

# Providing Water Parameters Monitoring Data through Interoperable Web Services

Anca Hangan<sup>1</sup>, Lucia Vacariu<sup>1</sup>, Octavian Cret<sup>1</sup> and Marian Muste<sup>2</sup>

<sup>1</sup>Computer Science Department, Technical University of Cluj Napoca, Cluj Napoca, Romania

<sup>2</sup>IIHR-Hydroscience & Engineering, University of Iowa, Iowa City, U.S.A.

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**Abstract:** The paper describes the design and development of a water parameters monitoring system for rivers. The system exposes a set of web services that can act as support for decision making in pollution control or as data provider for a wide range of informational, educational or research applications. A prototype based on the proposed system design was build and experiments were made on Somes River in Romania. Our prototype contains web based and mobile applications that provide access to the measurements made by the sensors and to the historical information as well.

## 1 INTRODUCTION

Two methods are widely used to evaluate the quality of water through water parameters monitoring: the traditional manual method and the automatic continuous monitoring with stations on the river shore. Both methods imply large costs: personnel and laboratory expenses on one side, development expenses and environmental impact on the other side (Jiang, et al, 2009). The automatic continuous monitoring systems are preferred nowadays (Gunatilaka, Moschetta, Sanfilippo, 2007).

Water management cyber-infrastructure needs to keep up with the advances in computational and communications technologies (McDonnell, 2008). New solutions need to be able to combine complex data from many heterogeneous resources (Muste, et al, 2012).

Automatic continuous monitoring of water parameters can be done by specialized stations placed on the river shore or, more recently, by wireless sensor networks (WSNs). Even though water shore stations usually provide measurements for a large variety of water parameters, there are very large development and maintenance costs. On the other hand, WSNs can monitor water quality parameters through the cooperation of a large amount of heterogeneous sensors with reduced environmental and financial costs. For this reason, in the last years, there has been an important research

interest towards the development of monitoring systems that use WSNs (Wang, et al, 2010).

A very important part of water parameters monitoring is constituted by high frequency water quality monitoring and estimation. It is impossible to sample all the potential pollutants in a watershed. An alternative solution consists of monitoring only a set of parameters called surrogates. Then, using mathematical equations, the measured values obtained from the surrogate sensors are converted into estimates of the variables of interest (Horsburgh, et al, 2010).

There are significant efforts made worldwide towards establishing standards for water quality monitoring. Knowing that there is a huge amount of information that should be handled as public information, one of the main concerns in the heterogeneous hydro-world information is to comply with standards.

In the European Union, the Water Framework Directive (WFD) establishes, among others, a guide for monitoring the quality elements of rivers, to assure the interoperability between different platforms (Water Framework Directive, 2003). The guide presents the appropriate selection of quality elements and parameters for rivers, lakes, transitional waters and coastal waters to support the implementation of the WFD and additional recommended quality elements, which have been identified by Member States for that particular water body type. To achieve the WFD targets, it is

necessary to develop some cost-effective instrumentation using advanced technology and shifting to automation to reduce overall analytical costs. The actual growing demand is requesting more and more that water quality be measured continuously and in real time. Due to interoperability requirements, new platforms must be compliant with the INSPIRE Directive of the European Union (INSPIRE, 2014) and with the OGC Sensor Observation Service Standard (Vitolo, Buytaert, Reusser, 2012).

This work describes the design and development of a water parameters monitoring system for rivers. Our system exposes a set of web services that can act as support for decision making in pollution control or as data provider for a wide range of informational, educational or research applications. One of our main concerns is to comply with the European Union standards for water quality monitoring and spatial data exchange. This will assure the interoperability with other platforms that are compliant with the INSPIRE Directive of the European Union and with the OGC Sensor Observation Service Standard. Furthermore, we will present the implementation of a prototype based on the proposed system design. Experiments were made on Somes River in Romania. Our prototype contains web based and mobile applications that provide access to the measurements made by the sensors and to the historical information as well. Integrating recent IT technology has increased the quality of the monitoring, communications and information presentation.

The paper is structured as follows: Section 2 shows the research context of water management in Romania. Section 3 describes the Cyberwater monitoring system. In section 4 the service-based architecture of the monitoring data provision is presented in detail. Section 5 presents two prototype systems that we developed on top of the proposed architecture. Section 6 presents conclusions and research ideas for future work.

## 2 RESEARCH CONTEXT

In Romania, water parameters monitoring is mostly done using the traditional method, which implies manual sampling and laboratory analysis, and with specialized continuous monitoring stations placed on the water shore. As floods and river pollution appear frequently, there is an obvious need for more advanced water management practices and tools (Tacheci, et al, 2012). There are projects that follow

the enhancement of the Romanian hydrologic observation network and the application of modern modeling tools for the improvement of water resources management (Mocanu, et al, 2013). However, there are very few similar projects and there is need for initiative in the direction of continuous real-time water parameters monitoring in Romania. There is also an imperative need to comply with European Union standards and directives.

In this context, Cyberwater is a Romanian project that has as main objective the development of an e-platform that uses advanced computational and communication technology for managing water and land resources in a sustainable and integrative manner, focused on pollution phenomena in rivers (Ciolofan, Mocanu, Ionita, 2013).

Our objective as part of Cyberwater project is to develop a water monitoring system that will be one of the main components of the e-platform. The monitoring system gathers data from sensors placed on the river shore and acts as a data provider for informational applications and as support for decision making in pollution control systems. It is important to store and provide the data in a standard form, to insure the interoperability with other water management or informational systems.

Figure 1 depicts the general architecture of the Cyberwater platform.

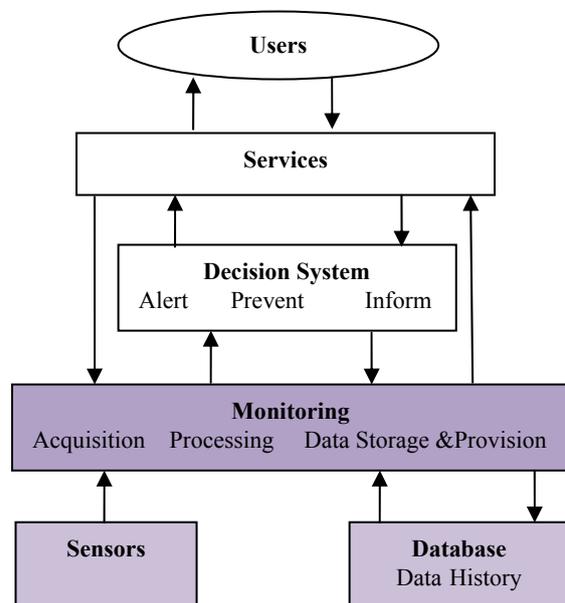


Figure 1: Cyberwater general architecture.

Our monitoring and data provider system places itself on the base layer of the Cyberwater general

architecture. Data received from the sensors is further used by the decision system, which offers support for the decision making process of the water management authorities, and by other information services exposed by the platform. Cyberwater platform is a service-oriented platform. The web services will be provided by both the decision system and by the monitoring system.

### 3 THE MONITORING SYSTEM

In this section, we will focus on describing the service-based architecture of the monitoring system. As the main feature of Cyberwater is to detect pollution in rivers, one of our objectives is to facilitate the measurement, acquisition and storage of water parameters, which can indicate this type of phenomenon. Water parameters such as temperature, pH, conductivity, and others are measured by sensors submerged in the river.

On the river shore, there is need for a local data acquisition sub-system (datalogger) that gathers data from all sensors in the area. To determine the architecture of the local data acquisition sub-system, the measurement setup has to be known. We consider two situations:

1. The measurements are made in a small area of the river (e.g. the distance between the sensors is less than 500 meters);
2. The distance between two subsequent measurement locations is larger than 1km (e.g. a measurement is made every 10 kilometers).

To implement the local acquisition sub-system we use National Instruments wireless solution (NI WSN) that allows integrating wired & wireless measurements, accessing remote data with secure web services and communicating with third-party wireless sensors (WSN NI, 2014).

In the first situation, several wireless nodes can gather data from the sensors. Because the nodes are relatively close to each other, they all send their data to a gateway node that handles long distance communication. Because the gateway collects and stores data from the entire area, local decision making is possible.

In the second situation, local nodes have to handle both data acquisition and long distance communication. Communication between subsequent nodes and local decision making based on combined sensor data is not possible because of the long distance.

The local data acquisition sub-system sends the data collected by the sensors to an application that

stores it. A feasible solution for handling long distance communication from the river shore is GSM communication. The local gateway is connected to a GSM provider. Gathered sensor data are transmitted to a GSM data storage service that will store the sensor data until a software component connected to the Internet gets the data from storage service, processes them (e.g. computes water parameter values from surrogates, transforms raw values received from sensors to required formats) and sends them to a database, using an XML format. Data from the database can be accessed through software services by remote monitoring applications connected to the Internet. Stored data are available to other applications that are part of the Cyberwater platform through web-services.

The monitoring system is depicted in Figure 2, at the base of the proposed service-base architecture of the monitoring data provision system.

### 4 THE SERVICE-BASED ARCHITECTURE

To make the data gathered by the monitoring system available to other users, we propose a service-based architecture.

We expose the monitoring data through web services that can act as support for decision making processes in pollution control or as data provider for a wide range of informational, educational or research applications.

One of the main requirements of this architecture is the interoperability. Because Romania is a member of the European Union, we have to comply with the INSPIRE Directive for keeping hydrographic data. The INSPIRE Directive provides data models specifications for spatial data, including hydrographic data. We use a sub-set of the Hydrography Model provided by INSPIRE, mainly the Hydro-Base and Hydro-Network Application Schemas (INSPIRE, 2014) to keep data about the monitored river basin.

By hydrographic data we understand: the river identifier, its geographical name, the river topology represented as a network with nodes and watercourse links, its localization, its flow direction and its length.

Moreover, to manage sensor data in an interoperable way, we use OGC Sensor Observation System Standard (SOS). The SOS Standard provides specifications for a web service interface that allows querying for sensor observations (measured values)

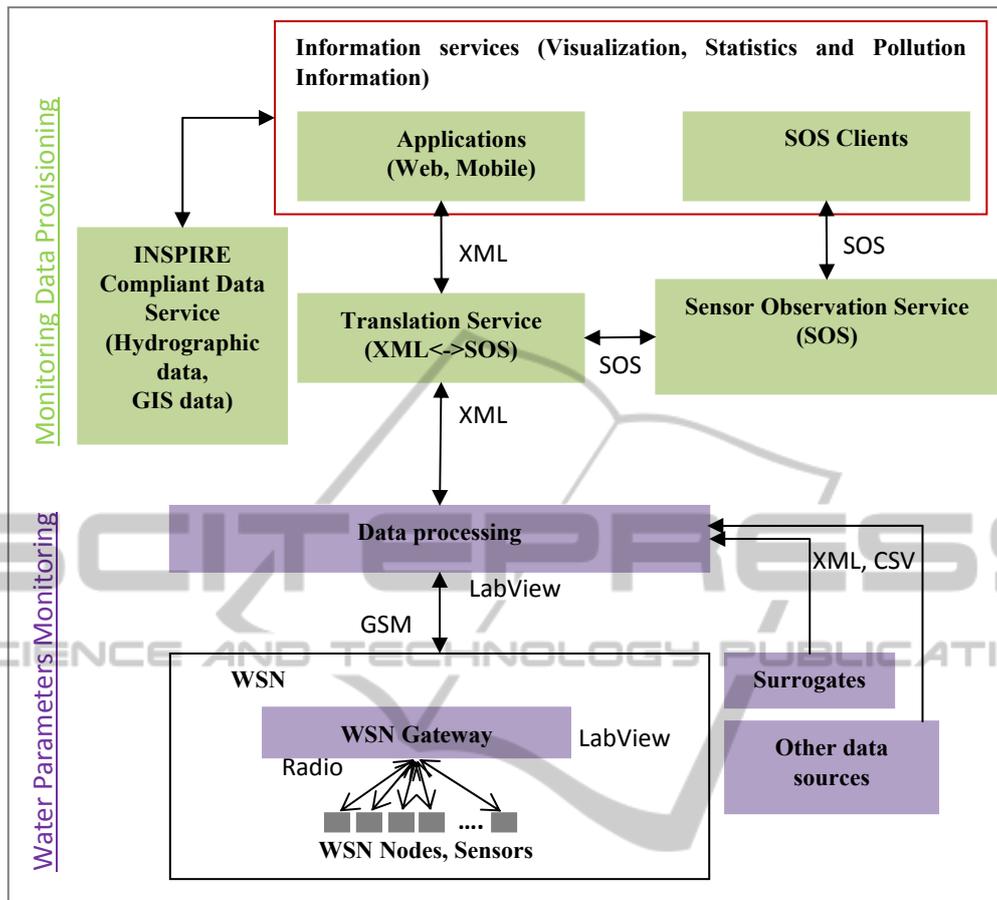


Figure 2: The service-based architecture of the monitoring data provision system.

and provides the means for registering sensors and for recording the sensors' readings (Sensor Observation Service, 2014). The standard requests accepted by the SOS component that we implemented are the following: query observation, insert observation, register sensor, remove sensor.

Figure 2 shows the service-based architecture of the monitoring data provision system. At the base of this architecture is the water parameter monitoring system. The monitoring system includes one or more WSNs that gather data from the water shore sensors and send it to the data processing component.

The data processing component receives data from WSNs, but it is also possible to receive data from other (external) sources that may be measured or surrogate values. Data can be in different formats (CSV, XML and others). The data processing component processes data and puts them into a uniform XML format. Data will be then sent to the Sensor Observation Service through the translation service that will form standard insert requests for the

SOS component. The SOS component will store the data.

The translation service component receives not only data from the data processing component, but also information about the sensors, in order to generate requests for registering (or unregistering) sensors with the SOS. This component receives, as well, requests from other applications or information systems that need to use the monitoring data that we provide. It is possible that these requests are not SOS compliant. The non-SOS compliant requests will be received and translated into SOS compliant requests by the translation component. Through this component, monitoring data will be provided in an XML format. SOS compliant clients will pass the requests directly to the SOS component.

The proposed architecture insures interoperability with SOS compliant systems as well as with INSPIRE compliant systems in the hydrographic domain. Moreover, the monitoring data can be requested by applications that are not

SOS-compliant.

## 5 THE PROTOTYPE SYSTEMS

To prove the validity of the proposed architecture, we implemented it in two prototype systems. The preliminary measurements were made on Somes River on a 1 km distance, in three points.

### 5.1 System for Pollution Detection in Somes River

We developed a prototype system for pollution detection in Somes River using the proposed architecture as basis. Data acquisition is made by a WSN located in the point where the river enters the city. The water parameters that we follow are: temperature, pH, specific conductivity, turbidity, dissolved oxygen and discharge. Using these values as surrogates we can determine a series of water quality constituents such as: alkalinity, suspended solids or chloride (Horsburgh, et al, 2010).

The system monitors the water parameters over time. Through a web interface, the user can follow the last measured water parameter values or can view a chart containing several readings over a period of time (Figure 3). If the parameters are outside some specified intervals, a pollution situation is detected and signaled.

When pollution is detected, the user can start a simulation that will provide as result an estimated propagation scenario for the pollutant in the river starting from the location of the sensors. The pollutant propagation estimation can be viewed in the same web interface on a map provided by Google Maps. To highlight the polluted segments of the river, a color code is used, as seen in Figure 4. In order to be able to estimate the pollutant propagation we used the model developed by (Ani, et al, 2010). The mathematical model was computed for a segment of Somes River.

The prototype system for pollution detection that we developed uses an INSPIRE Hydrographic data model to keep information about the monitored segment of Somes River.

Because the INSPIRE and the propagation model's coordinate systems didn't match, we needed to make some coordinates transformations to be able to use the propagation model in (Ani, et al, 2010).

The system is not SOS compatible. Therefore, to receive the measured values from sensors, it has to make requests to the translation service component.



Figure 3: Chart containing several readings of water pH value.



Figure 4: The pollutant propagation simulation viewed in the web interface.

### 5.2 Mobile Water Parameters Information System

The second prototype is a mobile water parameters information system implemented on Android OS. We developed it on top of the proposed service-based monitoring data provision architecture. Like in the previous example, this system uses data provided by the monitoring system set up on a segment of Somes River. The mobile application includes a SOS standard client component that is able to request data from the SOS component of the monitoring data provision architecture and from any other SOS server that provides similar data.

The main features of the mobile water parameters information system are the following:

- Temporary storage of the values retrieved from the SOS server. To obtain a better response time, responses from the SOS server are cached for a predefined period of time.
- Retrieve information from more than one SOS server at the same time.
- Visualization of sensor location and sensor data. Users are able to see on a map provided

by Google Maps the location of sensors and the measured values associated with the sensors as seen in Figure 5.

- Charts and tables with the water parameters measurements over time as seen in Figures 6 and 7.
- Support for spatial and temporal filters applied on the measurements provided by the sensors. The application is able to apply filters on the requested SOS observations and to provide the user information from a specific time interval or from a specific geographical area.
- User notification. The user is notified if the water parameters are outside regular value intervals (if pollution is detected).
- Adaptation to the performance capabilities (resource availability) of the mobile device.

The standard SOS client is an important component of the system. The SOS operations available are the following:

- **GetCapabilities** – get metadata and detailed information about the operations provided by a SOS server.
- **DescribeSensor** – provides metadata about the registered sensors.
- **GetObservation** – allows access to sensor observations; allows observations filtering.

The observations can be filtered based on the following parameters:

- Sensors that provide the observations.
- Time interval.
- Observed phenomenon.
- Geographical region (location of sensors).

The SOS client component can be extended with the implementation of other operations specified by the SOS standard.

## 6 CONCLUSION

In this paper, we proposed a service-based architecture for provisioning water parameters measured by a monitoring system implemented with WSN technology. The services that expose the hydrographic and monitoring data are compliant with INSPIRE regulations for Hydrography data models and with SOS standard for sensor data.

As proof of concept, we developed two applications on top of the proposed data provisioning architecture. These applications use hydrographic and monitoring data and allow the users to view information about the quality of water in Somes River.



Figure 5: Location of sensors on Google Maps.

Date pH		
Data/Ora	pH Sensor1	pH Sensor2
09/08/2013 13:00:00	6.9	6.9
09/08/2013 13:05:00	6.9	6.9
09/08/2013 13:10:00	6.9	6.9
09/08/2013 13:15:00	7	6.9
09/08/2013 13:20:00	7.1	6.8
09/08/2013 13:25:00	7.1	6.8
09/08/2013 13:30:00	7.1	6.9
09/08/2013 13:35:00	7.0	6.9
09/08/2013 13:40:00	7.0	6.9

Figure 6: Table with pH readings during a time interval (one hour).

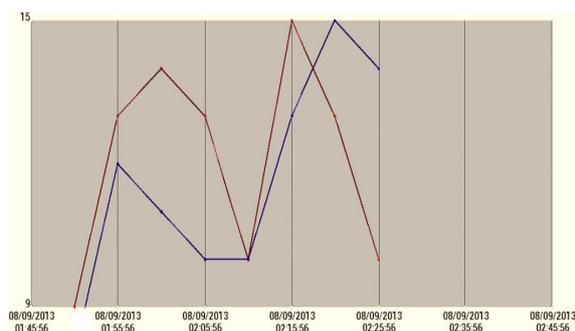


Figure 7: Chart for turbidity measurements over a time interval, from two sensors.

The experiments showed that the data provisioning platform and connected applications meet the initial requirements.

In the future we will develop a decision system, based on the results obtained up until now.

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