Towards a Modular Ontology for Event-Based Data Sharing in the Logistics Domain

Cornelis Bouter[1,*], Giulia Biagioni[1], Thom van Gessel[1], Wouter Korteling[1], Erik de Graaf[1] and Wout Hofman[1]

[1]TNO, Anna van Buerenplein 1, The Hague, The Netherlands

Abstract

We present ongoing work on developing a modular ontology to support event-sharing in the logistics domain across modalities (e.g., road and rail) as envisioned by the Digital Transport and Logistics Forum (DTLF). Our main contribution is an event module that describes a change in the state of logistics activities. Additionally, we contribute a modularised ontology architecture to relate existing (semantic) modelling efforts to the event module. All contributions are publicly available.

Keywords

Logistics, ontology development, interoperability, modularisation, data sharing, event, semantic technology.

1. Introduction

The Digital Transport and Logistics Forum (DTLF), an expert group organised by the Directorate General for Mobility and Transport of the European Commission, has adopted a proposed solution for multi-modal (e.g., between rail, road, and air transport) decentralised data sharing based on "events" [1]. Each future or current change in the state of logistics activities is represented by an event.

For example, a load event establishes the association between a piece of equipment (e.g., a container) and a transport means (e.g., a truck). An arrival event establishes the assignment between a transport means and an infrastructural or geographical location. Each event also has a counterpart that indicates the end of the assignment: a discharge and a departure event, respectively. A complete collection of events encompasses the whole logistics process.

In this work we present the main modules of the FEDeRATED Semantic Model to show how the DTLF principles can be adopted in the Connecting Europe Facility (CEF) FEDeRATED [2]. We show how the ontology modularisation can facilitate the process towards multi-modal event-based data-sharing. We first describe the Semantic Web background. Then we give an overview of the ontology through its functional requirements, modularisation, and a dedicated look at the Event concept.

SEMANTICS 2022 EU: 18th International Conference on Semantic Systems, September 13-15, 2022, Vienna, Austria
cornelis.bouter@tno.nl (C. Bouter); giulia.biagioni@tno.nl (G. Biagioni); thom.vangessel@tno.nl (T. v. Gessel); wouter.korteling@tno.nl (W. Korteling); erik.degraaf@tno.nl (E. d. Graaf); wout.hofman@tno.nl (W. Hofman)
0000-0002-5448-0543 (C. Bouter); 0000-0002-4686-0490 (T. v. Gessel); 0000-0001-8269-4402 (W. Korteling); 0000-0002-8615-6107 (W. Hofman)

2. Background

The Semantic Web is based on the principle of linking and reusing all relevant data sources [3]. This principle is supported by the process of modularisation, which is the practice of dividing ontologies into smaller parts that can be reused independently. This process additionally decreases the complexity of the model and may increase understandability and query scalibility [4].

The principle of reusing existing models is relevant for logistics, because many standards and ontologies have already been developed for the logistic modalities. Existing work is typically concerned with modelling the entities and/or the documents involved in the logistics process. The ERA Railway ontology [5], SmartRail[1], and the Rail Topology Ontology [6] model the domain from the perspective of the entities it contains. In the airways modality the International Air Traffic Association (IATA) OneRecord ontology takes a document centric view [7]. The Open Trip Model[2] (OTM), developed for the road modality, takes a combined view by modelling events, documents, and entities.

Similarly, there are multiple efforts geared towards semantic modelling infrastructure and geography, consisting of, among others, the EU Knowledge Graph [8], Geonames [3], GeoSPARQL[4], Kadaster KG [9]. These combined efforts provide dereferenceable URIs for every geographical or infrastructural location across the globe.

3. Ontology overview

The FEDeRATED Semantic Model[5] contributes to the existing literature by supporting the capacity for *event-based* and *multi-modal* sharing of logistics data. The event-based contribution lies in the domain-specific event module that we present, which conceptualises the various activities of the logistics process (e.g. pick-up, arrival, and discharge). The multi-modal contribution arises from the modularised ontology architecture that facilitates reuse of existing models of the various modes of transport.

The functional requirements of the ontology are described in a set of competency questions (CQs), derived by analysing the requirements set out in [1]. In Table 1 we highlight some competency questions of the Event module ordered by complexity, including the SPARQL query pattern to verify the CQ. The first questions therefore indicate the basic functionalities. The last indicate emergent properties of a set of events: by combining events from multiple sources in the semantic model, we can trace the unique identifier of a single entity (e.g., a container) across modalities.

---

[1] https://ontology.tno.nl/smart-rail/
[2] https://otm5.opentripmodel.org/
[3] http://www.geonames.org/
[4] https://www.ogc.org/standards/geosparql
[5] The current version of the FEDeRATED Semantic Model can be inspected on GitHub (https://github.com/Federated-BDI/FEDeRATED-Semantic-Model and browsed in a VoCol viewer [10] (http://www.federatedplatforms.eu/index.php/developer-portal).

Competency question	Example answer	SPARQL pattern
Which type of event is [this event]?	Arrival	`$this a event:Event, ?additionalType .`
Which digital twin(s) are involved in [this event]?	Vessel x and container y	`$this event:involvesDigitalTwin ?dt .`
At what time did or will [this event] take place? What is the qualifier of the timestamp?	2022-06-01 at 08:31:06, actual time	`$this event:hasTimestamp ?ts ;` `event:hasDateTimeType ?type .`
Is the estimated time still before the required time of an event?	Yes	`$reqEvent event:hasTimestamp ?reqTime .` `$estEvent event:hasTimestamp ?estTime .` `FILTER (?reqTime > ?estTime)`
What is the planned route of [this transport means]?	Rotterdam, Antwerp, Brussels, Luxembourg, Brussels, Antwerp, Rotterdam	`?event event:involvesDigitalTwin $this ;` `a event:ArrivalEvent ;` `event:hasDateTimeType event:Planned ;` `event:involvesPhysicalInfrastructure ?pi ;` `event:hasTimestamp ?ts .` `FILTER (?ts > "2022-07-04T00:00:00"^^xsd:dateTime)` `ORDER BY ?ts`

Table 1
A subset of the Competency Questions. The SPARQL queries were developed to verify that the CQs are modelled in the ontology. Dollar signs in the SPARQL queries indicate the CQ variables in square brackets.

3.1. Modularisation

We identified six ontology modules based on the FEDeRATED architecture requirements: the main *Event* module; *Business Service* describing enterprises and contracts, *Digital Twin* concerning all physical objects in the logistics domain, ranging from transport means to equipment (e.g., containers) and goods; *Classifications* to reuse existing non-Linked Data code lists; *Physical Infrastructure* for geographical and infrastructural objects; and *Logistic Roles* for a taxonomy of roles.

The *Event* module takes a central place in the modularisation (Figure 1). The type of an event is defined by its involved business transaction(s), physical object(s) and/or physical infrastructure elements. These entities are respectively described in the *Business Service*, *Digital Twin*, and *Physical Infrastructure* modules. The *Logistics Roles* module provides a taxonomy of roles that an enterprise, part of the *Business Service* module, may play in the context of an event.

The modules directly surrounding the *Event* module are intended as "interfaces" to align with and between external standards. In Section 2, we already identified several models for the various logistic modalities that can be aligned with *Digital Twin*, of which we implemented an alignment to the ERA ontology. The *PhysicalInfrastructure* module also facilitates the reuse of external vocabularies, namely Geonames, Place from Schema.org, and Geo (WGS84). In the *Classifications* we provide an RDF implementation of several commonly used codelists to reuse

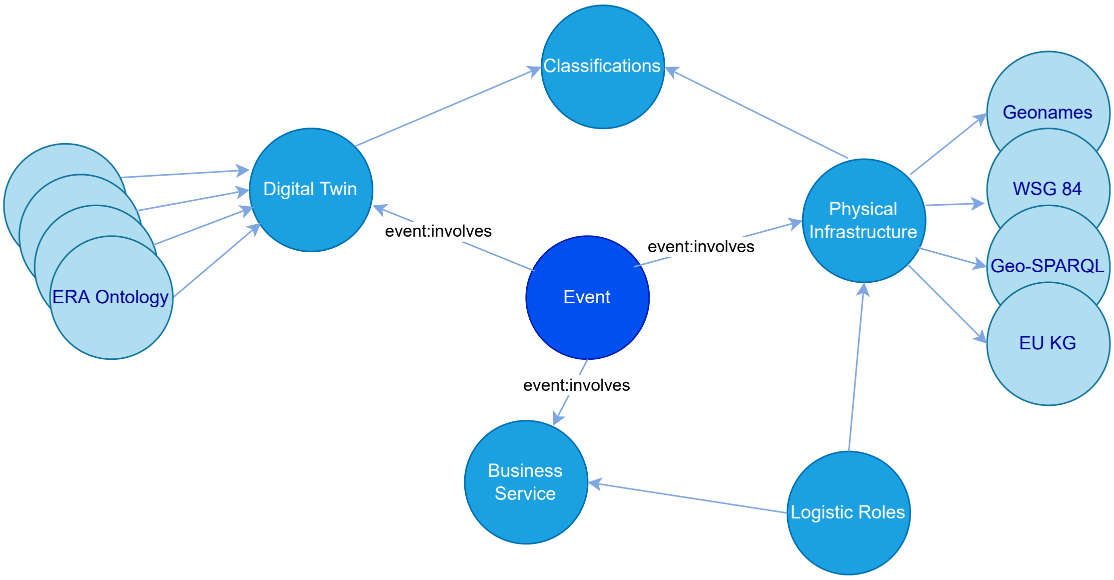

Figure 1: Modularisation of the FEDeRATED Semantic Model. The Event Module is dark blue, other modules are blue, and external ontologies are light blue.

existing attributes about physical entities or business transactions.

3.1.1. Event module

The properties that link the Event (Figure 2) to the other modules indicate that the Event has an association to those elements. The milestone of an event indicates whether the association is established ("Start") or removed ("End"). The type of event is defined by its associations. For example, a load event is the establishment of an association between a transport means and a container. A discharge event would constitute the end of that association. If an event has an association to another event we call it a complex event. This way we create a composite event. For example, a pickup event consists of an arrival event, some load events, and a departure event. Otherwise, we call it an atomic event. Additionally, each event has a qualifier on its timestamp: *actual*, *expected*, *estimated*, *planned* or *requested*. Taken altogether, Figure 3 shows an example event in Turtle syntax.

4. Discussion

In this work we have presented a modularised ontology consisting of a main Event module and complementary extensions to support multi-modal event-based data sharing in the logistics domain [2, 1]. Our main ongoing work is the integration of the semantic model with the proposed data sharing architecture [11], validating the model in ongoing usecases, the transformation of various data sources (e.g., OTM or enterprise data) using an RML-based mapper [12], and supporting the alignment of additional standards with the FEDeRATED Semantic Model.

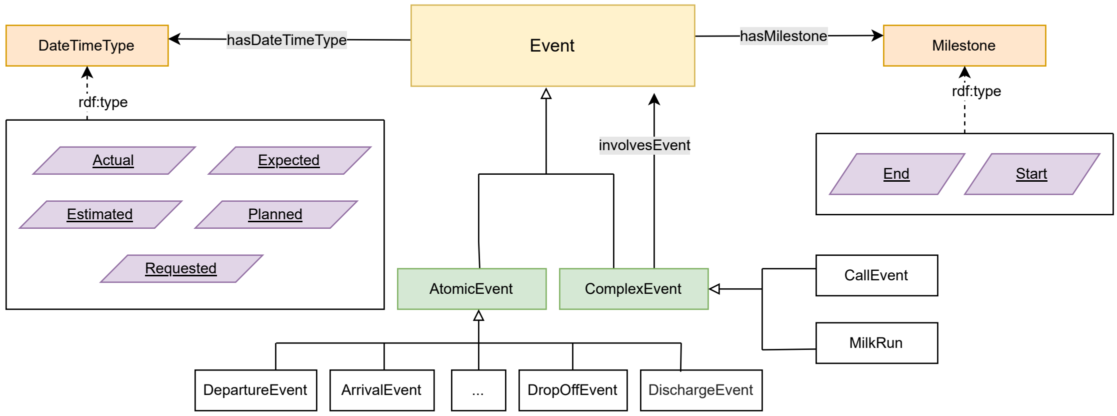

Figure 2: High level diagram of the *Event* module. For conciseness, the diagram leaves out the relation depicted in the modularisation and the full AtomicEvent taxonomy. **Legend:** Rectangles represent *classes*, with the main class in yellow, the first degree of the event taxonomy in green, the second degree of the event taxonomy in white, and other classes in orange; parallelograms (purple) represent enumerated *individuals*; arrows with white tips represent *rdfs:subclassOf* relations; and other arrows represent the indicated relations.

```
@prefix event: <https://ontology.tno.nl/logistics/federated/Event#> .
@prefix dt: <https://ontology.tno.nl/logistics/federated/DigitalTwin#> .
@prefix bs: <https://ontology.tno.nl/logistics/federated/BusinessService#> .
@prefix data: <https://www.example.com/enterprise/event#> .
@prefix lsp: <https://www.example.com/logisticServiceProvider#> .

data:event_1 rdf:type event:Event, event:ArrivalEvent ;
  rdfs:label "Example arrival event" ;
  event:hasDateTimeType event:Planned ;
  event:hasMilestone event:Start ;
  event:hasTimestamp "2022-01-19T14:04:00.9"^^xsd:dateTime ;
  event:involvesDigitalTwin lsp:transportMeans_1 ;
  event:involvesPhysicalInfrastructure <http://data.europa.eu/949/functionalInfrastructure/operationalPoints/NLERP> ;
  event:involvesBusinessService data:thisCompany .

lsp:transportMeans_1 rdf:type dt:Truck ;
  dt:hasLicensePlateNumber "00-BBB-1" .

data:thisCompany rdf:type bs:Enterprise ;
  bs:actorName "someCompany"^^xsd:string .
```

Figure 3: Example planned arrival event

Acknowledgments

This work is based on developments in the CEF FEDeRATED Action and the Digital Transport and Logistics Forum. This work is partly supported by the Horizon 2020 Magpie project under grant agreement 101036594.
The presented work is not adopted by EC DG Move as eFTI Implementing Act and is solely the proposal of the authors, based on concepts, principles, and architecture developed by the

Connecting European Facility (CEF) FEDeRATED Action and adopted by the DTLF.

References

[1] Digital Transport and Logistics Forum, Subgroup 2 - Corridor freight information systems - Intermediate report, 2022. URL: https://transport.ec.europa.eu/transport-themes/digital-transport-and-logistics-forum-dtlf_en#about-the-dtlf.

[2] FEDeRATED, Milestone 2 FEDeRATED interim master plan, 2021. URL: http://federatedplatforms.eu/index.php/library/category/2-masterplan.

[3] A. Hogan, The Web of Data, Springer International Publishing, Cham, 2020.

[4] C. Parent, S. Spaccapietra, An overview of modularity, Modular ontologies (2009) 5–23. doi:10.1007/978-3-642-01907-4{_}2.

[5] J. A. Rojas, M. Aguado, P. Vasilopoulou, I. Velitchkov, D. Van Assche, P. Colpaert, R. Verborgh, Leveraging semantic technologies for digital interoperability in the European railway domain, in: A. Hotho, E. Blomqvist, S. Dietze, A. Fokoue, Y. Ding, P. Barnaghi, A. Haller, M. Dragoni, H. Alani (Eds.), The Semantic Web – ISWC 2021, Springer International Publishing, Cham, 2021, pp. 648–664.

[6] S. Bischof, G. Schenner, Rail topology ontology: A rail infrastructure base ontology, in: The Semantic Web – ISWC 2021, Springer International Publishing, 2021, pp. 597–612. doi:10.1007/978-3-030-88361-4{_}35.

[7] A. Blaj, H. Mulder, D. Sauv, A. Lambert, C. Lambert, ONE record: One step closer to digital cargo with ontologies and linked data., in: ISWC (Demos/Industry), 2020, pp. 384–386.

[8] D. Diefenbach, M. D. Wilde, S. Alipio, Wikibase as an infrastructure for knowledge graphs: The EU knowledge graph, in: A. Hotho, E. Blomqvist, S. Dietze, A. Fokoue, Y. Ding, P. Barnaghi, A. Haller, M. Dragoni, H. Alani (Eds.), The Semantic Web – ISWC 2021, Springer International Publishing, Cham, 2021, pp. 631–647. doi:10.1007/978-3-030-88361-4{_}37.

[9] S. Ronzhin, E. Folmer, P. Maria, M. Brattinga, W. Beek, R. Lemmens, R. van't Veer, Kadaster knowledge graph: Beyond the fifth star of open data, Information 10 (2019). doi:10.3390/info10100310.

[10] L. Halilaj, N. Petersen, I. Grangel-González, C. Lange, S. Auer, G. Coskun, S. Lohmann, VoCol: An integrated environment to support version-controlled vocabulary development, 2016. doi:10.1007/978-3-319-49004-5{_}20.

[11] W. Hofman, C. Bouter, M. Burghoorn, E. Boertjes, E. d. Graaf, A. d'Auria, Towards a mobility data space: Data sharing via linked semantic data, an example for eFTI, in: Transport Research Arena (TRA) Conference 2022, 2022. In press.

[12] A. Dimou, M. Vander Sande, P. Colpaert, R. Verborgh, E. Mannens, R. Van de Walle, RML: a generic language for integrated RDF mappings of heterogeneous data, in: C. Bizer, T. Heath, S. Auer, T. Berners-Lee (Eds.), Proceedings of the 7th Workshop on Linked Data on the Web, volume 1184 of *CEUR Workshop Proceedings*, 2014.