APPLYING THE SWE FRAMEWORK IN SMART WATER UTILITIES DOMAIN

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Water leakage, water contamination, inability to detect water quality are some of the problems affecting the existing drinking water infrastructures. Unmanaged wastewater can be a source of pollution, a hazard for the health of human populations and the environment alike. The majority of wastewater infrastructures results in massive run-off and flooding of cities in case of extreme rainfall events. One of the ways to address these problems is by creating *smart* water utilities, equipping them of smart distributed sensing systems, integrated with advanced information systems. The integration of the diverse networked sensors involved in the water utilities management is not straightforward. The objective of this research work has been to develop a OGC SWE (Sensor Web Enablement) architecture across different applications in the smart water utilities domain, capable of integrating the various networks of in-situ sensors and processing sensor observations into decision support systems, realizing sensor related services and data delivery.

1. Introduction

The world is facing a global water quantity and quality crisis. The ageing infrastructure of the water systems coupled with the increasing demand is adding pressure to the water networks. Many problems arise in terms of water leakage, water contamination, inability to detect water quality and so forth.

Unmanaged wastewater can be a source of pollution, a hazard for the health of human populations and the environment alike. Wastewater can be contaminated with a myriad of different components: pathogens, organic compounds, synthetic chemicals, nutrients, organic matter and heavy metals. They are either in solution or as particulate matter and are carried along in the water from different sources, affecting water quality. Also, existing wastewater infrastructures of most cities are no longer appropriate resulting in massive run-off and flooding of cities in case of extreme rainfall events.

One of the ways to address these problems is by creating smart drinking water and wastewater networks that involve the use of smart sensing systems distributed along the infrastructures and in the surrounding environment, integrated with advanced information systems (e.g. GIS; DSS; SCADA, etc.) and dynamics and analytics modeling components, providing the operators with a comprehensive and more effective set of decision-making capabilities for a sustainable water utilities management. A constant and real time stream of data by sensor networks coupled with predictive modeling capabilities, enables operators of the water utilities to quickly assess events as they occur, identify potential problems before they reach a critical level, respond to operational challenges, and minimize downstream effects. The observation systems have to be involved in the water utilities management are essentially based on diverse sensors. Nevertheless, their integration is not straightforward due to the variety of sensor protocols and interfaces. Within this framework, the objective of this research work has been to investigate and develop a OGC SWE (Sensor Web Enablement) architecture across different applications in the smart water utilities domain, capable of integrating the various networks of in-situ sensors and processing sensor observations into decision support systems, realizing sensor related services and data delivery. The developed SWE architecture has been applied within two real water utilities management scenarios. More specifically, one scenario was centered on water quality dynamics monitoring and predicting along the real Santa Sofia aqueduct (Southern Italy). The second scenario focused on building a monitoring and warning system for contaminations along the wastewater network of the Massa Lubrense city (Southern Italy).

2. The SWE Architecture

Within water utilities monitoring and management systems, the developed SWE architecture provides functions ranging from integrating and accessing the various networked sensors involved, to retrieving events and alerts triggered through sensors, as well as browsing, querying the real time observation data through a sensor web client and a QGIS SOS client application, developed ad-hoc. This architecture (Figure 1) consists of the services SOS (Sensor Observation Service), SES (Sensor Event Service) and WNS (Web Notification Service) [1].

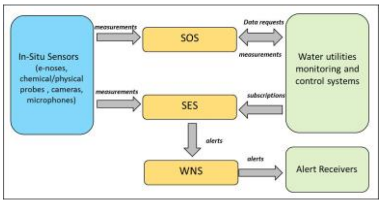

Figure 1 The SWE architecture developed for water utilities monitoring and control systems .

The SOS component allows clients (e.g. QGIS SOS client developed ad-hoc by ENEA) to access descriptions of associated sensors and their collected observations by a standardized web service interface. SES provides notification

services, with stream processing capabilities. Alerting and notification capabilities provides support for creating alarms and filter constructs by system users. Users may hence use created alarm constructs to subscribe to live sensor feeds and continuously receive notifications once events are detected during live streams processing. The notifications are processed by WNS that notifies the user by sending an email or sms with the notification received by SES.
The implementation of the proposed SWE architecture has been deployed by 52°North framework [2] version 4.0 and OGC SOS 2.0 standards. The deployed SOS endpoint uses a PostgreSQL database with a PostGIS spatial extension to store observation values and sensor metadata.

2.1. *The QGIS SOS Client*

A web SOS client has been developed as a web-based browser application extending the open source Sensor Web Client. It acts as an application layer to handle via web the rendering of queried observations in the form of graph, time series and geographic maps. A QGIS SOS client application (Figure 2) has been developed by ENEA for adding the ability to the open source GIS desktop QGIS to access sensor data served by SOS and delivering them to the simulation models (i.e SWMM, Epanet/MSX), the latters integrated in the QGIS as plugins (e.g. GHydraulics). Thus, the developed QGIS SOS client offers easy to use interfaces within QGIS to run the *GetCapabilities* operation by SOS 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. Similarity, the *GetObservation* operation, the core functionality of the SOS, is run by a specific interface allowing to access observations data within the QGIS viewer by table views. By another interface, new sensors can be easily registered and observations inserted, implementing the *Transactional profile* of the SOS specification.

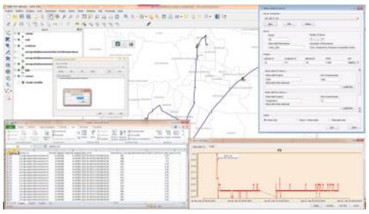

Figure 2 The developed **QGIS SOS client application** for the real use case of Santa Sofia Aqueduct

Thus, this client hides technical details of SWE services and protocols, so that even non-experts can use all components of the developed SWE architecture, transparently.

3. The use cases

The developed SWE architecture has been applied to two real water quality monitoring and controlling scenarios along an aqueduct and a urban sewage system. One scenario concerns the water quality dynamics (i.e. DBPs formation as well as free chlorine decay) to be monitored and predicted along the real Santa Sofia aqueduct. Thus, a wireless network of sensors was installed along the system which monitors physical and chemical water parameters (i.e. pressure, residual chlorine, conductivity, temperature and pH) and delivers data to hydraulic and water quality simulation models [3]. Additionally, on-demand deployable sensor platforms for measuring DBPs were used. The different sensor types have been encapsulated by SOS servers to allow a standardized access to the gathered data by the developed web client or the QGIS SOS client. The alerting functionalities of the SWE system have been provided using a SES instance in conjunction with a WNS. Thus, a sms is sent when critical scenarios occur i.e. water contaminants levels do not meet regulatory requirements (e.g., a disinfection residual higher than 0.2 mg/l for free chlorine and DBPs concentrations higher than 30µg/l). The second scenario concerns the development of a monitoring and warning system for contaminations along the wastewater network of the Massa Lubrense city. Different sensor types have been used in this use case ranging from total immersion probes for monitoring qualitative and quantitative parameters such as PH, COD, NH_3, and water level and conductivity to multi-sensor platforms composed by an e-nose for NH_3, H_2S, in conjunction with temperature and humidity sensors for adjusting the gas readings, and a microphone. The networked sensor platforms have been, installed in strategic locations of the wastewater network. Displaying time series data is fulfilled by SOS instance. For the real-time notification, the sensor data are transferred to the SES instance which filters the incoming data with regard to alert criteria specified. Thus, if a matching alert condition is found by the SES, the according alert is dispatched, by sending the notification request to the WNS instance.

4. Conclusions

Through the shown use cases, the proposed SWE architecture has fundamentally proven its applicability to smart water utilities domain. It is ready to be used for building sensor based systems for monitoring and controlling water utilities. For the future, this architecture will be integrated with SPS services.

Acknowledgments

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