

# Interoperable Data Management and Instrument Control Architecture for Ocean Observing Systems

Daniel M. Toma<sup>1</sup>, Joaquin del Rio<sup>1</sup>, Enoc Martínez<sup>1</sup>, Eric Delory<sup>2</sup>; Jay Pearlman<sup>3</sup>; Christoph Waldman<sup>4</sup>; Simon Jirka<sup>5</sup>

<sup>1</sup>*SARTI Research Group, Electronics Dept. Universitat Politècnica de Catalunya (UPC). Rambla Exposició 24, 08800, Vilanova i la Geltrú, Barcelona, Spain. +(34) 938 967 200  
daniel.mihai.toma@upc.edu(D.M.T); joaquin.del.rio@upc.edu(J.D.R.)*

<sup>2</sup>*Oceanic Platform of the Canary Islands ctra de Taliarte s/n, Telde 35200, Spain*

<sup>3</sup>*IEEE France Section, France*

<sup>4</sup>*University of Bremen, MARUM, Germany*

<sup>5</sup>*52°North - Initiative for Geospatial Open Source Software GmbH Martin-Luther-King-Weg 24  
48155 Muenster (Germany)*

**Abstract** – The complexity of marine installations for the ocean observing systems has grown significantly in recent years. In a network consisting of tens, hundreds or thousands of marine instruments, manual configuration and integration becomes very challenging. Simplifying the integration process in existing or newly established observing systems would have benefit system operators and is important for the broader application of different sensors. This article presents an approach for the automatic configuration and integration of sensors into an interoperable Sensor Web infrastructure. First, the sensor communication model, based on OGC's SensorML standard, is utilized. It serves as a generic driver mechanism since it enables the declarative and detailed description of a sensor's protocol. Finally, we present a data acquisition architecture based on OGC PUCK protocol that enables storage and retrieval of the SensorML document from the sensor itself, and automatic integration of sensors into an interoperable Sensor Web infrastructure.

**Keywords** – Sensor Web; standards; metadata; interoperability; SensorML

## I. INTRODUCTION

In Ocean Observing Systems, the infrastructure for data management, communication and instruments has to be a flexible network, because unanticipated needs may emerge and unprecedented context-aware applications may need to be enabled. For example, a given kind of sensor may be deployed on various platforms such as floats, gliders or moorings, and thus must be integrated with different data

acquisition systems. To achieve the interoperability in this infrastructure, the physical instruments must be reliably associated with software components for that operate the instruments and manage their data and metadata.

One of the critical issues in an ocean observing system is the communication with the instrument or sensor. In the oceanographic instrumentation sector there is no standardization of protocols used for the control and configuration of the instruments, and each manufacturer defines the syntax used and the set of commands for each of their instruments. Given the diverse nature of the instruments could be difficult to define a universal set of commands, but it would be feasible to use a common syntax and a set of common commands in addition to specific commands depending on the nature of the instrument.

The main objective of standardizing different basic processes in the operations of installation of a new instrument has the main purpose of reducing operating costs of the observatory. Since each instrument and manufacturer implements a different communication protocol and raw data format, it is necessary to invest much time in the programming of a software driver that allows the integration of the new instrument in the observatory network. On the other hand, there are marine observation platforms such as oceanographic buoys, where in addition to the installation of the configuration tool is needed, and in this case this operation can be performed under extreme conditions. Standardized these processes, minimizing the risk of failures due to manual configuration. Another of the benefits of the standardization process is to facilitate

maintenance and replacement of instruments in the observatory and maintain traceability of the data they generate [1].

Other benefits are the improved accessibility to data and interoperability between data sets. However, interoperability can only be achieved through extensive use of international standards. They specify regulations for data access, content, and exchange. The current situation is characterized by the fact that parallel approaches have been developed (IEEE 1451, the OGC set of standards, etc.) but still lacking community support. This paper introduces the Sensor Web architecture based on OGC set of standards as example how interoperable standards help, to facilitate the creation of an infrastructure for sharing oceanographic observation data and the integration of sensor data into applications [2].

## II. INTEROPERABILITY APPROACH FOR OCEAN OBSERVING SYSTEMS

Oceanographic instruments are traditionally developed by small companies, and lack standardization of the protocols for instrument control and configuration, or data retrieval. These instruments are often integrated into an observing system or sensor network, which provides a software infrastructure for functions such as data acquisition, data logging, and data transfer via hard-wired or wireless telemetry links.

In order to facilitate the integration of sensor into the ocean observing system, we propose a Sensor Web architecture based on the concepts of spatial data infrastructures and the Sensor Web Enablement (SWE) framework [3] of the Open Geospatial Consortium (OGC). The standards developed by OGC represent a conceptual model for Observations and Measurements (O&M) [4]. This standard describes how an *observation* is an action whose result is an estimate of the value of some *property of a feature of interest*, obtained using a specified *procedure*.

### A. OGC Observations and Measurements (O&M)

The O&M 2.0 standard describes a model and an XML Schema to encode data gathered by sensors (archived as well as real-time data). A basic observation designed with O&M is based on the following parameters:

- the **process** (e.g. a sensor) is constituted by the procedure which has performed a specific observation
- the **observed property** refers to the parameter which is observed (e.g. water level)
- the **feature of interest** stands for the geospatial object (e.g. a river section) in the real world for which the property is observed
- and the observation's **result** which is the value of the measurement (in this case a water level value in centimetres).

### B. OGC Sensor Model Language (SensorML)

The OGC Sensor Model Language (SensorML) is defined to describe the sensor or process metadata. Similarly to O&M the SensorML 2.0 standard describes the processes by data models and with the help of an XML encoding. A process is either a measurement procedure or processing of previously gathered data. A SensorML document may comprise for example the following parameters:

- **keywords**: short terms characterising the sensor
- **identification**: identifiers to ensure a unique reference of the sensor
- **classification**: classifiers for discovery
- **validTime**: time range, for which the sensor description is valid
- **inputs**: inputs for the process
- **outputs**: resulting outputs to the process
- **characteristics**: additional properties of the process that do not further qualify the output values (e.g. component dimensions, battery life)
- **capabilities**: properties which clarify or qualify the measurement process (units for the output, observed area)
- **contact**: institution, which operates the described sensor instance

The characteristic parameter may also describe for example the temporal availability and the position of the described process or sensor.

An extension based on SensorML is the sensor interface description, which describes the protocol of a sensor. With such a SensorML instance a data acquisition system can translate the communication from the sensor protocol into a standardized OGC SWE communication.

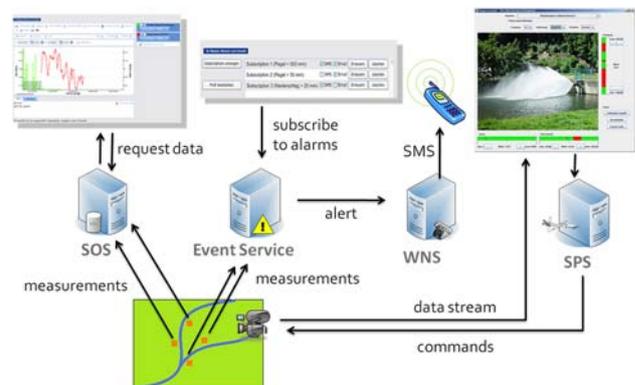


Figure 1 Overview of the standardized OGC SWE interfaces

The standardized SWE communication provides different sensor web service interface specifications for:

- interoperable access to measurement data and sensor metadata (**OGC Sensor Observation Service**)
- interface to send tasks and configurations to sensors (**OGC Sensor Planning Service**)
- subscription to defined events and alerting if the

defined events are detected (**Event Services**)

### C. Observing platforms requirements

As can be seen in table 1, oceanographic instruments that will be connected to observatories with a continuous and high bandwidth communication channel, will need the OGC Sensor Observation Service in order to retrieve data from the observatory (Data Access Service), or from shore, through the observatory. On the other hand, instruments deployed in platforms with a low communication bandwidth or discontinuous will need to use the OGC Sensor Observation Service to send data when a link to shore will be available (Data Push Service). Moreover, all these instruments will need to run the OGC Sensor Planning Service (Configuration Service) that will allow the platforms clients to configure the oceanographic instruments its functionality and others.

Table 1 Services requirements for different types of platforms

Type	LINK	Instrument Services		
		Data Access Service	Configuration Service	Data Push Service
Observatory	3G or better	✓	✓	✓
Gliders/ Profilers	Satellite		✓	✓
Boat	Satellite/ GPRS		✓	✓
FerryBoxes	Satellite/ GPRS	✓	✓	✓

## III. IMPLEMENTATION OF THE DATA MANAGEMENT AND INSTRUMENT CONTROL ARCHITECTURE

### A. Instrument interoperability approach

The dominant physical layer protocols used in the development of oceanographic instruments are RS232 and RS485 serial communications (although increasingly displaced by Ethernet), but in general each manufacturer defines distinct syntax and command sets for the instruments it produces [1]. To enable interoperability and automatic configuration of oceanographic instruments for these physical layer protocols, we use the OGC PUCK protocol. The OGC PUCK is a simple protocol that makes possible for instruments to carry information that enables sensor networks to use the instrument and its data. OGC PUCK defines a simple protocol to store and retrieve information from an instrument over RS-232 and Ethernet [5]. As shown in Figure 2, this information consists of a SensorML metadata file with sensor interface description. OGC PUCK has been implemented in instrument firmware augmenting the “native” instrument command set.

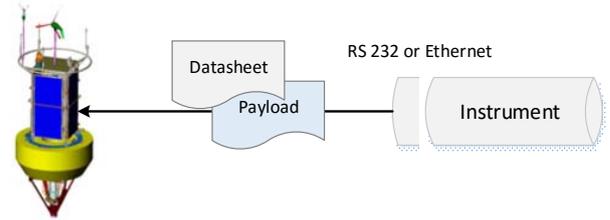


Figure 2 Host issues OGC PUCK commands to retrieve datasheet and payload

One key advantage of implementing the OGC PUCK is that the standard it enables in a very easy manner the automatic instrument integration into sensor network (‘Plug and Work’).

For the oceanographic instruments that are deployed on cable observatories, ships or buoys with Ethernet connection, most of them with RF link of limited bandwidth, the instruments are implementing a lightweight SOS [6] and SPS [7]. The oceanographic instruments that are deployed on glider and profiler technologies, used in global observation with communication via costly and energy-demanding satellite links of very low bandwidth and discontinuous, have these standard services implemented through software component, located on observatory platforms.

### B. Implementation

Based on the OGC standards we implement the interface of oceanographic instruments with basic standard protocols for sensor detection, identification, configuration, and execution of measuring operations. We demonstrate the use of this set of standards on two oceanographic instruments, an acoustic and an optical instrument shown in Figure 3 [8], which have been deployed on a oceanographic buoy.

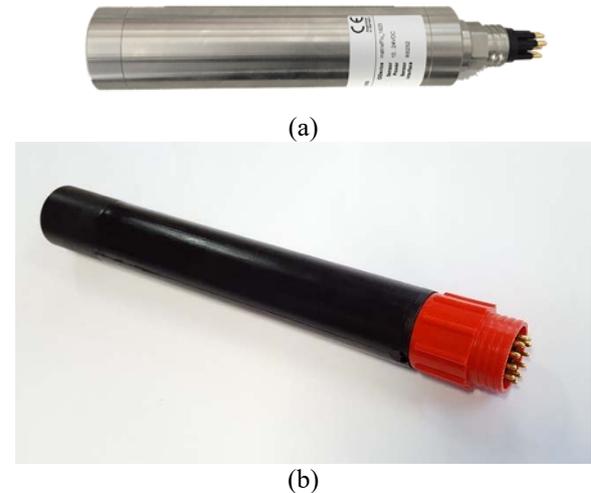


Figure 3 (a) Optical and (b) Acoustic instruments developed based on proposed architecture

There have been identified several categories of data shared between instrument/platform and web services. The following define each of these categories.

- Component descriptive data – Description of the platform/instrument configuration including instrument types, serial numbers, position of the deployment, calibration parameters.
- Command data – Commands and associated attributes such as when a command is scheduled to be executed.
- Instrument data – Data produced by the platform instruments, associated time tags, and attributes identifying the specific source instrument.
- Engineering data – Data describing the operational status of the system components.
- Metadata – Data describing the data. Metadata are data describing a resource like an instrument or an information resource.

To provide the description of all these categories of data SensorML 2.0 standard is used. As illustrated in figure below, SensorML supports the ability to describe the components and encoding of real-time data streams, and to provide a link to the data stream itself. This thus allows one to connect directly to a real-time data stream directly from a SensorML description and use a generic data reader to parse the data stream. Describing a data stream into or out of a process (or sensor/actuator) is accomplished by having the input or output be of type DataInterface. The DataInterface element allows one to describe the DataStream, as well as provides for an optional interface description.

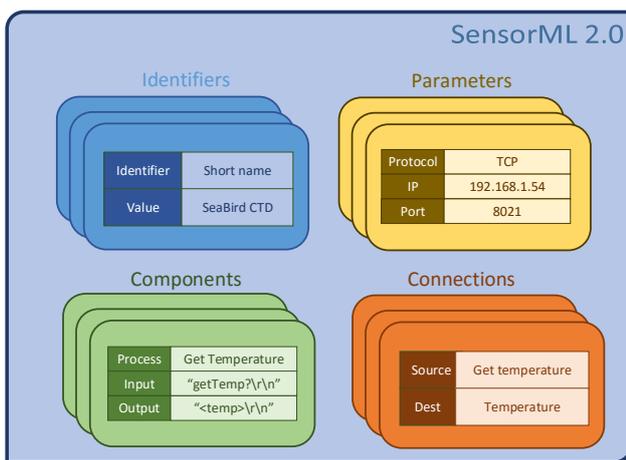


Figure 4 SensorML description of instruments capabilities and communication protocol

Figure 5 shows the process flow executed by the platform. At connection, the oceanographic instrument is identified by the platform acquisition system (SWE Agent) using the OGC PUCK protocol. Immediately after the detection, the SWE Agent retrieves the SensorML of the instrument.

Next, the SensorML it is decoded and the acquisition system starts to run the set of tasks described in the SensorML, starting the programmed instrument mission, and directly inserting the O&M resulting files into the standard SOS Server.

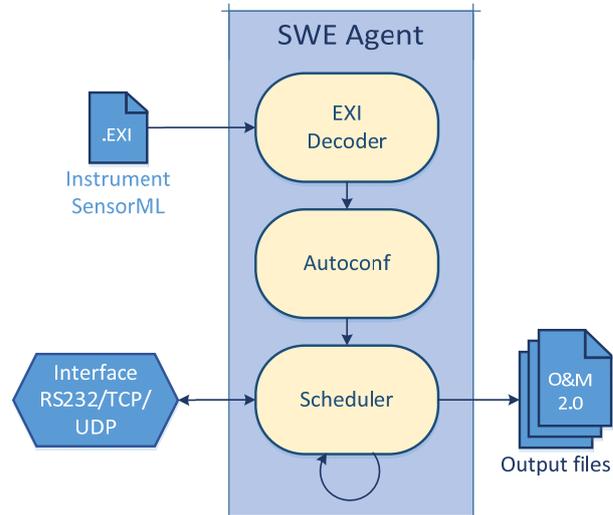


Figure 5 Data Acquisition process flow inside the oceanographic platforms

The SensorML description files are encoded in the EXI binary format [9] in order to save space and to reduce the amount of RAM memory used during the parsing of the those files. Efficient XML Interchange (EXI) is a binary XML format which was adopted as a recommendation by the World Wide Web Consortium (W3C). Its main objective is to encode XML documents in a binary data format, rather than plain text. The use of binary encoding greatly reduces the size of the resulting files. As an example a SensorML description file for an Oxygen Optode instrument, the Aanderaa 4330 [10], has a size of 19.4 Kbytes when encoded in XML, when it is converted to EXI the size is reduced down to 3.08 Kbytes, achieving a compression ratio of 6.3.

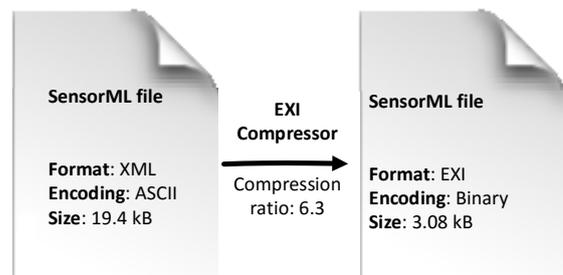


Figure 6 EXI Compression Ratio of the Aanderaa 4330 SensorML

#### IV. CONCLUSIONS

This architecture is able to fulfil the central requirements for establishing an interoperable exchange of oceanographic sensor data. While first components are

already available, it will be continuously developed and enhanced during this year. Based on currently ongoing evaluation activities of the first available implementations and further emerging requirements, the Sensor Web components will be advanced to a comprehensive suite of tools for sharing oceanographic observation data in an interoperable manner.

#### ACKNOWLEDGMENT

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