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OGC® Sensor Web Enablement Standards

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Abstract: This article provides a high-level overview of and architecture for the Open Geospatial Consortium (OGC) standards activities that focus on sensors, sensor networks, and a concept called the “Sensor Web”. This OGC work area is known as Sensor Web Enablement (SWE).

This article has been condensed from "OGC® Sensor Web Enablement: Overview And High Level Architecture," an OGC White Paper by Mike Botts, PhD, George Percivall, Carl Reed, PhD, and John Davidson which can be downloaded from http://www.opengeospatial.org/pt/15540. Readers interested in greater technical and architecture detail can download and read the OGC SWE Architecture Discussion Paper titled “The OGC Sensor Web Enablement Architecture” (OGC document 06-021r1, http://www.opengeospatial.org/pt/14140).

Keywords: Sensor web, OGC, sensor model language (SensorML), Sensor web enablement (SWE), observations and measurements (O&M), Sensor observation service (SOS), Sensor planning service (SPS), TransducerML (TML), Sensor alert service (SAS), Web notification service (WNS), IEEE-1451.

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1. Introduction

A sensor network is a computer accessible network of many, spatially distributed devices using sensors to monitor conditions at different locations, such as temperature, sound, vibration, pressure, motion or pollutants. Sensor Web Enablement refers to Web-accessible sensor networks that can be discovered and accessed using standard protocols and application program interfaces (APIs).

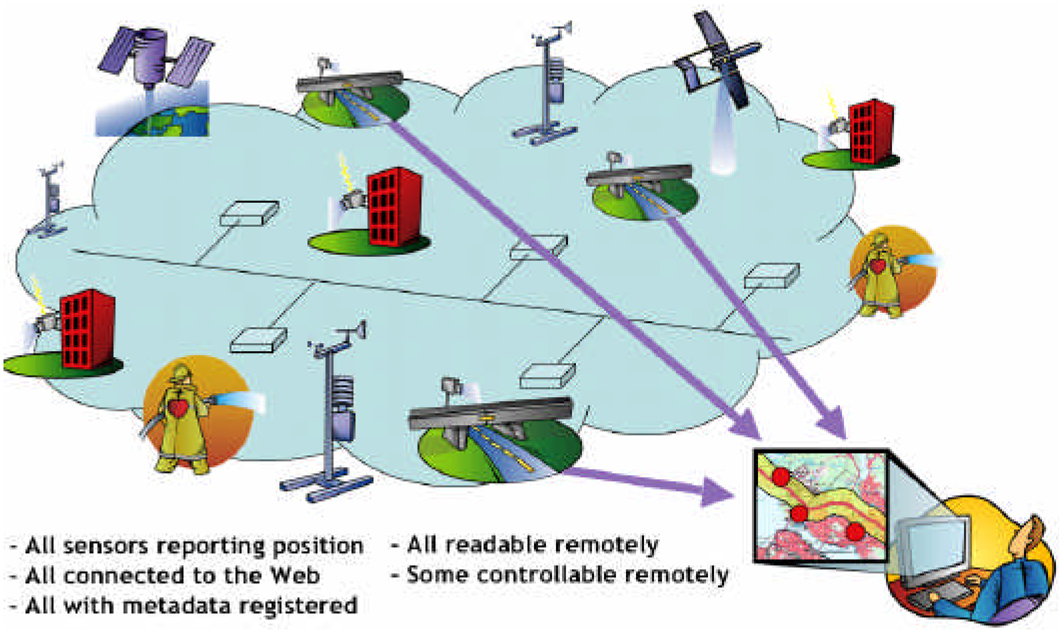

Fig. 1. Sensor Web Concept.

In an Open Geospatial Consortium, Inc. (OGC) (http://www.opengeospatial.org.) initiative called Sensor Web Enablement (SWE), members of the OGC are building a framework of open standards for exploiting Web-connected sensors and sensor systems of all types: flood gauges, air pollution monitors, stress gauges on bridges, mobile heart monitors, Webcams, satellite-borne earth imaging devices and countless other sensors and sensor systems.

SWE presents many opportunities for adding a real-time sensor dimension to the Internet and the Web. This has significance for science, environmental monitoring, transportation management, public safety, facility security, disaster management, utilities' Supervisory Control And Data Acquisition (SCADA) operations, industrial controls, facilities management and many other domains of activity. The OGC voluntary consensus standards setting process coupled with strong international industry and government support in domains that depend on sensors have helped SWE specifications to become established in all application areas where such standards are of use.

2. High Level Architecture

The OGC's SWE initiative develops standards to enable:

- Discovery of sensor systems, observations, and observation processes that meet an application or users immediate needs;

- Determination of a sensor's capabilities and quality of measurements;
- Access to sensor parameters that automatically allow software to process and geo-locate observations;
- Retrieval of real-time or time-series observations and coverages in standard encodings;
- Tasking of sensors to acquire observations of interest;
- Subscription to and publishing of alerts to be issued by sensors or sensor services based upon certain criteria.

Sensor location is a critical parameter for in-situ and mobile sensors on the Web. Therefore, SWE specifications are being harmonized with OGC geospatial standards as well as other relevant sensor and alerting standards such as the IEEE 1451 "smart transducer" family of standards and the OASIS Common Alerting Protocol (CAP), Web Services Notification (WS-N) and Asynchronous Service Access Protocol (ASAP) specifications.

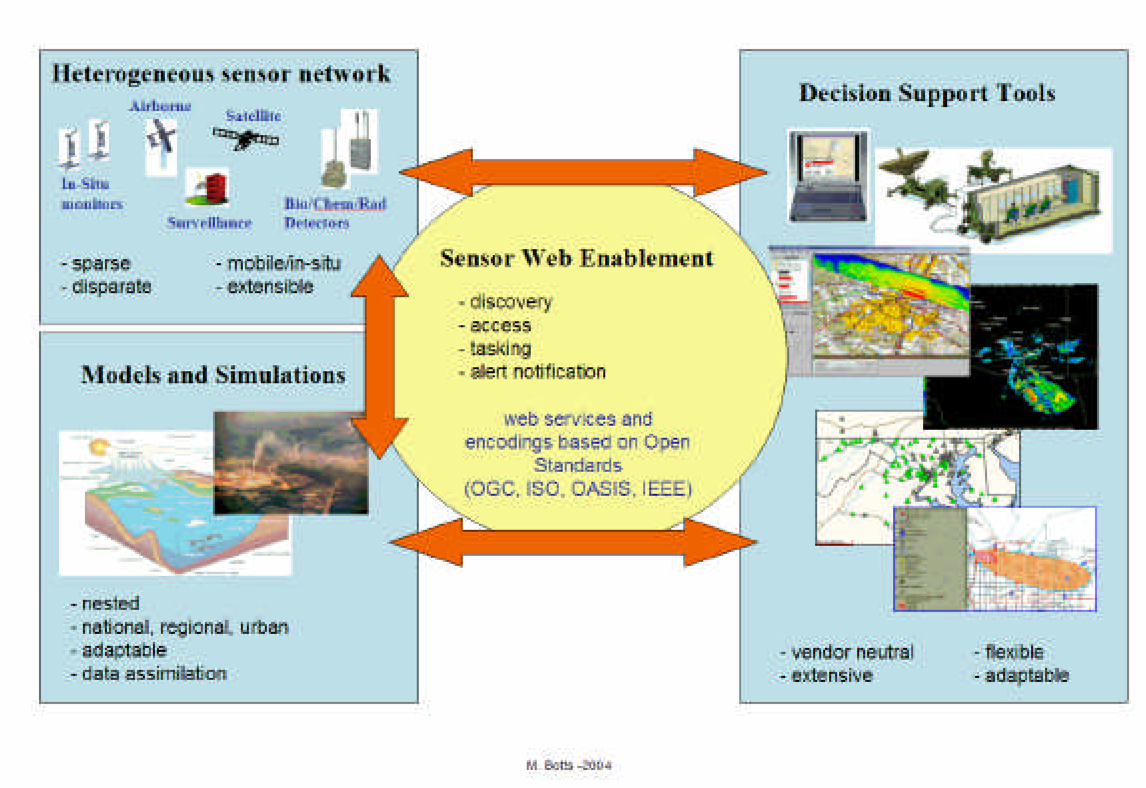

Fig. 2. The role of the Sensor Web Enablement framework..

A Web-based application might communicate with the sensor system through a proprietary or custom interface or through an interface that implements the IEEE 1451 standard. An object-oriented approach to sensor and data description also provides a very efficient way to generate comprehensive standard-schema metadata for data produced by sensors, facilitating the discovery and interpretation of data in distributed archives.

3. The SWE Standards Framework

There are currently seven proposed and adopted SWE specifications.

Observations & Measurements (O&M)

Observations and Measurements (O&M) provide a standard model for representing and exchanging observation results (http://portal.opengeospatial.org/files/index.php?artifact_id=14034). O&M provides standard constructs for accessing and exchanging observations, alleviating the need to support a wide range of sensor-specific and community-specific data formats. The O&M *Observation* provides a standard that combines the flexibility and extensibility provided by XML with an efficient means to package large amounts of data as ASCII or binary blocks.

As defined within the O&M specification, an *Observation* is an event with a *result* that has a value describing some phenomenon. The observation is modeled as a Feature within the context of the ISO/OGC Feature Model. An observation feature binds the result to the feature of interest, upon which it was made. An observation uses a procedure to determine the value, which may involve a sensor or observer, analytical procedure, simulation or other numerical processes. O&M has an accompanying OGC Recommendation Paper titled "*Units of Measure Use and Definition*" (OpenGIS® Project Document OGC 02-007r4). The basic information needed to understand a measured value is the value and the unit of measure. The document identifies eight different ways, and various options of these ways, to tie the value and the unit of measure. The goal is to develop a preferred way to structure this information in XML.

Sensor Model Language (SensorML) Implementation Specification

SensorML (see OGC's *Sensor Model Language (SensorML) Candidate Implementation Specification*, OGC Document 05-086r2 http://portal.opengeospatial.org/files/index.php?artifact_id=12606) provides an information model and encodings that enable discovery and tasking of Web-resident sensors, and exploitation of sensor observations.

The measurement of phenomena that results in an observation consists of a series of processes, beginning with the processes of sampling and detecting and followed perhaps by processes of data manipulation. The division between measurement and “post-processing” has become blurred with the introduction of more complex and intelligent sensors, as well as the application of more on-board processing of observations. The typical Global Positioning System (GPS) sensor is a prime example of a device that consists of basic detectors complemented by a series of complex processes that result in the observations of position, heading, and velocity. SensorML defines models and XML Schema for describing any process, including measurement by a sensor system, as well as post-measurement processing.

SensorML provides a functional model of the sensor system, rather than a detailed description of its hardware. Within SensorML, everything including detectors, actuators, filters, and operators are defined as process models. A *ProcessModel* defines the *inputs*, *outputs*, *parameters*, and *method* for that process, as well as a collection of metadata useful for discovery and human assistance. The inputs, outputs, and parameters are all defined using SWE Common data types. Process metadata includes identifiers, classifiers, constraints (time, legal, and security), capabilities, characteristics, contacts, and references, in addition to inputs, outputs, parameters, and system location.

TransducerML (TML) Implementation Specification

Transducer Markup Language (TML) is a method and message format for describing information about transducers and transducer systems and capturing, exchanging, and archiving live, historical and future data received and produced by them (http://portal.opengeospatial.org/files/index.php?artifact_id=14282). A transducer is a superset of sensors and actuators. TML provides a mechanism to efficiently and effectively capture, transport and archive transducer data, in a common form, regardless of the original source. Having a common data language for transducers enables a TML process and control system to exchange command (control data) and status (sensor data) information with a transducer system incorporating TML technology. TML utilizes XML for the capture and exchange of data.

TML response models are formalized XML descriptions of known hardware behaviors. The models can be used to reverse distorting effects and return artifact values to the phenomena realm. TML provides models for a transducer's latency and integration times, noise figure, spatial and temporal geometries, frequency response, steady-state response and impulse response.

Traditional XML wraps each data element in a semantically meaningful tag. The rich semantic capability of XML is in general better suited to data exchange rather than live delivery where variable bandwidth is a factor. TML addresses the live scenario by using a terse XML envelope designed for efficient transport of live sensor data in groupings known as TML clusters. It also provides a mechanism for temporal correlation to other transducer data.

TML was introduced into the OGC standards process in 2004 and is now part of the SWE family of candidate standards. It complements and has been harmonized with SensorML and O&M.

Sensor Observation Service (SOS) Implementation Specification

The goal of SOS http://portal.opengeospatial.org/files/index.php?artifact_id=12846 is to provide access to observations from sensors and sensor systems in a standard way that is consistent for all sensor systems including remote, in-situ, fixed and mobile sensors. The OGC Sensor Observation Service specification defines an API for managing deployed sensors and retrieving sensor data and specifically "observation" data.

Whether from in-situ sensors (e.g., water monitoring) or dynamic sensors (e.g., satellite imaging), measurements made from sensor systems contribute most of the geospatial data by volume used in geospatial systems today.

The SOS is the intermediary between a client and an observation repository or near real-time sensor channel. Clients implementing SOS can also obtain information that describes the associated sensors and platforms.

Figure 3 shows a SWE client making use of the SOS to automatically obtain observations and measurements from a collection of sensors. The SOS might also control the sensors for the client. The client depends on registries that provide metadata for the different types of sensors and the kinds of data that they are capable of providing.

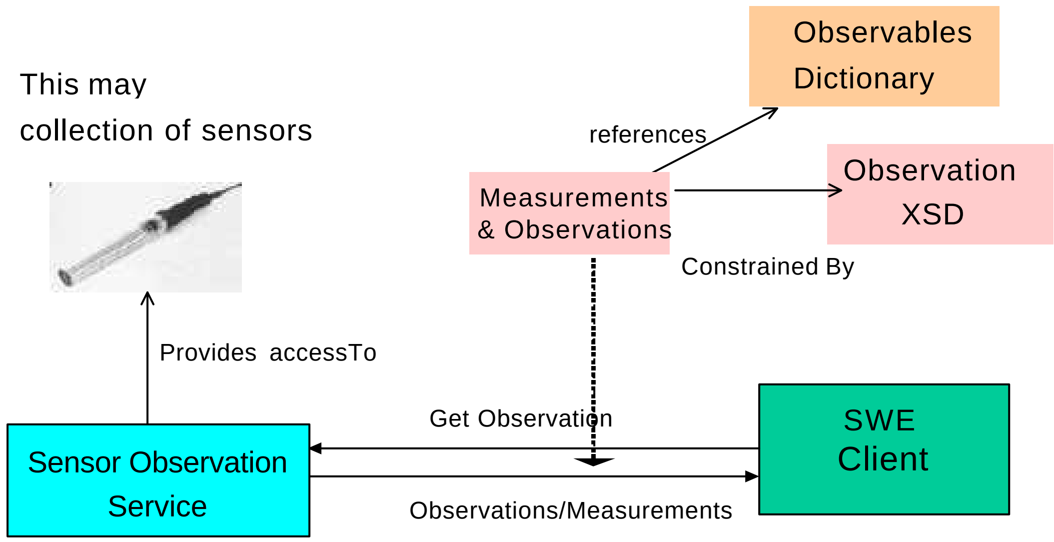

Fig. 3. Sensor Observation Service Concept.

Figure 4 shows the role that registries (also called catalogs) play in a fully operational Web Services based Sensor Web. The schema for each sensor platform type is available in a registry, and sensors of that type are also in registries, with all their particular information. The schema for each observable type is available in a registry, and stored collections (data sets) of such observables and live data streams of that type are also in registries. Searches on the registries might reveal, for example, all the active air pollution sensors in Los Angeles.

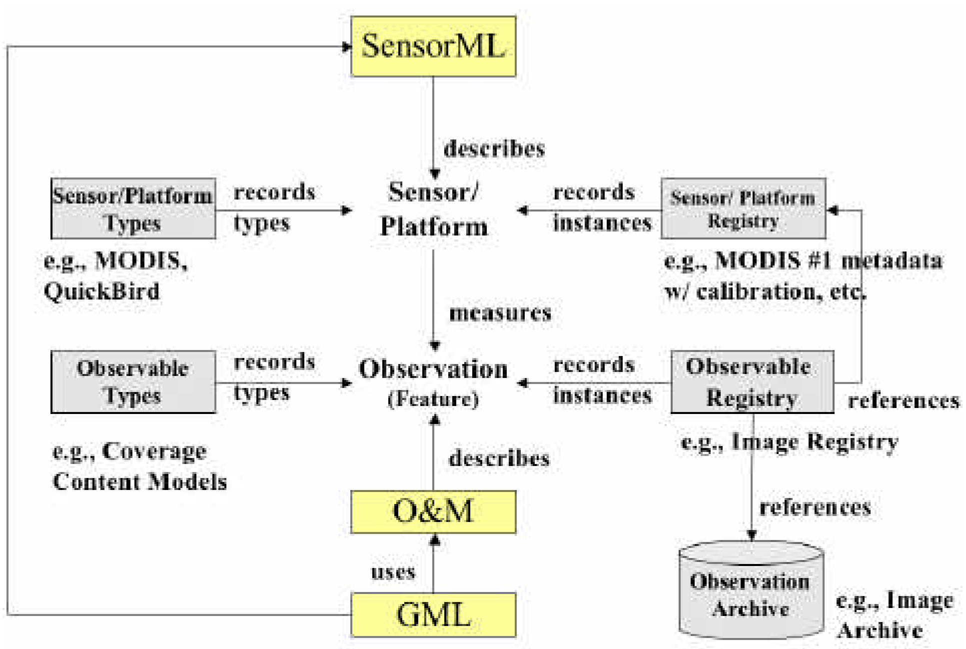

Fig. 4. Role of registries in the Sensor Web.

Sensor Planning Service (SPS) Implementation Specification

The Sensor Planning Service (SPS) Implementation Specification specifies interfaces for requesting information describing the capabilities of a SPS for determining the feasibility of an intended sensor planning request, for submitting such a request, for inquiring about the status of such a request, for updating or canceling such a request, and for requesting information about further OGC Web services that provide access to the data collected by the requested task.

SPS defines interfaces for a service to assist in collection feasibility plans and to process collection requests for a sensor or sensor constellation.

The developers and likely users of the SPS specification are enterprises that need to automate complex information flows in large enterprises that depend on live and stored sensor and imaging data.

OpenGIS® Sensor Alert Service (SAS)

The draft OpenGIS® document 06-028 specifies interfaces for requesting information describing the capabilities of a Sensor Alert Service, for determining the nature of offered alerts, the protocols used, and the options to subscribe to specific alert types. (http://portal.opengeospatial.org/files/index.php?artifact_id=12846). The document defines an alert as a special kind of notification indicating that an event has occurred at an object of interest, which results in a condition of heightened watchfulness or preparation for action. Alerts messages always contain a time and location value.

A SAS implementation relies on other alerting protocols and standards. For instance, users could register with a SAS enabled alert registry to receive OASIS Common Alert Protocol (CAP) alerts for specific types of observations, such as weather events or earthquakes.

OpenGIS® Web Notification Service (WNS) Interface Specification

WNS [OGC Document 05-114] http://portal.opengeospatial.org/files/index.php?artifact_id=1367 specifies an open interface for a service by which a client may conduct asynchronous dialogues (message interchanges) with one or more other services. As services become more complex, basic request-response mechanisms need to contend with delays/failures. For example, mid-term or long-term (trans-) actions demand functions to support asynchronous communications between a user and the corresponding service, or between two services, respectively. A WNS is required to fulfill these needs within the SWE framework.

The Web Notification Service Model includes two different kinds of notifications. First, the "one-way-communication" provides the user with information without expecting a response. Second, the "two-way-communication" provides the user with information and expects some kind of asynchronous response. This differentiation implies the differences between simple and sophisticated WNS. A simple WNS provides the capability to notify a user and/or service that a specific event occurred. In addition, the latter is able to receive a response from the user.

4. Other Areas of Sensor Web Standards Harmonization

IEEE 1451 Transducer interfaces

Developing an open standards framework for interoperable sensor networks requires finding a universal way of connecting two basic interface types – transducer interfaces and application interfaces. Specifications for transducer interfaces typically mirror hardware specifications, while specifications for service interfaces mirror application requirements. The sensor interfaces and application services may need to interoperate and may need to be bridged at any of many locations in the deployment hierarchy.

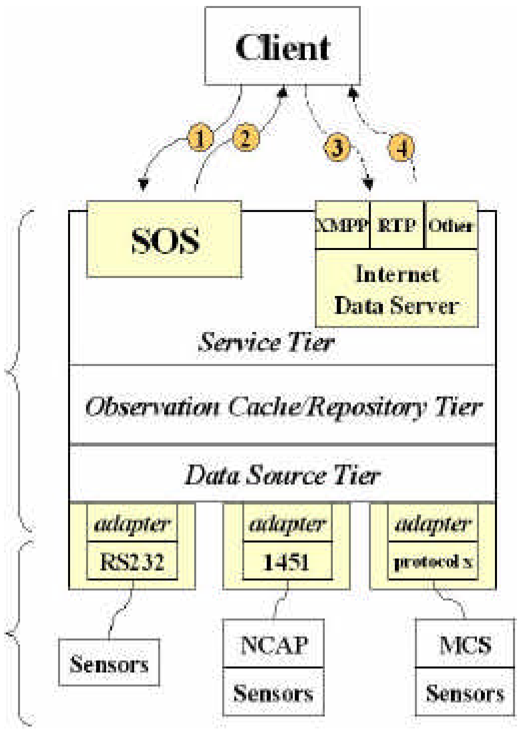

Fig. 5. Where 1451 Fits in the SWE Interoperability Stack.

At the transducer interface level, a "smart" transducer includes enough descriptive information so that control software can automatically determine the transducer's operating parameters, decode the (electronic) data sheet, and issue commands to read or actuate the transducer.

To avoid the requirement to make unique smart transducers for each network on the market, transducer manufacturers have supported the development of a universally accepted transducer interface standard, the IEEE 1451 standard http://ieee1451.nist.gov/intro.htm.

The object-based scheme used in 1451.1 makes sensors accessible to clients over a network through a Network Capable Application Processor, and this is the point of interface to services defined in the OGC Sensor Web Enablement specifications.

Imaging Sensors

SWE's sensor model is sophisticated enough to support encoding of all the parameters necessary for characterizing complex imaging devices such as those on orbiting earth imaging platforms. ISO and OGC have cooperated to develop two ISO standards that are relevant to the SWE effort: ISO 19130 *Geographic Information – Sensor and Data Model for Imagery and Gridded Data* and ISO 19101-2 *Geographic Information – Reference Model – Imagery (http://www.isotc211.org/).*

5. Conclusion

OGC's SWE specifications will be key parts of an integrated framework for discovering and interacting with Web-accessible sensors and for assembling and utilizing sensor networks on the Web. Many key interoperability elements have already been codified in specifications, and work will continue on these as the specifications are tested and implemented in products. OGC members will continue to address new areas of Sensor Web Enablement in the OGC Specification Program's committees and working groups and the OGC Interoperability Program's testbeds and pilot projects.

OGC invites additional participation in the consensus process and also invites technical queries related to new implementations of the emerging standards.

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