A federated interoperability approach for data driven logistic support in SMEs

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Abstract

Small and Medium-sized Enterprises (SMEs) in logistics experience practical barriers when trying to use, exchange, share, and exploit real-time data in their operational processes. Such barriers include the abundance of proprietary data formats and schemes, the cost of implementing standards, the lack of trust among partners, the lack of IT expertise, and the uncertainty about benefits and return on investments. This position paper introduces the goal and proposed approach of a recently started research project that aims at lowering these barriers. The core proposition revolves around the application of a federated approach based on the concepts of the International Data Space (IDS). In this paper we present a high level architecture underlying this goal and approach. Two main components of the architecture are discussed in more detail: (1) a connector store, offering connectors to realize data exchange between heterogeneous ICT environments, and (2) an interoperability simulator, to explore collaboration opportunities prior to implementation.

Keywords

international data spaces, federated interoperability, enterprise interoperability simulation logistics

1. Introduction

The sharing of real-time logistics data (e.g., contextual, trip, and planning data) can bring important innovations to the logistics sector. Data sharing can lead to a better coordination, more efficient decision-making, and can enable new applications and services that benefit both logistics companies and their customers. A survey in the logistics industry indicates that 23% of the 260 companies uses real-time data [10]. There are several barriers that prevent full exploitation of this potential. Examples are: different (proprietary and standard) data formats, costs of implementing standards, requirements on data sovereignty, lack of trust, and uncertainty about benefits and return on investments. Especially SMEs, which typically lack IT expertise and have limited resources, experience these barriers.

This paper presents an effort aiming at lowering these barriers and addressing two main problems: data interoperability (and in particular, data sharing needed for collaboration between logistics companies) and data sovereignty (to protect proprietary data that has strategic value for logistics companies). We follow the design cycle as prescribed by the design science research methodology [2] and target the design and validation of two complementary treatments for these problems. One is a connector store, consisting of predefined data connectors to enable logistics companies to join a collaboration network through the selection of a suitable data connector from the store. The other treatment is an interoperability simulator to support logistics companies to explore collaboration opportunities in dynamic networks prior to implementation.

2. Approach and related work

Our problem investigation consists of confirming and deepening our current understanding of the problem, which is based on previous research and initial input from the consortium partners. We will further ensure relevance and avoid duplication of work by aligning with and reusing the IDS knowledge produced in reference projects, more specifically in Data Logistics for Logistics Data [12], and in TKI

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IDS Service Environment [13]. We will conduct a systematic literature review to gather general requirements and construct an initial list of requirements. This list will be classified and verified by logistics companies for a final confirmation.

During the solution design phase, we design the logistics data space architecture and federated approach. More specific, our data architecture and approach will be based on the architectural principles of IDS [9] and will incorporate existing standards for logistics. Examples include data standards, such as eCMR [14] and OTM [18], data services offered by the Neutral Logistics Information Platform's (NLIP) [17] and standardized agreements such as iSHARE [16]. The solution design will be result in a consolidated overall architecture and methodology and detailed solution designs for the connector store and the interoperability simulator. To achieving interoperability, at conceptual level, we will make use of ontology and metamodel approaches building upon our earlier research in this area [1][3][4][6]. Based on the reviewers suggestions, we will also explore deep-semantics foundational ontologies, such as UFO, GFO or BFO.

During the solution validation phase, we plan to develop a prototype of the logistics data space, based on hybrid middleware integration platform technology (e.g., eMagiz [15] and other alternatives), to demonstrate the design and validate the research results. We follow a cyclic approach during solution design and solution validation, where functional increments of the architecture will be designed, prototyped and validated in three main cycles. Each cycle will result in a demonstrator with specific use cases from industry. We plan to extend the architecture described in [5] and instantiated in [7]. To explore alternative approach, the federated approach proposed in this research will be incorporated in the industry platform positioned in [8].

3. Motivating scenario

The proposed architecture will be designed to simulate interoperability and provide connectors for common interoperability scenarios. Together with our consortium partners we selected a motivating scenario, as shown in Figure 1, to position our contributions and explain how we expect to lower barriers for SMEs.

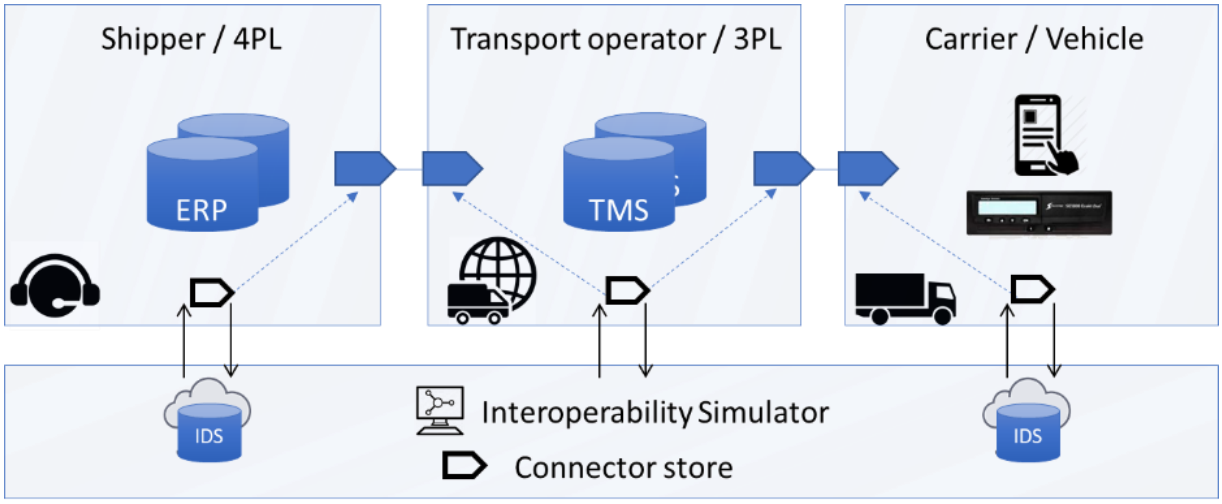

Figure 1: Reference architecture for IA driven schema matching

In this scenario, the actors in a logistics ecosystem utilize the interoperability simulator to analyze interoperability between their internal systems and the on-board computers or mobile apps. Visualization of the data usage of actors is expected to contribute to trust and data sovereignty. The involved actors use data connectors from the connector store to exchange data and connect with the logistics ecosystem based on the concepts of IDS. A federated approach to interoperability with pre-defined connectors is expected to reduce the time and efforts needed to integrate their systems.

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4. High level architecture

In this section we present our vision concerning the high level architecture for federated interoperability, as shown in Figure 2. The two main components are the connector store and an interoperability simulator.

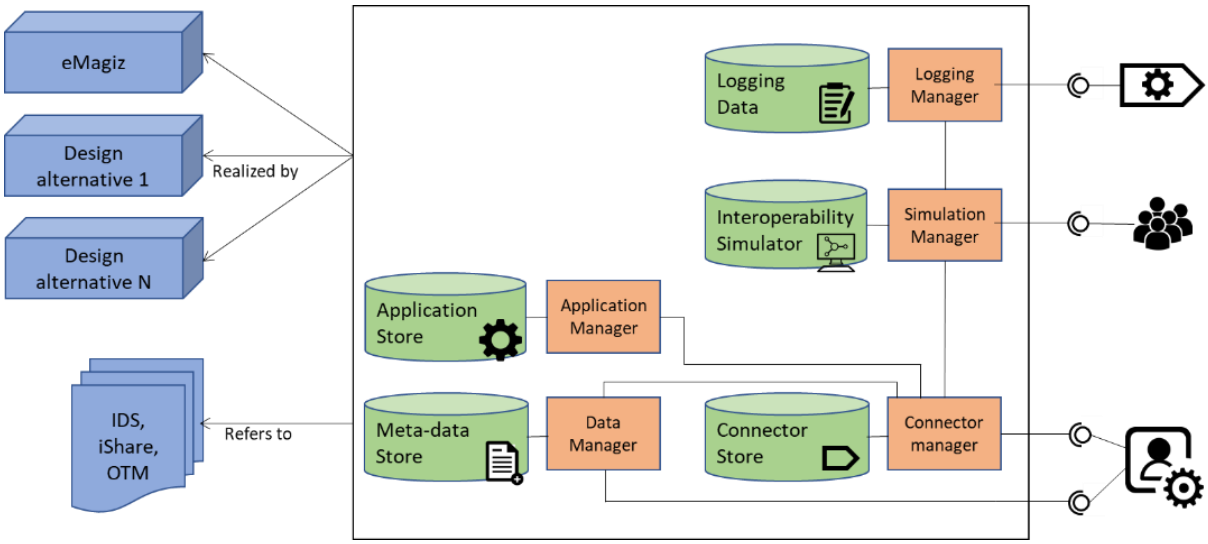

Figure 2: High level architecture for federated interoperability

The connector store is a broker system that offers data connectors to logistics companies. A data connector is an entry point for a logistics company to join and participate in a logistics ecosystem (a collaboration network of two or more logistics companies). The company can select and configure a data connector according to its own requirements and capabilities, constrained by the requirements of the ecosystem. The data connector can bridge between different data formats and schemas, hiding transformation details but externalizing important metadata about the data exchange. Metadata can include information on the schemas involved, the quality of the data, and the loss of information (due to incomplete mappings between the schemas).

The interoperability simulator is a tool capable of exploring and analyzing collaboration opportunities in logistics ecosystems. It consists of a modelling view and an analysis view. The modelling view is used to edit the users' roles, requirements, and capabilities, and the data sharing relationships between users. User requirements include data sharing and data protection requirements. Capabilities include supported data schemas, data formats, and network protocols. The analysis view is used to show the potential of efficient collaboration and innovative services based on data sharing, but also to identify potential issues in regard data interoperability, and data sovereignty. Identified issues could include incomplete schema mappings (possible loss of information) and inconsistencies between data protection requirements, and imposed usage restrictions (with possible loss of sovereignty).

The design of the connector store and interoperability simulator will be aligned in order to realize the following functionality: (1) the modelling view of the simulator is able to express the functional support that can be provided by data connectors from the store, (2) the output of the simulator is used to facilitate the selection and configuration of data connectors from the store and (3) configuration of applications, (4) meta-data for schemas and (5) logged events from a collaboration supported by data connectors is usable as input for the analysis view of the simulator.

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5. Discussion

This paper summarizes our vision concerning the development of a dedicated but generalizable approach and high level architecture for data exchange and sharing in the logistics sector. This vision is the starting point of a research project that will eventually lead to the specification of architecture design patterns supporting digital workflows in heterogeneous, distributed and (semi-) autonomous business ecosystems and supply chains. Specific attention is paid to the practical barriers and needs of SMEs. More specifically, we aim at developing new methods to cope with data heterogeneity and to lower the barriers for data exchange and sharing. These methods include design-time mechanisms to learn from existing schema mappings and runtime mechanisms to establish and improve such mappings and generate transformations on basis of specified mappings. With respect to the IDS, our research is expected to result in new applications (transformation, monitoring, control) and methods to support data provenance and sovereignty and new or improved analytical methods for exploring collaboration through data sharing in logistics ecosystems. These contributions add value to data sharing infrastructures as defined by IDS.

The proposed approach and architecture are expected to make the exchange and sharing of real-time data accessible and affordable to SMEs and to ensure cybersecurity through trusted IDS-based connectors. Furthermore, this approach enhances the end-to-end supply chain visibility, thus making logistics resources utilization and (nearly) real-time dynamic (re-)planning possible and efficient. The proposed data and middleware architecture and the interoperability simulator create a firm foundation for the development and testing of (big) data analytics and optimization tools. We align our work with the Dutch Top Sector Logistics' vision [11] to establish a logistics data sharing infrastructure, utilizing established standards for transport and logistics, and as such contribute to a blueprint for a coherent and secure data infrastructure, and the foundation of data interoperability.

Additionally, our approach and architecture can be extended with IDS roles, such as a certification authority, and a clearing house. More precisely, through our first objective, i.e., the connector store we facilitate the connection between the logistic IDS, and government's (open) data and communication platforms and systems, such as Portbase [19] and Cargonaut [14], and we can make available various collaborative services, and a data infrastructure, that is relevant for optimizing and coordinating logistics processes by both SMEs, and government organizations. Thus, government and logistic ecosystems can share real-time process execution data as needed. The second objective of this proposal, the interoperability simulator, provides a solid analytical basis for investigating not only data interoperability and data sovereignty, but also compliance with industry standards and laws and regulations. This way, we aim at improving the quality of data exchanged with partners and government organizations, and streamlining the processes in which they must interact. Additional use cases, and scenarios will be developed during the project.

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