An Interaction Pattern Ontology for Data Sharing about Logistics Activities

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Abstract

Data is crucial in planning and synchronizing outsourced business activities like transport and transshipment. This data is also required for compliance to regulations; authorities govern cargo flows based on access to data. The multitude of supply and logistics chains makes it unrealistic to model them all. Therefore, generic interaction patterns need to be developed, reflecting data sharing in commercial business transactions between any two actors, where these actors function in multiple chains. These interaction patterns are derived from BPMN 2.0 choreographies that can be used to specify data sharing. It is impossible to define every pattern, so the fundamental concepts behind these patterns need to be modeled to establish a foundation for specifying patterns through tools. We present an ontology model that describes these concepts, and we illustrate how an application would use it.

Keywords

Logistics, ontology development, interoperability, data sharing, semantic technology

1. Introduction

Some of the main aspects of seamless, interconnected transport networks (the Physical Internet) are full visibility, accessibility, use of business services for optimization, and situational awareness for optimal routing [1]. Data sharing is a prerequisite to realize this Physical Internet, where data is not always publicly available but needs to be validated against certain criteria [2] to address data sovereignty [3].

Besides data semantics and syntax, one of the aspects of data sharing is data sequencing as specified by for instance UML sequence diagrams [4]. There are basically two approaches to data sequencing, namely for individual logistics chains [5] or for one leg per chain, where the legs are managed by a control tower [6]. We adopt the latter approach, since it provides individual actors to organize their internal processes based on outsourcing strategies.

On a technical level, different approaches are possible. Firstly, one could model internal business processes as so-called swimming lanes and interconnect them via data sharing [4]. This again prescribes internal behaviour, which we propose to leave open to any organization. Secondly, one could model so-called sequence diagrams. This would lead to a variety of sequence diagrams, that would aggregate into our proposed, third, solution to model the interaction pattern for an outsourced business activity. Business Process Model and Notation (BPMN) 2.0

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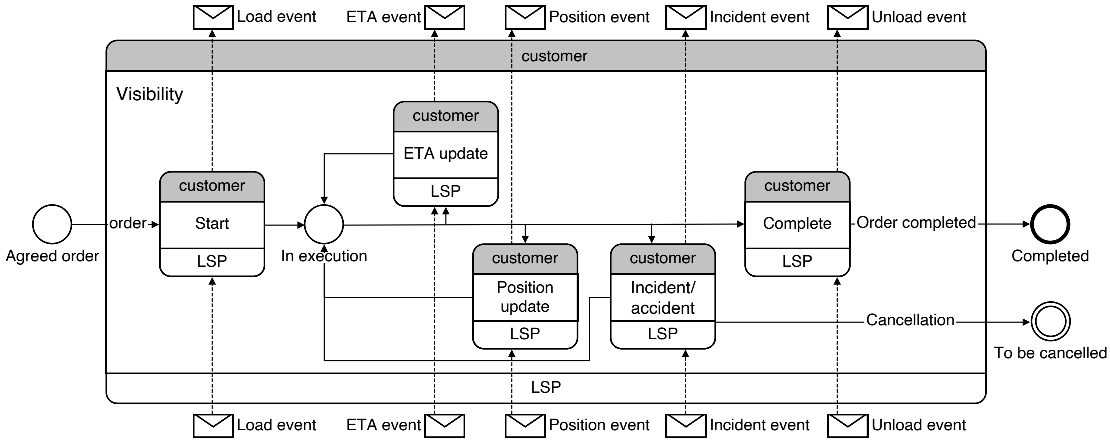

Figure 1: This diagram shows a choreography for sharing supply chain visibility events from a Logistics Service Provider (LSP) to its customer. The figure shows a start state 'agreed order' and two end states that can be reached, namely 'completed' and 'to be cancelled'. These states are reached via transitions like 'start' where an LSP sends a load event to his customer.

choreographies are used for this purpose.

To be able to execute state transitions, which are triggered by interactions and lead to state changes, we require a connection between process models on the one hand, and data about actual transactions on the other. Data about transactions can be modelled by a domain-specific ontology. We take the FEDeRATED ontology, designed to model logistics activities, as a starting point [7].

In this paper, we model the concepts of choreographies for outsourced business activities as an ontology. In Section 2, we first explain how we view choreography-based data sharing, and we give an overview of existing semantic implementations of process models. In Section 3 we propose our ontology and illustrate its intended use with an example. We end with a conclusion in Section 4.

2. Background

2.1. Choreography-based data sharing

Networked business models allow companies to conduct business in a more effective way, for instance by redistributing tasks between organizations [8]. It requires enterprises to quickly set up electronic relationships with their (potential) customers and suppliers for exchanging value, like modelled by the Resource, Events, Agent (REA) model [9]. It not only requires matching of customer's goals to capabilities [10] and dynamically compose and orchestrate chains [11], but interoperability is also a prerequisite for electronic data sharing. Models have been specified that describe the various components for interoperability considering binary- and multi-actor collaboration [5]. For example, choreographies [12] specify the allowed sequencing of interactions, synchronising states of the actors involved (Figure 1).

In this context of dynamic logistics chains in organizational networks and requirements for

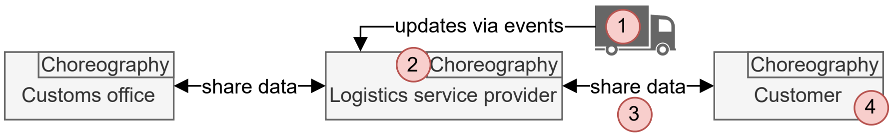

Figure 2: Data sharing procedure. A truck (1) sends events to its owner during the logistics operation about its arrival, (un)loading, and other activities. The choreography (2) prescribes to which partners the information should be shared (3), which should happen following an agreed safe procedure. Based on the received information, the recipient (4) knows the updated truck status details.

agility and resilience, the proposal is to model binary actor collaboration for data sharing. Multi-actor collaboration will be based on outsourcing strategies of actors involved, which will lead to so-called transaction trees based on DEMO [13]. A transaction tree depicts the hierarchical relationship between actors in their roles as customer and service provider respectively, showing the perspective of the root actor, most often a shipper. Each branch in such a tree represents a business transaction where data is shared.

2.2. Process Ontologies

Some ontologies revolving around the central concepts of process models (states and state transitions) are described in the literature. One example is BPMO [14], an ontology for business process modeling developed in WSML, which incorporates elements from BPMN and BPEL, but is no longer accessible online. S-BPM-Ont [15] is an OWL implementation of Subject-oriented BPM, an alternative to BPMN, which can be used to describe how subjects perform and synchronize activities by exchanging messages. It is shown in [16] that any BPMN model can be captured within this ontology. However, it does not seem to be publicly available, which hinders its potential for reuse. BBO [17] is an open source partial OWL implementation of BPMN 2.0 concepts.

Process Specification Language [18] is an extensive framework that can be used to represent process models, among many other things. An ontology has been implemented in CLIF [19].

In addition. there exist some ontologies that do not relate their concepts to business processes, but aim to describe UML state machines in general, such as [20], which does not seem to be open source, and [21].

Although some of the mentioned ontologies are publicly available in the form of OWL implementations, their common denominator is that they lack a mechanism to connect the concepts used for modeling business processes to any data regarding real transactions. We therefore introduce a new ontology in this paper, while suggesting that a detailed examination of alignment possibilities be undertaken in future studies.

3. Ontology

The adoption of a choreography can facilitate better data exchange among the various stakeholders in logistics operations (Figure 2). The choreography should be commonly agreed on by the partners in a data sharing environment. It prescribes to which partners information about

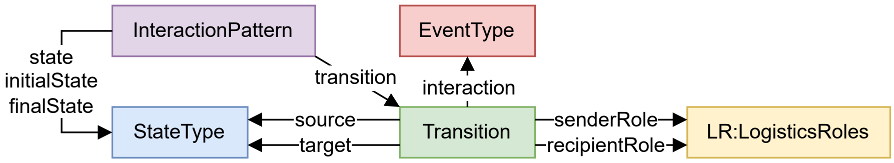

Figure 3: Class diagram of the Interaction Pattern ontology. Labelled arrows connect the domain and range of the indicated properties. LR is the namespace of the separate Logistic Roles module.

physical logistics events should be shared, including potentially additional data.

For example, the customer who orders the shipping of a product needs to be kept up to date on ETA (Estimated Time of Arrival) updates. A customs office may not be interested in times of arrival, but instead in moments when the goods cross the border. Organizations that enforce safety regulations may only be interested in events involving dangerous goods.

Data about logistics activities in the FEDeRATED ontology is centered around events [7]. This enables us to link the event types in our process models to the events in the data about logistics activities, by means of instantiation: an event type in the process model is a subclass of events in the FEDeRATED data model, and can thus be instantiated.

3.1. Design

The Interaction Pattern ontology module consists of four classes and nine object properties. The class diagram is shown in Figure 3. The implementation of the ontology in RDF/OWL is publicly available.[1]

The module is tightly connected with the FEDeRATED Event and State modules. An interaction pattern consists of states, connected by state transitions and triggered by events. Such a state or event in the interaction pattern is in this case an instance of the class StateType or EventType, respectively. By means of punning, these classes are connected to the other ontology modules: an instance of StateType must itself be a subclass of State (similar for EventType and Event). In this way, an event in actual logistics activities can be related to a particular process described in an interaction pattern. A state may feature in more than one interaction pattern, for example as a final state in one and the initial state in another. This makes explicit how interaction patterns relate to each other.

The proposed module is also integrated into other existing modules of the FEDeRATED ontology (Logistic Roles and Business Service): an interaction pattern is intended to be connected to a business activity (e.g. transport of goods) which is in turn related to an organizational profile (e.g. describing transport of goods by road) that some legal person (a particular carrier) might have.

3.2. Example

To demonstrate the intended application of the ontology, we present an implementation (see Figure 4) of the visibility choreography in Figure 1. In this example, each transition is connected

[1] See https://github.com/Federated-BDI/FEDeRATED-Semantic-Model/blob/master/InteractionPattern.ttl.

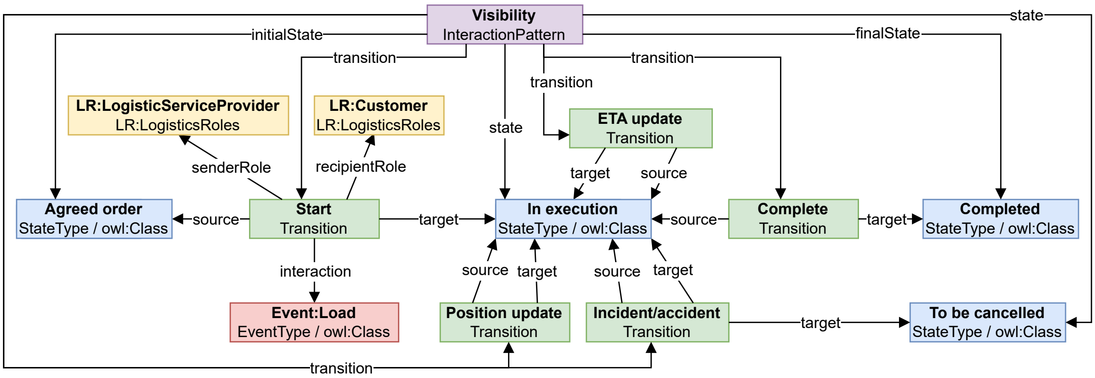

Figure 4: Visibility choreography. Roles and events connected to transitions other than Start are hidden to enhance readability of the diagram.

to an EventType that triggers the transition, and a sender and recipient role that indicate the direction of the data flow. The logistics roles correspond to the customer and LSP in Figure 2.

4. Conclusion

We have developed a simple Interaction Pattern ontology for logistics, and made the ontology available in RDF/OWL. The concepts in the ontology are explicitly related to the FEDeRATED Event and State ontology modules, thereby bridging the gap between concepts in process models and data about actual logistics activities. We have illustrated the intended use of the ontology with an example. As future work we see the implementation of the model into a proof of concept, experiments on how this improves data sharing efficiency, and the alignment of the model with a suitable process model standard.

Acknowledgments

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References

[1] M. De Juncker, Optimising routing in an agent-centric synchromodal network with shared information, in: Optimisation in Synchromodal Logistics: From Theory to Practice, Springer, 2022, pp. 171–185.

[2] S. M. Eckartz, W. J. Hofman, A. F. Van Veenstra, A decision model for data sharing, in: Electronic Government: 13th IFIP WG 8.5 International Conference, EGOV 2014, Dublin, Ireland, September 1-3, 2014. Proceedings 13, Springer, 2014, pp. 253–264.

[3] S. Dalmolen, H. Bastiaansen, E. Somers, S. Djafari, M. Kollenstart, M. Punter, Maintaining control over sensitive data in the physical internet: Towards an open, service oriented,

network-model for infrastructural data sovereignty, in: International Physical Internet Conference (IPIC2019), London, 2019, pp. 296–311.
[4] J. Rumbaugh, G. Booch, I. Jacobson, The Unified Modeling Language User Guide, Addison-Wesley, 1999.
[5] A. Schönberger, C. Wilms, G. Wirtz, A requirements analysis of business-to-business integration, Bamberger Beiträge zur Wirtschaftsinformatik und Angewandten Informatik (2009).
[6] W. Hofman, Control tower architecture for multi-and synchromodal logistics with real time data, ILS2014, Breda (2014).
[7] C. Bouter, G. Biagioni, T. van Gessel, W. Korteling, E. de Graaf, W. Hofman, Towards a modular ontology for event-based data sharing in the logistics domain, in: SEMPDW 2022: Posters, Demos and Workshops at SEMANTiCS 2022, 2022.
[8] C. Legner, B. Lebreton, Business interoperability research: Present achievements and upcoming challenges, electronic markets, Electronic Markets 17 (2007) 176–186.
[9] P. Hruby, Model-Driven Design Using Business Patterns, Springer-Verlag, 2006.
[10] D. Fensel, M. Kerrigan, M. Zaremba, Implementing semantic web services: The SESA framework, Springer-Verlag, 2008.
[11] W. Hofman, Runtime logistic process orchestration based on business transaction choreography, in: Business Process Management Workshops: BPM 2012 International Workshops, Tallinn., 2013, pp. 550–559.
[12] Object Management Group, Business Process Model and Notation (BPMN), Version 1.2, 2009.
[13] J. L. Dietz, H. B. Mulder, Enterprise ontology: a human-centric approach to understanding the essence of organisation, Springer-Verlag, 2020.
[14] L. Cabral, B. Norton, J. Domingue, The business process modelling ontology, in: Proceedings of the 4th international workshop on semantic business process management, 2009, pp. 9–16.
[15] K. M. Höver, M. Mühlhäuser, S-bpm-ont: An ontology for describing and interchanging s-bpm processes, in: A. Nanopoulos, W. Schmidt (Eds.), S-BPM ONE - Scientific Research, Springer International Publishing, Cham, 2014, pp. 41–52.
[16] R. Singer, An ontological analysis of business process modeling and execution, arXiv preprint arXiv:1905.00499 (2019).
[17] A. Annane, N. Aussenac-Gilles, M. Kamel, Bbo: Bpmn 2.0 based ontology for business process representation, in: 20th European Conference on Knowledge Management (ECKM 2019), volume 1, 2019, pp. 49–59.
[18] C. I. Schlenoff, The essence of the process specification language, Transactions of the Society for Computer Simulation 16 (1999) 204–216.
[19] M. Grüninger, Ontology of the process specification language, in: Handbook on ontologies, Springer, 2004, pp. 575–592.
[20] Y. Belgueliel, M. Bourahla, M. Brik, Towards an ontology for uml state machines, Lecture Notes on Software Engineering 2 (2014) 116–120.
[21] G. F. Schneider, Semantic Modelling of Control Logic in Automation Systems - Knowledge-Based Support of the Engineering and Operation of Control Logic in Building and Industrial Automation Systems, Ph.D. thesis, Karlsruhe Institute of Technology, 2019.