Applying OGC Sensor Web Enablement to Risk Monitoring and Disaster Management

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Abstract

This paper presents the practical application of the OGC Sensor Web Enablement Architecture to a set of use cases in the area of risk monitoring and disaster management. After introducing the OGC Sensor Web Enablement framework, use cases ranging from hydrological monitoring and measuring different types of pollution to fire fighting applications will be presented.

Keywords: OGC, Sensor Web Enablement, SWE, Sensor Networks, Registries Catalogues

1. Introduction

The Sensor Web Enablement (SWE) activities of the Open Geospatial Consortium (OGC) have led to a powerful set of standards allowing the integration of sensors and sensor data into spatial data infrastructures. The OGC SWE architecture comprises standardized encodings as well as service interfaces which can be used on the application level. The SWE encodings provide data formats for encoding sensor measurements (OGC Observations & Measurements) as well as sensor metadata (OGC Sensor Model Language). Furthermore, web service interfaces for accessing sensor data (OGC Sensor Observation Service), subscribing to alerts/events (OGC Sensor Alert Service) and controlling sensors (Sensor Planning Service) are available.

Within our paper, we will present two projects in which the OGC SWE architecture is used for building risk monitoring and disaster management systems. We will show how SWE concepts can be integrated into spatial data infrastructures and how the architecture consisting of different SWE services is designed. Especially the benefits of being able to integrate real time sensor data into spatial data infrastructures will be illustrated, as this is an essential requirement for reliably dispatching time critical alerts. In addition, experiences and lessons learned from the practical implementation will be discussed.

The OSIRIS project (Open architecture for Smart and Interoperable networks in Risk management based on In-situ Sensors, http://www.osiris-fp6.eu) will be introduced. The complementary OSIRIS uses cases illustrate the flexibility of the SWE framework: SWE components are used within scenarios ranging from forest fire fighting, water and air pollution assessment to the avoidance of false fire alarms in industrial environments.

In addition, a project which was conducted in cooperation with a German water body authority (Wupperverband) will be described. This project concerns the monitoring of flooding risks caused by rivers. Within the system architecture of this project, SWE services are used for monitoring precipitation as well as water levels and for sending alerts if critical situations occur.

2. Sensor Web Enablement

2.1 The Open Geospatial Consortium

The Open Geospatial Consortium (OGC) is an international, non-profit, voluntary consensus standards organization consisting of more than 380 companies, government agencies and universities. The overall goal of the OGC is to "geo-enable" the internet as well as location-based services and mainstream IT applications. Therefore, the OGC is defining standards for complex spatial information and (web) services that can be used by all kinds of further applications. One well-established example of an OGC specification depicts the Web Map Service (WMS), which offers web-based access based on spatial queries for the retrieval of maps (De La Beaujardiere 2006). Another well known standard is KML which recently became an official OGC implementation specification (Wilson 2008). Furthermore, the OGC standards form the basic building blocks for several spatial data infrastructure activities like INSPIRE[1] or GEOSS[2]. Current research related to the OGC activities focuses on the one hand on discovery of and semantic interoperability between geospatial data as well as an interoperable integration and exchange of geosensor data as described in this paper.

2.2 The SWE Framework

The OGC Sensor Web Enablement (SWE) working group defines standards for sensor data and sensor services. Following Botts et al. (2007) "a Sensor Web refers to web accessible sensor networks and archived sensor data that can be discovered and accessed using standard protocols and application program interfaces (APIs)". A Sensor Web can hence be seen as a huge internet based sensor network and data archive.

To achieve the vision of the Sensor Web, the SWE initiative defines standards for encoding of sensor data as well as standards for service interfaces to access sensor data, task sensors or send and receive alerts. As the specifications are based on common OGC standards such as OWS Common (Whiteside 2005) and the Geography Markup Language (GML) (Cox et al. 2004), the SWE standards enable an easy integration of sensor data into common spatial data infrastructures, which consist of already established standards such as the WMS. The SWE specifications can be grouped into the SWE information model, which defines encodings for sensor data and the SWE service model, which contains the service interface specifications for sensor data access, alerting and sensor tasking.

2.2.1 Observations & Measurements

The Observations & Measurements (O&M) specification defines basic models and encodings for observations and measurements made by sensors (Cox 2007). An observation can be interpreted as an act of observing a phenomenon, whereas a measurement depicts a specialized observation in which the result is a numerical value. The basic observation model contains five components (as shown in Figure 1): The procedure element points to the procedure (usually a sensor), which produced the value of the observation. The phenomenon that was observed is referenced by

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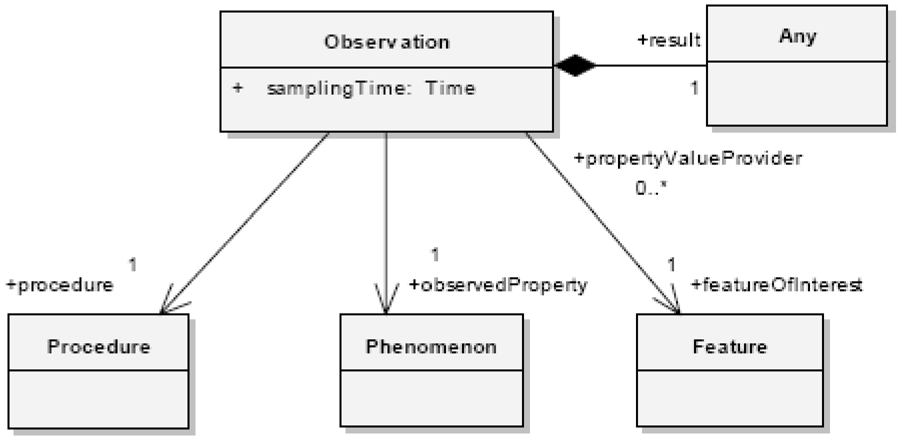
1 The Infrastructure for Spatial Information in the European Community (INSPIRE) depicts an initiative of the European Commission with the goal of building an unified European spatial data infrastructure. More information can be found at http://inspire.jrc.ec.europa.eu/.

2 The Global Earth Observing System of Systems (GEOSS) aims to provide an infrastructure for sharing environmental data between different communities. More information can be found at http://www.earthobservations.org/.

the observedProperty element. The featureOfInterest refers to the real world object to which the observation belongs. The referenced feature also contains the location information of the observation. The samplingTime attribute indicates the time, when the observation was sampled. The observation value itself is contained in the result element. In addition, there are further attributes like quality information, which are not displayed in the diagram for simplicity.

Figure 1: Simplified basic observation model of the O&M specification



2.2.2 Sensor Model Language

The SensorML specification (Botts 2007) provides models and encodings to describe any kind of process in sensors or post processing systems. Therefore, the basic type of all SensorML descriptions is the process type. The process type is defined through its input and output elements and several optional additional parameters. Additional metadata like quality, calibration information or technical attributes can also be nested in SensorML descriptions. Different subtypes of the process type are specified which can be used to depict diverse kinds of detectors, actuators or systems of processes.

2.2.3 Sensor Observation Service

The Sensor Observation Service (SOS) provides a standardized web service interface which allows clients to access descriptions of associated sensors and their collected observations (Na et al. 2007). Like all OGC Services, the SOS offers the GetCapabilities operation to request a service description containing the spatial and temporal extent of the offered observations as well as a list of the sensors and observed features. In addition, users can request SensorML or TML encoded sensor descriptions using the DescribeSensor operation. The GetObservation operation offers access to observations and thus provides the core functionality of the SOS. Within a GetObservation request, spatial, temporal or value filters as well as sensor ids or ids of the observed phenomena can be defined in order to constrain the observation response. These three operations form the Core profile of the SOS and have to be offered by every SOS implementation.

To allow registering new sensors and inserting observations, a SOS instance can implement the Transactional profile of the SOS specification. This profile contains the RegisterSensor operation for registering new sensors to the SOS by sending a SensorML or TML description of the sensor. The SOS returns an id for the sensor, which can be used afterwards to insert new observations into the SOS using the InsertObservation operation.

Besides this, several further operations are defined (e.g. for retrieving the geometries of measurement locations). These operations are summarized in the Enhanced profile and will be not described further in this paper.

2.2.4 Web Notification Service

The Web Notification Service (WNS) defines a service to enable asynchronous dialogues (message interchanges) between SWE components (Simonis & Echterhoff 2006). This service is especially useful, if multiple collaborating services are required to satisfy a client request, and/or if significant delays occur when processing requests. Additionally, the WNS can act as protocol transducer by converting e.g. HTPP into XMPP messages. Thus, a WNS can enable the support of additional protocols like email, SMS or phone calls.

The WNS specification defines two communication patterns: the one-way-notification represents a simple notification, which means that the sender does not expect a response from the receiver. In contrast, in the two-way-notification the recipient has to create a response message and has to send it back to the caller. In the SWE framework, the WNS can be used in conjunction with SPS and SAS instances for allowing asynchronous messaging between service instances and clients.

2.2.5 Sensor Planning Service

The Sensor Planning Service (SPS) provides a standardized interface for tasking sensors and sensor systems to acquire observations at a certain time in a certain area (Simonis 2007). Before submitting a task to the SPS through the Submit operation, the client can request the information needed to prepare a valid tasking request. Additionally, the GetFeasibility operation can be used in advance for cheking, whether the execution of a task is feasible for a certain sensor. As the SPS does not offer access to the observations gathered by the tasked sensors, it offers the DescribeResultAccess operation for determining the access points to the collected data. Furthermore, the SPS interface offers functionality for managing submitted tasks. This includes operations for retrieving the status of a task, for updating tasks or even cancelling them.

Several use cases require a SPS to communicate with the client of a task asynchronously (e.g. in case of a request to a satellite system, the system might not be able to answer an a request before a human operator has taken his decision). Therefore, a SPS can use a WNS.

2.2.6 Sensor Alert Service

The Sensor Alert Service (SAS) specification defines a service interface which can be used by clients for subscribing to self defined alert conditions and to receive notifications in case the conditions are matched (Simonis 2007). This corresponds to the publish-subscribe communication pattern and is obviously in contrast to the pull based approach of SOS. The SAS itself offers only operations for managing the event notification system. Thus, the implementation of the underlying messaging server (which is used for publishing and notifying) is up to the service provider (usually an XMPP server is used for messaging). The SAS offers the capability for producers to advertise alerts and to renew or cancel an advertisement. Consumers can use the Subscribe operation to subscribe for certain alerts. Also, the subscription could be renewed or canceled.

There are two ways of delivering alerts, e.g. notification of the consumer: on the one hand the notification can be based upon pure XMPP communication, on the other hand alerts can be delivered via WNS instances. The latter is called the last-mile-mode because clients may not always be connected to the Internet so that the last mile between the Internet and these clients is bridged using the WNS.

3. Application of SWE in the OSIRIS Project

The European project OSIRIS (Open architecture for Smart and Interoperable networks in Risk management based on In-situ Sensors) is an integrated project funded by the European Union within the Sixth Framework Programme. Main objectives of the project are the definition, development and testing of services for surveillance and crisis management tasks. OSIRIS (http://www.osiris-fp6.eu) provides a Service Oriented Architecture based on standards in order to deliver functions ranging from in-situ earth observation to user services. Within OSIRIS, the efficiency of the in-situ data processing chain is improved by enabling end-users to access multi-domain sensor information. The in-situ sensors are connected via an intelligent and versatile network infrastructure. Four use cases demonstrate the effectiveness of OSIRIS: forest fires, industrial fires, fresh water pollution and air pollution in urban areas. These experiments are described in the following sections.

The OSIRIS project is coordinated by Thales Communications (France). In addition several partners contributed in the technological domain as well as in the practical realization of the demonstration scenarios. The practical implementation of the different scenarios was coordinated by specific OSIRIS partners: THALES and Remifor for the “Forest Fire” scenario, GMV and AUVASA for the “Air Pollution” scenario, APS and the Fire Department of Aachen for the “Industrial Risk” scenario and LAMMA and the region of Tuscany for the “Water Pollution” scenario.

3.1 Forest Fire Fighting

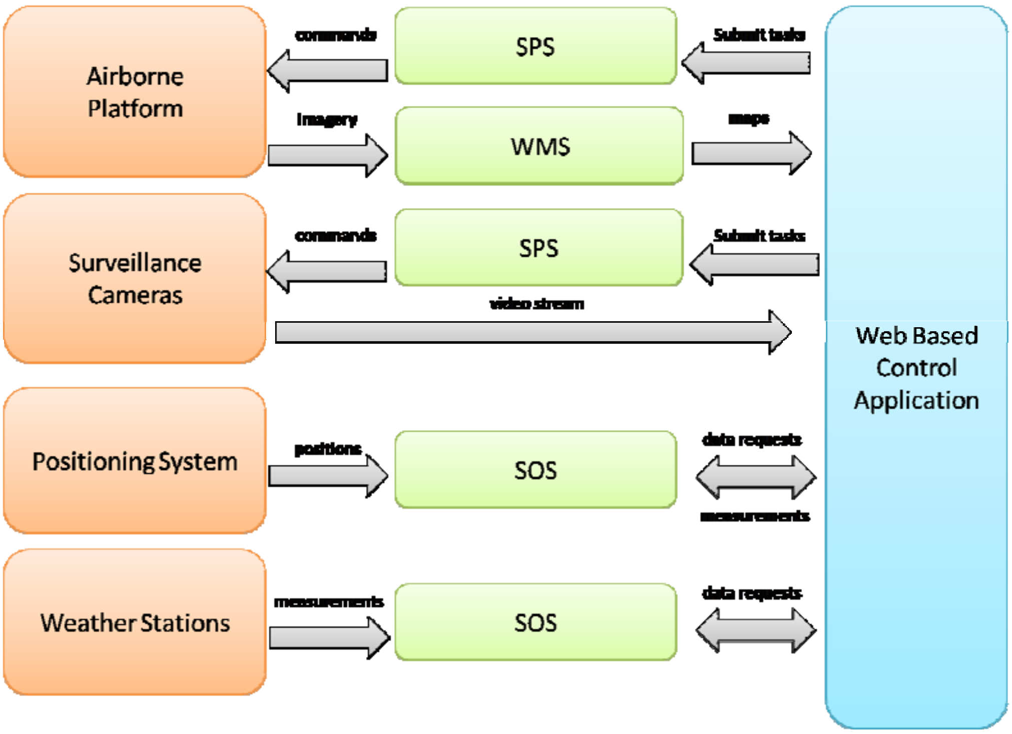
This scenario of the OSIRIS project is centered on the fighting of forest fires. The OSIRIS framework is used to manage the hazard with advanced fire-fighting strategies. It uses the functionalities of the developed architecture for generating added value in the monitoring and management of a forest fire situation. Besides a improved early detection of forest fires, a up-to-date assessment of the current situation is provided, including information about the current fire extend as well as the locations of fire fighters.

A practical demonstration of this scenario was conducted in the south of France in the “Département de Lozère”. There, forest monitoring and forest fire management are the responsibility of CODIS (“Centre Opérationnel Départemental d'Incendie et de Secours” engl. “Departmental Operational Centre for Fires and Emergencies”) which is the regional authority in charge of coordinating resources during fires and disasters.

During the scenario two phases were distinguished. First, the forest monitoring phase within which critical areas and risk zones were identified and the starts of local fires were detected. The second phase was the forest fire crisis phase. This phase addressed the reporting of alerts and alarms to decision-makers and operational forces. Also, this phase included the operational deployment of intervention forces and sensors as well as the management of the fire-fighting situation itself.

Overall, this scenario includes four different kinds of sensors. Firstly, an airborne platform equipped with a high-resolution digital camera is used to provide aerial imagery. This enables the emergency centre to gain a general overview of the situation and to identify areas of interest like threatened zones. Further on, it allows observing the fire frontline and it its evolution over time. The images captured by the HAP are ingested by a WMS instance which allows the standardized retrieval of these images. This service enables widely-used WMS clients to easily access and display the aerial imagery. Secondly, wireless cameras were used for the surveillance of areas such as evacuated zones, strategic traffic points or zones threatened by a fire. The tasking and controlling of the cameras as well as the airborne platform was realized by the means of the SPS interface. Thirdly, in case of a fire occurrence positioning sensors are deployed around the forest fire area to track and locate fire-fighters. It also enables fire-fighters to send alarms in case of an emergency. Fourthly, mobile weather stations were deployed to gather information about the local weather conditions such as wind, precipitation or humidity. The firemen positions as well as the data gathered by the mobile weather stations were served via an SOS interface.

Figure 2: Architecture overview of the forest fire fighting system



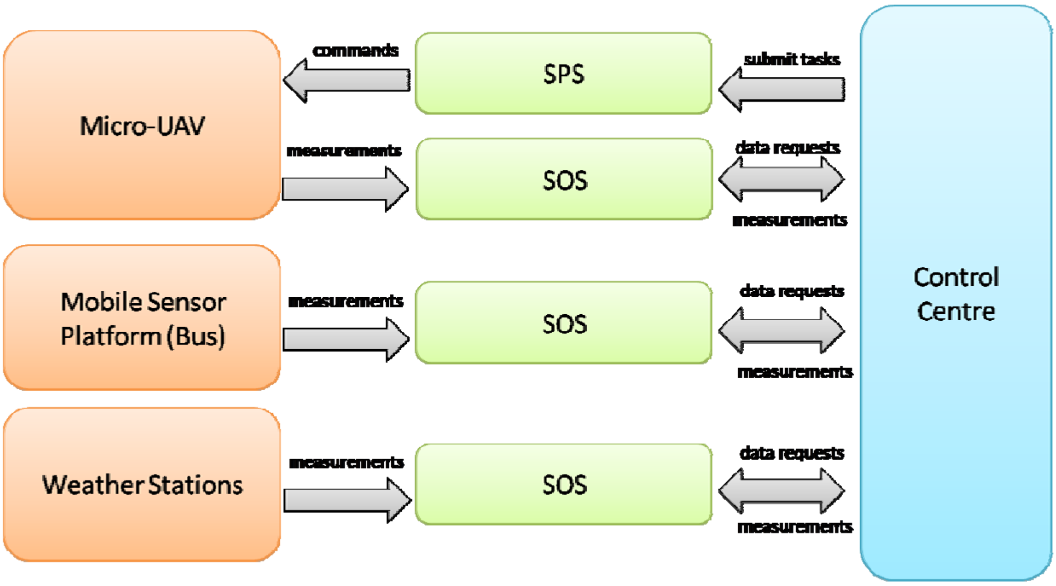
3.2 Air Pollution

This scenario was developed for providing a powerful solution for air quality monitoring and prediction. Sensor information is used to monitor the level of pollution in an urban area and to track the evolution of pollutant clouds in the case of a crisis situation. A practical implementation of this scenario was performed in the city of Valladolid in the north of Spain. This scenario is subdivided into two sub-scenarios.

Firstly, an air quality monitoring scenario within which air quality sensors are assembled on a bus to measure NO, NO_2 and noise was realized. An on-board communication system sends the sensor data tagged with time and position to the control centre. Dispersion models are then able to compute and combine the measurements from the fixed stations of Valladolid and the measurements from the mobile sensors into city pollution maps. The data gathered by the mobile sensor platforms are provided by a SOS server.

The second sub-scenario is the air hazard scenario. It is assumed that due to an accident toxic substances are emitted and propagate in the atmosphere. A micro-UAV is deployed to take air samples and to give meteorological information of the affected area. Then, dispersion models are used to predict the phenomenon evolution. These computations are combined with the measured meteorological input data coming from the fixed network of air quality monitoring stations in the surrounding area. The SPS is used to provide a standardized interface for controlling the micro-UAV. The data measured by the micro-UAV as well as the data from the meteorological stations are provided via SOS servers.

Figure 3: Architecture overview of the air quality monitoring system



3.3 Reliable Fire Detection in Buildings

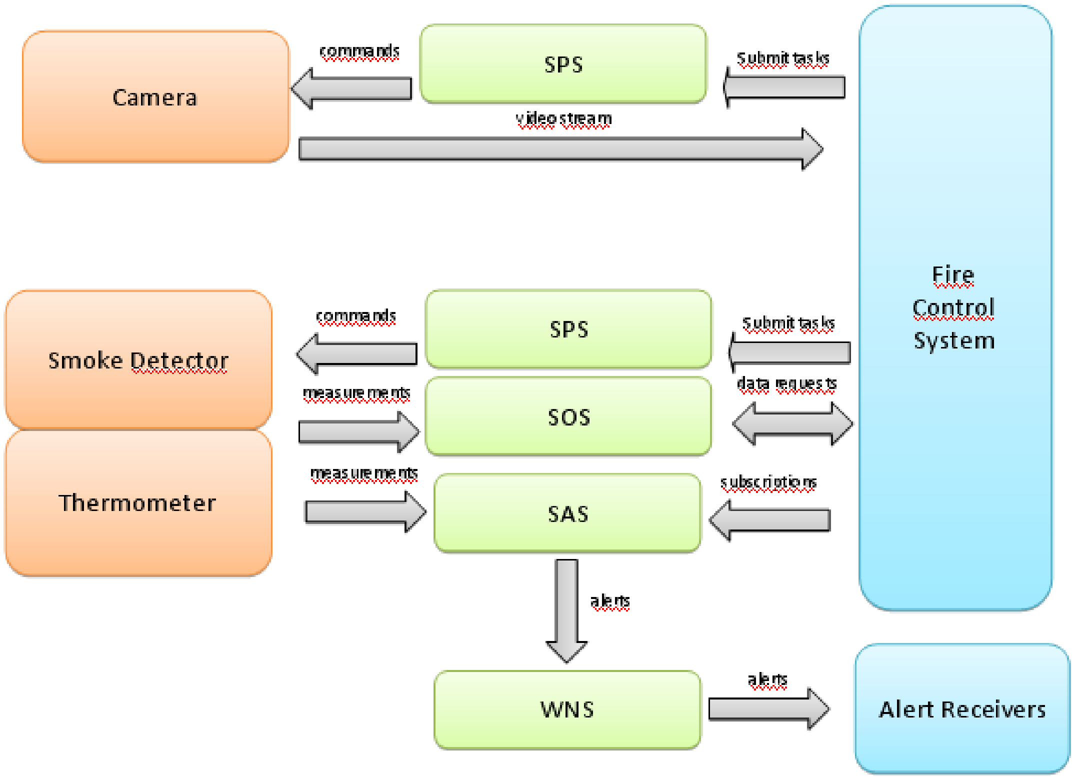
This scenario focuses on managing fire threats in industrial facilities. A network of wireless sensors is used to detect fires with a higher reliability. A special focus is put on the avoidance of false alarms by combining various types of sensors. Smoke as well as temperature sensors are combined in order to ensure that for example cigarette smoke (smoke but no increased temperature) or high temperatures in the summer (no smoke but increased temperatures) are not interpreted as fire events.

The validation of the developed system was realised in a real fire training environment at the fire department of the German city Aachen. A fire was caused within to demonstrate the fire detection capabilities of the system developed using the OSIRIS framework.

The wireless sensor network consisted of three types of sensors: smoke detectors, cameras and thermometers.

To allow an interoperable usage of these sensors three different SWE services were used. The SOS was used to access data gathered by the different sensors. The tasking of sensors to modify internal parameters was done via the SPS. And to allow users a registration for certain alerts and events (e.g. detection of smoke) the SAS was applied.

Figure 4: Architecture overview of the fire monitoring system



3.4 Water Pollution

This use case addresses with the threat of fresh water pollution within the Tuscany region in Italy. This region is faced with a high concentration of arsenic with a probably geological origin which is critical to the population and their water demand. Thus, a sensor network was installed which monitors the critical water ingredients and delivers data to a water quality simulation. A real monitoring system was set in-place to control the arsenic pollution.

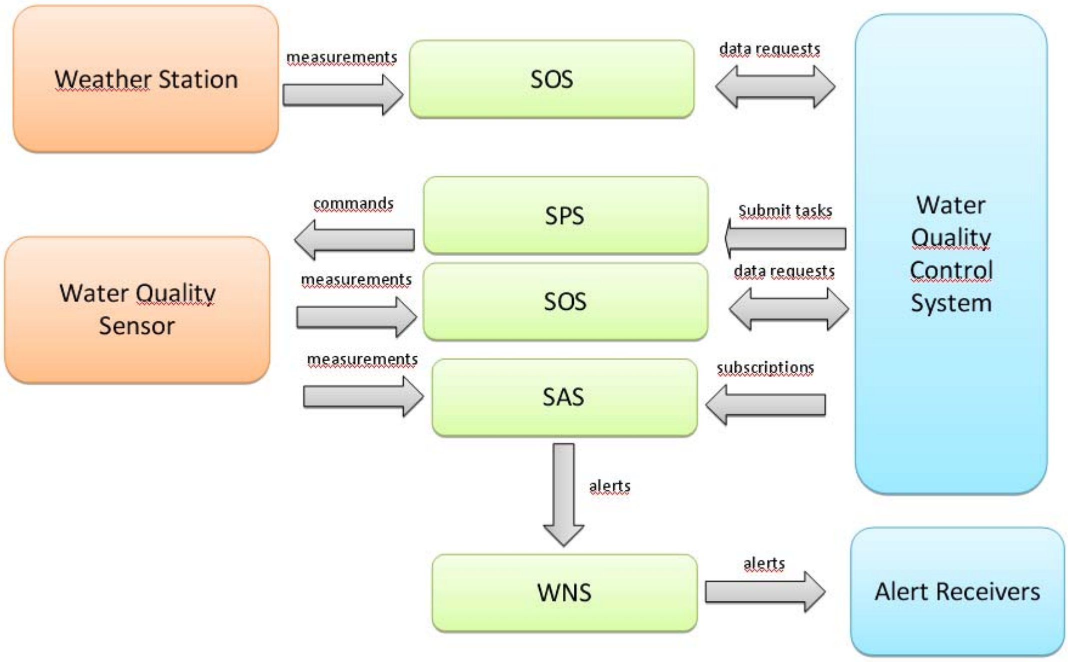
An additional sub-scenario deals with sudden emergencies (e.g. truck accidents) which cause hydrocarbon contaminations in vulnerable areas near fresh water springs. In case of an accident with dangerous goods, the water could be polluted. To assess the incident, sensors are installed to assess the threat and to react with appropriate means to guard the civilians.

The two sub-scenarios demonstrated an advanced monitoring strategy of ground water resources using the OSIRIS framework.

A range of different sensor types were utilized in this water pollution use case. A flux sensor with continuous sampling was located at the main ground water spring and monitored about 80% of the aquifer water. Additionally, two portable sensor platforms, an analyser for direct measure of arsenic and other specific parameters (e.g. pH) as well as on-demand deployable sensors for hydrocarbon, are used. Further on, a transportable meteorological-station is used to for gaining additional data about local weather conditions in case of an emergency.

These different sensor types are encapsulated by SOS servers to allow a standardized access to the captured data. The alerting functionalities of the system are provided using a SAS instance in conjunction with a WNS.

Figure 5: Architecture overview of the water quality monitoring system



4. Monitoring of Flooding Risks

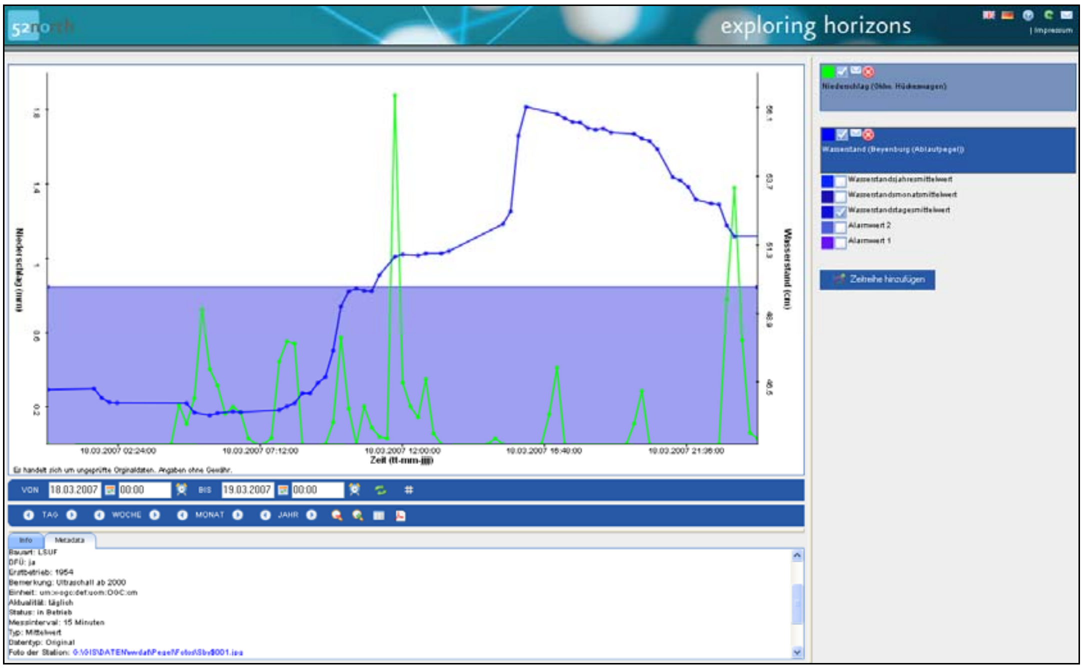
After presenting in the previous section the four scenarios addressed by the OSIRIS project, this subchapter will provide information about a fifth use case. Here, an application is presented that relies on SWE components for building a monitoring and warning system for floods along a river. It was built as a cooperative effort of the Open Source Initiative 52° North and a public authority in North Rhine-Westphalia in Germany, the Wupperverband (Spies and Heier, 2008). The Wupperverband is responsible for the water management within the catchment area of the Wupper River. These activities include flood protection as well as water level management.

For the design of the monitoring and warning system three different functionalities have to be considered that are required:

1. Display of time series data for water level gauges and precipitation
2. Real time notification in case of exceeded alarm values
3. Video surveillance of rain detention basins

The first of these functionalities is fulfilled using a SOS instance. As the data measured by the water and rain gauges is already available in an internal database, it is possible to rely on existing infrastructure for transferring the data from the sensors to a central server. The visualization of the data provided by the SOS is provided by a web based client, which is capable of rendering time series charts. An example of this visualization is shown in Figure 6.

Figure 6: Visualisation of time series data

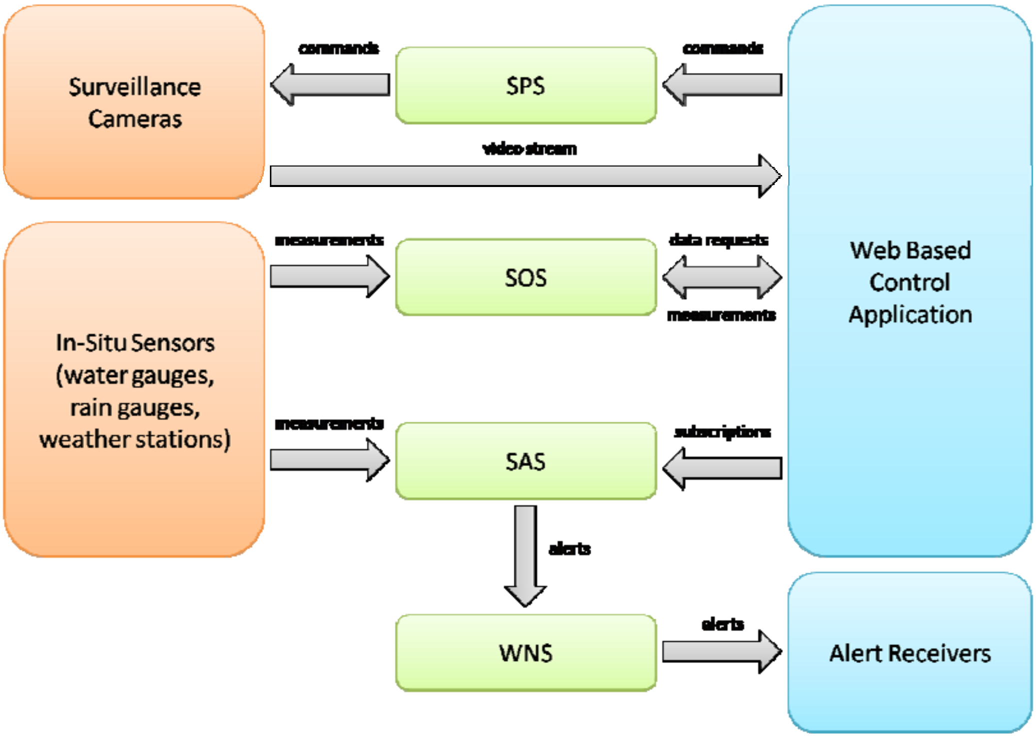


The next aspect, the real-time notification in case of exceeded alarm values, is based on the same set of data. In this case, the sensor data is transferred to a SAS instance which filters the incoming data with regard to alert criteria specified by users. The specification of such alert criteria through users can be made using a web based form. In this form, interested users can specify the alert conditions they are interested in (e.g. I want to be alerted if the water level at water level gauge XY is above 500 cm). Furthermore, this form allows defining the communication channels to which alerts shall be sent (e.g. SMS to a certain mobile phone number or email to a specific address). Thus, if a matching alert condition is found by the SAS, an according alert is dispatched. This is achieved by sending an according notification request to a WNS instance which then, relays to alert to the specified communication end point.

The final use case addresses a control mechanism for surveillance cameras in remote areas. As several water management infrastructure elements are quite remotely located, there is a need for delivering, especially in case of alerts, a visual overview of the affected location. By using controllable cameras (e.g. setting zoom, pan, tilt), it is possible to move the focus of the camera to the details which are of interest to the user. Within the system build by 52° North and the Wupperverband, this is achieved through a SPS instance.

In summary, this example has illustrated, as shown in Figure 7, how another risk management tool, a flood monitoring and warning system, can be build by relying on a set of SWE components.

Figure 7: Architecture overview of the flood monitoring and warning system



5. Experiences and Outlook

The implementation of the applications described within this article leads to the experience that the OGC SWE architecture has now reached a solid and mature state. Especially, the standardized interfaces of SOS and SPS but also the encodings O&M and SensorML provide a sound foundation for building web based applications on top of sensors and sensor networks. The broad selection of use cases ranging from monitoring air quality and hydrological parameters to fire detection and fire fighting scenarios allowed verifying the SWE architecture in very heterogeneous contexts. Thus, it can be stated, that the applicability of SWE in a wide variety of different contexts can be achieved without the need to perform complex customization and adaptation work on the interfaces and data formats. As a consequence, the implementations of SWE services are not bound to specific use cases; instead they can be exchanged and transferred independently of the domain they are used in.

However, for the future several work items remain in order to complete the SWE framework or to enhance its capabilities.

During the realization of the different systems described in this article, the often generic character of the OGC specifications was very challenging. The definition of profiles, describing subsets of OGC service interfaces and data formats, that are adapted to specific domains, would significantly facilitate their practical application. Furthermore, it would be desirable to develop domain specific best practice guidance documents that can be used by non-SWE-experts as reference when building SWE based systems.

Another aspect that results especially from the experiences gained during the OSIRIS project was the lack of sensor discovery and sensor network maintenance solutions. Users need to be able to find the sensors and SWE services they are interested in. Furthermore, they need a basic set of sensor network maintenance functionality (e.g. finding sensors that are not working properly). Although one of the services developed by the OSIRIS project provides such functionality, this functionality is not yet part of the SWE framework. Furthermore, there is a need to align solutions for sensor discovery to already existing standards, i.e. the OGC Catalogue Service.

The SAS specification is currently still in the standardization process. However, whereas the capabilities of the SAS were fully sufficient for the flood monitoring and warning system, within the OSIRIS project a few aspects that might need to be extended were identified. These extensions are mainly related to the filtering capabilities of the SAS:

- more sophisticated spatial filtering (e.g. using complex geometries (polygons))
- aggregation and linking of alert conditions
- temporal filtering (e.g. for detecting differences of values within a certain time period)
- support of all compare operators (currently ≤ and ≥ are missing)

Finally, a further work item is the integration of sensors into the SWE architecture. Whereas the SWE standards are mainly intended to provide an interface on top of which application level components can be created, the way how sensors are linked into SWE services is not fully specified (except approaches like the Transactional profile of the SOS). Due to the extreme heterogeneity of sensor and sensor network technologies, this is a very complex and challenging task. However a first step could be the provision of best practice guidelines how the link between sensors/sensor networks and SWE components can be realized. A more comprehensive, technical solution for this challenge will be subject of future work.

6. Conclusion

As outlined before, the SWE architecture has now reached a mature and solid state and has proven its applicability to a broad range of domains. This assessment was also confirmed during the development and validation process of the SWE applications described in this article.

For the future, several research topics will need to be addressed. This comprises the creation of profiles of SWE standards, solutions for sensor discovery and sensor network maintenance, enhanced (event) filtering capabilities for sensor data and solutions for facilitating the sensor integration.

However, despite these remaining work items, the application of the SWE architecture showed that it is ready to be used for building productive sensor based systems.

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