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SENSORTHINGS API AND THE OGC API FAMILY OF STANDARDS: A NEW GENERATION OF INTEROPERABILITY STANDARDS FOR RESEARCH DATA INFRASTRUCTURES TO FURTHER IMPROVE THE SHARING OF OCEAN OBSERVATION DATA

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Abstract

This article discusses the potential of standards such as the OGC SensorThings API and the new OGC API family of standards to develop a new generation of marine Sensor Web systems. While standards such as the OGC Sensor Observation Service were already used within several projects, the new generation of OGC standards promises several advantages such as more lightweight interfaces and encodings. Thus, combining the results and experiences of previous projects and established systems with more lightweight standards (i.e., OGC SensorThings API and the different modules of the OGC API framework) is a chance to further increase the adoption of interoperability standards within marine research data infrastructures. In this paper, the potential changes as well as the challenges that need to be resolved are discussed.

Keywords: Sensor Web, Interoperability, Research Data Infrastructures, Observation Data, Standardisation

1. Introduction

Over the last years, several projects have addressed the challenge to ensure interoperability when sharing (*in situ*) ocean observation data within research data infrastructures. Most of these activities were centred around established standards such as those of the Open Geospatial Consortium's (OGC) Sensor Web Enablement (SWE) framework: Sensor Observation Service (SOS), Sensor Model Language (SensorML), as well as Observations and Measurements (O&M).

Based on these standards, different best practices to improve syntactic and semantic interoperability were achieved. However, due to the rather complex nature of these standards, the efficient development of client applications remains a challenge.

The existing specifications are now being complemented by a new generation of standards: the emerging OGC API standards with several specifications for sharing geographic information as well as the OGC SensorThings API which is gaining more and more attention. As these new specifications are especially designed to facilitate application development through the use of more lightweight technologies, they have a significant potential to further enhance the value of research data to users.

Consequently, this contribution is intended to discuss the opportunities associated with the new generation of interoperability standards. Specific consideration will be given to potential pathways on how to integrate these new approaches with the achievements that resulted from the Sensor Web-related activities that were conducted during the last years.

2. Marine Sensor Web Deployments

The ideas presented within this article were developed as part of the JERICO-S3 (Joint European Research Infrastructure of Coastal Observatories: Science, Service, Sustainability) project. This project aims to provide a state-of-the-art research infrastructure for high-quality data on European coastal and shelf seas. Among other aspects, also the use of Sensor Web interoperability standards will be one foundation for the infrastructure development. However, there is a broad range of further projects which demonstrated or are demonstrating the use of Sensor Web standards to facilitate the exchange of marine observation data.

For example, the European ODIP II (Ocean Data Interoperability Platform) project has developed best practice recommendations on how to apply the OGC Sensor Web Enablement standards for marine data (<https://github.com/ODIP/MarineProfilesForSWE>). Special emphasis during this project was put on ensuring semantic interoperability by using on vocabularies to reference to the meaning of specific concepts and elements (Kokkinaki *et al.*, 2016).

Projects such as NeXOS (Next generation, Cost-effective, Compact, Multifunctional Web Enabled Ocean Sensor Systems Empowering Marine, Maritime and Fisheries Management, <https://www.nexosproject.eu/>) have developed approaches how to use Sensor Web standards to handle to full path of data flows between sensor (platforms) and end user applications. This has included both, approaches for facilitating the data integration but also for data download, processing and visualisation (Del Rio *et al.*, 2019). As part of the BRIDGES project (Bringing together Research and Industry for the Development of Glider Environmental Services, <http://www.bridges-h2020.eu/>) it was further explored how such a technological approach can be applied to ocean gliders.

Finally, projects such as SeaDataCloud (<https://www.seadatanet.org/>) and EMODnet Ingestion (<https://www.emodnet-ingestion.eu/>) have applied Sensor Web standards in order to facilitate the integration of (near real-time) observation streams into research data infrastructures. This has resulted in components such as dedicated ingestion and viewing services (Jirka and Autermann, 2018). In cooperation between the EMODnet Ingestion and the EUROFLEETS+ (<https://www.eurofleets.eu/>) projects it was shown how Sensor Web standards may be used to handle, deliver and explore tracking data of research vessels (Autermann *et al.*, 2021).

3. The OGC sensorthings API and the OGC API family of standards

This section is intended to provide an overview of the different Sensor Web standards of the OGC which are available or are in development. This overview shall serve as a baseline to subsequently discuss the opportunities provided by the new generation of Sensor Web specifications.

3.1 OGC Sensor Web Enablement (SWE)

The original standards of the OGC Sensor Web Enablement (SWE) framework comprise a series of interface and data model/encoding standards (Bröring *et al.*, 2011). Especially the following standards need to be considered when working with marine observation data:

- Sensor Model Language (SensorML) (Botts and Robin, 2014): A data model and encoding standard to provide a broad range of metadata to describe the whole chain through which measurements were generated. This also includes descriptions of the involved sensor hardware as well as the platforms to which sensors are attached;

- Observations and Measurements (O&M) (Cox, 2011) (ISO TC 211, 2011): A data model and encoding for observation data itself. This standard defines the necessary properties (e.g., time stamps, spatial reference, etc.) that need to be included in order to provide meaningful measurements;
- Sensor Observation Service (SOS) (Bröring et al., 2012): An interface standard that enables Remote Procedure Call (RPC)-based access to sensor data and the corresponding metadata. The SOS standard defines a set of operations and their query parameters to provide this access functionality.

These standards can be considered as a baseline, which has been applied in a broad range of projects over the last years (see section 2). In the next subsection the OGC SensorThings API (STA) is introduced as a complementary element of the SWE framework, which is currently gaining more and more acceptance.

3.2 OGC SensorThings API

The OGC SensorThings API (STA) standard (Liang et al., 2016) provides a more lightweight addition to the SWE framework. While the standards introduced in section 3.1 are mostly relying on XML-based encodings, the STA introduces technologies such as JSON and REST into the SWE framework. On the one hand, this results in encodings which are often easier to handle by client developers. On the other hand, the RESTful interface of the STA makes it easier to explore and query the data offered by an STA server. In addition, the approach of relying on the OData protocol adds additional query and data retrieval options which make the interface more flexible.

Furthermore, the STA offers dedicated support of event-based data flows, primarily relying on the Message Queuing Telemetry Transport (MQTT) (<https://mqtt.org/>) protocol. Based on this protocol, it becomes possible to establish push data flows from devices into STA servers. At the same time, the MQTT protocol can also be used to directly deliver data from STA servers to subscribers in order to immediately deliver the latest published observation data.

3.3 OGC API Family of standards

A further development that needs to be considered is the OGC API family of standards (<https://ogcapi.ogc.org/>). This family of standards can be seen as a new generation of the OGC baseline architecture. Based on mainstream technologies such as OpenAPI, this set of standards will provide a coherent and modular framework comprising the functionality currently offered by typical OGC Service such as Web Map Server, Web Feature Service, Catalog, etc. However, due to its more mainstream oriented approach, it can be expected that the OGC API standards will achieve a higher degree of adaption than the currently existing standards.

As part of the OGC API family, especially the Environmental Data Retrieval (EDR) API (<https://ogcapi.ogc.org/edr/>) might be relevant for sharing marine observation data. Because this API will provide functionality for accessing environmental data in a way that is aligned to the overall OGC API approach, a special value of the EDR API might be to provide observation data closely linked to other geographic information provided via other modules of the OGC API (e.g., feature data containing information about sensor stations or data about investigation areas).

4. Chances offered by the new generation of standards

The new generation of OGC standards to share observation data offers several potential advantages. An overview of important new features and opportunities will be provided in this section.

While the previous generation of SWE standards already provides very powerful and comprehensive data models for sensor data (O&M) and the corresponding metadata (SensorML), the mostly XML-based encoding has some drawbacks. Also, the interfaces such as the SOS specification offer important functionality to enable reliable data flows. However, at the same time these interfaces are not optimised to develop lightweight client applications to explore and visualise observation data. This issue is addressed by the new generation of standards relying on efficient RESTful interfaces with powerful query options and developer-friendly JSON encodings.

A further useful aspect is the support of MQTT data streams by the STA specification. This enables the efficient push-delivery of observation data from devices into data repositories but also further on to end-user applications. As a result, the latency of the data provision can be significantly reduced. Furthermore, a push-based delivery mechanism has the potential to supply larger numbers of clients with up-to-date data while ensuring a good scalability.

Finally, the new OGC API family of standards and its modular structure will facilitate the interlinking between different types of resources. For example, it will be possible to access observation data as well as the corresponding geographic base data relying on the same interaction patterns and communication flows.

5. Open challenges

While the new generation of interoperability standards offers a high potential to further improve the provision of observation data in marine research data infrastructures, several challenges will need to be addressed in order to make use of the potential of these standards. This section introduces a set of selected challenges which need to be addressed in a mid-term perspective.

Projects such as ODIP II and SeaDataCloud have put significant efforts into the development of marine SWE profiles. In order to transfer the conceptual achievements of these projects to the new generation of OGC standards, it will be necessary to define how the developed concepts shall be represented within the new data models and encodings. For example, it will be necessary to transfer the SensorML profiles for providing metadata about marine observations into corresponding JSON-based representations.

Furthermore, within the SWE framework several dedicated observation types that can be used for marine observations were established. An important example are the specialised observation types proposed as part of the European INSPIRE framework (INSPIRE MIG sub-group MIWP-7a (2016)). For these data types it would be important to create corresponding equivalents that can be used to define the outputs of STA implementations for marine observation data.

Also, for the use of MQTT as a data delivery protocol, it would be necessary to further specify the corresponding payloads. While the STA specification already offers guidance on how to transmit the observation data itself, further types of payload would be necessary to enable more automated data flows (e.g., enabling the (self-) registration of new sensing devices, etc.).

Besides this, further work will need to be invested in order to improve the link to existing vocabularies in order to increase semantic interoperability. Another aspect is the addition of fine-grained access control mechanisms into the new data access protocols for making specific data sets available only to selected user groups. Furthermore, it will be necessary to enhance the existing SWE best practice documentation for marine applications to the new generation of standards.

6. Conclusion

In summary, the new generation of OGC standards, especially the OGC API standards and the OGC SensorThings API offer valuable enhancements and improvements to further increase the adoption of interoperable Sensor Web applications. Through the provision of more developer friendly interfaces and encoding as well as the enablement of event-driven push data flows, new opportunities arise. Also, the improved linkage to other geospatial data has a high potential.

In addition, there are still several open challenges which should be addressed in order to provide the necessary extensions and profiles to consider the specifics of marine observation data and research data infrastructures. However, by addressing these challenges in future projects, it can be expected that the adoption of OGC standards in the marine community will further increase.

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