An Ontology Framework for Multisided Platform Interoperability

Quan Deng[1,2], Suat Gönül[3], Yildiray Kabak[3], Nicola Gessa[4], Dietmar Glachs[5], Fernando Gigante[6], Violeta Damjanovic-Behrendt[5], Karl Hribernik[1,2], Klaus-Dieter Thoben[1,2]

[1] BIBA- Bremer Institut für Produktion und Logistik GmbH, Hochschulring 20, 28359 Bremen, Germany
[2] University of Bremen, Bibliothekstraße 1, 28359 Bremen, Germany
[3] SRDC Yazilim Arastirma, Gelistirme ve Danismanlik Anon. Sti., Ankara, Turkey
[4] ENEA, Via Martiri di Monte Sole 4, 40129 Bologna, Italy
[5] Salzburg Research, Jakob Haringer Str. 5/II, 5020 Salzburg, Austria
[6] AIDIMME, Benjamin Franklin Str. 13, 46980 Paterna (Valencia), Spain

Abstract. A successful B2B marketplace must ensure that suppliers and producers in a supply chain can find each other, communicate and negotiate in an effective way, while performing business processes. To this, we present an approach that involves two core ontology modules, e.g. the Catalogue Ontology and the Business Process Ontology, which can be extended by adding specific domain ontologies. For the representation of certain business aspects, the Catalogue Ontology exploits the Universal Business Language (UBL), while for the description of product characteristics related to different domains, this ontology makes use of the relevant industrial standards (e.g., the furniture ontology is based on the FunStep ISO 10303-236 standard and the eClass ontology is based on eCl@ss standard). The Business Process Ontology encompasses machine readable vocabularies for the semantic description of business processes, and could be extended by adding new ontologies or data schemas. Finally, we validated the design and functionality of the ontology framework by defining and performing a set of queries related to product and services retrieval.

Keywords: Interoperability, Multisided Platforms, Ontologies, Taxonomies.

1 Introduction

Multisided platforms are characterized by interactions and interdependence between multiple groups of surrounding organizations [1]. The main aim of this paper is to design an ontology framework for enhancing semantic interoperability of cloud-based, multisided platforms and their instances operating under various regulatory norms, business rules and in heterogeneous working domains. Our use case study built on practical experiences gained during the implementation of a European research project NIMBLE (Grant Agreement No. 723810), which aim is to create multisided platform for collaboration, inter-sectoral and cross-sectoral interoperability in the EU. In NIMBLE, we advance conventional enterprise paradigms and allow marketplace participants to communicate with each other and to perform business interactions of various complexity over the platform. Although, in NIMBLE, various

marketplace participants operate over the same multisided platform, the problem of heterogeneity in the description of resources, business transactions, documents and contracts to be exchanged between participants remains present on the platform. Hence, this paper addresses an approach for the improvement of the enterprise interoperability by raising the abstraction from domain data models and taxonomies to standardized metamodels. In that context, we discuss here an extensible ontology framework, which consists of two core ontologies: the Catalogue Ontology and the Business Process Ontology. For the semantic representation of business features in the Catalogue Ontology, we use the Universal Business Language (UBL) standard, while the description of business transactions in the Business Process Ontology is based on Moda-ML (Middleware Tools and Documents to enhance the Textile/Clothing supply chain through XML) framework [2]. The presented ontology framework is extensible for the description of products, services and business transactions in various sectors, e.g. in the furniture sector. A comprehensive report on the NIMBLE Ontology Framework is given in [3].

Paper organization. Section 2 describes our main motivation for the design of the NIMBLE Ontology Framework. Related works are discussed in Section 3. Section 4 presents the structure of our ontology framework and its modules. Section 5 demonstrates a specific use case in furniture sector, for which we demonstrate an advanced query based reasoning system, combining SPARQL query filters and the results obtained via Apache Marmotta Linked Data platform. Finally, Section 6 draws conclusions and states overall future steps.

2 Motivation

Our motivation for the design of the NIMBLE Ontology Framework relies on an attempt to create a scalable knowledge network for ensuring interoperability, information integration and information exchange through business processes. A typical supply chain scenario consists of the following steps:

1. Supplier A publishes a catalogue of one or more products via the platform;
2. Supplier A creates new process model or reuses an established process model that specifies the documents to be exchange through business interactions;
3. Producer B searches for products via the platform, e.g. *"Who in Spain can deliver product X which has a feature F, in the next Y days, at price P?"* ;
4. Producer B obtains the search results and selects supplier A as the best match;
5. Producer B initiates a business transaction with supplier A, and exchanges specified business documents.

It is common that companies describe their products using different data models and vocabularies that relates to a specific sectoral knowledge. However, the lack of common structures and/ or vocabularies for product description, results in interoperability and findability issues. One possible solution for the improvement is to use XML Schemas Definitions (XSD) and define common data structures with user-preferred vocabulary. However, XSD cannot enable semantic interoperability, which calls for ontologies and their formal specifications of common vocabularies to be employed for the description of enterprise domains. The NIMBLE Ontology Framework addresses search issues with an extendable Catalogue Ontology and

improves interoperability in business interactions using a specifically created Business Process Ontology. The Catalogue Ontology supports publishing and searching of products with fine-grained technical (e.g. percentage of volatile organic compound in furniture sector) and commercial details (e.g. delivery, pricing). The Business Process Ontology allows the description of business transactions for different enterprise sectors from various aspects, e.g. *behavioral* (the order of execution of activities), *organizational* (business roles and entities in the business process) and *document consumption aspects* (data exchanged in business activities) [4].

3 Related Work

For the description of offered resources in an e-commerce platform, various attempts were undertaken so far to provide syntactic and semantic interoperability for B2B systems and services. E.g., the international product and service classification standard eCl@ss with its transformation into eClassOWL ontology [5]; the lightweight ontology GoodRelations, initially used for describing offerings of goods and commodity services on the Web [6] which today covers many B2B aspects, including Web resources, offers, prices, terms and conditions, etc. However, many important B2B concepts, such as business entity, delivery, warranty and payment, are not sufficiently detailed yet to effectively support enterprise interoperability. Meanwhile, the UBL standard (ISO/IEC 19845:2015) provides a free library of standard XML business documents for e-commerce [7]. UBL covers concepts such as `Address`, `Item`, `Payment`, `Delivery`, `Warranty`, which are used to describe offers of various resources in an e-commerce platform. As UBL is defined in XSD format, it cannot express semantic relationships among business concepts. In addition, UBL contains many elements which are not needed for the resource description. Some efforts have been taken to tailor UBL schemas to UBL catalogue [8] or transform UBL schemas to OWL format [9]. However, little have been done to derive a practical catalogue ontology from UBL, which can be extended with additional product taxonomies for the description of various offered resources.

For the purpose of business process descriptions, business process modelling languages have been developed, e.g. Business Process Model and Notation (BPMN) [10], Petri Nets [11]. Different business process modelling ontologies have been proposed for bridging semantic gaps in various business process models [12-14]. These ontologies are too generic and have little concentration on the description of business transactions in B2B marketplace for different enterprise sectors. Some efforts have been made in specific sectors. For example, in textile/ clothing sector, Moda-ML [2] is developed as a vertical standard for data exchange. The Moda-ML Business Process Ontology defines concepts (vocabulary terms) and exchange documents related to activities in textile sector [15]. The defined shared concepts support the development of business transactions models, which should be understandable to all entities interacting via the platform.

In short, there is a lack of practical extensible ontology framework, which can provide sufficient support for resource discovery and business transactions in B2B marketplace for different enterprise sectors, while performing business processes.

4 NIMBLE Ontology Framework

In context aware systems, business processes can be automated as long as there is a common agreement on knowledge behind those processes and their context. The NIMBLE Ontology Framework is a semantic collection of domain specific concepts, e.g. furniture taxonomy, Moda-ML Business Process Ontology. As illustrated in Figure 1, the core NIMBLE Ontology Framework consists of Catalogue Ontology and Business Process Ontology. Catalogue Ontology enables semantic publishing and searching of products and services, business transaction executions are controlled by the concepts defined in Business Process Ontology.

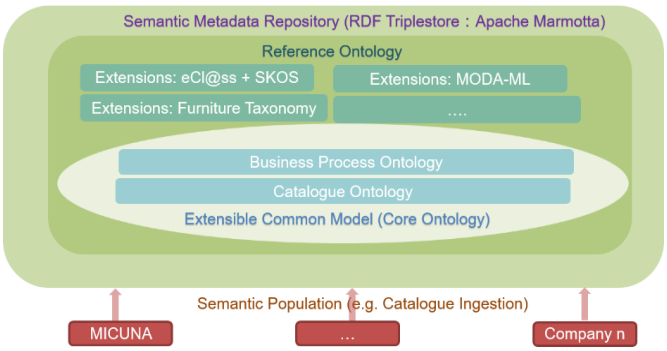

Fig. 1. Structure of the NIMBLE Ontology Framework

The NIMBLE Ontology Framework can be extended by introducing new ontologies encompassing various domains. For example, eClass can be used to specify the description of individual resources, while the furniture sector taxonomy enables description of resources in the furniture industry. While the core ontology must be pre-filled to drive the main functionality of the NIMBLE platform, new domain specific extensions can be added at any time by means of the NIMBLE platform.

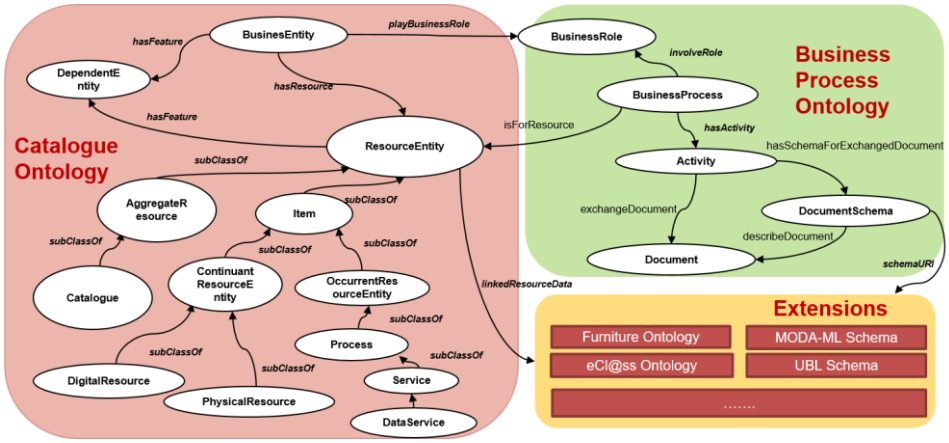

Fig. 2. NIMBLE Ontology Framework: classes and properties

The relationships between the ontologies in the NIMBLE Ontology Framework are illustrated in Figure 2. The ontologies will be populated through the provision in the NIMBLE platform of services that allow the ingestion of product catalogs offered by the participants to the platform.

Relevant concepts, their properties and relationships in the ontology framework are maintained in the semantic metadata repository. In NIMBLE, this repository is driven by Apache Marmotta (http://marmotta.apache.org), which is an open source implementation of the Linked Data Platform (LDP) (https://www.w3.org/TR/ldp/).

4.1 Catalogue Ontology

Catalog Ontology in NIMBLE is based on UBL, a world-wide standard providing a royalty-free library of XML business documents used in supply chain operations [16]. UBL covers various concepts in cross-sector use cases, including concepts for the description of companies, persons, catalogues, products, product properties, delivery terms, trading terms, etc.

In order to have catalogue ontology, we firstly presented a mapping between the UBL concepts and the concept in use cases in the NIMBLE project. Secondly, we adopted the concepts from GoodRelations ontology [6] and Svekatalog UBL Catalogue 2.1 [8], and finally categorized the relevant concepts. For the transformation of the UBL schema into Catalogue Ontology, we used Ontmalizer (https://github.com/srdc/ontmalizer), which is a tool that transform concepts (e.g. `Catalogue` and `Item`) in XML schema to RDF classes in ontology. Followed the automatic transformation is then manual adaptions and optimizations.

Figure 2 shows the major elements of Catalogue Ontology:

- **Business Entity** can be a legal Party or a Person, offering some resources or taking part in business transactions.
- **Resource Entity** is a product/ service that is held by a Business Entity. Each Resource Entity has resource specific characteristics or properties, e.g. price.
- **Dependent Entity** is derived from `Dependent Continuant Entity` of the Basic Formal Ontology (BFO) [17], which includes entities that are ontologically dependent on `Independent Continuant`. Examples of `Dependent Continuant Entity` are weight or color, and an `Independent Continuant` could be a tomato.

In Catalogue Ontology, `Dependent Entity` concepts can be used to specify the `Business Entity` and `Resource Entity` in a more detailed way. To enrich the specification of resources in different domains, Catalogue Ontology is extended with domain product category taxonomy. The extension of Catalogue Ontology can be done using either inheritance mechanisms, which combine product properties from Catalogue Ontology and product category taxonomy, or by using the Linked Data mechanisms (shown in Figure 3). Here, RDF triples connect the *subject* from Catalogue Ontology with the *object* from the extension modules. This way, the specification of the resource instance in Catalogue Ontology is enriched with the instance descriptions in the product category taxonomy. Furthermore, a resource instance may be linked to multiple instances in product category taxonomies.

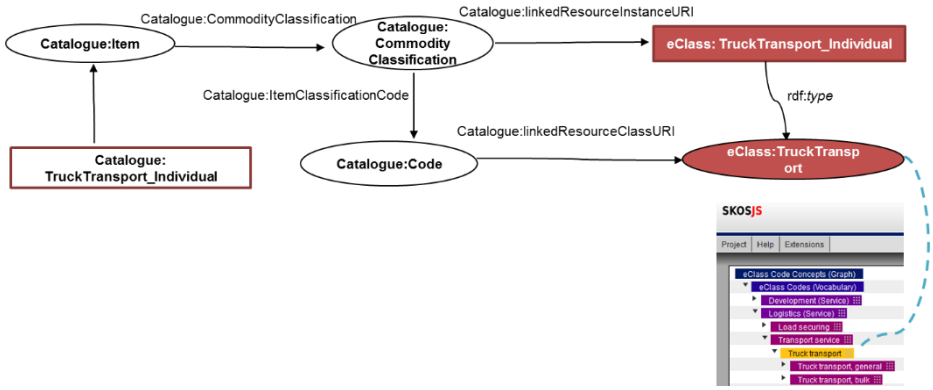

Fig. 3. Example extension with Linked Data mechanisms

Beside Linked Data mechanisms, NIMBLE supports abstracting the details of target concepts from users and presenting these details as a flat data structures so that users need to specify only values for the presented attributes. Figure 4 illustrates this modified approach that links product categories from external taxonomies, e.g. a `Commodity Classification` to the resource instance `Item`. RDF resources describing product categories can be accessed through `linkedResourceClassURI` of `Code` class. Finally, we create `ItemProperties` for those properties specified by all categories that represent the product. Subsequently, each `ItemProperty` has a link to the corresponding property definition.

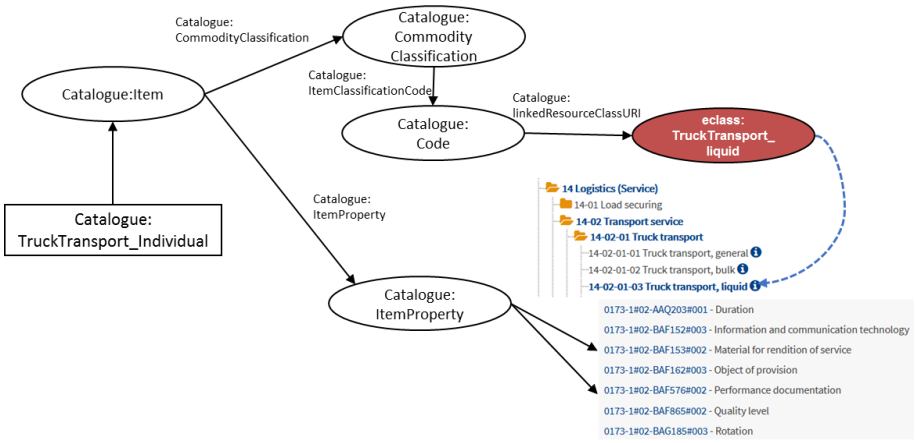

Fig. 4. Example extension based on modified Linked Data extension mechanism

The current version of the NIMBLE Ontology Framework includes the following extension modules:

1. eClass taxonomy, which is an ISO/IEC compliant industry standard for cross-industry product and service classification; and

2. Furniture sector taxonomy, which merges an old release of furniture taxonomy (capturing industrial processes, machinery, techniques and materials used in manufacturing processes, components and product catalogues in furniture industry) and the furniture ontology, which is based on the funStep ISO standard (FunStep ISO 10303-236, see: http://www.funstep.org).

4.2 Business Process Ontology

For the description of business transactions in NIMBLE, we reuse the concepts in Moda-ML Business Process Ontology. Moda-ML Business Process Ontology is formalized in OWL (Web Ontology Language) and built around the following concepts: `Process`, `Actor`, `Activity`, and `Document`. Moda-ML Business Process Ontology contains more than 100 classes of various documents and about 30 types of business transaction activities in textile sector. For the representation of metadata of exchanged documents, the `DocumentSchema` concept has been derived from the `DataSchema` concept in the DRM (Data Reference Model) ontology (http://vocab.data.gov/def/drm).

As shown in Figure 2, Business Process Ontology in the NIMBLE ontology framework includes the following main concepts:

- **Business Entity** is shared with Catalogue Ontology and has a specific Business Role.
- **Business Role** defines a specific role that can be played in a Business Process, by a Business Entity.
- **Business Process** is a set of structured activities with logical behavior that produce a specific service or product [14].
- **Activity Entity** is a specification of an activity that is carried out with the aim to perform a Business Process. An Activity Entity can be atomic (cannot be split into further detailed activities) or compound (consists of several atomic activities).

In single atomic activity, one and only one **Document** can be exchanged; e.g., a purchase order is a document that can be exchanged between the buyer and the seller in a business transaction activity. Documents are described by **Document Schema** with metadata that provides common understanding to different actors. The entities in the document schema are categorized into different types, following the UBL standard; e.g. `InvoiceDocumentSchema` contains metadata of invoice documents.

With respect to the high variability of vocabularies and document schemas in specific business transactions, sector-specific business process ontologies should be introduced to extend the current Business Process Ontology. Its extensions can be achieved either using the inheritance mechanisms or Linked Data mechanisms. For example, `SubcontractedFabricManufacturing` process in Moda-ML Business Process Ontology can extend `ProductionProcess` in our ontology using the inheritance mechanisms. Linked Data mechanisms enable reuse of the document schemas that are defined in other standards (e.g. UBL) or by other business entities. For example, document schema `TextileOrderStatusReport` in textile

ontology extends the Business Process Ontology using a data property `schemaURI` that specifies the exchange documents in textile transactions.

5 Use Case Study

In the following, we present an example of the NIMBLE Ontology Framework and its use for search and discovery of products and business transactions as a first step towards the complete validation of the project. Here, Catalogue Ontology is extended with a sector-specific furniture ontology, and Business Process Ontology is linked with the products from the furniture ontology.

The following example demonstrates the use of ontology modules for performing a single search request. The data and ontologies used in the following example are available online from: http://nimble-ldp.salzburgresearch.at.

Search request. *"Who in Spain can deliver an un-foldable product from furniture category Cradle, in the next 8 days, at price less or equal to 200 Euro, and can generate the Certification of Origin document as a part of business transactions?"*

By using predefined RDFPath, the search request could be automatically transformed into a SPARQL query. At present, SPARQL query is manually created, defining a search filter with the information on delivery period and delivery unit (e.g. 8 days), price (e.g. less or equal to 200 Euro), country (e.g. Spain), and feature of product is "unfoldable", etc. The search filter in the following SPARQL query produces the output by looking in Catalogue Ontology, sector specific extension modules, Business Process Ontology, and an extension document schema.

```
SELECT  ?supplierName ?supplierTel ?furnitureEAN ?furnitureColor
(concat(str(?deliveryPeriodDecimal), " ", str(?deliveryPeriodUnit)) as ?deliveryTime)
(concat(str(?priceDecimal), " ", str(?currencyID)) as ?price)
(concat(str(?minOrderQuantiyDecimal), " ", str(?minOrderQuantiyUnit)) as ?minOrderQuantity) WHERE {
  ?party nimble_ubl_aggregate:Contact/nimble_ubl_basic:Telephone ?supplierTel;
    nimble_ubl_aggregate:PostalAddress/nimble_ubl_aggregate:Country/nimble_ubl_basic:Name ?countryName;
    nimble_ubl_basic:Name ?supplierName;
    nimble_ubl_catalogue:Catalogue/nimble_ubl_aggregate:CatalogueLine ?catalogueLine;
    nimble_ubl_aggregate:DeliveryTerms/nimble_ubl_aggregate:EstimatedDeliveryPeriod
    /nimble_ubl_basic:DurationMeasure ?deliveryPeriod.
  ?deliveryPeriod nimble_ubl_basic:ValueDecimal ?deliveryPeriodDecimal;
    nimble_ubl_basic:unitCode ?deliveryPeriodUnit.
  ?catalogueLine nimble_ubl_aggregate:GoodsItem/nimble_ubl_aggregate:Item ?item;
    nimble_ubl_aggregate:RequiredItemLocationQuantity ?requiredItemLocationQuantity.
  ?requiredItemLocationQuantity nimble_ubl_aggregate:Price/nimble_ubl_basic:PriceAmount ?priceAmount;
    nimble_ubl_basic:MinimumOrderQuantity/nimble_ubl_basic:ValueDecimal ?minOrderQuantiyDecimal;
    nimble_ubl_basic:MinimumOrderQuantity/nimble_ubl_basic:unitCode ?minOrderQuantiyUnit.
  ?priceAmount nimble_ubl_basic:ValueDecimal ?priceDecimal;
    nimble_ubl_basic:currencyID ?currencyID.
  ?item nimble_ubl_aggregate:CommodityClassification ?externalItemLinke.
  ?externalItemLinke nimble_ubl_basic:ItemClassificationCode
    /catalogue:linkedDataURI/rdfs:subClassOf*  furniture:Cradle;
    catalogue:ItemInstanceURI ?linkedFurnitureItem.
  ?linkedFurnitureItem furniture:isFoldable ?isFurnitureFoldable;
    furniture:hasEAN ?furnitureEAN; furniture:hasColour ?furnitureColor.
?bp bp:isForResource furniture:Cradle; bp:hasActivity ?activity.
?activity bp:hasDocumentExchangedFromRole/^bp:playBusinessRole ?party;
  bp:hasSchemaForExchangedDocument/bp:schemaURI ?schemaURI.
FILTER (?deliveryPeriodDecimal <= "8"^^xsd:decimal && ?deliveryPeriodUnit = "DAY"^^xsd:string
   &&  ?priceDecimal <= "200"^^xsd:decimal && ?currencyID = "EUR"^^xsd:string
   &&  ?isFurnitureFoldable = "false"^^xsd:boolean  && ?countryName = "Spain"^^xsd:string
   &&  regex(str(?schemaURI), "CertificateOfOrigin"))}
```

Sample features in catalogue ontology

Sample product features in sector specific extension module

Link to business process ontology

Link to extension document schema

By using sample data, provided in http://nimble-ldp.salzburgresarch.at, the above-presented SPARQL query creates the output, as shown in Fig. 5. It founds that the company "MICUNA S.L." in Spain (this information is based on international calling code, +34) can deliver un-foldable white Cradle in next 7 days, at price 150 Euro, with a minimum quantity of order that is 201 packages.

supplierName	supplierTel	furnitureEAN	furnitureColor	deliveryTime	price	minOrderQuantity
"MICUNA S.L."	"+34 [redacted]"	"8431830130773"	furniture:White	"7.0 DAY"	"150 EUR"	"201 PK"

Fig. 5. Sample output from the example query

6 Conclusion

The ontology framework presented in this paper is designed to enhance interoperability of activities and transactions performed via the NIMBLE multisided platform. Here, we firstly considered several existing enterprise ontologies, arguing that they are not sufficient for supporting knowledge exchange, interoperability and multi-sidedness of current and future platform solutions. Starting from this analysis, we designed our ontology framework to support information retrieval and enhance search and negotiation activities via the NIMBLE platform.

The presented ontology framework consists of two ontology modules: Catalogue Ontology and Business Process Ontology, which can be further extended to cover new enterprise domains. Both modules are based on standards for facilitating semantic and cross-domain interoperability. For example, the current knowledge extension of the NIMBLE Ontology Framework includes Furniture Ontology (based on FunStep ISO 10303-236), the eClass ontology (based on eCl@ss) and textile taxonomy (based on Moda-ML standard).

We preliminarily tested and validated the design and functionality of the NIMBLE Ontology Framework through the definition of queries that demonstrated its searching potential. Future work on this ontology framework will focus on the inclusion of other product and domain ontologies. The diversity of enterprise sectors, their business models and opportunities to collaborate via the platform will further drive the design and the extensions of the NIMBLE Ontology Framework. As next steps, the ontology framework will be extended and validated in further industrial use cases to ensure interoperability between suppliers and producers in a supply chain, while performing business processes.

Acknowledgments

This research has been funded by the European Commission within the H2020 project NIMBLE (Collaborative Network for Industry, Manufacturing, Business and Logistics in Europe), No. 723810, for the period between Oct. 2016 - Sep. 2019.

References

1. Boudreau K., Hagiu A. (2009), "Platform Rules: Multi-Sided Platforms As Regulators." In Platforms, Markets and Innovation, edited by Annabelle Gawer. Cheltenham, UK: Edward Elgar Publishing, 2009.
2. Gessa, N., De Sabbata, P., Marzocchi, M., Vitali, F. (2004), Moda-ML: Building a collaborative sectoral framework based on ebXML, Proceedings of CAISE '04 - INTEROP 2004 Workshop on "Enterprise Modelling and Ontologies for Interoperability" EMOI, Riga, Latvia, June 7-11 2004, edited by Grundspenkis/Kirikova, 2004, ISBN-9984-9767-3-4.
3. NIMBLE D2.2 (2017). Semantic Modelling of Manufacturing Collaboration Assets.
4. Axenath, B., Kindler, E., and Rubin, V. (2005). The aspects of business processes: An open and formalism independent ontology. TR-RE-05-256, University of Paderborn, http://wwwcs.uni-paderborn.de/cs/kindler/Publikationen/copies/AKR05.pdf, April 2005
5. Hepp, M. (2005): eClassOWL: A Fully-Fledged Products and Services Ontology in OWL. In: Poster Proceedings of the 4th International Semantic Web Conference (ISWC2005), November 7–11, 2005. Galway, Ireland, 2005
6. Hepp, M. (2008). GoodRelations: An ontology for describing products and services offers on the web. In Proceedings of the 16th International Conference on Knowledge Engineering and Knowledge Management, Acitrezza, Italy, 2008
7. ISO/IEC 19845:2015 (2015), https://www.iso.org/standard/66370.html Last visited 2017-09-20
8. Forsberg, M. (2011). Svekatalog UBL Catalogue 2.1. http://www.sftiverifiering.se/svekatalog/XSD/1_1.htm. Last visited 2017-09-20
9. Yarimagan, Y., Dogac, A. (2009): A Semantic-Based Solution for UBL Schema Interoperability. In IEEE Internet Comput. 13 (3), pp. 64–71. DOI: 10.1109/MIC.2009.50.
10. White, S.A., Miers, D. (2008), BPMN Modeling and Reference Guide: Understanding and Using BPMN, Future Strategies Inc., 2008
11. Reisig, W. (1985), Petri Nets: An Introduction, Springer-Verlag New York, Inc., 1985
12. Hepp, M., Roman, D. (2007): An Ontology Framework for Semantic Business Process Management, Proceedings of Wirtschaftsinformatik 2007, Karlsruhe
13. Rospocher, M., Ghidini, C., Serafini, L. (2014): An ontology for the Business Process Modelling Notation. In: 8th Int. Conf. on Formal Ontology in Inf. Systems (FOIS). (2014)
14. Von Rosing, M., Laurier, W. and Polovina, S. (2015). The BPM ontology. In: The complete business process handbook. Elsevier, 101-121, 2015
15. Gessa, N., Busanelli, M., De Sabbata, P., Vitali, F., (2006). "Extracting a semantic view from an ebusiness vocabulary", in proceedings of IEEE CEC 2006, San Francisco, 2006, Published by IEEE Computer Society, ISBN 0-7695-2511-3.
16. Universal Business Language Version 2.1. 04 November 2013. OASIS Standard. http://docs.oasis-open.org/ubl/os-UBL-2.1/UBL-2.1.html.
17. BFO (Basic Formal Ontology). Online: http://ontology.buffalo.edu/bfo/, Last visited 2017-09-20