NEXT GENERATION OF WEB ENABLED OCEAN SENSOR SYSTEMS

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Abstract—The complexity of installations in the oceans to carry out observations on specific processes and for detecting long-term trends have grown significantly in the past years. This applies also to the type and number of sensors that are in use in observing systems. In these days, sensors shall be compatible to different platforms that are in use like floats, gliders or moorings, and accordingly also different data acquisition systems. Facilitating the integration process in existing or newly established observing systems comes with a real benefit for the operators and is important for the broader application of different sensors. Therefore, the situation at this point in time is characterized by the fact that parallel approaches have been developed (IEEE 1451, the OGC set of standards, etc.) that are ready to be evaluated but still lacking the support by the community. The objective of the European FP7 project NeXOS (Next generation Low-Cost Multifunctional Web Enabled Ocean Sensor Systems Empowering Marine, Maritime and Fisheries Management) is to develop several sensor systems for specific technologies and monitoring strategies such as: ocean passive acoustics, ocean optics, and EAF monitoring (Ecosystem Approach to Fisheries), that will provide an integrated, technologically coherent system for multi-scale, multi-parameter monitoring of the oceans. For all these sensors system, NeXOS will develop the Smart Electronic Interface for Sensors and Instruments (SEISI) which is a set of standards and functionalities to enable Web-based sharing, discovery, exchange and processing of sensor observations, and operation of sensor systems. The architecture will satisfy international standards, defined by ISO, OGC, and the INSPIRE directive, to enable integration of marine sensors with existing observing systems. The SEISI will provide a multifunctional interface for many types of current sensors and instruments as well as the new multi-parameter sensor systems, and a standard interface for existing observing systems platforms such as: cabled observatories, buoys, gliders or Ferryboxes on ship or vessel of opportunity. To achieve the compatibility with all these platforms, the sensor systems developed in NeXOS based on SEISI will be designed to accomplish two main requirements of these platforms regarding the communication bandwidth and the power consumption.

Keywords— Multifunctional ocean sensors, Interoperability, OGC; standards, SensorML

I. INTRODUCTION

Ocean observing systems may include a wide variety of sensor and instrument types, each with its own capabilities, communication protocols and data formats. Connecting disparate devices into a network typically requires specialized software that can translate command and data protocols, between the individual instruments and the platforms on which they are installed [1]. The platforms typically require extensive manual configuration to match the driver software and other operational details of each network port to a specific instrument. Moreover, there are a high number of systems and sensor types deployed in practice which rely on different communication protocols, interfaces and data formats. This makes the integration of sensor data into the tools of researchers a challenging task which often requires significant efforts. Consequently, an approach is needed on how the collected data can be made efficiently accessible for users. The development of such an architecture concept and implementation is one of the core objectives of the European Seventh Framework Programme (FP7) project NeXOS (Next generation Low-Cost Multifunctional Web Enabled Ocean Sensor Systems Empowering Marine, Maritime and Fisheries Management). The main objective of standardizing different basic processes in the operations of installation of a new instrument has the main purpose to reduce operating costs of the observatory. On the other hand, there are marine observation platforms such as oceanographic gliders or buoys, where in addition to the installation a configuration tool is needed, and in this case this operation can be performed under extreme conditions. Standardizing these processes will minimizing the risk of failures due to manual configuration. Another of the benefits of the standardization process is to facilitate interoperability, maintenance and replacement of instruments in the observatory and maintain traceability of the data they generate [2]. This paper introduces the Sensor Web architecture for the NeXOS project 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]. Technological foundations of the NeXOS Sensor Web architecture are the concepts of spatial data infrastructures and the Sensor Web Enablement (SWE) framework [3] of the Open Geospatial Consortium (OGC). As a result an architecture concept has been defined, which is introduced in this paper. Moreover, the paper introduces the Smart Electronic Interface for NeXOS Sensors and Instruments, which is a set of standards and functionalities to enable Web-based sharing, discovery, exchange and processing of sensor observations, and operation of sensor systems.

II. MOTIVATION AND REQUIREMENTS

The sensors developed and deployed within NeXOS collect data for oceanographic research and society at large. Because there is a high number of different systems and sensor types, an approach is needed on how the collected data can be made accessible for researchers and further users. This is exactly the objective of the Sensor Web architecture presented in this paper. For the design of the NeXOS Sensor Web architecture several functional requirements were identified. These comprise:

- Pull access to observation data (i.e. following a request-response pattern)
- Push delivery of observation data
- Visualisation of the collected observation data for all NeXOS sensors, accounting for sensor specificities
- Transfer of collected observations from sensors into the Sensor Web components (i.e. by delivering the data into an observation database)
- Automatic conversion of sensor readings into a Sensor Web protocol.

Besides these functional needs, a driving factor behind the design of the Sensor Web architecture for NeXOS was the provision of a cost-efficient solution which allows data providers to integrate their sensors and sensor data easily into a Web-based infrastructure. This aim of a cost-efficient approach is achieved through several characteristics of the developed architecture:

- Re-Usability: The components and implementations of the NeXOS Sensor Web architecture shall be as generic as possible and shall follow international standards. Thus, data providers shall be able to re-use the resulting architecture and software in multiple application contexts beyond NeXOS.
- Interoperability: Through the use of international standards, the integration of sensor data into applications shall require less effort. As soon as new sensor data sets are available in the NeXOS Sensor Web infrastructure, all clients compatible to the applied standards will be able to access the data immediately.
- Open Source: For each component of the NeXOS Sensor Web infrastructure at least one open source implementation will be provided. This will allow data providers to rely on free implementations. Furthermore, the open source license of the developed components will make sure that users of the software are not bound to one single vendor. The following section illustrates how the NeXOS Sensor Web architecture has been designed to meet these requirements.

III. THE NEXOS SENSOR WEB ARCHITECTURE

Figure 1 shows an overview of the NeXOS Sensor Web architecture. It outlines the main components of the architecture and illustrates how sensors are coupled to the architecture either through dedicated bridge components or directly by implementing the so called Smart Electronic Interface for Sensor Interoperability (SEISI) specification. While the measurement data sets are stored in an observation database, several Web service interfaces exist for providing sensor related functionality. These interfaces comprise the OGC Sensor

Observation Service (SOS) for accessing the measured data, the OGC Sensor Planning Service (SPS) for controlling sensor parameters, and an approach for subscribing to push-based sensor data streams.

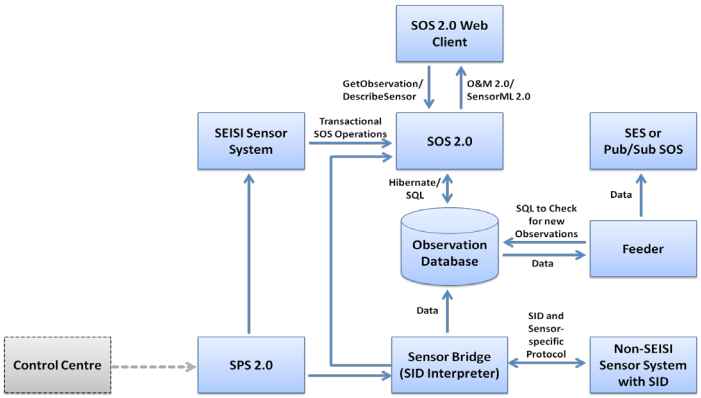

Figure 1. Overview of the NeXOS Sensor Web Architecture

IV. SMART ELECTRONIC INTERFACE FOR SENSOR INTEROPERABILITY

A new hardware and software architecture called "Smart Electronic Interface for Sensor Interoperability" (SEISI) is proposed to enable interoperable Web access to marine sensors. The architecture will satisfy international standards, defined by ISO [4], OGC [5, 6], and the INSPIRE directive [7], to enable integration of marine sensors with existing observing systems. As shown in Figure 2 the SEISI will provide a multifunctional interface for many types of current sensors and instruments, as well as new multifunctional detectors.

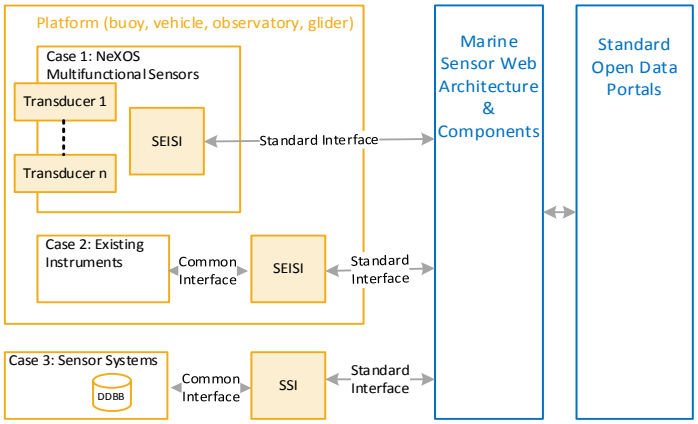

Figure 2 Oceanographic observing systems based on SEISI

The SEISI will develop a set of standard services for data distribution and easy access for the provider and end user of the NeXOS sensor systems [8]. Hence, SEISI will provide standard services for Data Access Service, Data Push Service and Configuration Service based on the existing standard specifications. Therefore, the sensor systems that will be deployed on cable observatories, buoys or ships, most of them with RF link of limited bandwidth, will have all the services mentioned above through a light implementation of OGC Sensor Observation System (kvp SOS) [9] and OGC Sensor Planning Service (SWE IoT SPS) [10]. The glider and profiler technologies used in global observation with communication via costly and energy-demanding satellite links of very low bandwidth and discontinuous will have only a Data Push Service which will be defined based on the available standard solution. The link between the NeXOS Sensor Web architecture components and the SEISI platforms is based on open standards that are maintained by the Open Geospatial Consortium (OGC). Based on the OGC standards, the SEISI interface will provide, as shown in Figure 3, basic standard protocols for sensor detection, identification, configuration, and execution of measuring operations.

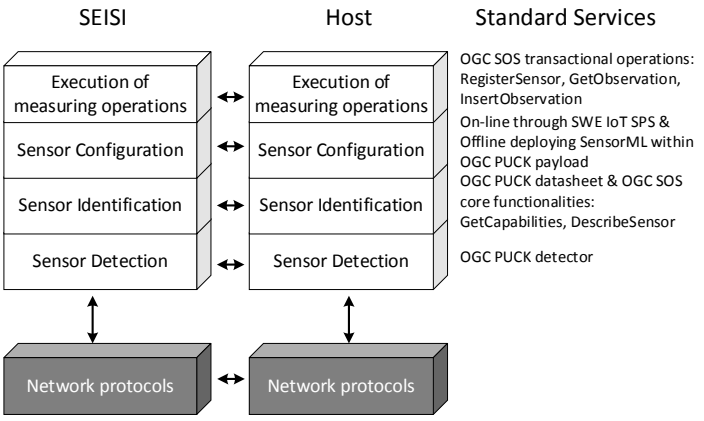

Figure 3 Standard processes between Marine Sensor Web architecture and components and the SEISI

The SEISI and the host controller running the tool for connecting marine sensors with the NeXOS Sensor Web architecture components will use the OGC programmable underwater connector with knowledge (PUCK) protocol [11] to handle the initial connection to the SEISI and to retrieve information stored in the SEISI about its own identity and sensor descriptions. Next, the host controller can use the sensor description retrieved from SEISI that includes all the sensors information (calibrations, processing, accuracy limits, etc.) using SensorML standards necessary for the network to collect and interpret its data. The sensor description, which may be stored in the instrument and retrieved through the PUCK protocol, allows a tool on the host controller to control the SEISI, parse its data and provide access to SEISI descriptions and data using a Sensor Observation Service (SOS) and the corresponding XML O&M (Observations and Measurements) encoding (please note: specific raw data formats such as acoustic data (WAV or AIFF files) will not be encoded in XML; instead the O&M documents will contain references (URLs) through which the raw data can be accessed). Since SensorML is a very comprehensive standard, which has to be downsized to be easy to use in a specific domain like marine observations, a SensorML standard subset useful for NeXOS will be defined as a dedicated profile.

To allow the users to setup the sensor systems for different scenarios, SEISI will provide also an auto configuration functionality based on the SensorML contain information about itself and located inside each SEISI system in the OGC PUCK payload. This comprises simple settings such as the sampling rate of a sensor but also complex setting such as for the auto management of new sensors connected to his input interfaces. OGC PUCK protocol will be used to retrieve this information from the sensor system and to save this information to the sensor system. The figure below shows the functional blocks of the SEISI hardware which will provide interfaces for many types of current sensors and instruments, as well as new multifunctional detectors, and the auto configuration functionality based on the SensorML.

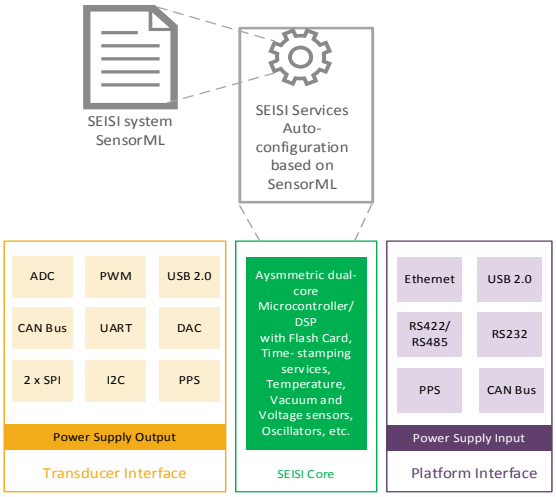

Figure 4 SEISI reads SensorML from PUCK payload to automatically configure the onboard services (enable/disable SEISI input interface, such as the ADC, I2C or SPI or enable/disable output interface Ethernet, RS232,etc.).

V. CONCLUSION AND OUTLOOK

This work in progress has introduced the NeXOS Sensor Web architecture. 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 the next three years. Based on currently ongoing evaluation activities of the first available implementations and further emerging requirements, the NeXOS Sensor Web components will be advanced to a comprehensive suite of tools for sharing oceanographic observation data in an interoperable manner.

Besides making the underlying components available as open source software, NeXOS will also contribute to the advancement of the relevant conceptual foundations. This concerns especially international spatial data infrastructure and Sensor Web standards relevant for the NeXOS Sensor Web architecture. As these standards are usually designed in a domain independent manner, further guidance how to apply them in the field of oceanography will strengthen interoperability as well as the acceptance among relevant stakeholders. For this purpose, partners of the NeXOS consortium are planning to define oceanography profiles for Sensor Web standards, building on developments from European and international initiatives, e.g. ESONET-EMSO, Seadatanet, GROOM, JERICO, FixO3, Oceansites.

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