An Intelligent Arrival Time Prediction Service in a Federated Data Ecosystem: the Minimum Viable Demonstrator of the GAIA-X 4 ROMS Research Project

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Abstract

Reliable arrival and departure forecasts from transport service providers are now an important basis for the successful planning of operational work processes for many commercial enterprises. A lack of interoperability, data standards and interfaces for exchange on the one hand, and a lack of a basis for cooperation on the other, hinder the flow of data along the supply chain and thus the fulfillment of the customer's demand on transport service providers for reliable forecasts.

The consortium research project "GAIA-X 4 ROMS" (Remote Operation for Automated and Connected Mobility Services), funded by the German Federal Ministry of Economics and Climate Protection, is developing the prototype of a novel value network for the intelligent fleet management of automated and connected vehicles in intermodal transport chains. Data and services, such as remote operation and planning services, are exchanged securely and sovereignly on the basis of a federated, decentrally organized data space. The innovative concept of Gaia-X for the design of federated data spaces will be used, which promises data sovereignty and standardized data exchange for all network participants.

This paper presents the concept of the first Minimum Viable Demonstrator (MVD) of the research project. In the MVD, the principle functionality of the data space and the data exchange between participating network nodes via data connectors is to be demonstrated using the use case of arrival time forecasting for vehicle fleet operators. In the further course of the project, the forecast service developed for this purpose will form an elementary functional module for an AI-based planning tool for the dynamic real-time planning of road-based mobility services in public passenger transport as well as in commercial road freight transport. The paper concludes with the current challenges in implementing the innovative data space technologies in the MVD and the related outlook for the further course of the project.

Gaia-X GAIA-X 4 ROMS Data Space MVD Demonstrator Public Transport Fleet Management Data Sovereignty Data Ecosystem

1. Data for reliable arrival time forecasts as a driver of logistics planning

With the globalization of goods flows and complex manufacturing processes spanning several companies, the demands on intermodal transport chains in terms of plannability as well as time and resource efficiency have increased enormously. Shippers and recipients of goods expect transparency in the flow of goods as well as punctual and undamaged deliveries " in time" - even if transport routes extend over continents, means of transport and transport service providers change many times and transport goods have to be transhipped just as often into perhaps just as many transport

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loading containers. Reliable arrival and departure forecasts from transport service providers are now an important basis for many commercial enterprises for the successful planning of operational processes with interfaces to transport logistics systems. But transport service providers can also benefit from improved forecasts if they optimize their planning, minimize waiting times and thus achieve ecological and economic improvements by increasing vehicle utilization and avoiding empty runs.

In addition to the ability to carry out transports in the required complexity and quality (i.e. often just means being able to procure and control transport capacities on the market along the supply chain), reliability and transparency of service are essential success criteria for competitive transport management in order to survive and grow on the market. Effective coordination of the parties involved in the transport chain, from industrial shippers and globally operating logistics giants to individual and contracted carriers, is thus a necessary prerequisite for transport service provision.

Efficient coordination and cooperation between the actors involved in the intermodal transport chain is based on reliable planning. However, this does not take place just once before each transport. Rather, it is an ongoing process that takes into account current developments in the traffic situation during a transport as well as changing conditions at the loading or unloading location. To this end, digital planning tools draw on real-time data from the traffic systems, the position and destination data of the transport vehicles, and a range of other data. In complex supply chain structures, modern planning and control systems (e.g., yard management systems) not only take into account the immediate incoming and outgoing transport service providers, but also include parts of the supply chain further upstream or downstream - provided their data is available.

In principle, the more data relevant to the application and the more detailed the data is collected, the better the forecast tends to be, on the basis of which planning and control can be based.[1] Complex, data-intensive forecasting tools use artificial intelligence (AI) and machine learning (ML) methods to infer future conditions from past patterns. To efficiently train the algorithms, developers rely on suitable data that also fits the use case. The algorithms developed for this purpose are becoming more and more sophisticated in order to achieve better forecasts and will represent their own business values in data-based companies, which will be increasingly measured in the future.

The problem of missing data

The availability of data is currently the real challenge in creating transparency and the effective and efficient planning and management of supply chains (Liebig et al., 2017). In some cases, the transport loading units used on the road (e.g. trailers, swap bodies) are already equipped with supporting IT systems (e.g. telematics) and have a digital equivalent of themselves, i.e. a digital twin, for their own data management. In some cases, however, such capabilities are still completely lacking and the transport loading vessel is not accessible for intelligent control, or is only partially accessible through the existing range of cloud-based data services. Just like the digital connectivity of the vehicles, the IT infrastructure and data system landscape of the companies involved in the intermodal transport chain is highly fragmented and diverse. On the one hand, the systems used are not interoperable and there is a lack of binding data standards and interfaces for exchange. On the other hand, the lack of a basis for cooperation and coordination hinders the flow of data along the transport chain and thus the effectiveness of data-intensive planning methods.

Exceptions here are regularly the systems of global players who, due to their market position, can oblige subcontractors to provide data in the desired format or who are able to map a large part of

[1] The relevance of data quality is evident, for example, in Jain et al. (2020).

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the transport chain and thus also the data value chain within their organization. In this system, the transfer of customer or transport-related data to upstream or downstream companies in the transport chain is controlled by a central actor according to its specifications. This means for other companies, they receive data only to the assigned extent and only for the fulfillment of the intended task. However, this can hinder their own planning process and inhibits data-based innovations.

Challenges for data platforms

This dilemma of uncooperative behavior in a heterogeneous information system environment has been recognized as a central problem in the industry and the establishment of digital customer and partner ecosystems a market- and society-driven consequence. Many different frameworks are being developed to establish interoperability - some by states and some by individual companies (Guijarro, 2017). Such peer-to-peer data platforms are being developed and operated, increasingly forming their own viable digital business models based on sole data sovereignty by platform operators. In this context, there are multiple challenges for the users as well as for the operators , some of which will be briefly discussed below:

- **Data sovereignty**: Regardless of whether the operator of such a platform is a market competitor or an industry-independent institution, companies and organizations face the question of their own data sovereignty if their data is to be made available on the platform. Broad acceptance by stakeholders without a credible guarantee is unlikely. Data trustees as platform operators, who have no vested interest in the "content" of the data but only in making it available, could be helpful. In addition, technical solutions that have anchored data sovereignty in their algorithms are considered convincing and trust-building.
- **Data security**: As with data sovereignty, the platform must ensure that sensitive data is protected from unauthorized access. As a general rule, the more sensitive the data, the less users are likely to be inclined to share it. Unfortunately, it is often precisely such data sets that contain particularly interesting insights that can only be determined using intelligent data analysis methods (AI, ML).
- **Market relevance**: Development and operation on the one hand, and participation / connection of the company's own IT systems to the platform on the other, are associated with investment costs, some of which are considerable. For all parties involved, a return on investment (ROI) / added value from the platform only develops as soon as its size gives it market relevance for providers and buyers of data and services alike.
- **Innovation potential**: The value of data is measured less in its individual ownership than in its intelligent processing and cross-actor use. The know-how required for this is highly specialized and therefore not readily available on the market. High data availability and scalability attract innovative forces, which in turn can develop and offer innovative services for more than one company / organization on the platform. The establishment of a corresponding data and services ecosystem is therefore important.
- **Low-threshold entry into the ecosystem with positive business-promoting prospects for the participants at the same time**: Technical standards for data exchange, clear rules and enforcement options for the same with regard to data sovereignty and security are just as fundamental requirements for the platform as low-threshold access for companies and organizations. The technical complexity of connecting one's own IT systems to an ecosystem is a resistance that should not be underestimated when deciding to participate. "Plug & play" solutions and "as-a-service" concepts for cloud-based data services and infrastructures offer sensible options here.

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To successfully solve the problem of missing data, an infrastructure should therefore be created that makes sovereign data sharing easy. A decentrally organized data and services ecosystem could develop suitable answers to these challenges. The contribution of the GAIA-X *4* ROMS research project to this is presented in the following chapter 2. Chapter 3 then discusses data space technologies that will be applied in the project. The first application in the Minimum Viable Demonstrator (MVD) GAIA-X *4* ROMS is described in Chapter 4. The concluding Chapter 5 identifies challenges and gives an outlook on their expected remedies.

2. GAIA-X *4* ROMS

As outlined at the beginning, the ability to exchange data sovereignly in logistics-related data and service ecosystems can be an important success factor in the future. The Fraunhofer Institute for Software and Systems Engineering even calls it a "key capability in the age of digitalization" (Fraunhofer, 2022). In the "GAIA-X *4* ROMS" research project, which is funded by the German Federal Ministry of Economics and Climate Protection and is part of the "GAIA-X *4* Future Mobility" project family (Gaia-X *4* Future Mobility, n.d.), the participants in the consortium project are focusing on this aspect. The goal of the project is the conception and development of the data space "ROMS" for digital applications from the area of support and remote operations of automated and networked mobility services. In the first focus area, services developed with data-space capability, such as integration, organization and dispatching of automated vehicles, are to supplement road-based local public transport in the future. The second focus area is the optimization of the entire transport chain for parcel deliveries in the main leg and on the first and last mile via the data space. For this, services such as dispatching and management of autonomous vehicles and use of real-time data for routing, remote operations and capacity planning will be created. Finally, the prototypically implemented data services will be connected and evaluated in a data space demonstrator for the two use cases "Smart Managed Public Transport Fleet" and "Smart Managed Freight Fleet"[2] executable with data sources and users.

Research Goals

The research project aims to create the prototype of a new type of value network for automated driving with various interoperable data services. This network is to take the form of a federated, decentrally organized data space. To this end, the focus is on the development of suitable technology modules. In addition, a central research goal is the creation of an AI-based dynamic planning tool for the real-time planning of networked mobility services. This is intended to reconcile the efficiency requirements in vehicle operation with the needs of road users and goods recipients.

In a first MVD, the consortium is developing a simple arrival time prediction service that is requested via the data space, receives the necessary data for the prediction calculation via sovereign and secure data exchange, and transmits the result to requesting entities. In its final development stage, the service will be an essential building block for the AI-based dynamic planning tool as a smart Estimated Time of Arrival (ETA) service. In terms of exploitation, the service will also be used to demonstrate how services can be made available to new use cases via Gaia-X and used there.

The MVD is implemented on the basis of innovative data space technologies, which are presented in more detail in the following Chapter 3.

[2] The concept of "Smart Managed Freight Fleet" for the ROMS project is described in detail in Heinbach et al. (2022).

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3. Data Space Technologies

Data spaces are built using special data space technologies. The essential terminology in this context is explained in the first section of this chapter. In its implementation, the GAIA-X *4* ROMS research project makes use of the conceptual and, in the future, also the implemented basics of the Gaia-X initiative. A brief introduction is given in the second section of this chapter.

3.1. Data Spaces

This section is intended to provide an initial classification of central concepts in connection with data space technologies to the extent that appears necessary for understanding the following chapters. This is fundamentally subject to further development and concretization in the future. So far, there is no generally accepted definition of the terms, either from a technical or a regulatory perspective. For example, a statement by the Bitkom association on data spaces and data ecosystems points out that the EU Commission and the GAIA-X AISBL, two of the central European players in this context, already define these two terms in different ways (Bitkom, 2022, p.6 f). It is not the purpose of this article to comment on the ongoing discussions about the definitions of the terms or to add a further interpretation. In this respect, a more in-depth analysis of the different definition approaches is not provided here. Only the "commonsense" of the following terms, which are central for the research project GAIA-X *4* ROMS, is given: "data ecosystem", "data space", "federation", "decentralization", "data sovereignty" and "data connector".

A "data ecosystem" is an organizing principle for data that conceives of the interaction between different actors and their environment as an integrated whole. In a technical context, it refers to a set of loosely coupled actors that together form an economic community and create associated benefits (Gaia-x European Association for Data and Cloud AISBL, 2022a, p.7) Data ecosystems use data spaces for sovereign data exchange. (Gaia-x European Association for Data and Cloud AISBL, 2021, p.69)

A "data space" is a concept for rule-based (compliance, terms of use) data exchange between equal participants via IT networks without an intermediary / central node. The International Data Space Association defines the data space technically as a distributed network of data endpoints that enables secure, interoperable data exchange and guarantees data sovereignty (Otto et al., 2019, p. 110).

A "federation" is an organizational form of data ecosystems (and data spaces) in which network participants submit to a commonly defined rule and policy control and enforcement entity for the purpose of orderly service exchange. Federated services provided by federators are intended to enable and facilitate interoperability and portability of resources within and across ecosystems and to ensure data sovereignty. They provide trust between and among participants, make resources searchable, discoverable and consumable, and provide means for data sovereignty in a distributed ecosystem environment (Gaia-x European Association for Data and Cloud AISBL, 2022a, p.8). They thus assume an important role in the data ecosystem. In a data ecosystem, other essential roles are usually found: "Data providers" are entities that have data and are willing to make it available via the data space under defined conditions. Their counterparts are the "data consumers" who want to obtain data from data providers via the data space under defined conditions. Analogous to this pair are the "service providers" and "service consumers" in their interpretation of the term.

The term “decentralization" refers to an organizational principle of networks or organizations that does not require a central, controlling authority for data exchange and service use. Regulation takes place via federation services, or via an (open) "protocol for self-regulation" (Blockchainhub Berlin, 2019).

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The term "data sovereignty" refers to control over (one's own) data and its collection, storage, and processing. In relation to a person, this also refers to the protection of personal data.

"Data connectors" are concrete software components that realize communication in a data space between network nodes / data endpoints in the peer-to-peer principle (P2P). They form a logical link with one or more data applications, which in turn can be located "in the data space". Each component in a connector is able to follow at least some rules of the data space.

The following figure 1 illustrates the interplay of these concepts. The diagram shows a section of a data ecosystem with the essential roles. A data provider and a data consumer exchange data securely and sovereignly peer to peer (P2P) by means of connectors. The data connection between the two connectors form a data space whose rule set is implemented through federation services. To federate the data ecosystem, they also provide other services.

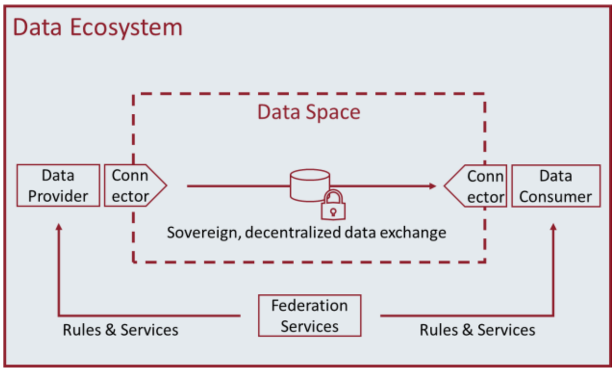

Figure 1 Conceptualizations in the data space schema and their linkage.

Many of these definitions are taken from the concept papers of the Gaia-X initiative, which is important for the GAIA-X *4* ROMS research project, or from its central organization GAIA-X AISBL[3]. The initiative will be briefly introduced in the next section.

3.2. Gaia-X

Gaia-X is a project initiated jointly by Germany and France and now supported by 17 countries from Europe and the world to strengthen European digital sovereignty (Gaia-X European Association for Data and Cloud AISBL, 2022b). Representatives from business, politics and academia are working together to create a federated data infrastructure. Businesses and citizens should be enabled to easily and securely share and aggregate data and derive value from its analysis.[4] At the same time, data owners always retain sovereignty over their data and can themselves define and enforce conditions on how their data can be handled in the data value chain.

The Gaia-X architecture is based on the principle of decentralization and defines a standard for building and operating federated data ecosystems. It takes into account roles of the infrastructure ecosystem as well as the data and services ecosystem, which are connected via federation services (Gaia-X European Association for Data and Cloud AISBL, 2022). The framework currently includes the Gaia-X federation services, a labeling framework for certifying data nodes, terms of use and rules, and the architecture concept. This standard technically translates the common European values of

[3] These specification concepts can be found in their current version at Gaia-x European Association for Data and Cloud AISBL (2022c).

[4] This is also urgently needed, according to the results of a survey conducted by the Bitkom association in May 2022, in which German companies were asked about the degree to which they create data value as part of the development of digital business models. According to the survey, 63% of the companies questioned do not share their data (Streim & Schönwerth, 2022).

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openness, transparency and trust into an innovative data infrastructure. Gaia-X thus does not create a new cloud provider in competition with international hyperscalers. It enables data ecosystems that "meet the highest standards of digital sovereignty and promote innovation" (Gaia-X Hub Germany, 2022). An important effect that can occur when using common standards is the principle interoperability of ecosystems. The interconnection of data ecosystems, or their technical meshing, represents a current field of research. It is shown in Figure 2 below, which illustrates the data ecosystem landscape created by the use of Gaia-X principles.

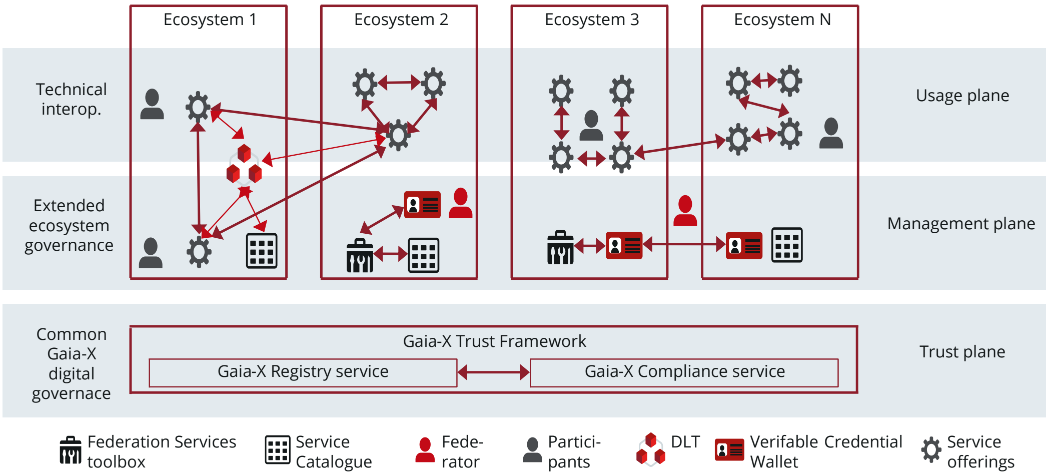

Figure 2 Principle of the Gaia-X ecosystem landscape. Based on Gaia-X European Association for Data and Cloud AISBL, 2022.

How the Gaia-X architecture will be used to implement the use cases in the GAIA-X *4* ROMS research project is the subject of the following Chapter 4, which also discusses the development status of the reference architecture and current challenges.

4. The Minimum Viable Demonstrator GAIA-X *4* ROMS

In the GAIA-X *4* ROMS research project, a minimum viable demonstrator is being designed for the use case of a simple arrival time forecast for vehicle fleet operators and will be implemented by the end of 2022. This demonstrator should already map the essential data space functionalities along the usage process (see Figure 3) and demonstrate the principle functionality of the decentrally organized, secure and sovereign data flow between data providers, a data service and various service consumers. By being integrated into the data space, such a prediction service should have decentralized access to position and destination data of a large number of vehicles, vehicle fleets, and other transportation units across enterprises. This data trains the service AI and, in turn, the service provides an increasingly accurate forecast to the requesting transportation units.

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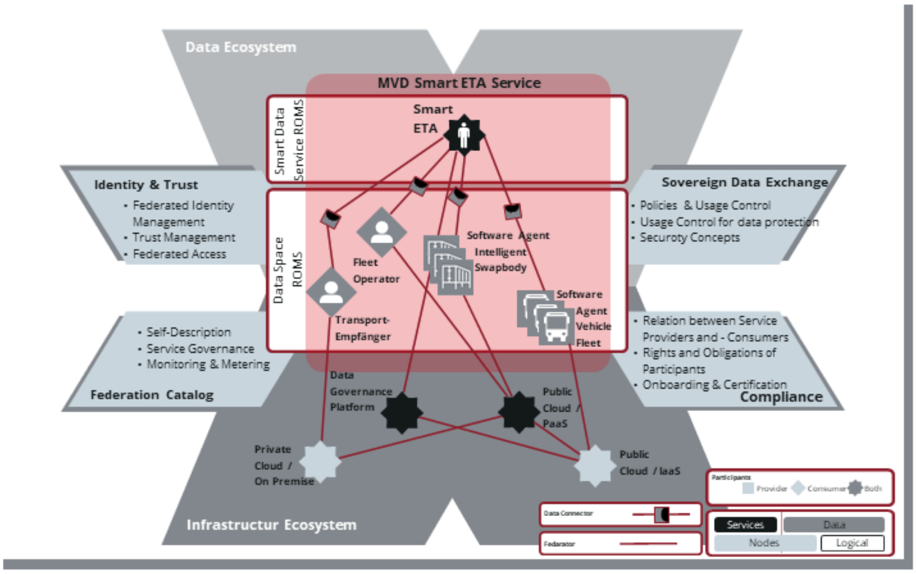

Figure 3 Mobility data space ROMS in the Minimum Viable Demonstrator. Adapted from Gaia-x European Association for Data and Cloud AISBL, 2022a, p.7.

The sequence diagram shown in Figure 4 illustrates the flow in the overall MVD system with the iWT agent, ETA service, trailer gateway and cockpit components.

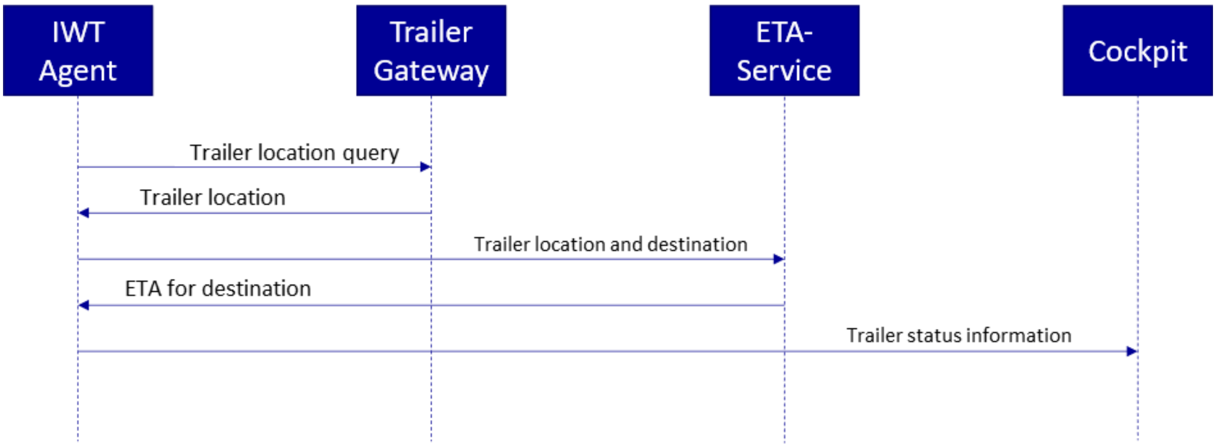

Figure 4 Sequence diagram MVD.

The arrival time prediction service, referred to as Smart ETA in Figure 3, is to process requests in the MVD as follows: It receives a service request via the data space from a software agent in a representative capacity (that is, a conceptually as well as technically extended digital twin) of a vehicle or a connected intelligent swap body and trailer (iWT)[5] connected to the data space. After automatic negotiation of the service and data usage conditions, a data connection is established and the current position and destination data is exchanged between the software agent and the iWT. Then, an appropriately trained AI algorithm evaluates the data and determines a prediction result.

The result is finally fed back to the iWT software agent of the requesting transport unit. In principle, the result can also be made directly available to other authorized requesters, such as transport

[5] A smart swap body is a non-self-propelled, interchangeable transport unit for road transport by truck and trailer. A common format is the 9 foot container. The swap body has extendable and retractable legs. It can be parked separately from the carrier vehicle. This makes the swap body a mobile storage option. For more information, see Warehousing1 (n.d.).

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receivers or fleet operators, via the data space. In the MVD, the software agent transmits the ETA value to a cockpit, where it is displayed as trailer status information in a graphical user interface.

Data exchange between the nodes of the data space is realized via data connectors. Figure 5 shows an example of this mode of operation for obtaining training data. The telematics-supported transport loading units transmit their sensor data to the software agent on request via an interface ("trailer gateway"). As an IT system, this is not necessarily tied to the transport loading units but can also be localized in a cloud environment. In any case, the computationally intensive Smart ETA service uses such a cloud environment. The iWT software agent is connected to the data space via a data connector and in this scenario initially acts as a data provider that can offer and provide a data source. The data consumer here is the Smart ETA service, which wants to use the offered data for training the service.

The connectors of data providers and data consumers automatically negotiate terms of use and control data exchange according to agreement. Data Space Connectors (DSC) based on the specification of the International Data Space Association (IDS) (Fraunhofer ISST, 2021) will be used in the MVD. They will be further developed and used in the mFUND research project Mobility Data Space (Mobility Data Space, 2022b), among others. The DSCs have a graphical user interface, can technically map 21 patterns of different usage policies so far, and have communication capabilities to various IDS components needed to manage data spaces (e.g., logging of communication and contract negotiations, identity management, data merchants).

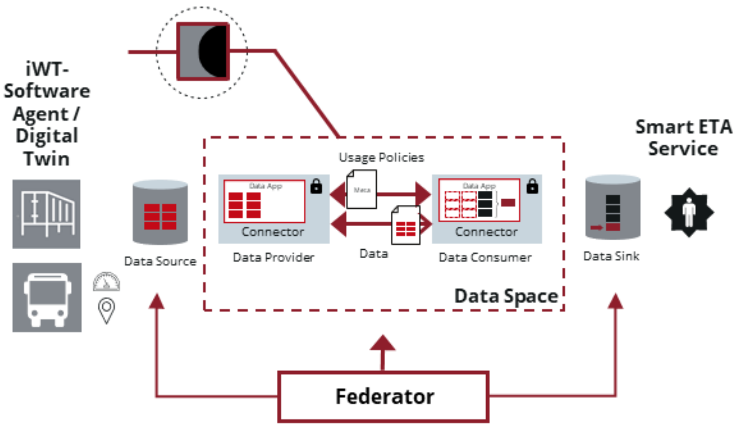

Figure 5 Data connector: Sovereign data exchange via machine-to-machine communication. Adapted from Mobility Data Space, 2022a.

5. Challenges

The consortium is currently working on technology components for data exchange. There are several challenges in the technical implementation of the data space technologies, which will be presented very briefly in this concluding chapter together with an outlook for the research project. The data connectors as well as the federation services will be considered.

The DSC data connector is to be used in the MVD. This is by definition not Gaia-X compliant, among other things because it is not consistently compatible with the conceptualized federation services. Only its successor, the Eclipse Data Space Connector (Eclipse Foundation, n.d.) (EDC) will be. After an initial evaluation in the consortium, however, it was determined that the currently available reference implementations do not yet achieve the range of functions envisioned in the MVD, which is why the DSC will be used for the MVD. In addition, the currently available sample implementations of the terms of use for the connectors are not yet sufficiently complex or combinable for real-world

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applications. Substantial further developments are expected here in the further course of 2022 and the following year. Until then, only very simple conditions of use can be demonstrated, such as an expiration of the data usage release after a defined period. Accordingly, the implementation plans in the research project are limited to less complex conditions of use, but this only slightly restricts the mapping of use cases in the demonstrator. Beyond the MVD, research is being conducted into which technological alternatives exist for protected sovereign data exchange to ensure interoperability between data spaces.

The current implementation status of the Gaia-X Federation Services (gxfs) is like that of the connector technologies. The first reference implementations here were still under development until the end of Q2/2022 and are now starting a first evaluation phase (Gaia-X Federation Services, 2022). This will make them too late for use in the MVD. Alternatively, an implementation of the IDS specification IDS DAPS (International Data Spaces Association, 2022) will be used as an identity and trust server in the MVD for authentication and authorization of the data space nodes and their communication. However, as the project progresses, the successive availability of reference implementations of Gaia-X federation services for Identity & Trust, Federated Catalog, Sovereign Data Exchange, Rule Conformance, and Portal & Integration can then be expected. The implementation project led by eco-Verband der Internetwirtschaft e.V. has announced this for 2022 (Eco, 2022). By September 30, 2024, the end of the GAIA-X *4* ROMS project period, there should thus be a realistic chance to prototypically integrate these reference implementations and evaluate them in the context of the research goals.

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