# A Model-based Environment for Data Services: Energy-Aware Behavioral Triggering using ADOxx

Wilfrid Utz and Robert Woitsch

BOC Asset Management GmbH, Operngasse 20b
1040 Vienna, Austria
{wilfrid.utz, robert.woitsch}@boc-eu.com

**Abstract.** This paper demonstrates an application case for the concept of Data Service design and composition techniques established by the Big-Data Data Service (BD-DS) modelling method realized using the ADOxx meta-modelling platform. In the domain of energy-efficiency assessments of buildings and their operations, the collection of energy related data does not pose a problem anymore as the necessary infrastructure is available in a non-intrusive way, at low installation and operation costs. An issue identified relates to the realization of value-adding services based on these continuous data streams in such distributed, heterogeneous environments. In the context of the ORBEET project, a dynamic, close-to-real-time data access/composition design and exploration framework has been realized. This framework builds upon the concept of Energy Data as a Service combining different sources for a dynamic and enhanced operational rating deployed in 4 different pilot sites in Europe.

**Keywords:** Data as a Service, IoT, Sensor Network, Big Data, Service Composition, Energy Rating and Certificates, Modelling, Meta-modelling

## 1 Introduction

The design of data access and processing mechanism has gained importance in the past years as a result of the technological evolution on device and infrastructure level. This evolution allows to install and use sensors in various situations and settings, to access, to store and to process larger amount of diversely structured data from the environment surrounding us. A technological challenge that has been identified in [1] relates to the continuous evolution and update of schema information. Since any connected device, application or service deployed online is potentially a data source that could be used to as input to implement value-adding capabilities as an identified trend in [2], (e.g. enable understanding and decision support) a novel approach is required to handle this variability in access and composition. Data is not hand-crafted anymore, but continuously generated by computers, devices, sensors, search results [3]; The related schema is evolving over time along the development of new devices and sensors. When realizing functionality that builds on these dynamically changing and/or attached sources, a flexible approach is needed to continuously adapt access and processing mechanisms accordingly. The “Big-Data Data Service” (BD-DS) modelling method as described in [1] established an approach and tool support for the concept of Data Services. Using diagrammatic, conceptual models as put forward in [4], following a well-structured modelling procedure, it is possible to design access to data sources of any type, classify composition techniques and provide standardized interfaces for integration, having the format, syntactical and semantical characteristics of the sources and intended target schema as a guiding frame; at the same time the design is readable by the user, externalizing the calculation techniques and methods. The stakeholders involved along the line of realization of novel functionalities (visualization, analysis) are involved and work collaboratively on the design.

This paper demonstrates the application of the above method in an application case from the energy efficiency assessment domain. BD-DS acts as a mitigation layer between energy sensors, visualization/prediction techniques and the end-user in a close to real-time setting. Based on the requirements of the project, the modelling method has been extended and adapted to the specifics of the domain.

The remainder of paper is structured as follows: section II provides background information on the OrbEEt project and related work to set the results presented in context of its objectives. Section III introduces the challenges and requirements from a conceptual perspective, observed and mapped to the BD-DS approach. Section IV describes the prototypical implementation and preliminary results of evaluation in the pilot settings. The paper concludes by outlining future work in the context of the project and beyond.

## 2 Energy Data as a Service: The OrbEEt Case

The contribution presented in this paper is based on the work performed in the OrbEEt project (http://www.orbeet.eu/), a research and innovation action funded by the European Commission's Horizon 2020 Energy Efficiency programme. The objective of the project is to introduce an innovative ICT solution to facilitate public and social engagement to action for energy efficiency by providing real-time assessments of the energy impact and energy-related organisational behaviour [5]. As such it combines and integrates building and operations/business process information with energy data on high granularity level. In current energy assessment techniques three major deficiencies have been identified:

a) Assessment Approach: as put forward in the legal framework [6] by the European Commission, the objective is to reduce energy use by 20%. Current assessments are performed by expert teams in a static way. Static means that it is done periodically (e.g. yearly) by expert consultants, information of results achieved are not set in context of the changing organisation and occupants' behaviour. Therefore the impact of the results is limited;
b) Correlation capabilities are limited and do not allow for a combination of the information with operational behavioural aspects. The solution presented in this paper aims to propose a solution to this challenge.
c) Collaboration techniques and analysis of the environment in a virtualized setting: energy-efficiency initiatives need to be run in a balanced way, therefore collaboration is required between involved stakeholders in the business ecosystem [7]. Such balancing must consider behaviour of the

stakeholders, strategy considerations of the organisation, operation and business process adaptation and impact of the supply-chain and distribution network, resulting in a multi-dimensional collaborative composition and aggregation of information as discussed in [8].

Fig. 1 shows the overall concept of the project. In this paper we focus on the Systemic Enterprise Operational Rating (SEOR) Engine that acts as a mitigation layer between data sources (energy, operation, building characteristics and location, baselining) and the representation/interaction layer (enhanced Display Energy Certificate, behavioral triggering, gamification). Further details on the project's objective are available in [5].

The SEOR Engine accesses data from different sources, granularity and variability: Energy data is provided in 10min intervals by sensors, business process/operation information is less variable but space and people aspects needs to be considered and annotated. As output from the engine, harmonized data streams, are required that feed into visualization and behavior triggering frameworks, updating and changing the energy behavior of occupants and operations.

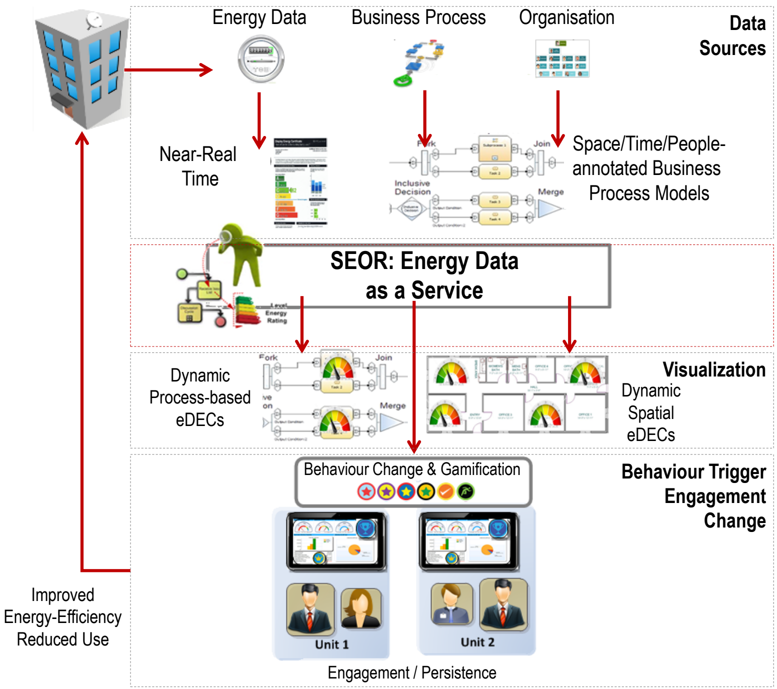


**Fig. 1.** OrbEEt Overall Concept [9]: Positioning the SEOR Layer

As a collaborative project, the consortium is composed of nine partners from six European countries with different competences and experiences. A strong aspect in the consortium relates to the involvement of pilots. These pilot building are located in

4 different countries (Spain, Austria, Germany, and Bulgaria) with different operational usages and construction characteristics. The project started on March 1, 2015 and will run for a period of 36 month with a budget of 1.7 MEUR.

## 3 Concept: Extending BD-DS for Energy Data as a Service

As a starting point for conceptualizing the of the SEOR mitigation layer, the BD-DS modelling method has been selected. Based on the generic modelling method framework developed by Karagiannis and Kühn in [10], the modelling method comprises of the modelling procedure realized as a domain-independent guideline, supported by a corresponding model structure and model processing mechanisms/algorithms.

Further details on the modelling method components are available in [1], complemented by a proof-of-concept implementation (modelling toolkit and operation/deployment mechanisms for data services) available online via the Open Models Initiative Laboratory (www.omilab.org) at [11]. Following the Agile Modelling Method Engineering approach [12], BD-DS is iteratively extended to include domain-specific aspects.

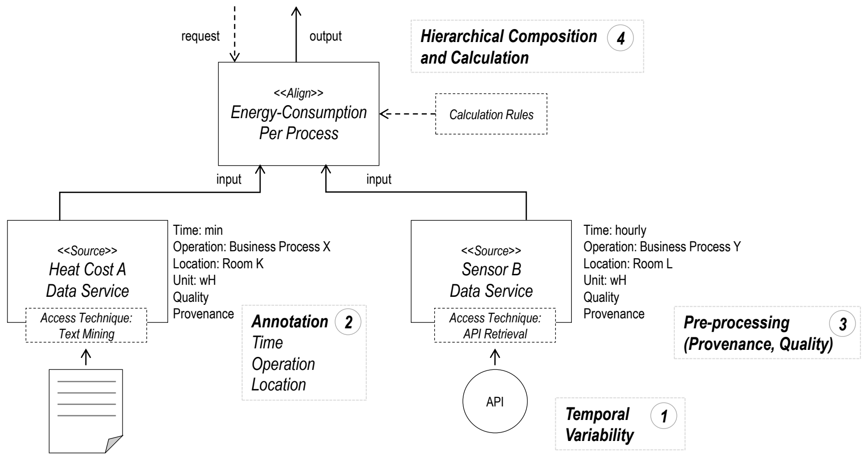


**Fig. 2.** SEOR Data Service Definition Example

For the domain of energy data and assessment, specific requirements have been identified from the project's pilot cases. Fig. 2 shows these requirements visually, detailed below. The core challenge relates to support decision making and behavior triggering in a distributed, heterogeneous environment, whereas distribution is understood from a technical observation but also organizational (e.g. skills, competences, involved stakeholders). The user of the system should have the possibility to understand the meaning of data and its impact on the behavioral triggers that are put in place in a transparent way. Graphical models act here as the knowledge-bearing entity: they can be interpreted by the end-user, providing means to reason and derive action from the provided results and are also machine executable by a real-time access and composition engine. The requirements for the extension are:

1. *Temporal Variability:* as data sources with varying temporal dimensions are input to the composition, harmonization techniques need to be applied to create combinable data series. An example for this challenge relates to the different update intervals of energy sensors: electricity sensors provide their input in 10min intervals, whereas heating data is captured on a bi-monthly to monthly basis. Operation information is captured manually by analyzing the business processes with a lower variability and the building structure is described as the Building Information Model (BIM) using the gbXML standard[13].
2. *Semantic Annotation:* during the design of data service compositions, modelling support mechanisms are required. Through semantic annotation of data sources, initial compositions and filters become feasible using the temporal, spatial and operational context annotations as input.
3. *Data Quality, Provenance:* due to the technical distribution of providing sources and integration via a loosely-coupled architecture as detailed in [14] and [15], quality and provenance information needs to be captured dynamically and composed along the calculation logic.
4. *Hierarchical Composition:* the calculation of complex data services is designed in a hierarchical manner. Calculation techniques are made available as plugins to provide flexible extension and modification mechanisms. The processing engine interprets the hierarchy, binds the calculation plugins dynamically and performs the composition as well as orchestration.

The extensions to BD-DS on a conceptual level based on the above requirements are discussed in the following.

### 3.1 Modelling Language Extension: Metadata Annotation

The BD-DS modelling language as presented in [5, Fig. 4] is extended to provide means for annotation of data-services with energy related metadata and contextual information. The objective of this extension is to keep the core meta-model stable and provide dynamic means to extend the semantic expressiveness of artefacts created. The Semantic Lifting approach from [16] is re-purposed for BD-DS, extending the available "Metadata" view. The characteristic of the extension is twofold: a) it establishes on tool-level a dynamic and adaptive mechanisms to cope with changing domain-specific semantics and their evolution, and b) enriches the semantic expressiveness of the artefacts created to realize model-value functionality in the form of domain-specific analysis features, graph-rewriting techniques and composition layouts. Model-value capabilities aim to elevate the model quality from a user interaction and interpretation point of view with the graphical conceptual models used to specify the data service logic.

This repository for annotation is made available as an ontological representation using RDF syntax [17] on vocabulary and instance level: the energy domain semantics of OrbEEt are captured in a custom, high-level vocabulary that can be imported into the system, updated and modified. Related instances are derived from the domain context of the observed building, device sensor and operation. Instance information is considered to reside in an external environment. The combination of both vocabulary and instance information represents the annotation and tagging base as shown in Fig. 3.

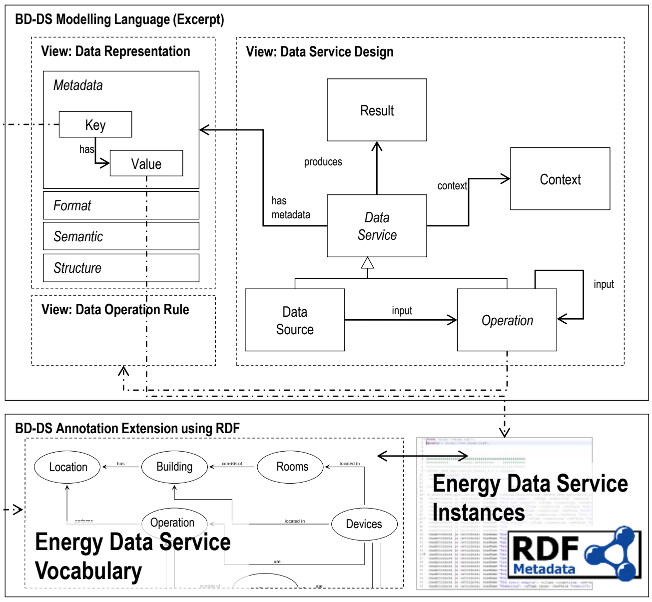


**Fig. 3.** Extended BD-DS meta-model with RDF annotations

### 3.2 Mechanisms and Algorithms: Annotation-based Modelling Support

The annotation technique of above is used as input to dynamically derive data service compositions. Based on the context made available in the model, composite services are dynamically created and added to the model. The algorithmic solution is available as pseudo code below. The algorithm uses defined data source services from a common information layer (an abstraction from actual sensor information) and their annotations as input.

Pseudo-code: Annotation-based Composite Data Services

```
# retrieve all source services
set sources to GET_BASE_DATA_SOURCES
set annotations to map (a_key, a_value_list)
for i=0 to source.size
  set a_src to GET_DATA_SOURCE_ANNOTATIONS (source(i))
  set annotations to union(annotations, a_src)
endfor
# create aggregate service
```

```
set r_list to annotations.get(r_key).values
for k=0 to r_list.size
  CREATE_AGGREGATE_DATA_SERVICE (l, r)
  set rel_src to GET_SERVICE_BY_ANNOTATION (r_key,
room(k))
  CREATE_INPUT_RElATlON (new_aggrate_ds, rel_src)
endfor
RADIAL_WEDGE_LAYOUT (model)
```

The algorithm is available for the end-user to create complex design, validate the composition logic and visualize results interactively.

Through these extensions on meta-model and mechanism/algorithm level, the requirements of the energy domain in data service design can be satisfied. Evaluation was performed by realizing a prototypical implementation of the extension and validating its operation with the OrbEEt framework.

## 4 Evaluation: SEOR Data Service Designer and Engine

The proof-of-concept implementation has been performed as the SEOR Data Services Designer, supporting the modeling of energy data as a service, and Engine supporting the operationalization of these services in the cloud.

### 4.1 SEOR Data Service Designer

The realization of the prototype builds upon the available implementation of BD-DS on ADOxx [18] resulting in the SEOR Data Service Designer. The extensions have been implemented using metamodeling concepts and techniques, adapting the meta-model with required constructs for annotation and temporal update definitions for dynamic data series.

Fig. 4 shows the results of the implementation in the SEOR Data Service Designer:

1. Data sources are retrieved from the abstract sensor information layer. The step is performed through automated import mechanisms (detection) and manual interaction of the energy expert.
2. The domain expert annotates the data source services with semantic constructs, imported in RDF Turtle syntax. Annotation is performed for location, operational and temporal attributes as well as energy type, based using RDF subjects and objects (see Fig. 4 a));
3. The tool derives additional properties are using ADOxx Expressions (composition serial, temporal cron expressions).
4. The system automatically creates the composed data services based on the annotation (see Fig. 4 b)) and performs a radial layout algorithm on the model for better readability.

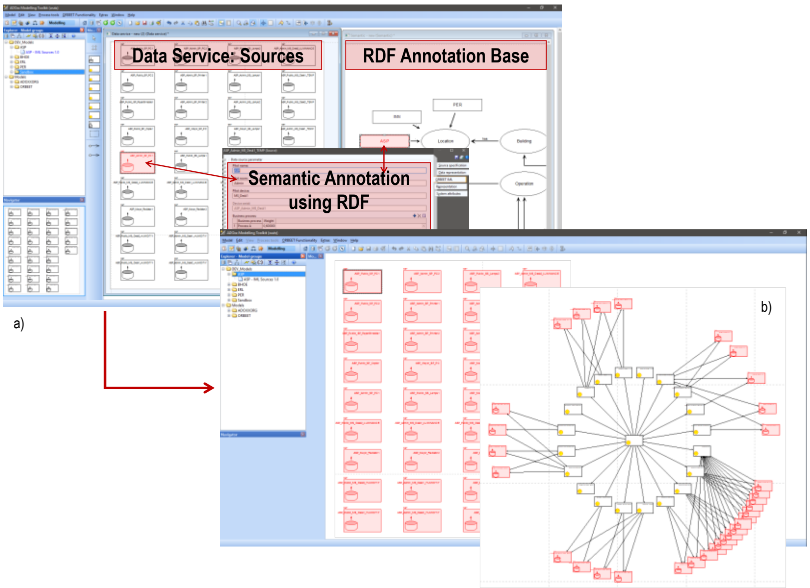


**Fig. 4.** SEOR Data Service Designer: a) Annotation and b) Composite Service Generation

The SEOR Data Service Designer enables additional interaction capabilities, provided by the meta-modelling platform ADOxx such as visualization options, analysis and query techniques, reporting and open interfaces.

### 4.2 SEOR Data Service Engine

The SEOR Data Service Engine has been implemented as a web-application using Java 8.0 on the server side and JavaScript/HTML5/CSS for the user interface. The applications logic is dynamic upon the design artifacts and operationalizes them using web-service technologies. As an interaction layer with the engine, all data services (source- and composed service) are accessible through standard service protocols (SOAP and ReST) to reduce integration effort. A validation UI is provided to assess the operational status of each service, values and historical information.
The characteristics of this implementation are summarized below:

- *Interpretation of conceptual model:* the engine interprets the diagrammatic representation in the designer and executes them. This approach provides flexibility to the designer as artifacts created can be verified and validated in operation without further implementation/coding
- *Plugin-based Composition Logic:* Composition and aggregation logic in the engine is supported by a plugin-based approach, meaning that arbitrary composition techniques for data services can be realized as individual plugins in the engine, dynamically made available in the designer following [19].
- *Time-series handling:* to support the requirement of temporal variability and data quality, the engine builds on locally cached, streamed data. According to the derived temporal variability, the engine runs update threads for each service in the

background and enables close to real-time processing. Additional aggregation techniques are supported to condense/expand a time-series. In the evaluation environment for the project, growing time-series data of 531 data services (atomic and composed) consisting of 9700 entries per series (as of writing this publication) are handled in a performant and efficient way. A re-design of the composition logic is by the designer is supported at any point in time.

– *Dynamic filtering and visualization techniques*: review results of the SEOR engine execution for specific time-frames and visualize results as charts.

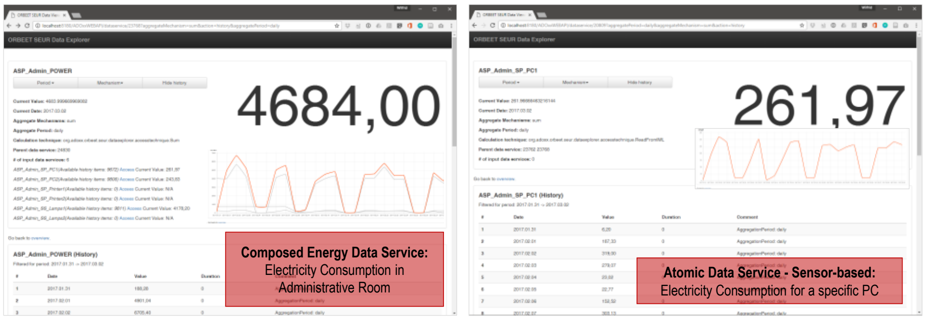


**Fig. 5.** SEOR Data Service Engine: Data Explorer (atomic and composed)

**Fig. 5** shows the SEOR Data Service Engine's user interface. The Data Explorer provides functionality to access data services in a hierarchical manner, visualize the change history and drill-down/up to related services.

## 5 Conclusion and Outlook

The work presented in this paper provides insights into results achieved within the energy data modelling and composition task of the OrbEEt project, applying the BD-DS Data Service concept in a practical setting. An initial technical and user evaluation of the results took place, resulting in the finding that due to the flexible approach, an efficient design and deployment process as well as agile adaptation in the system could be performed. A challenge identified during the work relates to the observed knowledge gap between business views captured in the operation and data processing experts. Interpretation of finding and therefore optimization techniques on both ends are currently only of limited value due to this gap. Different levels of visual and conceptual techniques are going to be developed in the coming period, summarized under the keyword "Conceptual Analytics", to foster the creation of value-adding, innovative service offerings in the domain and their application in networked organisational settings. This work contributes to elevate (big) data related work to a conceptual and decision making level, involving stakeholders from different background, expertise and create organisational value, not only through data analytics but also in conceptually understanding data assets in the company.

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