Interoperable Data Management and Instrument Control, Plug and Play Concepts and Sensor Registry Experiences at OBSEA

Joaquin del Rio, Tom O'Reilly, Daniel Mihai Toma, Jordi Sorribas, Eric Delory, Antoni Manuel

SARTI – UPC Spain; MBARI USA
UTM – CSIC Spain; dBscale Sensing Technologies - Spain

Introduction

ESONET needs a Web portal with real-time web interface from online observatories.
In order to do so, online data are urgently needed.
This was one strong demand during the 2009 review of ESONET in Brussels.
Actually each observatory has their own software architecture and data management processes. Some standards can be applied on top of each observatory's data management in order to access data from internet in a standard way. Some of these standards can be SensorWebEnable, IEEE1451.0. or initiatives like DataTurbine for high speed real time data streaming.
The use of these standards in an observatory to access data and metadata from a general web interface can provide interoperable data visualization from the user point of view.
Another issues, not related with data access or data visualization, are important to archive interoperability between observatories as plug and work capabilities of the instrument. Initiatives as MBARI PUCK protocol (for RS232 or IP), interfaces like the SmartSensorBoard (Ifremer,UPC) or recently the SID, Sensor Interface Descriptor (52North), are being tested at Western Mediterranean Observatory OBSEA (Figure 3).
Other interoperability issues for standardization about access to data archives is now starting at OBSEA taking into account the experience about previous initiatives like SeaDataNet and standards proposed by INSPIRE for metadata specification like ISO19115 and NetCDF for data transport.
Time synchronization in cabled observatories by Ethernet networks can be achieved implementing IEEE1588 Precision Time Protocol (PTP) versus NTP or SNTP for applications with needs of synchronization under milliseconds. Actual observatories had been deployed before IEEE1588v2 was released, and for these reason junction boxes are not equipped with IEEE1588v2 Ethernet switches. Some test experiments has been carry out in order to test PTP under non PTP switches in order to evaluate the time synchronization accuracy for these type of networks. Figure 6 shows one of the test setup to provide GPS information to an instrument through a IEEE1588 synchronization network.

About OBSEA

OBSEA is a cabled seafloor observatory 4 km offshore Vilanova i la Geltru (Barcelona, Spain) coast located in a fishing protected area, and interconnected to the coast by an energy and communications mixed cable.
The main advantage of having a cabled observatory is to be able to provide power supply to the scientific instruments and to have a high bandwidth communication link. In this way, continuous realtime data is available. The proposed solution is the implementation of an optical Ethernet network that transmits continuously data from marine sensors connected to the observatory. With OBSEA, we can perform a real time observation of multiple parameters in the marine environment. SARTI research group from the Technical University of Catalonia (UPC) is devoted mainly in the design and deployment of sensor networks, from the elecronical, mechanical and data managment point of view. In this case, OBSEA was a new challenge, and now it is a perfect place where scientist are able to collect data, test new instrumentation and procedures.

Fig.3 - OBSEA Structure: this cabled observatory is located in 10 m depth and is now operational for one year.

From the land station we provide power supply and fibre optics communication link Furthermore we have installed a general alarm management to detect any failure in the system and/or in the storage capacity. The land station is connected at the beach dock through a cable of 1000 m, from where the marine cable starts its route to the main node, 4 km offshore and at 20m water depth.

IEEE-1451 and OGC SWE Integration into Actual Observatories

In most cases, actual observatories are using a proprietary Data Management and Instrument control framework. We can divide the interoperability problems in different parts from bottom (instrument or sensor side) to top (user access to real-time data and archive). At figure 4 we can see a simple approach to achieve interoperability to real time data. The integration at the actual proprietary Data Management system of different observatories of different services like IEEE1451 server or SWE SOS server can offer access to data using web clients without disturbing the actual functionality off the observatory.

The IEEE 1451 provides a specification to add a digital layer of memory, functionality, and communication to sensors. For example it enables sensors to be controllable and their measurements accessible through a network with sufficient information on the sensor characteristics and history.

OGC Sensor Web Enablement (SWE) provides a specification to Web-enabled sensors to be accessible and, where applicable, controllable via the Web. SOS provides a broad range of interoperable capability for discovering, binding to, and interrogating individual sensors, sensor platforms, or networked constellations of sensors in real-time, archived or simulated environments.

IEEE-1451 and OGC SWE are rather complex, which is to be expected as these standards are also quite comprehensive. This complexity presents challenges for instrument manufacturers who must thoroughly understand the standard and who must correctly implement it in firmware.

Moreover embedded instrument processors are often designed for low cost and low-power environments, and hence may not be capable of fully implementing the standards.

Another drawback is that manufacturers would likely have to abandon existing instrument firmware that does not implement the standard; this existing firmware often represents a very considerable investment by the manufacturer.

A third drawback is that IEEE-1451 and OGC SWE are still evolving, again due to the comprehensive nature of these standards. Thus either the standard revision process must be very carefully managed to ensure "backwards compatibility", or instrument firmware must be occasionally upgraded to remain compliant with the latest standard.

Both of these alternatives present non-trivial challenges to instrument manufacturers and standards bodies.

For these reasons, up to now, we can consider these standards in the top level services to provide real-time data to users in a standard way.

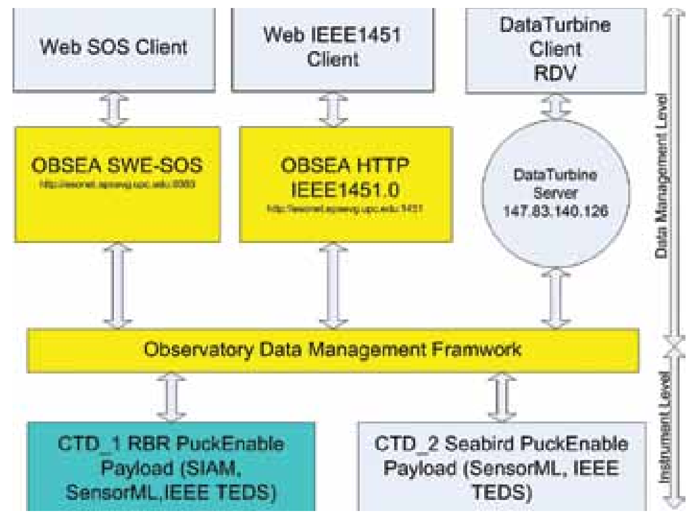

Fig.4 - Access to real-time data using standards like SWE SOS or IEEE1451

Sensor Registration in ESONET's SDI

The ESONET sensor registry is largely based on the OGC SWE architecture concept. The creation of templates for registering ESONET observatory instruments required pre-establishing the requirements, starting with a feature matrix and registration interface prototype that account for the various sensing technology areas, i.e. biological, physical, chemical, and multiparameter instruments. As all collected specifications have to be mapped to a dictionary for metadata discoverability and computer usability, the on-line templates for registration have been designed accordingly, for example using standard methods and common practice or de facto standard ontologies. The metadata format follows an internationally recognized standard, SensorML, which was chosen according to the following criteria: availability of open transformation tools, medium/low-complexity, ESONET scientific and system architects consensus, and global interoperability. Sensors are attributed a unique identifier. Part of the work was to organize the collection of instrument specifications and eventually make a proposal for a multi-science use case scenario, so as to evaluate the quality of, and identify gaps in, the registration process. Besides providing feedback on the effort for future improvements, this use case scenario will demonstrate the benefit of the project. The following picture is a screenshot of the ESONET Sensor Registration Interface (current test URL: vps.dbscale.com:8080/esonet , at a later stage the registration interface will be accessible from ESONET SDI portal through secured access). Available functions include mapping of IEEE1451 Transducer Electronic DataSheet XML mapping.

PUCK Protocol and SensorML with Sensor Interface Descriptor (SID)

Another approach for instrument manufacturers is to implement PUCK protocol in their instrument firmware. PUCK has been formally proposed as an OGC Sensor Web Enablement standard. PUCK does not itself fully implement interoperability, but rather provides the lower tier in a hierarchy of standards that achieve this goal. PUCK protocol is a simple command protocol that helps to automate the configuration process by physically storing information about the instrument with the instrument itself. The protocol defines a small "PUCK datasheet" that can be retreived from every compliant instrument; the datasheet includes a universally unique identifier for the instrument as well as metadata that includes manufacturer and model. Additional information called "PUCK payload" can be stored and retrieved from the instrument. The payload format and content are not constrained by PUCK protocol, and can include executable driver code that implements a standard operating protocol as well as metadata that describe the instrument in a standard way, or any other information deemed relevant by the observing system. PUCK protocol commands augment rather than replaces existing instrument commands, and so manufacturers do not have to abandon their existing software. PUCK protocol is simple, and readily implemented in even simple instrument processors; several manufacturers now implement MBARI PUCK protocol in their instruments. PUCK protocol was originally defined for instruments with an RS232 interface. A proposed revision extends the protocol to Ethernet interfaces; the "IP PUCK" protocol includes the use of Zeroconf to enable easy installation and discovery of sensors in an IP network.

The OBSEA team has developed an automatic algorithm to detect the installation of RS-232 PUCK instruments. The host computer periodically interrogates the serial ports for a PUCK enabled instrument. When the host receives a PUCK response from the serial port, the host retrieves the UUID to determine if a new instrument has been installed. If so, the host retrieves the PUCK payload and uses this information to collect data from the instrument and register it in WEB using standards like IEEE 1451.0 or OGC SWE. The detection algorithm for IP PUCK-enabled instruments is based on the Zeroconf standard. When an IP PUCK instrument is plugged into a local area network (LAN), it automatically gets an IP address and is registered as a PUCK service via Zeroconf. An application that runs in the same LAN can discover the instrument and retrieve the PUCK payload through PUCK protocol and automatically register the new instrument in a standard way in WEB.

Thus standard IEEE-1451 and OGC SWE components can be automatically retrieved and installed by the host when a PUCK-enabled instrument is plugged in, overcoming the difficulties of manual installation.

An important component to achieve the plug and play capability with PUCK protocol is the payload information attached to each instrument. The payload should describe entirely the functionality of the instruments in a standard way and should be machine and human readable. To accomplish this task SensorML with Sensor Interface Descriptor (SID) can be used, which provides standard models and an XML encoding for describing sensors, measurement processes, and instrument control information. As we know, instruments are using proprietary command protocols to communicate. The development of software drivers is needed in order to integrate them in each platform. SID can help to avoid the process of write instrument drivers. The generation of a machine readable document with information about how to communicate and parse the information will help the plug and play process.

Figure 5 shows how services running a SID interpreter can establish the connection to a sensor and are able to communicate with it by using the sensor protocol definition of the SID. SID instances for particular sensor types can be reused in different scenarios and can be shared among user communities.

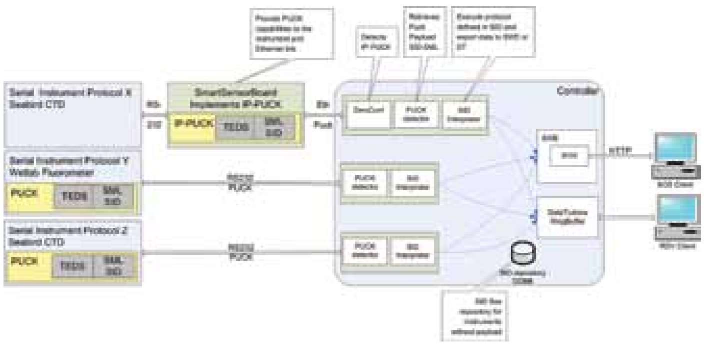

Fig.5 - SID interpreter in a data Acquisition System (proposed to OGC by 52North)

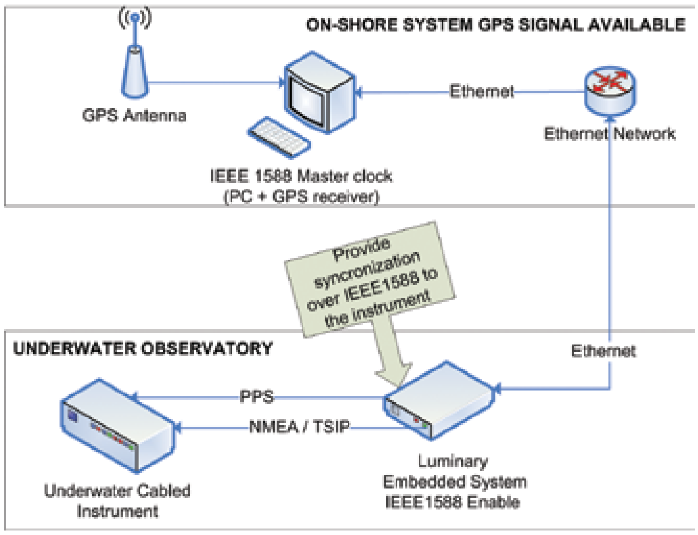

Fig.6 - Testing IEEE1588 PTP for underwater instruments

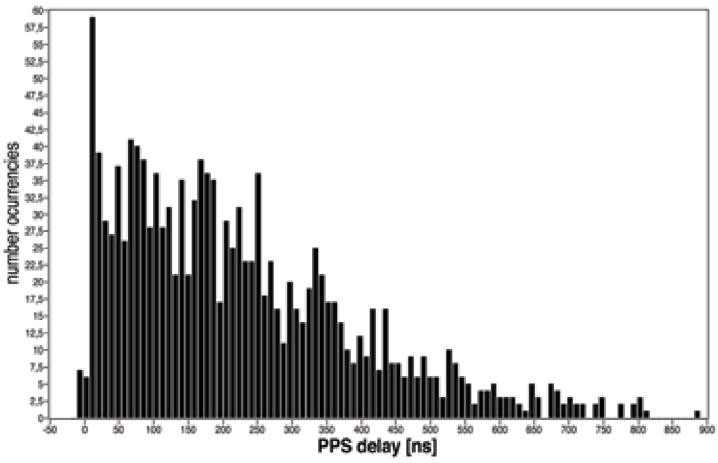

Fig.7 - PPS signals delay histogram with PTP IEEE1588v1 using COTS Ethernet Switch.

The Smart Ocean Sensors Consortium

The Smart Ocean Sensors Consortium (SOSC) is a group of manufacturers and users dedicated to improving the reliability, utility and economy of hydrographic sensor networks. The SOSC aims to accomplish these goals through the development, adoption and promotion of practical standard interfaces and protocols. The SOSC was founded on the initiative of Canadian instrument manufacturer RBR Ltd in early 2009 following an OGC-sponsored interoperability workshop in St John's Newfoundland. Neil Cater of Memorial University's Marine Institute was elected first consortium chairman. Sensor manufacturer members include European companies SEND Electronics Gmbh and SiS Gmbh, as well as manufacturers from Canada and the USA. Non-manufacturer members include representatives from ESONET, SARTI-UPC, the Monterey Bay Aquarium Research Institute (MBARI), the US Ocean Observatories initiative, NOAA, and other organizations. Members pledge to offer and use instruments that comply with interfaces and standards designated as "consortium approved". Membership is open to organizations that share consortium goals, and membership requests are subject to approval by the SOSC chairman.
The SOSC collaborates with the Open Geospatial Consortium (OGC), which has established the Sensor Web Enablement suite of interoperability standards. The two consortia have signed a formal memo of understanding, resolving that they will cooperate to pursue common goals. SOSC manufacturers plan to provide a standard description of each of their instruments, and are evaluating the OGC's SensorML markup language for this purpose. The manufacturers also agree to define a standard protocol to uniquely identify the make, model, and serial number of each compliant instrument. The two consortia have agreed to collaborate on formal submission of PUCK as an OGC standard. Instrument manufacturers provided very useful feedback to the OGC standard working group during this process, and SOSC member SARTI-UPC has actually implemented an "Ethernet PUCK" instrument to verify the feasibility of the proposed standard. The SOSC and OGC also work together to demonstrate sensor network technologies such as PUCK, OGC Sensor Web Enablement, IEEE 1451, and other standards. These "live" demonstrations are held at conferences, and usually involve SOSC-OGC team members and sensors distributed across the planet, integrated in real-time thanks to the Internet and interoperability standards.

Following EU's Maritime Policy on Data an Metadata at OBSEA

The EU's Maritime Policy Blue Book, welcomed by the European Council in December 2007, undertook to take steps towards a European Marine Observation and Data Network (EMODNET) that would improve availability of high quality data. Basic design principles of EMODNET have been formulated by the Commission together with a specially-constituted Expert Group. These are:
1. Collect data once and use it many times
2. Develop standards across disciplines as well as within them
3. Process and validate data at different levels. Structures are already developing at national level but infrastructure at sea-basin and European level is needed
4. Provide sustainable financing at an EU level so as to extract maximum value from the efforts of individual Member States
5. Build on existing efforts where data communities have already organised themselves
6. Develop a decision-making process for priorities that is user-driven
7. Accompany data with statements on ownership, accuracy and precision.
8. Recognise that marine data is a public good and discourage cost-recovery pricing from public bodies.
The overall objective is to migrate fragmented and inaccessible data into interoperable, continuous and publicly available data streams for complete maritime basins. The EMODNET data and metadata infraestructure complies with European Directive INSPIRE by means of using ISO19115 as the basis for metadata and data sets description. The Common Data Index (CDI), developed under the SeaDataNet framework has been used as basic (metadata formats and technology for access to data sets.
The aim in OBSEA is also to harmonize its data management with the EMODNET metadata and data formats and procedures. In this way the data sets produced in OBSEA could be accessed trought EMODNET or SeaDataNet portals using the appropriate mechanisms such shopping basket, authentication procedures, data formats, and common communication standards.
The OBSEA historical data sets will be described and catalogued using CDI metadata files, and ODV ASCII and netCDF with CF conventions file formats will be used for data dissemination throughout OBSEA web portal.
Inside CDI files references to OGC SWE services will be included in order to provide better sensor description and access to real-time data throughout SOS. However metadata fields and vocabularies used should be harmonized and sincronized in order to avoid inconsistences in system description.

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PESOS Group Reports on the Activities in Regard to Standardization

Klaus Schleisiek (SEND Off-Shore Electronics GmbH - Rostocker Str. 20 - D-20099 Hamburg, Germany) (www.send.de)

Standardization

There are currently two standardisation directions in the ocean science observatory community, which are or will become relevant to us as equipment manufacturers: PUCK and IEEE1451. Up to now it cannot be foreseen whether either one will be accepted and enforced. However, the underlying concepts and architectures are of relevance for the implementation of ocean observatories.

Fig.8 - Underwater camera at OBSEA observatory. The system is remotely controlled via a standard communication link

PUCK

The first activity addresses the intelligence that should be added to an instrument (sensor) in order to automate its integration (or replacement) into an ocean-bottom system. To this end, MBARI has proposed the PUCK protocol (see: www.mbari.org/pw/puck.htm), which is quite mature and has been submitted to become an OGC (Open Geospatial Consortium) standard. From MBARI's website: "PUCK is a simple command protocol that helps to automate the configuration process by physically storing information about the instrument with the instrument itself. The stored information could be an instrument description (metadata), driver code, or any other information deemed relevant by the observing system.
When a PUCK-enabled instrument is plugged into a host computer the host can retrieve the information from the instrument through PUCK protocol and deal with the information appropriately. For example, the host may install and execute instrument driver code that has been retrieved from the instrument. We refer to this automated configuration process as plug-and-work."
At present PUCK protocol has been specified for RS232 interfaces only. Similar to the old days of the Hayes modem, PUCK defines an escape sequence, which gives access to 12 simple commands. The "PUCK datasheet" consumes 96 bytes and uniquely identifies the instrument such that the system controller can retrieve its metadata.
The "PUCK payload", if at all present, is an area of non-volatile storage space, which may be written and read using the PUCK protocol. It may actually hold the metadata, which is necessary to operate the instrument in a certain environment. Experiments have been made were the same sensor has been plugged into different ocean-bottom systems. Appropriate metadata had been stored for these environments and therefore, the instrument could be integrated into these environments automatically. I like PUCK. Because it is useful. Because it is simple. Because only a minimal set of properties is standardized and there is a lot of room for installation specific extensions. Its implementation into an existing instrument takes on the order of 10 engineering days. Given that enough flash memory is available, of course.

IEEE1451

The second activity addresses independence from any idiosyncratic way of manipulating instruments. Right now, instrument manufacturers have invented various proprietary ways of how their instrument must be controlled. Incompatible access philosophies and syntaxes prevail.
Pretty much like Postscript (PDF) solved the problem of hardware dependence for printing, a similar universally accepted language for manipulating ocean-bottom instruments would be nice to have, because it would simplify the integration of instruments into ocean observatories considerably. And it would allow to create „higher level" control software (e.g. sensor web enablement), which could be used universally instead of being a „one off" solution for one specific observatory.
In essence, what we need is an „ocean-observatory control language" (OOCL), an abstract instrument (sensor) language, which would be able to address all aspects of potential ocean-observatory topologies. To this end, an Esonet workshop in Brest succeeded in devising a reference model for