. The DSS successfully used the gathered data and simulations to support the user with notifications and alerting proposals. The DSS warned if critical infrastructure was affected so that the users could prioritize and plan next steps in fighting the fire and send warning messages to the public.

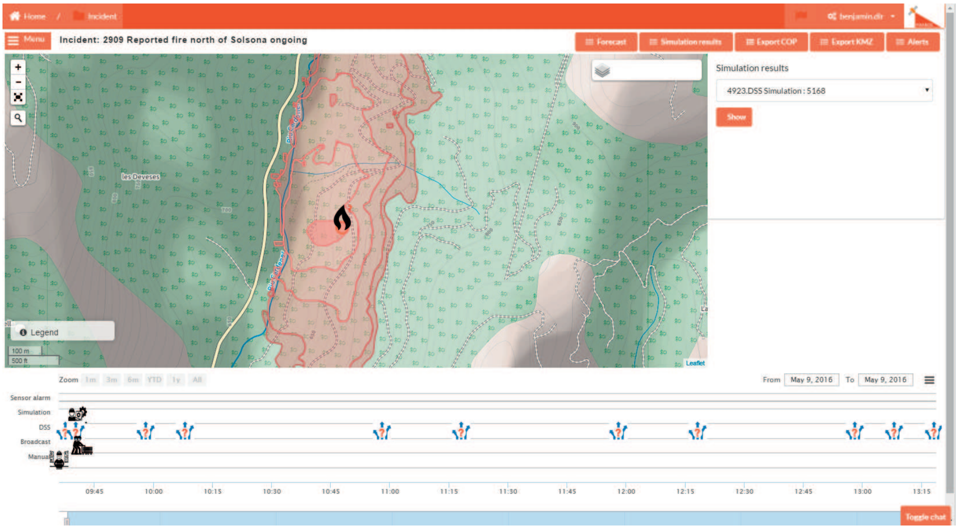

Fig. 6: PHAROS GUI showing simulation results

4.5 Communication with First Responders and Public Alerting

During the demonstration the users could use the communication tools at any time to communicate with the fire fighters on the field and warn the public. First responders were equipped with smart phones with a derivative of the mobile application that also provides a chat feature and the possibility to send the location of the device to the PHAROS SP. In addition, they also receive the message intended for the public warning.

In order not to disturb the public peace alerts were not transmitted via real channels to the public. They were transmitted and received in a lab environment. Smart phones with receiver applications connected to the alerting services via a VPN were present in the control room for this.

A second channel demonstrated for alerting purposes was cell broadcast. The cell broadcast alerting services consists of two building blocks: (i) a cell broadcast broker (CBB) which basically receives the message from the AG and forwards it to the users (described in more detail in [Mu14c], [Ba15]), (ii) the PHAROS cell broadcast network, which is implemented in a lab environment with OpenBTS, to implement the Mobile Operator Domain. For lab type research purposes, we were using a very small transmitter of only 100 mWatt, being allowed for research purposes, strong enough to test a couple of mobile receivers or mobile handsets, roamed on the used research network and placed within about a meter of the software radio set up.

5 End User Evaluation Results

The PHAROS system received a generalised positive feedback. The end users described the system as a spine of the emergency system. The novel component of this platform is that it integrates an emergency prevention and prediction system, as well as simulation and evaluation tools. Altogether, the different components of the platform will allow a better decision making before and during the early stages of the emergency, allowing then to prevent natural and humanitarian disasters. In general, minor improvements were suggested to increase the effectiveness of the platform to manage disaster emergencies. The highly valuable feedback given by the end users has been translated into recommendations to constitute a basis to advance in the development and implementation of the PHAROS platform. These recommendations and detailed feedback on the single components can be found at [Pr16]. Besides suggesting improvements on the existing features, new additional features were advised, e.g. the integration of a variety of existing/current systems such as TETRA, traffic management (TMC), and 112 services. Integration of additional systems and capabilities with PHAROS modular and scalable design will be relatively straightforward.

The end users reported that the mobile application was very useful and they particularly liked how it was integrated into the wider PHAROS system. A recommendation from the users in relation to the mobile application was that they would have liked to have even more textual and visual information displayed on the smart phone.

Besides the wide spectrum of improvements and augmentations that could be added to the PHAROS system, there also exists a major opportunity to provide a standardized emergency response alert system, in collaboration with mobile network operators, manufacturers and governmental agencies.

6 Conclusion and Outlook

In this paper we show that the PHAROS concept of a open integrated platform is able to be adapted to the forest fire case and successfully supports the crisis management. We describe the recent implementation of the PHAROS system and the execution of the pilot demonstration. For the PHAROS pilot three prescribed burns were organized and executed and the different parts of the PHAROS system were tested. Around 100 invited stakeholders from different organizations attended the PHAROS presentation and 25 of them could interact with the platform. This wide range of participants had a positive impact in order to provide an accurate feedback. The demonstration involved the fire fighters experts that are commonly taking decisions during wildfires in the test region. They had the possibility to explore the platform during a real forest fire event and carry out the simulation exercises that were prepared for them in the context of this pilot demonstration.

7 Acknowledgement

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