OData - Usage of a REST Based API Standard in Web based Environmental Information Systems

Désirée Hilbring[1], Kevin Becker[2], Markus Eisenla[3], Katharina Emde[4], Hylke van der Schaaf[5], Horst Spandl[6] and Martina Tauber[7]

Abstract: Environmental information in existing custom-build environmental information systems is manifold. Sharing this information via Web APIs for diverse client types to fulfil the needs of ongoing digitisation efforts is still a challenge. This paper analyses the open standard OData (Open Data Protocol) as a possible communication protocol between independent servers and clients. Of interest is also the question, if the protocol is not only capable of sharing environmental data between independent systems but also if the information provided via OData is sufficient for directly creating a web-based end user client. The developed prototypical implementation is tested in two environmental applications from different domains: a small data overview for decision makers and the integration of information in an environmental platform.

Keywords: OData, Environmental Information Systems, REST, WaterFrame®

Addresses Sustainable Development Goal 9: Industry, innovation and infrastructure

1. Introduction

In recent years many environmental information systems (EIS) have evolved for different environmental domains supporting specified purposes. Taylor analysed a typical environmental agency's products and services and found 63 distinct internet offerings [P16]. They range from providing complex environmental information applications for domain experts through web services providing geoinformation to simple web sites sharing environmental information to the general public. However, achieving interoperability is still a struggle for many projects that try to fulfill the need for digitisation and environmental information sharing.

This paper analyses the use of OData (Open Data Protocol, an open protocol standard for realizing RESTful APIs) for sharing environmental information. It addresses the question

[1] Fraunhofer IOSB, ILT, Fraunhoferstr. 1, 76131 Karlsruhe, Deutschland, desiree.hilbring@iosb.fraunhofer.de
[2] Fraunhofer IOSB, ILT, Fraunhoferstr. 1, 76131 Karlsruhe, Deutschland, kevin.becker@iosb.fraunhofer.de
[3] Fraunhofer IOSB, ILT, Fraunhoferstr. 1, 76131 Karlsruhe, Deutschland, markus.eisenla@iosb.fraunhofer.de
[4] Fraunhofer IOSB, ILT, Fraunhoferstr. 1, 76131 Karlsruhe, Deutschland, katharina.emde@iosb.fraunhofer.de
[5] Fraunhofer IOSB, ILT, Fraunhoferstr. 1, 76131 Karlsruhe, Deutschland, hylke.vanderschaaf@iosb.fraunhofer.de
[6] LUBW Landesanstalt für Umwelt Baden-Württemberg, Postfach 100163, 76231 Karlsruhe, Deutschland horst.spandl@lubw.bwl.de
[7] LUBW Landesanstalt für Umwelt Baden-Württemberg, Postfach 100163, 76231 Karlsruhe, Deutschland martina.tauber@lubw.bwl.de

how environmental data can be shared and accessed easily in a generic way and which main characteristics of the data can be shared via the protocol. Furthermore it discusses first ideas how this information can be used by web clients.

A commonly used IT architecture for web applications is a client server architecture with communication via REST based interfaces. OData is a standard collocating a set of best practices for such RESTful APIs.[8] It is an OASIS standard and ISO/IES approved. It iuses the HTTP Protocol to provide CRUD (create, read, upload, delete) operations and supports the JSON Format. It provides a common semantic for data and metadata exchange. The standard has been originally launched by Microsoft and is also used by IBM and SAP[9].

The goal for this paper is to analyse the usage of this standard in the scope of sharing environmental information and data. The following analysis questions have been asked:

- What generic requirements for sharing environmental information exist and can OData fulfil them?
- Is the standard capable of sharing information between independent environmental information systems?
- Is the standard capable for sharing information ready for clients creating an environmental web-based application?

2. Related Work

An overview about Environmental information systems gives Fischer-Stabel in "Umweltdaten und Umweltinformationssysteme" [F21]. They cover a wide field of applications, can be categorized into different system categories (national/international EIS, statewide EIS or regional EIS and operational EIS. They all manage multimodal data about water, air, soil and organisms and try to monitor and control environmental impact.

The Open Geospatial Consortium (OGC)[10] defines many widely accepted standards for modelling and sharing geospatial information. They are designed for many specific use cases, like sharing maps via Web Map Service (WMS) [B06], sharing geographic information via Web Feature Service (WFS) [P09] or sharing IoT sensor data, basically observation data via the Sensor Things API (STA) [LHK15]. Other well-known OGC standards exist. Additionally, many of these standards are used as INSPIRE network services for spatial data[11]. Environmental Information Systems often deal with geospatial information and for sharing such information picking the appropriate service and providing the geospatial information is advisable. However, besides the spatial information further information exists, which needs to be shared in environmental

[8] https://www.odata.org, last access 22 June 2022
[9] Overview of the OData Standard | Nordic APIs |, last access 22 June 2022
[10] The Home of Location Technology Innovation and Collaboration | OGC, last access 22 June 2022
[11] Network Services | INSPIRE (europa.eu), last access 22 June 2022

information systems. The information is often domain specific and modelled in relational databases. Therefore, for data where the semantic data model is crucial and geospatial information is less important other standards need to be considered.

In this paper we are focussing on the question how data, which has often been collected for years and stored in relational databases of environmental agencies can be provided by Web APIs. Since the OData protocol is easily capable of modelling information from relational databases, we analyse this approach. The article "Web APIs for environmental data – state of the art investigation" gives an overview about existing practises for the publication of environmental data using Web APIs focussing on APIs used by organisations handling data similar to meteorological data [P16], which is a sub-set of environmental data. Taylor identifies the following challenges for environmental data: variety, volume, velocity and veracity. OData is only mentioned in context with the SensorThing API. In "Open Data!" Hübener discusses the possibilities for Open Data starting with data available at the German Environmental Agency (Umweltbundesamt – UBA) and considers OData as part of the proposed IT infrastructure [H12]. Wohlgemuth et al. discuss similar ideas in their paper "Entwicklung eines Open-Source basierten Baukastens zur Unterstützung und Etablierung der Ressourceneffizienz in KMU" focusing on SMEs [VZT14]. The client sever communication on the proposed architecture uses the OData-Protocol while Boß and Wohlgemuth uses OData in an operational EIS for energy management [BW15].

3. Functional Requirements for web based Environmental Information Systems

This section lists functional requirements which - according to our expertise - are relevant for sharing environmental information from existing environmental systems. These requirements are the basis for the analysis of the OData protocol implementation in our examples. Requirement for sharing environmental information are similar and manifold in comparison to sharing any other type of information. Main requirements may differ depending on the client using the interface: is it another system or an end user? Is information only presented or is write functionality needed? We marked the lists of common functional requirements with #keyword. This is used to show which requirements help to answer the main questions of the paper from section Introduction.:

- #environmental: a concept, which is widely used and especially important for environmental application.
- #geospatial: a concept, which includes handling of geospatial information.
- #system: a concept, which is needed to share information with another system.
- #user interface: a concept, needed when information shall be presented to end users.

Requirement 1: Environmental data bases are often home-grown relational databases using domain specific information models using strong specific schemas. Relationally structured information, needs to be shared differently compared to non-relational data stored in documents (#environmental). The content of relational databases can often be visualized using tables. For management and sharing of the strongly structured data a list of sub requirement exists:

1. The usual CRUD (create, read, update and delete) operations are necessary (#system, #user interface).
2. Support for common data types like Integer, String, etc. (#system, #user interface).
3. Since environmental information often contains data collected over decades search functions are essential (#system, #user interface).
4. For sharing environmental information, often commonly used key lists are defined for an easy exchange of specific information: Examples are manifold: a taxonomy with biological water organisms, a list of chemical parameters defining common identifiers like CAS or UBA-Code. (#environmental, #system, #user interface)
5. Handling of mandatory and optional attributes. (#system, #user interface)
6. Defining default values for attributes. (#system, #user interface)
7. Handling of valid value ranges. (#system, #user interface)
8. Defining rules for formatting (#system, #user interface)

Requirement 2: Authentication and authorisation play a key role. Managing complex domain information need role concepts (#environmental).

Requirement 3: Error Handling providing information about system or domain errors is necessary (#system, #user interface).

Requirement 4: Presentation of domain specific standard forms, as defined and widely used by domain experts play a key role in environmental information systems (#environmental, #user interface)

Requirement 5: Handling of geospatial information is also common in environmental information systems. The difficulty is to decide, how important the geospatial information is for the application. Does it only support the main goals of the application, or is it so important that a specific OGC standard is obvious to be used (#geospatial).

4. Implementation

EIS address a wide range of specific domains, realized by manifold systems. To test our OData requirements for sharing environmental data between independent systems we extended an existing platform (WaterFrame®) for developing EIS with OData.

4.1 Environmental Applications with WaterFrame®

The WaterFrame® platform from Fraunhofer IOSB provides a framework with basic functionality to develop easy configurable low-code environmental applications based on relational data models: XCNF (Extensible Database Application Configurator)[12]. The platform is used to develop EIS regarding ground water, surface water and water protection, but also for other domains like soil, wind energy or nature protection.

With XCNF thematic views can be easily con^^^^^^d by developers or XCNF experienced users. These views are essentially SQL queries that gather data from one or more database tables, combined with additional meta-data defining how the data should be visualised and edited. The XCNF-Views provide the CRUD functions for the data of the application. For each attribute of a view functional access rights based on role concepts can be configured. Furthermore, analysis code evaluating the attribute data can be integrated. For each view generic import and export functionality can be provided. A combination of these views builds the environmental application.

4.2 OData Concepts

Information to be shared via the OData protocol needs to be mapped to the *Entity Data Model (EDM)* which is the abstract data model of OData and can be identified and manipulated via URLs with simple HTTP messages. Central concepts of the EDM are entities, relationships, entity sets, actions and functions.

To describe the information for clients the OData protocol provides a metadata document in JSON or XML format describing all available entities. It contains all *entity types* along with their properties with name and type, as well as the structure of the entity types via navigation links. It is possible to enhance the instance elements contained in the meta data document with so called *Annotations*, an interesting extensibility point for OData. With metadata annotations characteristics of properties can be further described.

4.3 Extension of an existing environmental framework with OData

XCNF as part of the WaterFrame® platform provides the possibility to create environmental applications domain independent. Therefore we extended XCNF with an

[12] WaterFrame® - Gewässerinformationssysteme - Fraunhofer IOSB, last access 22 June 2022

OData based REST Server. Fig. 1 shows how the existing architecture of XCNF has been extended to integrate an OData Server. The XCNF-Core capable of handling Oracle or H2 databases has been extended with an OData REST API interface of version 4.01 [HP20a] integrated in a jetty web server.

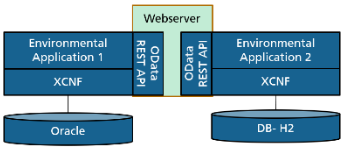

Fig.1: Integration of OData in XNCF architecture

To provide the information from the data model of the environmental application to OData a mapping to the OData EDM needed. In the mapping thematic structured *XCNF views* are automatically mapped to OData *entity types* (see Fig. 2). Thus, for all environmental applications based on XCNF existing thematic views can be adapted or new views can be created from which the content is provided via the OData REST API.

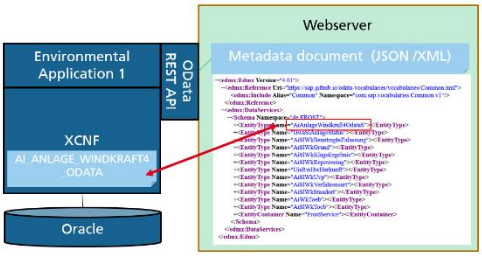

Fig.2: Mapping of XCNF Views to OData Entity Types

With that the common CRUD operations are available to share and manipulate information form the underlying XCNF based application over the internet.

4.4 OData Clients

Information provided by the OData Server can be consumed by different client types.

Generic clients are able to interpret the standardized protocol information in the metadata document and are able to connect directly to different OData Servers:

- One well known example is **Excel**, that can access data from OData 4.0 Servers since Excel version 2019.
- Another generic client has been developed in our project. It is able to interpret the metadata documents of different OData Servers to visualise the information in a web client and provides the user with CRUD operations.

Specific clients have different sub types. They can directly access information from a specific OData Server for their own tasks (e.g. exchange a specific environmental information piece from and with an external system). Furthermore, specific clients can be designed using the standard OData protocol functions and additionally interpret *Annotations* from a specific OData Server to provide more functionality for their users.

4.5 Addressing the Requirements via OData

In this section we compare the requirements for environmental information applications with the capabilities of the OData Protocol [HP20a].

Requirement 1: Environmental information structured in a relational way can be usually mapped directly to the *Entity Data Model* of OData and therefore the domain information can be provided via the basic functionality of the protocol (#environmental) and fulfil the sub requirements #system and #user interface:

1. CRUD operations are provided by the basic functionality of OData.
2. Common data types are provided by the basic functionality of OData.
3. OData defines a number of query options in section 11.2.1 of the OData protocol as basic functionality. Our implementation supports the $filter functionality and further functions to control the result sets: $count (number of results), $orderBy (result order), $select (limit the result set to specific properties).
4. With the $expand function OData provides a possibility to directly expand navigation links in a query as basic functionality. This function can be used to directly integrate the values of key value pairs of keylists into an OData result set.

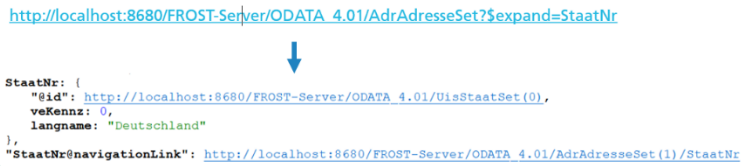

Fig.3: The *StaatNr* from Keylist *UISStaatSet* is expanded directly to *Deutschland*.

5. The handling of mandatory and optional attributes can be addressed using additional annotation functionality in OData.
6. Default values can be defined using annotations.
7. The handling of valid value ranges can also be addressed via annotations. The following examples may be used for this: Defining the maximal length of texts or defining the precision of attributes.
8. More complex formatting rules for attributes can be derived via annotations using

regular expressions.

Requirement 2: Authentication can be handled in OData just like in any way a generic RESTful API can be secured. In our test implementation the goal is to reuse the already existing underlying authentication and authorization concept of XCNF (#environmental).

Requirement 3: Error Handling can be realized via using common HTTPs Status Codes[13]. An example maybe using 401: "Unauthorized" for a missing authorization for writing or reading specific attributes (#system, #user interface).

Requirement 4: Another aspect is the question how hints for the layout of forms via the OData protocol can be delivered. Using *Annotations* like *"@inTab("Name of Tab")* grouping of elements belonging together is possible (#environmental, #user interface).

Requirement 5: To decide which standard fits best OData or a geospatial one, one needs to weight the importance of the geospatial information. Consider the following two examples: firstly, showing a nitrate distribution of an area in a map, a typical use case for an OGC WMS. Secondly, information needed for the status overview of complex permission processes of wind generators. That information is not structured in a widely used data model. Only the places of the generators are of interest. The coordinates can be defined using the geometrical types of OData. They are parts of the OData Primitive Types following the OGC Simple Feature Specification [HP20b], which contains widely used types like points or polygons (#geospatial).

Thus, as generic protocol for client server communication of web applications OData provides well known working concepts and functions for exchanging common information types. This applies also for generic concepts with important roles in many environmental applications like a structured data model, a decent role concept or key lists. Using OData gets more specific when trying to provide highly specified forms information with specific layout requirements for end users. The Annotation concept can deliver layout hints for clients. Additionally, providing geospatial information is possible, but depending on the use case other suitable geospatial standards may be preferable.

5. Example Applications

We started to test the prototypical implemented REST-based OData interface for environmental XCNF applications of the WaterFrame® platform in two use cases from different domains, wind energy and ground water. They use different client types: generic and specific.

5.1 Usage in a Wind Energy Application

[13] https://de.wikipedia.org/wiki/HTTP-Statuscode, last access 22 June 2022

The LUBW[14] develops in the domain of trade supervision an environmental application based in XCNF for the data management of the permission process of wind energy generators. The permission process for wind energy generators is complex. Legal impacts in the domains of pollution control, building legislation, nature protection, air transportation, and mobility need to be considered. Therefor the permission process for a wind energy generator might need several years. The goal of the expert users of the environmental application is to manage this permission process, analyse the different states of the processes and identify critical processes. An overview view containing this information uses the basic functions of the OData protocol and can therefore be visualised using generic clients. Fig. 4 shows the data of the corresponding XCNF View provided via the OData Server visualised in the generic client and as result of the OData feed in Excel.

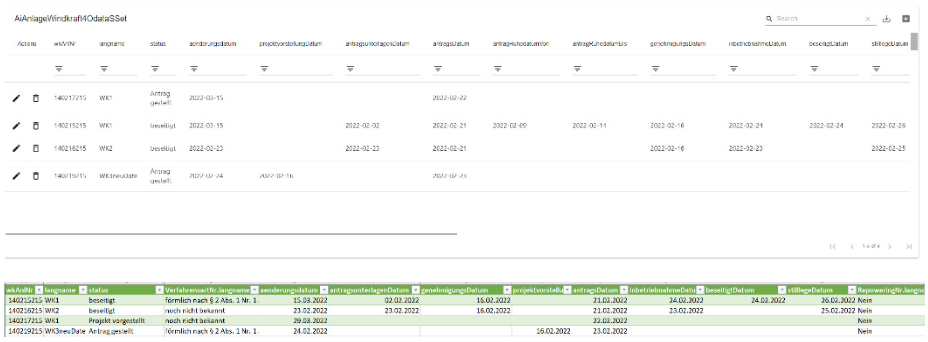

Fig.4: Approval process of wind energy generators available in two generic OData clients.

5.2 Usage in NiMo 4.0

The project NiMo 4.0 is funded by Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) in the support programme AI Lighthouses for Environment, Climate, Nature and Resources. The main goal of the project is to develop ML algorithms supporting nitrate research in ground water. The results of these algorithms are integrated in the NiMo platform for end users. One example is a time series nitrate forecasting at a point of measurement. In this project on the one side a classic geoinformation standard is used. The OGC SensorThings API standards manages the handling of time series for nitrate and other chemical quality observation parameters [LHK15]. Furthermore, the end users of the NiMo platform are interested in additional hydrogeological metainformation of the survey stations. This information was already available in an existing information system for domain experts: an XCNF based WaterFrame® environmental information systems managing ground water measurements

[14] Landesanstalt für Umwelt Baden-Württemberg: https://www.lubw.baden-wuerttemberg.de/, last access 22 June 2022

and analysis of TLUBN[15]. The new OData interface of XCNF has now been used to configure an XCNF-View with hydrogeological information and provide it via the REST based OData interface. This information can be now accessed and integrated into the NiMo platform. The NiMo platform on the one side is independent of WaterFrame® and it shows end user information. Thus, the NiMo platform is in context of this paper a specific client. Fig. 6 shows the XCNF-View collecting hydrogeological information and the result of the GET request reading this information:

http://localhost:8680/FROST-Server/ODATA_4.01/GwMstDatenloggerHydroNimoSet?$expand=TeilraumNr .

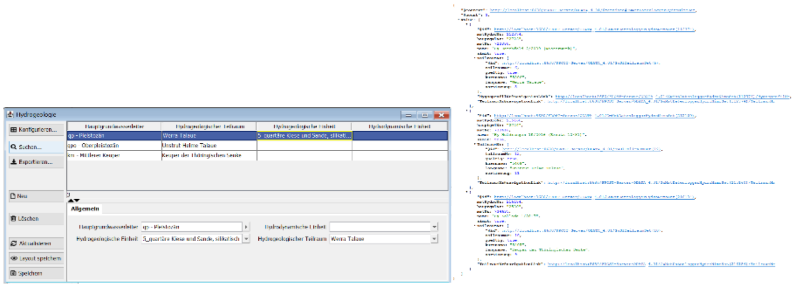

Fig. 5: Hydrogeological Information via OData GET request

6. Conclusion and Outlook

The analyses of the OData prototype showed that providing commonly used environmental data to web applications via the OData protocol is possible. OData is capable of sharing environmental information for different use cases, but depending on the structure of the information to be shared (relationally structured environmental information or geospatial information) other well know open standards should be considered. Since this paper describes work in progress and just presented first results, we are positive about the already reached generic possibilities for sharing environmental data from all WaterFrame® platform applications, not only limited to our example test cases. Adaption of existing or creation of new views sharing data via the OData protocol is configurable and does not need extra implementation effort. In future we plan to investigate and realize the proposed usage of OData Annotations to enhance the information about delivered entity types for our environmental clients.

[15] Thüringer Landesamt für Umwelt, Bergbau und Naturschutz: https://tlubn.thueringen.de/, last access 22 June 2022

Bibliography

[B06] Beaujardiere, J.; OpenGIS Web Map Server Implementation Specification, Version 1.3.0, 06-042, 2006

[BW15] Boß, J., Wohlgemuth, V.:Integration und Weiterentwicklung bestehender Energiemanagement-Applikationen mit dem OpenResKit Framework, INFORMATIK 2015, Bonn 2015

[F21] Fischer-Stabel, P, Umweltdaten und Umweltinformationssysteme (UIS) in Umweltinformationssysteme, ISBN 978-3-87907-700-7

[H12] Hübener, J: Open Data! EnviroInfo, Dessau, Part 2: Open Data and Industrial Ecological Management, Shaker Verlag Aachen, ISBN: 978-3-8440-1248-4, 2012

[HP20a] Handl, R., Pizzo,M (ed): OData Version 4.01. Part 1:Protocol, OASIS Standards, 2020, http://docs.oasis-open.org/odata/odata/v4.01/odata-v4.01-part1-protocol.html, last access 22 June 2022

[HP20b] Handl, R., Pizzo,M (ed): OData Version 4.01. Part 1:Protocol, OASIS Standards, 2020, Section 3.3 Primitive Types, https://docs.oasis-open.org/odata/odata-csdl-json/v4.01/odata-csdl-json-v4.01.html#sec_PrimitiveTypes, last access 22 June 2022

[LHK15] Liang, S, Huang C.-Y., Khalafbeigi, T (ed): OGC SensorThingsAPI Part 1:Sensing Version 1:0, 15-078r6, 2015

[P09] Panagiotis, P: Web Feature Service 2.0 Interface Standard – With Corrigendum, Version 2.0.2, 09-025r2, 2009

[P16] Tayler, P: Web APIs for environmental data – state of the art investigation, Technical Report, 2016, DOI: 10.13140/RG.2.2.17817.83047

[VZT14] Wohlgemuth, V, Ziep, T, Schiemann, L: Entwicklung eines Open-Source basierten Baukastens zur Unterstützung und Etablierung der Ressourceneffizient in produzierenden KMU, 6. BUIS Tage, 16. Tagung der Fachgruppe Betriebliche Umweltinformationssysteme der Gesellschaft für Informatik e.V., Berlin, 2014