Data Spaces Business Alliance

Unleashing the Data Economy

BDV BIG DATA VALUE ASSOCIATION

FIWARE FOUNDATION

gaia-x

INTERNATIONAL DATA SPACES ASSOCIATION

Technical Convergence

Discussion Document

Version 2.0

2023-04-21

Table of Contents

Copyright information

Publisher

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https://data-spaces-business-alliance.eu/

Release Notes

The goal of the Data Space Business Alliance is to provide a common view on data spaces including a common technical framework based on the scope of work of the partners and the technical alignment achieved between its members: BDVA/DAIRO, FIWARE Foundation, Gaia-X, IDSA. This is a joint process that must include the acceptance of all members of the different organizations.

Each organization stays autonomous and can at all time take decisions which differ from this document or complement it.

Each organization stays committed to inform the rest of the DSBA members and work on future alignment to improve technical convergence.

Changelog

Version	Date	Description	Editor
1.0	2022-09-21	First public version of the Discussion Paper	See Authors below
1.0.1	2022-09-26	- Adding the Changelog. - Gaia-X is not meant to be a standardization organization (see section 6, 2nd paragraph). Removing the statement.	Pierre Gronlier Sebastian Steinbuss
2.0	2023-04-21	● Restructuring the document to achieve further modularity ● Adding section 2 on the DSBA common vision on Data Spaces ● Adding chapters and sections for pillars of the OpenDEI Building Blocks not addressed in detail before (Data Interoperability and Data Value Creation) ● Adding further description on Data Interoperability and Data Value Creation ● Updating section on Access and Usage Control and include in chapter about Data Sovereignty and Trust pillar ● Further additions and updates	Juanjo Hierro Sebastian Steinbuss Pierre Gronlier

		according to the developments in FIWARE, Gaia-X and IDSA	

1 Introduction

1.1 Background

Data spaces are viewed as key to achieving sovereign, interoperable and trustworthy data-sharing across businesses and societies – a key step to the Data Economy of the future. In September 2021, the Big Data Value Association (BDVA), FIWARE Foundation, Gaia-X and the International Data Spaces Association (IDSA) decided to join forces and formed the **Data Spaces Business Alliance (DSBA)** aimed at driving the adoption of data spaces across Europe and beyond.

Members of the DSBA came with a 100-days Implementation Plan that is described in the following picture.

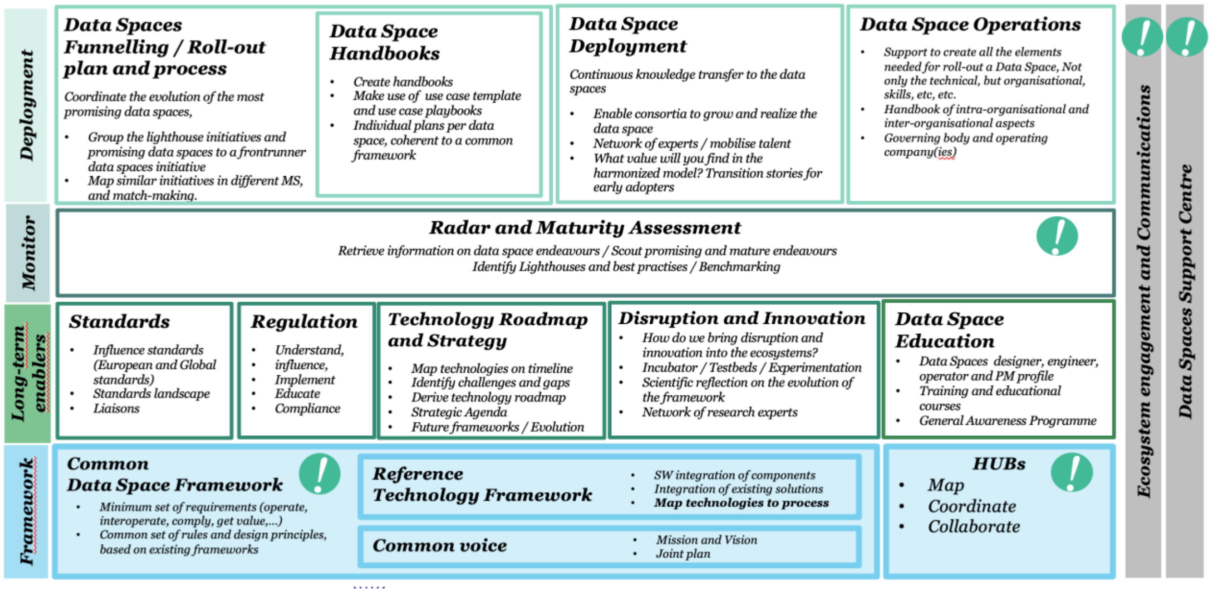

Deployment
Data Spaces Funnelling / Roll-out plan and process
Coordinate the evolution of the most promising data spaces,
• Group the lighthouse initiatives and promising data spaces to a frontrunner data spaces initiative
• Map similar initiatives in different MS, and match-making.
Data Space Handbooks
• Create handbooks
• Make use of use case template and use case playbooks
• Individual plans per data space, coherent to a common framework
Data Space Deployment
Continuous knowledge transfer to the data spaces
• Enable consortia to grow and realize the data space
• Network of experts / mobilise talent
• What value will you find in the harmonized model? Transition stories for early adopters
Data Space Operations
• Support to create all the elements needed for roll-out a Data Space, Not only the technical, but organisational, skills, etc, etc.
• Handbook of intra-organisational and inter-organisational aspects
• Governing body and operating company(ies)
Monitor
Radar and Maturity Assessment
Retrieve information on data space endeavours / Scout promising and mature endeavours
Identify Lighthouses and best practises / Benchmarking
Long-term enablers
Standards
• Influence standards (European and Global standards)
• Standards landscape
• Liaisons
Regulation
• Understand,
• influence,
• Implement
• Educate
• Compliance
Technology Roadmap and Strategy
• Map technologies on timeline
• Identify challenges and gaps
• Derive technology roadmap
• Strategic Agenda
• Future frameworks / Evolution
Disruption and Innovation
• How do we bring disruption and innovation into the ecosystems?
• Incubator / Testbeds / Experimentation
• Scientific reflection on the evolution of the framework
• Network of research experts
Data Space Education
• Data Spaces designer, engineer, operator and PM profile
• Training and educational courses
• General Awareness Programme
Framework
Common Data Space Framework
• Minimum set of requirements (operate, interoperate, comply, get value,...)
• Common set of rules and design principles, based on existing frameworks
Reference Technology Framework
• SW integration of components
• Integration of existing solutions
• Map technologies to process
Common voice
• Mission and Vision
• Joint plan
HUBs
• Map
• Coordinate
• Collaborate
Ecosystem engagement and Communications
Data Spaces Support Centre

Figure 1.1 DSBA 100-days Implementation Plan

As part of this plan, members of the DSBA agreed to work towards defining a common reference technology framework, based on the technical convergence of existing architectures and models, leveraging each other’s efforts on specifications and implementations. The goal was to achieve interoperability and portability of solutions across data spaces, by harmonizing technology components and other elements.

1.2 Implementation-driven Plan

In order to materialize the desired technical convergence, an implementation-driven plan is proposed around evolution through subsequent versions of a Minimum Viable Framework (MVF) enabling creation of data spaces.

A first version of the MVF was the result of a first workstream (**workstream 1**) targeted to provide a minimum set of building blocks required to cover the three major technology pillars for creation of data spaces:

- **Data Interoperability**: NGSI-LD API and smart data models for actual data exchange, extending the interoperability mechanisms of the IDS-RAM with a special focus on the IDS-Infomodel and the Vocabulary Hub.
- **Data Sovereignty and Trust**:
  - An eIDAS and EBSI -compatible Trust Anchor framework

- A decentralized Identity and Access Management (IAM) framework based on:
    - A set of Verifiable Credential issuing protocols (OpenID Connect for Verifiable Credential Issuance, Self-Issued OpenID Provider v2 (SIOPv2), via DIDComm channel, etc)
    - A set of verifiable presentation protocols (ex: OpenID Connect for Verifiable Presentations (OIDC4VP), Presentation Exchange, etc)
    - An ABAC (Attribute Based Access Control) framework based on Verifiable Credentials, comprising components implementing PEP, PDP, PAP/PMP, and PIP functions
- **Data value creation**: Centralized Service Catalogue and Marketplace functions based on TM Forum standards

Note this first version of the MVF was just a starting point: a number of parallel workstreams have been proposed addressing concrete topics that are relevant to achieve a technical convergence:

- **Workstream 2**: Incorporation of IDS Connector functions and support to ODRL for the definition of access/usage control policies
- **Workstream 3**: Shared Catalogue and Federated Marketplace services based on TM Forum standards and aligned with Gaia-X and IDS RAM specifications
- **Workstream 4**: Incorporation of additional IDS architectural elements for usage control

Once significant alignment within a given workstream is achieved, a new version of this Technology Convergence document will be published mapping to a new version of the MVF and enabling implementations of such MVF to be started.

1.3 How to read this document

A mention to the Glossary can be added. We will be working on a separate Glossary document which will then be added when completed as annex to this one.

2 Common vision on Data Spaces

2.1 Overview

A data space can be defined as a data ecosystem built around commonly agreed building blocks enabling an effective and trusted sharing of data among participants for the creation of value.

Just like other technology infrastructures (e.g. the world wide web), data spaces basically are sector-agnostic, with many requirements and functions being similar or even identical across different sectors and data spaces. Therefore, creating the basis for data spaces primarily is not so much a technological challenge, as there are plenty of technical solutions and standards available. The main challenge towards interoperable data spaces is to agree on building blocks and design principles that are accepted by all participants.

Interoperability is a key concern in data spaces because, simply put, nothing works without it. Further, interoperability can be addressed on multiple levels. The New European Interoperability Framework defines an interoperability model with four layers of interoperability: technical, semantic, organizational and legal.

Technical and semantic interoperability are covered by technology building blocks. Legal interoperability and organizational interoperability can be achieved by the Policies and Rules of a specific dataspace instance and are typically managed by a dataspace governance authority.

In addition to the new European Interoperability Framework, which is applicable to all digital public services, ISO/IEC 21823-1:2019 introduces a five-facet model specifically for IoT systems and ISO/IEC 19941:2017 (E) for Cloud Computing systems technical interoperability: transport, syntactic, semantic, behavioral and policy interoperability. Although they use slightly different names, both frameworks address very similar concepts.

Figure 2.1 depicts a taxonomy of building blocks based on the one identified in the white paper Design Principles for Data Spaces that resulted from a collaborative effort involving 40+ experts from 25+ companies under the coordination of the Open DEI project.

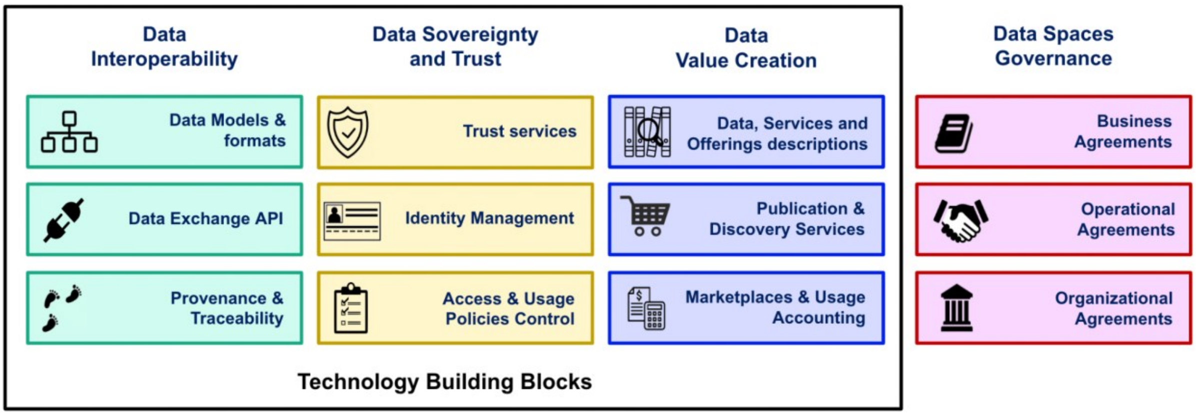

Data Interoperability
Data Sovereignty and Trust
Data Value Creation
Data Spaces Governance
Data Models & formats
Trust services
Data, Services and Offerings descriptions
Business Agreements
Data Exchange API
Identity Management
Publication & Discovery Services
Operational Agreements
Provenance & Traceability
Access & Usage Policies Control
Marketplaces & Usage Accounting
Organizational Agreements
Technology Building Blocks

Figure 2.1 (modified from the OpenDEI Design principles for Data Spaces)

As shown in the figure, a number of technology building blocks are required to materialize data spaces ensuring:

- **Data interoperability** - Data spaces should provide a solid framework for an efficient exchange of data among participants, supporting full decoupling of data service providers and consumers. This requires the adoption of a "common lingua" every participant uses, materialized in the adoption of common APIs for the data exchange, and the definition of common data models. Common mechanisms for traceability of data exchange transactions and data provenance, are also required.
- **Data Sovereignty and trust** - Data spaces should bring technical means for guaranteeing that participants in a data space can trust each other and exercise sovereignty over the data they share. This requires the adoption of common standards for managing the identity of participants, the verification of their truthfulness and the enforcement of policies agreed upon data access and usage control.
- **Data value creation** - Data spaces should provide support for the creation of multi-sided markets where participants can generate value out of sharing data (i.e., creating data value chains). This requires the adoption of common means for the description of terms and conditions (including pricing) linked to data

services and data service offerings, the publication and discovery of such offerings and the accountability of all the steps during the lifecycle of contracts established when a given participant acquires the rights to access and use a given data service.

Besides the adoption of a common technology foundation, data spaces also require a number of **governance building blocks**, matching a number of business, operational and organizational agreements among participants. Business agreements, for example, specify what kind of terms and conditions can regulate the sharing of data between participants and the legal framework supporting contracts established through the data space. Operational agreements, on the other hand, regulate policies that have to be enforced during data space operation like, for example, compliance with GDPR (General Data Protection Regulation) or or the 2nd Payment Services Directive (PSD2) in the finance sector. They may also comprise the definition of tools that operators of cloud infrastructures or global services supporting data spaces must implement, enabling auditing of certain processes or the adoption of cyber-security practices. Last but not least, organizational agreements establish the governance bodies (very much like ICANN for the Internet). They deal with the identification of concrete specifications that products implementing technology building blocks in a data space should comply with, as well as the business and operational agreements to be adopted.

Despite the mentioned Open DEI white paper represents a major milestone in the right direction, the description of technology building blocks provided in that white paper is still too high level. Interoperable data spaces require the selection of very concrete de jure or industry standards, filling standardization gaps when needed and specifying how standards can be used together. When the Big Data Value Association (BDVA), FIWARE Foundation, Gaia-X and the International Data Space Association (IDSA) launched the Data Spaces Business Alliance (DSBA) one of the main goals was to join forces towards the definition of a common reference technology framework tackling these aspects, thus helping to make data spaces happen. A later version of this document may extend to define a common policy framework.

2.2 Systems Architecture view

The taxonomy of building blocks shown in Figure 2.1 is purely functional. Complementing it, a common reference technology framework needs to identify what kind of systems have to be instantiated in a data space and who operates them. In this respect, we have to distinguish two perspectives. First, the overall data space perspective, which translates into the kind of systems that are required or may exist at overall data space level. Second, the perspective of a participant joining the data space, which translates into the kind of systems it has to instantiate and operate in order to participate into the data space.

The figure 2.2 below provides an overview how the Building Blocks from figure 2.1 can be mapped to a systems architecture view provided in the remainder of this section. However, this mapping cannot be conducted on this perspective exactly and some aspects require further elaboration. The section 3, 4, and 5 provide a detailed view on this. The Data Space Connectors act as agents on behalf of a participant in a data space and realize parts of the nine building blocks. The building blocks for Data Sovereignty and Trust, as well as the building blocks for Data Value Creation are supported by other roles in the ecosystem by Federated Services. A special focus lies on the Trust Services, which realize the Data Space Registry provided by a Data Space Authority.

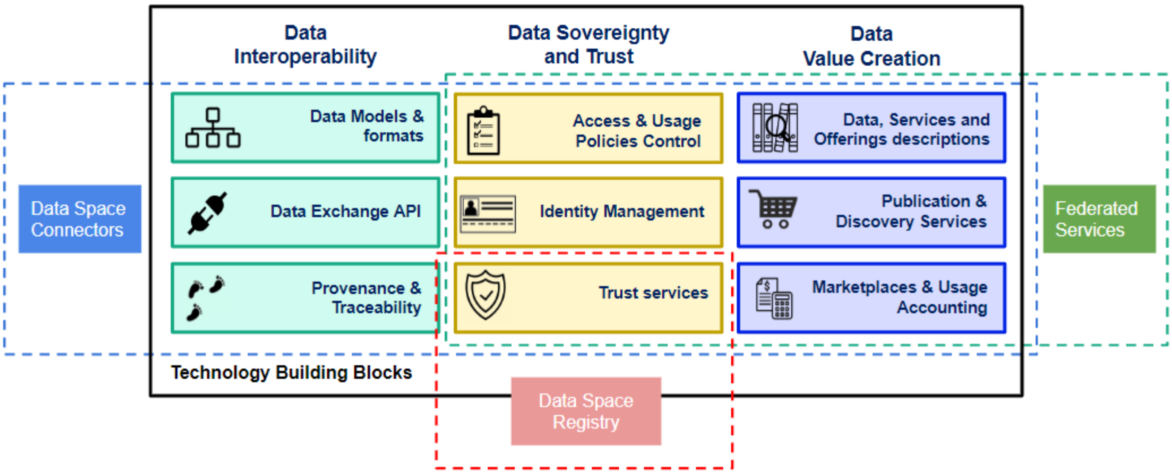

Data Interoperability
Data Sovereignty and Trust
Data Value Creation
Data Models & formats
Access & Usage Policies Control
Data, Services and Offerings descriptions
Data Space Connectors
Data Exchange API
Identity Management
Publication & Discovery Services
Federated Services
Provenance & Traceability
Trust services
Marketplaces & Usage Accounting
Technology Building Blocks
Data Space Registry

Figure 2.2

Figure 2.3 illustrates main actors involved in a data space and the systems they have to instantiate and operate. Following subsections provide a high-level description of those systems.

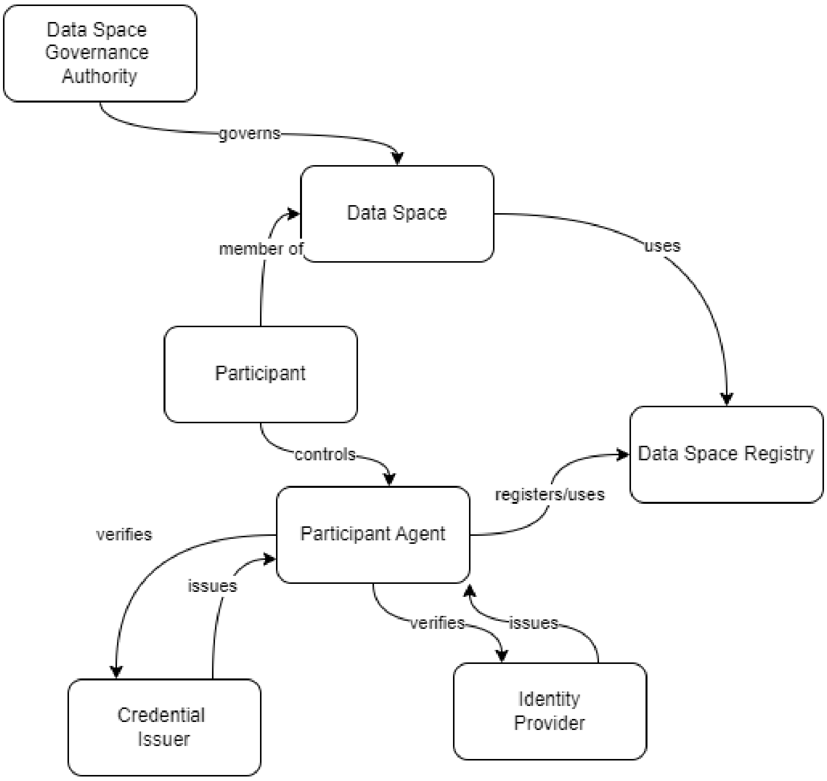


Figure 2.3 Data Space Actors and Systems

2.2.1 Data Space Registry

The Data Space governance authority defines the rules for a data space and therefore provides the governance of a data space. To do so, it makes use of a Data Space Registry, which manages the registration of participants in a data space based on the rules given.

To enable cross data space interoperability as defined in ISO/IEC 21823-1:2019, a common governance and rules should be adopted by the Data Space governance authorities with the use of a common meta registry such as the Gaia-X Registry.

The Data Space registry can be realized as a public or private registry and may make use of different measures to realize itself and the mechanisms for the identification of trusted participants. In the DSBA Reference Technology Framework such identification relies on the use of Verifiable Credentials (VCs) issued by Trusted Issuers registered in, or accredited via, the Data Space Registry. As described in the IDSA Rulebook, typical models are:

- Centralized approaches,
- Decentralized approaches, or

- Federated approaches

The creation of a decentralized approach is described in the remainder of the document. A centralized approach is used in the current IDS-RAM. Gaia-X shall provide means for the setup of the 3 options available.

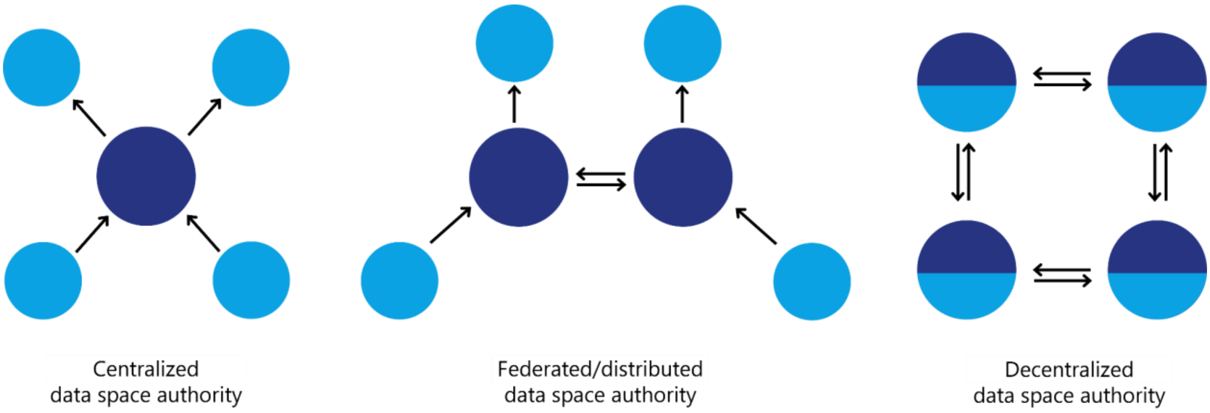


Figure 2.4 Models for the creation of a data space authority

2.2.2 Data Space Connectors

A data space participant is a legal or natural person being responsible and liable for its role in the data space. To participate as a data service provider, consumer or both, a participant makes use of a system in the combination of hardware and software acting as an agent in the data space. This agent is referred to as Data Space Connector, which realizes standardized interfaces and behaviour for each and every transaction. The interaction shall make use of standards as much as possible to achieve interoperability and one of the goals of the DSBA Technology Converge is to agree on a common set of such standards.

The Dataspace Protocol family is a set of specifications designed to facilitate interoperable data sharing between participants of data spaces, governed by usage control and based on Web technologies. The Dataspace Protocol family defined by IDSA brings the foundation for it even though there are still elements to be completely specified.

More specifically, the Dataspace Protocol family defines how:

1. Data services offered by the participant running a Data Space Connector can be made available as DCAT Catalogs.
2. Rights to use a data service can be acquired (i.e., the data service is procured)
3. Policies that govern data usage are syntactically expressed in ODRL and electronically negotiated via a Contract Negotiation Protocol.

4. Data services are accessed using data transfer API/protocols and how interaction using those APIs/protocols can be governed using a Data Transfer Control Protocol.
5. Transfer API/protocols usage logs are generated for each transaction, enabling monitoring and accounting of data services

The Dataspace Protocol family builds on protocols located in the ISO OSI model (ISO/IEC 7498-1:1994) layers, like HTTPS. The purpose of the Data Space Connector Protocol is to define interactions between Data Space Connectors independent of such protocols, but describing how to implement it in an unambiguous and extensible way. To do so, the messages that are exchanged during the process are described in the Data Space Connector Protocol specification and the states and their transitions are specified as state machines, based on the key terms and concepts of a data space. On this foundation the binding to data transfer protocols, like HTTPS, is described.

The Dataspace Protocol family specification does not cover the data transfer process as such. While the data transfer is controlled by the Transfer Process Protocol mentioned above, the data transfer itself and especially the handling of technical exceptions is an obligation to the Transfer API/Protocol. As an implication, the data transfer can be conducted in a separated process if required, as long as this process is to the specified extent controlled by the Transfer Process Protocol.

2.2.3 Data Space Federated Services

Optionally, a number of services may exist at global level within data spaces. Examples of such services are:

- Catalogue Services, supporting the registration of data services and data service offerings descriptions provided by participants in the data space, as well as navigation and discovery functions through registered descriptions.
- Marketplace services, often defined as an extension of Catalogue Services adding functions for managing the procurement, payment and billing of data services.
- Metadata Broker Services, typically as alternative to global Catalogue Services, supporting global searching of data services and data service offerings based on discovery/crawling and indexing functions they implement.

Note that these services may be offered by operators acting at overall data space level or may be fully decentralized based on P2P functions supported at data connectors level. Global operators of these services may be bound or not to the governance authority of the data space.

2.3 Conceptual model

2.3.1 Description of main entities and their relationships

The following picture shows main entities in the conceptual model underlying data spaces and the relationships among them. This conceptual model comes as a result of reconciling elements of the vision in Gaia-X, IDS RAM and FIWARE. Concepts linked to catalog and marketplace services are, in turn, aligned with TM Forum recommendations.

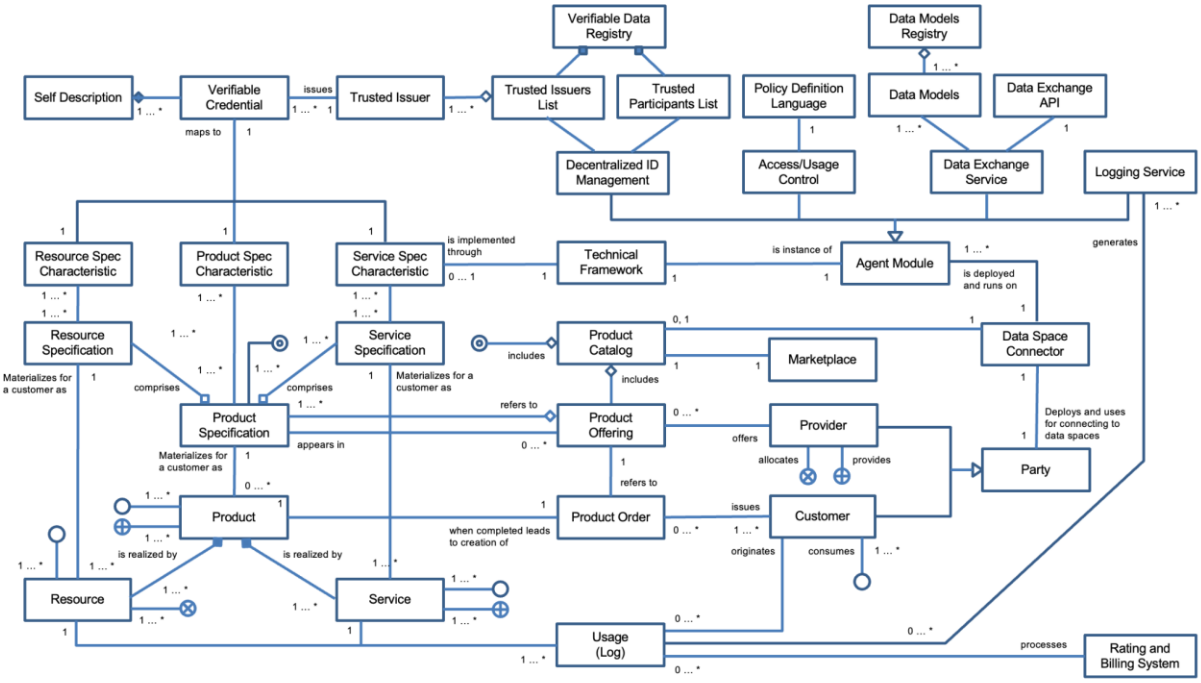


Figure 2.5 Data Spaces Conceptual Model

Following is a description of the figure above:

- A **Party** (or **Participant**) of the Data Space can play the role of a **Provider** or **Customer** (or **Consumer**) of **(Data) Products**. Parties of a Data Space are registered in the **Trusted Participant List** (in any means) that is part of the **Verifiable Data Registry (Dataspace Registry)** associated with the Data Space.
- A **(Data) Product** is realized as a combination of **Services** and/or **Resources** that are provisioned and activated for a particular Customer, Resources being typically required for the execution of the Services. As an example consider an Air Quality Monitoring Application as a Data Product. It comprises a number of

Services (e.g., web portal, set of RESTful API endpoints, etc) and Resources (e.g., not only computing resources required for executing the Application for the customer but for this example, the Air Quality Monitoring IoT devices that need to be deployed on the Customer premises).

- A **(Data) Product Specification** has name, version, description and other attributes including the set of characteristics that complying Data Products have. Besides, a Data Product Specification comprises a set of **Service Specifications** and **Resource Specifications**. Similarly, a Service/Resource Specification has name, version, description and other attributes including a set of characteristics that complying Services/Resources have.
- A concrete (Data) Product gets created (provisioned and activated) when a **(Data) Product Offering** published by a Provider is procured by a Customer, which means a **Product Order** was issued to the Provider by the Customer and the order got successfully completed. Note that completion of a Product Order is not always instantaneous but may take days. Continuing with the example of the Air Quality Monitoring Application, completion of the Procurement Order requires that the Air Quality Monitoring IoT devices are successfully deployed in the field and connected to backend services.
- A given (Data) Product Specification comprises several **Product Specification Characteristics**. Among them we may find certificates issued by trusted certification agencies that are registered in the **Trusted Issuer List** that is in the **Dataspace Registry** of the Data Space. Other characteristics correspond to self-attested characteristics. In all the cases, each of these Product Specification Characteristics get mapped into a **Verifiable Credential**.
- A given Service Specification, in turn, comprises a number of **Service Specification Characteristics**. Among them, there may be characteristics associated with the **Technical Frameworks** that services complying with that specification will instantiate. This information is very relevant for Customers to understand how interoperability with the Service can be achieved. Thus, among the characteristics of a given Service Specification we consider the Technical Framework used for **Data Exchange**, which in turn defines the APIs used for Data Exchange with the Service and the Data Models describing what to exchange about, the Technical Framework used for **Identity Management**, the Technical Framework used for **Access and Usage Control** or the Technical Framework implementing a **Logging Service** that will generate Usage logs. These and other Service Specification Characteristics get mapped into Verifiable Credentials. The Access and Usage Control Technical Framework characteristic of a Service enforces access and usage policies defined based on a concrete Policy Definition Language.

- Similarly, a Resource Specification may comprise a number of **Resource Specification Characteristics**. Continuing with the example, the IoT devices required to be installed for an Air Quality Monitoring application may have several characteristics, some of them corresponding to certificates the IoT device has to comply with, including support to specific protocols. Same as with Product Specification Characteristics and Service Specifications Characteristics, Resource Specifications Characteristics get mapped into Verifiable Credentials.
- The combination of Verifiable Credentials associated to characteristics of a (Data) Product, Service or Resource get the form of a **Verifiable Presentation** also referred as **Self-Description**.
- Providers and Customers connect to a Data Space through **Data Space Connectors**. The Data Space Connector associated with a given Product Provider or Customer brings a controlled execution environment where the **Agent Modules** instantiating the Technical Frameworks required to access Services associated to the Product are instantiated and run.
- Each time a Product, Resource or Service is used, a **Usage Log** should be created, which typically is used to calculate how much can be charged to Customers and paid to Providers or conduct audit logging for data transactions including provenance tracking. In the former case, calculation is performed by a **Rating and Billing System** which processes Usage Logs.
- (Data) Product Specifications and (Data) Product Offerings are published through **(Data) Product Catalogs**. There may exist **Marketplace Services** running in a Data Space each of which manage a Data Product Catalog comprising Data Specifications and Data Product Offerings from multiple Providers. Those Marketplaces Services help Customers to discover available Data Products and support the procurement process as well as monetization of Data Products. However, a given Provider may instantiate and operate a Data Product Catalog for its own Products, also taking direct care of the management of Procurement Orders. Those would be functions that may be additionally managed under the scope of its corresponding Data Space Connector.

The architecture coherence within the DSBA is ongoing work and some terms and definitions are not completely aligned. The following table shall provide an overview on the used terms and definitions.

FIWARE/TMForum	Gaia-X	IDSA
Party	Participant	Participant
Provider	Provider	Data Provider
Customer	Consumer	Data Consumer
Data Product (comprises resource and services)	Resource & Services	Data Asset
Trusted Participant List		IDS-DAPS + IDS-ParIS
(Data) Product Specification	Gaia-X Schema	IDS-Information Model + Vocabulary
(Data) Product Offering	Service Offering	Part of Self-Description
(Data) Product Catalogs.	Federated Catalogue	IDS-Meta-Data-Broker
Service Specification Characteristics.	Gaia-X Credentials (formerly known as Self-Description)	Connector Self Description
Logging Service	Data Exchange Services	Observability/Clearing House

2.3.2 Detailed Information Model

The detailed description of attributes and relationships of entities part of the Conceptual Model described here will map to the Information Model that serves as the domain-agnostic, common language of Data Spaces. As with the high-level conceptual model, this Information Model will come as a result of reconciling elements of the vision in Gaia-X, IDS RAM and FIWARE, taking TM Forum recommendations with regard to catalog and marketplace services.

The Information Model is an essential agreement shared by the participants and components of a Data Space, facilitating compatibility and interoperability. The primary purpose of this formal model will be to enable (semi-)automated exchange of digital resources within a trusted ecosystem of distributed parties, while preserving data sovereignty of Data Owners. The Information Model therefore will support the description, publication and identification of data products and reusable data processing software. Once the relevant Data Products are identified, they can be exchanged and consumed via easily discoverable services. Apart from this, the

Information Model describes essential constituents of the Data Spaces, its participants, its infrastructure components, and its processes.

The Information Model will be a generic model, with no commitment to any particular domain. Domain modeling is delegated to shared vocabularies and data schemata, as provided, e.g., by domain-specific communities of the International Data Spaces. The Information Model does not provide a meta-model for defining custom datatypes comparable to standards such as OData or OPC-UA. Concerns beyond the scope of modeling Digital Resources and their interchange are considered out of scope. The Information Model therefore does not deal with the side effects of data exchange (e.g., in scenarios in which data is used for time-critical machine operations). Capturing extensions of the IDS Information model is described in the IDS Vocabulary Hub.

The following picture illustrates the interaction between a Consumer (Customer) and a service linked to a Data Product it has gained the rights to use. This interaction may be based on a request/response or a subscription/notification model of interaction, in which the customer and service provider play the role of data provider and data consumers alternatively. While the components requesting, providing and consuming data through dataspaces may make use of different technologies, a dataspace connector supports the interaction for all parties by providing basic means for the connection. Those are fundamental operations for data asset publication and contract negotiations and utilizing both aspects, also the data exchange making use of appropriate measures. During the whole data transaction, the data subject, or the person/organization in charge of the data shall keep the control of the data by specifying access and usage policies, which needs to be respected by both parties and beyond. The data exchange may utilize third party value adding services, which must respect the policies adhered to the data to achieve data sovereignty. By such means, a certain degree of interoperability and data sovereignty/ control over the data is achieved. To achieve full interoperability further means are required(see subsequent section).

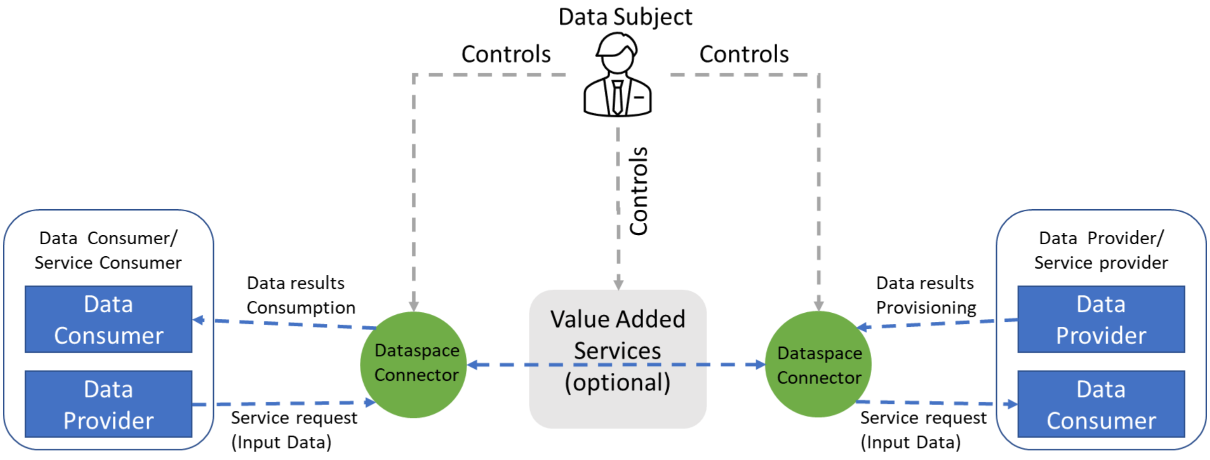

Data Subject
Controls
Controls
Controls
Data Consumer/ Service Consumer
Data Consumer
Data Provider
Data results Consumption
Service request (Input Data)
Dataspace Connector
Value Added Services (optional)
Dataspace Connector
Data results Provisioning
Service request (Input Data)
Data Provider/ Service provider
Data Provider
Data Consumer

Figure 2.6 Interaction between Provider and Consumers

2.3.3 Vocabulary Hub

The IDS-RAM provides a comprehensive view of the structure and the concepts in a Data Space. Using a layered approach, the different concepts are described.

The ecosystem of the IDS comprises several basic tasks being carried out by the various participants as described in the IDS-Reference-Architecture Model. The set of these tasks can be derived from relevant objects in the IDS and the activities along the respective life cycle. Among those objects are the Vocabularies, which are ontologies, reference data models, or metadata elements that can be used to annotate and describe datasets, usage policies, apps, services data sources etc.

The Vocabulary Intermediary technically manages and offers vocabularies (i.e. ontologies, reference data models, or metadata elements). The Vocabulary Intermediary typically assumes the basis roles of the Vocabulary Publisher and Vocabulary Provider. Vocabularies are owned and governed by the according Standardization Organization.

Vocabularies can be used to annotate and describe data assets. These data assets may comprise at least:

- Information Model of Data Spaces, which is the basis for the description of data sources and other elements of the architecture.
- Domain-specific vocabularies which are essential for the interoperability within the data space and, therefore, its overall success. Domains are e.g. represented in the very common set of linked open data

- Legal terms: To describe usage policies and to enable smart contracting, legal terms must be coded in a machine-readable and -understandable manner. For example, the Open Digital Rights Language (ODRL) to describe usage policies. Still, Data Space communities such as a (closed) supply chain network or a domain-specific Data Space initiatives could define additional (complementary or alternative) vocabularies, e.g. depict the International Commercial Terms (Incoterms) as an ontology.

There is no dedicated or exclusive role that creates vocabularies. Usually, standardization organizations such as ISO, EN, IEEE etc., but also industrial associations define standards that can be formulated as a vocabulary (Vocabulary Creators and Owners). Except the Data Space information model, there can be multiple vocabularies describing the same context (e.g. different types of smart contracts or usage policy descriptions). A single vocabulary for the same context supports standardization and, thus, compatibility efforts. Multiple vocabularies provide flexibility and competitiveness.

In specific Data Space ecosystems, domain-specific adaptations – also known as Application Profiles – of the Information Model may be used to describe Resources, Participants, infrastructure and other constituents of a Data Space.

Further, independent domain-specific Vocabularies, which are not necessarily derived from the Data Space Information Model, may be used to describe, for example, the data a given data service is able to process and publish.

The Vocabulary Hub in Data Spaces addresses, as described above, the need for managing vocabularies during the life cycle. From the perspective of a data provider and a data consumer, two phases should be distinguished, the Design Phase and the Runtime Phase.

During the creation of the Data Offering the Data Provider may reuse, as described above, existing standards for the (semantic) description of the data itself or create a (semantic) description of the data. These Vocabularies can be published to a Vocabulary Hub and linked to the self-description. This Design-time step supports the semantic interoperability in Data Spaces. While semantic models for the description of data in data spaces are in general a good practice, Vocabularies can also make use of other concepts.

A Metadata Broker does not serve Vocabularies but provides a reference to a vocabulary and, if required, a reference to a Vocabulary Hub, included in the Self-Description during Runtime when a connector is searching for a data provider or a data set. The Data Consumers connector may verify if the data is provided by using a vocabulary that is consumable by the connector, when querying a Metadata Broker or when querying the Self-Description directly from a Data Providers Connector. If the data is not provided in a consumable way, the connector may:

- request the data in a different format from the data provider or search and invoke another service that can conduct a transformation of the data according to another data scheme,
- implement the required structures (interfaces) to consume the data. As this could be a manual task to implement the required interfaces or code fragments, this could be a time-consuming task, or
- choose a different data provider, which provides the required data in a schema and format that is usable by the data consumer.

When a Vocabulary related to the data is provided by Data Provider, the Data Consumer may validate the provided schema by reasonable means before initiating the contract negotiation.

The detailed description of the technical processes are part of the IDS-RAM section 3.4.

2.4 Positioning of DSBA organizations

The organizations of the Data Space Business Alliance DSBA joined forces with the goal to provide one common technology framework for data space, as the four of them provide different key capabilities for a common framework:

- BDVA: knowledge and general understanding for data usage
- FIWARE Foundation: components for digital twin data exchange, decentralized IAM relying on existing trust frameworks, and data services publication/trading
- Gaia-X: Global cross-dataspace governance based on European values
- IDSA: Data Space Connectors, Usage Contract Negotiation, and general creation of a data space

It is worth pointing out that Gaia-X and IDSA main mission is to produce specifications as well as tools and procedures for testing compliance of products with those specifications. FIWARE Foundation, together with its members, aims at influencing development of specifications in relevant bodies and fostering their fast adoption in the market following an open source implementation driven approach. Two of these bodies are precisely Gaia-X and IDSA, hence, the FIWARE Foundation is actively involved in Gaia-X and IDSA Working Groups besides other industry bodies (e.g., ETSI, TM Forum).

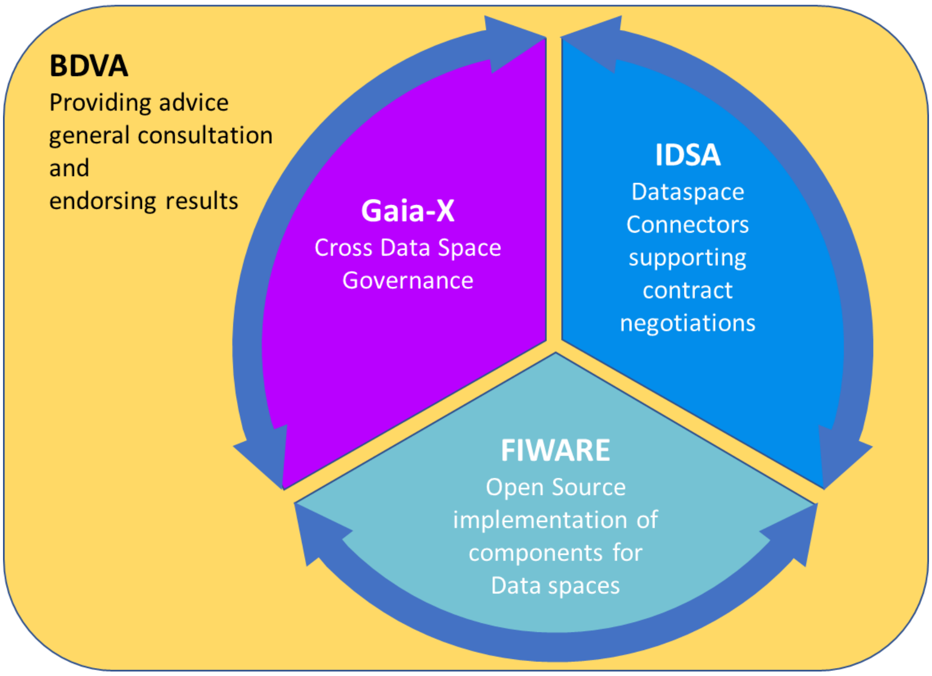

BDVA
Providing advice general consultation and endorsing results
Gaia-X
Cross Data Space Governance
IDSA
Dataspace Connectors supporting contract negotiations
FIWARE
Open Source implementation of components for Data spaces

Figure 2.7 Core contributions of the DSBA organizations to the common framework

2.4.1 Big Data Value Association (BDVA)

The Big Data Value Association (BDVA) is an industry-driven organisation with a mission to develop an innovation ecosystem that enables the data-driven digital transformation of the economy and society in Europe.

BDVA has over 240 members all over Europe and a well-balanced composition of large, small, and medium-sized industries as well as research and user organizations. It focuses on advancing in areas such as big data technologies and services, data platforms and data spaces, Industrial AI, data-driven value creation, standardisation, and skills. BDVA has been the private side of the H2020 partnership Big Data Value cPPP, it is a private member of the EuroHPC JU and is also one of the founding members of the AI, Data and Robotics Partnership.

In the BDVA Task forces, members contribute to the European data, and AI R&I agenda and develop guidelines and strategic roadmaps for industry and policymakers. Events give opportunities to build collaborations and co-create projects. Through the BDVA community, the members gain higher visibility on the European level. BDVA services are designed to give timely updates on all the latest developments in the fields of data and AI.

BDVA is an open and inclusive community and is always eager to accept new members who share these ambitious objectives. These include Data Users, Data Providers, Data Technology Providers and Researchers. BDVA enables existing regional multi-partner cooperation, to collaborate at European level through the provision of tools and knowhow to support the co-creation, development and experimentation of pan-European data-driven applications and services, and know-how exchange.

BDVA is generally technology agnostic and has not as a mission to produce concrete architecture reference specifications nor drive any implementation initiative, therefore their role in this technology convergence activity is focused in providing advice, general consultation and endorsing results.

2.4.2 FIWARE Foundation

FIWARE Foundation, together with its members, aims at driving the definition, and fostering the market adoption, of open platform standards required for the creation of smart solutions in multiple sectors. It does so by following an open source implementation-driven approach, contributing to standard specifications the experience gained implementing compliant products as well as integrating with other standards or widely adopted open source technologies.

FIWARE Foundation does not intend to be an industry specification body but contribute, together with its members, to the development, integration and fast-adoption in the market of relevant specifications from different industry bodies.

Thus, together with some of its members, FIWARE Foundation has driven the definition in ETSI of the NGSI-LD API for managing access to digital twin data. FIWARE Foundation also plays a coordination role in the Smart Data Models initiative (see website and github). Both NGSI-LD and Smart Data Models are considered core building blocks addressing digital twin data interoperability within data spaces.

The FIWARE Community has also driven the implementation of components to be deployed by participants of a data space which implement an decentralized Identity and Access Management (IAM) framework that complies with Self-Sovereign Identity standards from W3C (DID, VC/VP) and OIDC (SIOPv2, OID4VP, OID4VCI) and may rely on Gaia-X compliant trust frameworks. It has also implemented components based on TM Forum Open APIs for the trading of data services which can be described in compliance with Gaia-X specifications (self-descriptions) or components enabling data publication based on DCAT standards. These components may be the basis for creating data space connectors as well as global catalogs and marketplace services.

2.4.3 Gaia-X

Gaia-X defines a common Governance with specific rules to connect the Data and Infrastructure Ecosystems and relies on 3 conceptual pillars to achieve that:

1. Gaia-X Compliance: Decentralized services to enable via a common shared governance a objective and measurable trust
2. Data Spaces / Federations: Interoperable & portable (Cross-) Sector datasets and services
3. Data Exchange: Anchored contract rules for access and data usage

The framework constituted by three deliverable types – functional specifications, technical specifications, code – under the three pillars – Compliance, Federation, Data Exchange – is generally referred to as the Gaia-X Framework.

The operationalisation of the Gaia-X Framework is done via the GXDCH (Gaia-X Digital Clearing House) – the one-stop place to go and get verified against the Gaia-X rules to obtain compliance in an automated way. The operationalisation of this shared governance is required to enable cross-dataspace interoperability. The technical interoperability not enforced by this shared governance is achieved by other means described by the DSBA in this document.

2.4.4 International Data Spaces Association (IDSA)

The vision of IDSA as a member driven organization, is to create the environment for trusted data exchange taking place through federated, international data spaces that are globally certified. IDS-certified products, services and systems open the door to a data economy in which businesses can share data up and down the value chain without security concerns. The aim is to create a global standard for Data Spaces, as well as fostering technologies and business models that will drive the data economy of the future in Europe and around the globe.

Two important publications of the IDSA are the IDSA Rulebook, focussing on governance of dataspaces. And the IDS-RAM V4 which goes into more detail on the architecture of data spaces. The Dataspace Protocol is a set of specifications designed to facilitate interoperable data sharing between entities governed by usage control and based on Web technologies developed under the umbrella of IDSA. These specifications define the schemas and protocols required for entities to publish data, negotiate usage agreements, and access data as part of a federation of technical systems termed a dataspace.

Certification is a major aspect of the IDS-RAM V4 to achieve Data Sovereignty. Interoperability, and compliance criteria are tested and validated based on an Open

Source testing framework the IDS-Reference-Testbed. The overarching view on a vibrant Data Space community as perceived by IDSA is part of the Data Space Landscape document. Data Sovereignty is expressed in IDS based on human and machine readable Usage Policies, which can be enforced in technology or organizational manners. Therefore, the definition, description, specification and validation of Data Space Connectors, which implement policy negotiation and enforcement are the most important aspect of the IDSA work, including the interaction of the Data Space Connectors with other components and services in Data Spaces.

3 Data interoperability

3.1 Overview

Providers of data products within data spaces must be able to offer data services at well defined endpoints knowing that customers, unknown by them a priori, will know how to consume their data services through those endpoints. Customers of data products, on the other hand, must know how data services available through endpoints they discover can be consumed. This means that all participants in data spaces should 'speak the same language', which means adopting 1) common APIs for the exchange between data service providers and consumers (the syntactic rules applicable for constructing sentences) and 2) common data models that can be translated to data formats compatible with those APIs (the vocabulary used in constructed sentences).

The definition of common APIs for the exchange between data service providers and consumers covers both the transport and syntactic interoperability of ISO/IEC 21823-1 which, in turn, cover part of the technical interoperability aspects of the European Interoperability Framework (EIF). On the one hand, transport interoperability has to do with guaranteeing the communication and error-free delivery of data between providers and consumers, which may be connected to different networks, when they use APIs. Quality of Service (QoS) requirements such as timeliness, ordering, durability and lifespan are considered in this facet. On the other hand, syntactic interoperability enables that the formats of the exchanged information can be understood by the participating systems. Technical aspects of transport and syntactic interoperability include interface specifications, interconnection services, data integration services, data presentation and exchange, and secure communication protocols.

As described in ISO/IEC CD 21823-3, semantic interoperability enables the exchange of data between entities using understood data information models (or semantic meanings). According to the AIOTI Whitepaper[1], semantic interoperability is achieved when interacting systems attribute the same meaning to an exchanged piece of data, ensuring consistency of that meaning across systems regardless of individual data format. This consistency of meaning can be derived from pre-existing standards or agreements on the meaning of data or it can be derived in a dynamic way using shared vocabularies either in a schema form and/or in an ontology driven approach.

So, in short, transport interoperability deals with data delivery (i.e. sending the data); syntactic interoperability allows reading the data in a known format and grammar; whereas semantic interoperability is responsible for the meaning, enabling the unambiguous interpretation and understanding of data.

All these aspects are addressed in the following building blocks on Data Models and Formats and Data Exchange APIs.

3.1 Data Models and Formats

As described above, Data Models and Formats deal with the semantic understanding of data in Data Spaces. The subsequent sections describe the DSBA approaches to handle semantic interoperability.

It shall be mentioned that the concept of the Vocabulary Hub as described in section 2.3.3 is a mean to support the usage of common Data Models and Formats in Data Spaces, but is not described in detail in this section.

3.1.1 Smart Data Models

Launched by the FIWARE Foundation, the Smart Data Models initiative[2][3] provides a library of data models for which the description and rendering in multiple data formats is provided. JSON and JSON-LD formats are compatible respectively with the NGSIv2 and NGSI-LD APIs as well as any other RESTful interfaces compliant with the Open API specification. Data models published under the initiative match existing de-facto or widely adopted de-jure standards when they exist, either cross-domain (e.g., schema.org) or domain-specific (e.g., IEC CIM for the Energy domain). Lack of standard data models is addressed following an community-driven approach where multiple organizations are contributing and jointly curating models they have designed,

[1] Martin Bauer et al., “Towards semantic interoperability standards based on ontologies. AIOTI white paper.,” Jun. 2019

[2] Github: https://github.com/smart-data-models

[3] Website: https://smartdatamodels.org/

implemented and tested in real projects. Agility is a key principle adopted in the Smart Data Models initiative, translated into a fast growth in the number of data models covered during the last two years and organizations contributing to the initiative, reaching publication of resources linked to 1000+ data models at the time of publication of this document.

The initiative solves one major issue developers are facing, like the fact that a given data model specification may be mapped into JSON or JSON-LD in many different ways, all of them valid. Actually, thanks to the Smart Data Models initiative, developers can rely on published mappings into JSON/JSON-LD that are compatible with the NGSIv2/NGSI-LD APIs or other OpenAPIs. This avoids interoperability problems derived from alternative mappings.

Figure Y illustrates how resources are organized within the Smart Data Models initiative on GitHub. Data models are grouped into “subjects” (weather, parking, aquaculture, etc) which in turn are referred from repositories associated with the multiple application domains being considered (Smart Cities, Smart Agrifood, Smart Manufacturing, Smart Water, Smart Energy, etc). Note that there are subjects which are very specific to a given application domain (e.g., “smart parking” with regards to smart cities and communities) while others may be relevant to multiple domains (e.g., “weather” that is relevant to almost every domain or “sewage” that is relevant to the Smart Cities and Smart Water domains).

An open governance model has been defined for the Smart Data Models initiative defining the lifecycle of data models comprising incubation of brand new data models as well as curation of data models via harmonization of different contributions. Processes and procedures for management of the different activities follow best practices from open source communities, guided by principles of transparency and meritocracy. Relevant organizations like TM Forum, OASC or IUDX are joining forces with the FIWARE Foundation bringing support to such open governance model.

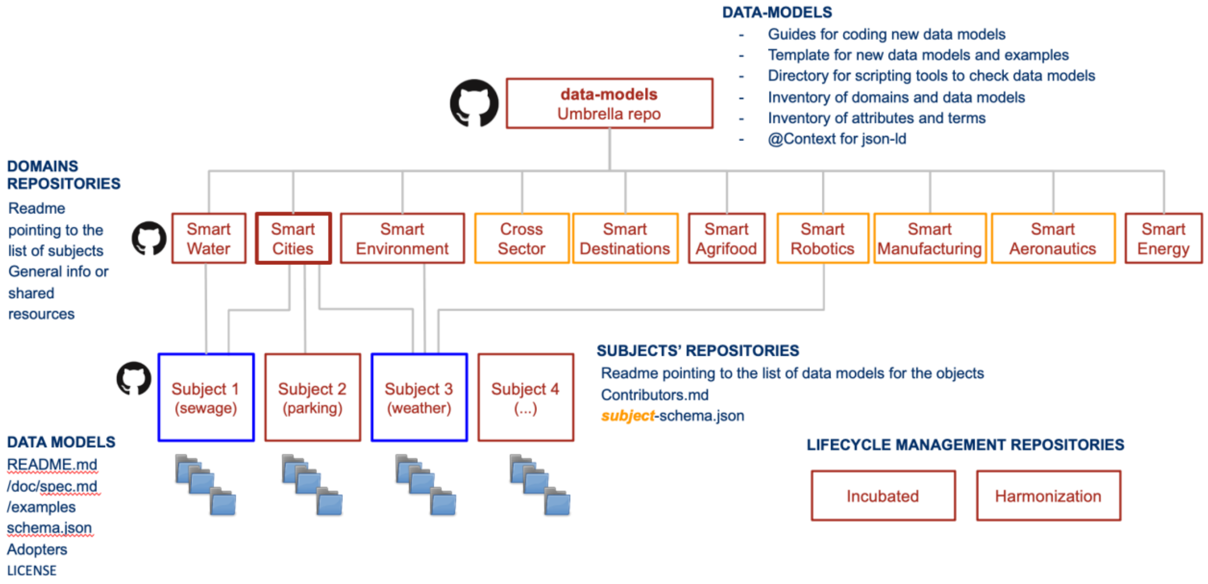


Figure 3.1 - Smart Data Models organization on GitHub

3.2 Data Exchange APIs

Data Exchange and Data Sharing while maintaining Data Sovereignty are an important aspect of Data Spaces and of the work of the DSBA. When it comes to Data Exchange APIs the two aspects of the control phase and the data exchange phase need to be distinguished. During the control phase the data assets and the data exchange contracts are described and exchanged. After the successful agreement on a contract, the actual data transfer is started and stays under the control plane of a data connector as described above.

In the context of the DSBA, NGSI-LD is proposed as the transfer protocol among participants of a Data Space. In addition, Dataspace Connector Protocols are proposed as foundation for Data Asset publication, Contract Negotiation and Control of data exchange.

3.2.1 NGSI-LD

The NGSI-LD API provides a simple yet powerful RESTful API for getting access to context / digital twin data. NGSI-LD came as an evolution of the NGSIv2 API designed by the FIWARE Community to incorporate support for Linked Data and other powerful features. Evolution of the specs is currently driven under the umbrella of the ETSI Context Information Management Industry Specification Group (ETSI CIM ISG).

In NGSI-LD, a "digital twin" (also referred to as "context entity") is an entity which digitally represents a real-world physical asset (e.g. a bus in a city, a milling machine in a factory) or real-world entity (e.g., a claim ticket by a customer, a packet delivery order). Each digital twin:

- is universally identified with an URI (Universal Resource Identifier),
- belongs to a well-known type (e.g., the Bus type, or the Room type) also universally identified by an URI, and
- is characterized by several attributes, each of which can be classified as:
  - a property holding data describing part of the state of the entity (e.g., the "current speed" of a Bus, or "max temperature" in a Room) or
  - a relationship, holding the URI(s) identifying third digital twin entities the entity is linked to (e.g., the concrete Building where a concrete Room is located).

Attributes of a digital twin may vary ranging from attributes that are quite static (e.g., the "license plate" of a Bus), to attributes that change very dynamically (e.g., the "speed" or "number of passengers" in a Bus) or attributes which still change but not that often (e.g., the "driver" in a Bus which may change twice a day). Very important, the attributes of a digital twin are not only limited to observable data but also inferred data. Thus, for example, the digital twin of a Street may not only have an attribute "current traffic", which may be automatically measured through sensors or cameras, but an attribute "forecasted traffic in 30 minutes" which might be calculated based on AI algorithms that keep the value of this attribute updated based on current traffic data, other relevant data impacting traffic (e.g., current weather observed and forecasted, schedule of events nearby, etc) and historical information about traffic in the given Street. Therefore, the Digital Twin data representation of the world that is managed through NGSI-LD is expected to contain not only measurable data but also other augmented insights and knowledge acquired over time.

In a Data Space following DSBA Technology Convergence recommendations, participants interact using the NGSI-LD API. A data service provider will always host an NGSI-LD endpoint but also data service consumers may host their own NGSI-LD endpoints. The NGSI-LD API is offered through any of these NGSI-LD endpoints allowing, among other things, to:

- Create and delete digital twin entities.

- Perform queries and updates on attributes linked to one or more digital twin entities. Geo-queries are supported. Queries are also supported on historical data.
- Perform subscriptions which will trigger notifications reporting the value of certain attributes linked to digital twin entities when certain conditions occur. Those notifications may be propagated through subsequent RESTful requests or as an event stream using different protocols.
- Register other NGSI-LD endpoints in order to implement different kind of synchronizations on the value of attributes linked to digital twin entities as well as the creation/deletion of entities.

Note that since data service providers and their consumers can host NGSI-LD points, multiple styles of communications are supported.

3.2.2 Management of transfer within Data Space Connectors

While the data exchange is conducted between participants using protocols like NGSI-LD, the data connector stays in control of the data exchange to ensure the enforcement of the agreed policies. In this regard, the data exchange protocols cover the technical aspects of starting, pausing, resuming and stopping the data transfer for technical reasons. The Data Space Connectors implement a control sequence based on the Dataspace Protocol to keep track of the data exchange and may, pause or resume transactions from a contractual or business related perspective during the transfer process.

3.3 Provenance and Traceability

In data spaces with highly regulated data, it is necessary to make the data sharing process **observable**. This can be done for legal reasons to prove that data has been processed only by authorized entities, or for business reasons to provide a marketplace and billing function through a trusted third party.

Depending on the architecture of the data space, multiple solutions are possible. For a centralized architecture a central observer (sometimes called clearing house, auditor or monitoring agent) can be implemented. But this design has two shortcomings when implementing large-scale data spaces: It presents an additional vulnerability that could affect the sharing of mission critical data. And a central observer has data on all DCAs which represents potentially valuable knowledge about the participants. This can be exploited for financial gain, making it a target for bad actors.

In a decentralized observer architecture, every participant keeps the information about the agreed agreements and their execution in their own environment. Meaning that there are at least two copies of corresponding logging information in the data space. The two copies can always be identified through a correlation ID linking them. The observer then matches the corresponding logging information and reports any irregularities to the parties participating in the agreement (or to the respective regulator if required).

To audit the contracts of a participant, the auditor would simply request the log data which could then be published as data contract offers with an access policy which restricts access to the auditor. To verify the validity of those log entries, a digital signing mechanism can be used or the corresponding log data from other participants can be requested (and again published as data contract offers). This would limit access to sensitive observation data to observers that are participants of the data space, have special credentials which qualify them as trusted auditors and are bound to the policies of those contracts due to the contracts on the collected log data. Observer actions are automatically logged by the system and can be tracked and monitored. This would enable a trust relationship in which auditors can be audited by participants.

To simplify the observability of a data space, the Data Space Governance Authority can mandate that participants make their audit data available as events or streams per default. Then trusted auditors would not need to request publication but could simply negotiate the relevant contracts, which are only accessible to participants with valid auditing and monitoring credentials.

Following the same pattern, additional optional functional roles can be implemented: a payment clearance service, notary services, regulatory reporting, and beyond, which are subject to the Data Value Creation Pillar.

The IDS-RAM proposes the Clearing House Service to implement observability, provenance and traceability. Further information on observability are part of the IDSA Rulebook.

4 Trust and Data Sovereignty

4.1 Overview

Any Data Space requires a Trust Anchor Framework and associated Decentralized Identity and Access Management Framework to enable the trusted operation of the system without requiring a central entity intermediating in all interactions among participants. This is required to ensure trust in the information published on the data space by providers, as well as to enable customers to access the dataspace portal services, manage their profile and seamless login into federated marketplaces where they can benefit from a tailored experience.

In this section we describe a Trust Anchor Framework that extends the Gaia-X Trust Framework to implement specific Data Space requirements like decentralised Identity and Access Management and a set of Trusted Lists specific to a Data Space which are required for the efficient onboarding, operation and monitoring of the Data Space. It uses Verifiable Credentials signed with eIDAS digital certificates issued by EU Trust Service Providers (TSPs), and an associated Identity and Access Management Framework using Verifiable Credentials that is compatible with the Gaia-X Trust Framework and therefore also with the EBSI initiative and aligned with the recently published European Digital Identity Wallet Architecture and Reference Framework.

The following diagram will be used in the detailed explanations in this section:

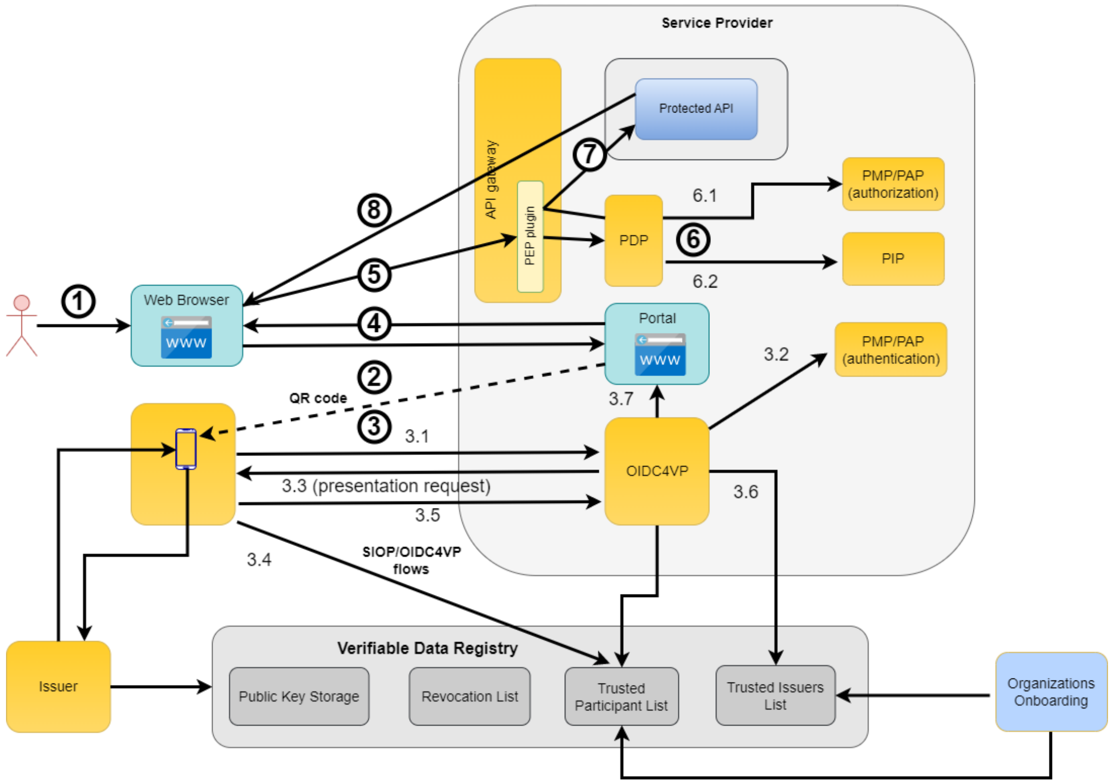


Figure 4.1. General overview of the components and their interactions.

4.2 Trust Anchor framework

The Trust Anchor Framework defines and enforces a set of rules in addition to the ones specified by the Gaia-X Trust Framework, leveraging the interoperability provided by the shared governance defined in gaia-X. In this way, all services and organizations can use their digital identities and attributes in a consistent and trusted manner. This makes it easier for organizations and users to complete interactions and transactions or share information with other participants.

The Trust Anchor Framework is implemented using a Verifiable Data Registry (using the W3C Verifiable Credentials terminology) to store and query relevant information, as described in Figure 4.1.

The operationalisation of the Verifiable Data Registry by Gaia-X is called the Gaia-X Registry and a service deployed as part of the Gaia-X Digital Clearing House (GXDCH) nodes.

We also present a Decentralized Identity and Access Management Framework based on Verifiable Credentials/Verifiable Presentations and leveraging the Trust Anchor

Framework to provide an efficient, scalable, and Decentralized IAM that participants can use not only to interact with the data space and marketplaces, but they can also adopt for interactions between themselves and their product/service consumers.

The Trust Anchor Framework addresses the following issues:

- **ID Binding**: How to verify that a given identifier corresponds to a valid legal identity of an entity in the real world?
- **Proof of participation**: How to verify that the entity is trusted because it is a subscribed participant in a given ecosystem (e.g., to check the trust of the Shared Catalogue of Product Specifications and of Product Offerings)?
- **Proof of Issuing Authority**: How to check that the credentials presented by a participant have been issued by another entity that can be considered a Trusted Issuer of that type of credentials? This enables the verifier to put the right amount of trust in the facts attested by the Verifiable Credentials presented by a participant.

To enable transactional activity in the marketplace, the Decentralized Identity and Access Management Framework leverages on the above and provides an IAM system addressing additionally:

- **Identification**: How to verify that an identifier sent by a participant to another entity has been sent by the participant and not by an impostor that knows about the identifier? In addition, we need to cryptographically bind the identifier to the Verifiable Credentials sent by the participant so the facts attested in the credentials can be used for authentication and authorization.
- **Authorization**: How to use the attested facts in the Verifiable Credentials presented by a participant to perform advanced RBAC/ABAC access control and policy enforcement?

4.2.1 ID Binding

At the root of any trust framework there is the requirement to verify the identity of an entity in the real world and the assignment of some identifier that can be used later in representation of the real entity in the online processes. This association between an identifier (including some metadata) and the real identity of an entity is what we call **ID Binding**.

Please note that at this level, ID Binding states only who the entity is in the real world, not any additional properties that may be interesting for other purposes. For example, ID Binding establishes that the entity is a business incorporated in the EU, but it does not say what products it sells or the characteristics of the product, or the markets in which it operates, or in which data spaces it participates.

Many ecosystems assign a proprietary identifier to entities when they are onboarded in the ecosystem, creating silos of identifiers, and making very difficult the interoperability across ecosystems.

We propose to rely on identifiers already used in digital certificates issued by the Trust Service Providers (TSPs) authorized by the relevant European laws. The combination of digital certificates issued by TSPs, and Verifiable Credentials contributes to the legal validity and interoperability of the cross-border data-related transactions in the European Union facilitating the cross-border validation of eSignatures, eSeals, and more. Essentially, Verifiable Credentials and Presentations (including Product Specifications and Offerings) used in the ecosystem will be signed using digital certificates using the JAdES format as defined in ETSI TS 119 182-1 (Electronic Signatures and Infrastructures (ESI); JAdES digital signatures)

In addition, we propose the use of a specialized type of Verifiable Credential that we will call VerifiableID, in line with the terminology used by EBSI. A Verifiable ID is a special form of a Verifiable Credential that a Natural Person or Legal Entity can put forward as evidence of who he/she/it is, and that can be used for identification and authentication purposes as described later in this document.

Some of the characteristics and advantages of using this type of ID Binding are described below.

4.2.1.1 Cross-border use of mutually recognised electronic identification means

We propose that during onboarding of a new member, the Data Space and its participants accept a digital certificate or seal if it is issued by any European TSP.

The Regulation on electronic identification and trust services for electronic transactions in the internal market (**eIDAS Regulation**) states that in order to contribute to their general cross-border use, it should be possible to use trust services as evidence in legal proceedings in all Member States. DOME is fully aligned with the objectives of the eIDAS regulation, specifically Article 17 of the eIDAS Regulation, says that Member States should **encourage the private sector** to voluntarily use electronic identification means under a notified scheme for identification purposes when needed for online services or electronic transactions. The possibility to use such electronic identification **enables the private sector to rely on electronic identification and authentication already largely used in many Member States at least for public services and to make it easier for businesses and citizens to access their online services across borders**.

In this way, interoperability of Verifiable Credentials across the public and the private sector can be achieved in large Digital Ecosystems (e.g., Data Spaces) across the EU.

Article 22 of the Regulation on electronic identification and trust services for electronic transactions in the internal market (**eIDAS Regulation**), obliges Member States to **establish, maintain and publish trusted lists**. These lists should include information related to the qualified trust service providers for which they are responsible, and information related to the qualified trust services provided by them.

In order to contribute to their general **cross-border** use, it should be **possible to use trust services as evidence in legal proceedings in all Member States.**

In practice, each Member State publishes its Trusted List, and the Commission publishes the List Of Trusted Lists (**LOTL**). There are different ways to access the lists, but one which is machine-processable (XML) is located at https://ec.europa.eu/tools/lotl/eu-lotl.xml which contains the addresses of each of the Trusted Lists published by each Member State. This is represented in the following figure:

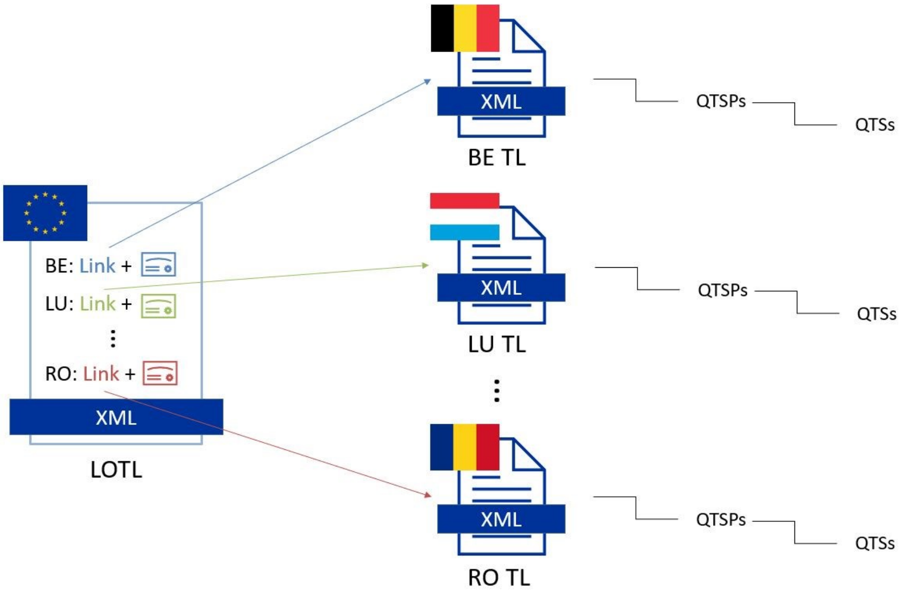


Figure 4.2 Trusted Lists in the EU

We propose to use an integrated, easy and performant way to perform ID Binding based on the digital certificates provided by the EU TSPs, including transparent access to the consolidated list of TSPs when applications in the Data Space must perform ID Binding (typically during onboarding and verification of signatures of credentials).

4.2.1.2 ID Binding and the Verifiable Credential

As mentioned at the beginning of the section we propose the use of a specialized Verifiable Credential called VerifiableID, to solve a problem related to ID Binding when a participant sends online a Verifiable Credential to another participant. We need to make sure that the credential has been sent by an entity authorized to do so and not by an impostor. This is called ID Binding of the credential. Later in the document we describe and implement a simple approach to perform this using widely used public key cryptography and leveraging on the trust already provided by the digital certificates used in the ID Binding described above. From now on we will use the terms VerifiableID and Credential interchangeably, but it should be clear what type of credential we are referring to if we are in the context of identification/authentication.

The detailed description can be found later in this document, but the essential characteristics are below.

We assume that the issuer of the VerifiableID has an eIDAS certificate (we will use this term for a digital certificate or seal issued by a TSP in the EU Trusted List), and that the issuer is a participant in the Data Space (the concept of participation is elaborated in the next section).

A natural or legal person wants to receive a credential from the issuer. Given that we are interested in VerifiableIDs, in this context we will use the expression "the natural or legal person is the subject of the credential", even though this is not true in general for Verifiable Credentials (there can be more than one credentialSubject in a single credential). The credential is an attestation of something that the issuer knows about the subject. That means that **there should be a previous close relationship between the issuer and the subject** and there is a pre-existing trusted identification mechanism that the issuer uses for everything related to the subject (again, we assume that the type of credential used here is used to convey some attested attribute about the subject, which will also have to be the holder in the case of a VerifiableID). It could be physical (e.g., a student going to the secretary to request the credential) or electronic (e.g., the student using the "traditional" identification mechanisms for accessing the online University services).

In other words, for a VerifiableID it is not possible that an issuer provides such a credential to a subject that it does not know. Or better said, such a VerifiableID would be useless in our context because the facts attested inside the credential cannot be really trusted for the purposes of identification and authorisation described in this section.

In this context, the approach is the following:

1. The subject authenticates to the issuer with whatever mechanism has been used during the previous relationship. In the example of the Diploma, the student uses whatever identification mechanism was provided by the University when the student enrolled in the studies.
2. Once an authenticated session exists, the subject generates a pair of public-private keys and sends the public key to the issuer, keeping the private key private (that's the meaning of its name, obviously). The actual mechanism uses

a digital signature of a challenge to ensure that the subject controls the private key associated with the public key sent to the issuer.

3. The issuer creates a credential with the relevant attestations and includes also the public key received from the subject as an additional attestation.
4. The issuer digitally signs the credential with its eIDAS certificate and makes the credential available to the subject. The specific mechanism to "send" the credential to the subject can be diverse. Given that there is a previous relationship, the credential could be sent inside the authenticated session when it is generated or made available in the "electronic office space" of the subject, or sent encrypted via email, or even printed in physical media and sent via mail, if required. The Verifiable Credential is essentially a file with data in JSON (or JSON-LD) format and digitally signed by the issuer. It can be sent from the issuer to the subject with whatever secure transmission mechanism that the issuer and subject have been using in the past, or if they want, with a new mechanism as will be described in this document.

With this mechanism, the receiver of the credential can have the same level of trust in the "normal" attested attributes inside the credential and in the public key inside the credential.

For example, if the receiver of a Diploma has a given level of trust in that a certain University

4.2.1.3 About identifiers for legal persons

We use W3C Verifiable Credentials with DIDs as identifiers. A DID is a simple text string consisting of three parts: **1)** the did URI scheme identifier which is the word "*did*", **2)** the identifier for the DID method which specifies the mechanism used for resolving a DID, and **3)** the identifier specific to that DID method.

As mentioned before, when using eIDAS digital certificates for identity binding, it does not make sense to "invent" identifiers or to promote the usage of different DID methods that are not well integrated with eIDAS certificates and that generate identifiers which are not in general legally recognised in the EU for economic transactions (e.g., that can be used in electronic invoices across the EU).

In general, an ecosystem may accept one or more DID methods and their associated DID resolution mechanisms (e.g., did:web, did:peer, etc.). For Legal Persons, we propose that one of the DID methods used is the following, using as identifiers the same identifiers that are already embedded in the eIDAS certificates that conform to the relevant ETSI standards.

ETSI EN 319 412-3 V1.2.1 (2020-07) "**Electronic Signatures and Infrastructures (ESI); Certificate Profiles; Part 3: Certificate profile for certificates issued to legal persons**" states in section 4.2.1:

> *"The subject field shall include at least the following attributes as specified in Recommendation ITU-T X.520:*
>
> - *countryName*
> - *organizationName*
> - ***organizationIdentifier** and*
> - *commonName"*

And regarding the *organizationIdentifier* attribute it says:

> *The **organizationIdentifier** attribute shall contain an identification of the subject organization different from the organization name. Certificates may include one or more semantics identifiers as specified in clause 5 of ETSI EN 319 412-1 [i.4].*

And the document referenced, ETSI EN 319 412-1 V1.4.2 (2020-07) "**Electronic Signatures and Infrastructures (ESI); Certificate Profiles; Part 1: Overview and common data structures**" states in section 5.1.4:

> *When the legal person semantics identifier is included, any present **organizationIdentifier** attribute in the subject field shall contain information using the following structure in the presented order:*
>
> - *3 character legal person identity type reference*
> - *2 character ISO 3166 [2] country code*
> - *hyphen-minus "-" (0x2D (ASCII), U+002D (UTF-8)) and*
> - *identifier (according to country and identity type reference)*
>
> *The three initial characters shall have one of the following defined values:*
>
> 1) *"VAT" for identification based on a national value added tax identification number.*
> 2) *"NTR" for identification based on an identifier from a national trade register.*
> 3) *"PSD" for identification based on the national authorization number of a payment service provider under Payments Services Directive (EU) 2015/2366 [i.13]. This shall use the extended structure as defined in ETSI TS 119 495 [3], clause 5.2.1.*
> 4) *"LEI" for a global Legal Entity Identifier as specified in ISO 17442 [4]. The 2 character ISO 3166 [2] country code shall be set to 'XG'.*
> 5) *Two characters according to local definition within the specified country and name registration authority, identifying a national scheme that is considered*

> *appropriate for national and European level, followed by the character ":" (colon).*
>
> *Other initial character sequences are reserved for future amendments of the present document. In case "VAT" legal person identity type reference is used in combination with the "EU" transnational country code, the identifier value should comply with Council Directive 2006/112/EC [i.12], article 215.*

That means that any eIDAS digital certificate issued by TSPs to legal persons compliant with the ETSI standards including an organizationIdentifier attribute can be used to derive a DID from the ETSI standard identifier by applying the following rule:

did:elsi:organizationIdentifier

Examples:

- **International Data Spaces**: *did:elsi:VATDE-325984196*
- **Gaia-X**: *did:elsi:VATBE-0762747721*
- **FIWARE Foundation**: *did:elsi:VATDE-309937516*
- **TNO**: *did:elsi:LEIXG-724500AZSGBRY55MNS59*

Where:

- "did" is the W3C did uri scheme.
- "elsi" stands for ***E****TSI* ***L****egal* ***S****emantic* ***I****dentifier*, which is the acronym for the name for this type of identifier used in the ETSI documents.
- "organizationIdentifier" is the exact identifier specified in the ETSI standard, and that can evolve with the standard to support any future requirement.

In this way, there is a **bidirectional mechanism to derive DIDs from the eIDAS digital certificate** and inversely.

Proving the control of an ELSI DID, as required by W3C Verifiable Credentials implementations is possible using the associated digital certificate: including the certificate with any signature can do that. By the way, this means that any existing digital signature of any type of document (not only Verifiable Credentials) is already compliant with this DID method specification, just by making a simple translation.

In other words: any legal person can have a standard eIDAS certificate with an automatically associated DID identifier complying with the ELSI did method specification. There is no need to invent new identifiers or have a central entity in a Data Space assign identifiers to participants.

4.2.1.4 About identifiers for natural persons

In principle, we could use the same approach for natural persons as for legal persons. The ETSI standards referenced above also cover natural persons and they define a "Natural Person Semantic Identifier".

However, legal persons are completely different to natural persons, especially from the point of view of privacy (look at the GDPR to see some differences). It is for those privacy reasons that a different approach should be used for the identifiers of natural persons participating in a sharing ecosystem like a Data Space.

4.2.1.5 About identifiers for connectors, gateways and application context

In addition to identifiers for legal and natural persons, identifiers are required for IDS-connectors or more in general gateways respectively in the application context. Such software components require identification on a similar basis. From an organizational perspective the application context must be linked with legal and/or natural persons identifiers to clarify the delegation of power to the application context. Such identifiers could be realized as X.509 certificates or as DID. The current version of the IDS-RAM describes the use of X.509 certificates. The use of DIDs should be described in the IDS-RAM based on the results of this document.

A valid identifier should contain at least:

- Issuer distinguished name
- Subject distinguished name
- Serial number
- Version information
- Validity information

4.2.2 Proof of participation

Depending on the use case, we may require verifying a Verifiable Credential/Presentation, where we must address the following:

1. How do we determine whether or not the **issuer** of the Verifiable Credential is a **participant** in the concrete ecosystem (e.g., a given Data Space) where we are also participants? (For the general case of being able to verify Verifiable Credentials that are issued by parties that may not be a participant of the ecosystem, see the section on 4.2.3 Proof of Issuing Authority).

2. How do we determine whether or not the **subject** of the Verifiable Credential is a **participant** in the concrete ecosystem (e.g., a given Data Space) where we are also participants?

We propose to use a **Trusted Participant List** including the identities and associated metadata of all legal persons participating in the concrete ecosystem. The Trusted Participant List is updated during the onboarding process of an entity and is managed by one or more collaborating trusted **participants** in the concrete ecosystem. Please note that this list is different from the EU Trusted List with the identities of TSPs authorized to issue digital certificates/seals in the EU.

There are different ways to implement the Trusted Participant List but in any case, the users of the Trusted Participant List should not be aware of the technology used to implement it. The users of the Trusted Participant List just use an API to query the list on verification, and the maintainers use a different API to register and update the list.

This way, it is completely possible to use a mix of centralized and decentralized technology without the users noticing it. Or to migrate transparently from one technology to another depending on the requirements of the specific ecosystem.

Having said that, we propose that one of the implementations uses a federated set of interoperable EBSI-compatible blockchain networks for the maintenance of the Trusted Participant List, providing a decentralized, hyper-replicated, efficient and resilient mechanism for querying the list. Anyone can create a replica of the information using centralized systems if they wish.

We propose to base the API in the one defined by EBSI for Trusted Lists of different types. For example:

GET /participants and ***GET /participants/{did}*** to get the list of participants or to check a given participant if we have its DID, respectively.

There are several other APIs to get attributes/metadata associated with the participants, and APIs to maintain the list, used by the entity or entities responsible for the list. The full specification is described in the EBSI documentation.

We propose to follow this principle:

> *If something we need is already in EBSI, just use it. Otherwise define it trying to be as consistent as possible with EBSI, unless there is no chance to do so.*

4.2.3 Proof of Issuing Authority

Given that anyone can have access to the technology needed to create Verifiable Credentials and anybody can issue credentials and digitally sign them with their eIDAS digital certificate, the problem is how a verifier knows that the Verifiable Credentials received from the subject have been issued by an entity which is entitled or authorized to issue that type of credential.

The primary mechanism to solve this problem is the use of **Trusted Issuer Lists** (there may be several lists, one per domain or type of credential). A **Trusted Issuers List** is a register of trusted public entities which can issue Verifiable Credentials belonging to a given domain or of a given type. It is assumed that an entity must be first in the Trusted Participant List before it appears in the Trusted Issuers List. This list includes the identifiers, public keys for verification of signatures and their accreditations in the form of Verifiable Credentials/Presentations from third parties, enabling the entity to issue credentials of a given type. All information in the registry is validated and signed by trusted legal entities of the corresponding domain (Conformity Assessment Bodies and third-party auditors).

Using Trusted Issuers Lists (there may be several lists, one per domain or type of credential) is the simplest mechanism. However, in very complex ecosystems with many entities issuing credentials of different types, the management of Trusted Issuer Lists can be difficult to scale. For those ecosystems we can use the combination of Trusted Issuer Lists with the "*chaining*" of Verifiable Credentials, like the certificate chaining used with traditional X.509 digital certificates:

- At the root of the trust hierarchy there is a set of Trusted Issuers Lists as described above, containing the primary trusted entities in the ecosystem.
- The entities in those Trusted Issuers Lists can issue special Verifiable Credentials to other entities, authorising them to be also **Trusted Issuers, even if they are not included in a Trusted Issuer List**. The signature of the special Verifiable Credential attests that the subject of the credential is explicitly authorized by the signer to issue a given type of credentials (usually a subtype of the parent type, but not necessarily; the specific rules have to be defined in the corresponding governance model for the domain/ecosystem). This mechanism can be also used by those Trusted Issuers not in Trusted Lists if we need several levels in the hierarchy, though usually two or three layers (including the root Trusted Issuers List) should be enough to handle large ecosystems.

There is a trade-off in choosing one or another mechanism. Having all Trusted Issuers in one or more Trusted Issuers Lists makes verification very simple: the verifier of a credential just checks once in the Trusted Issuers List corresponding to the type of certificate. Checking a credential using the chained mechanism is more involved: the verifier has to check the chain of signatures for the relevant Verifiable Credentials until it reaches an issuer which is in a Trusted Issuers List for the domain (or if no issuer is in any Trusted Issuers List, then the Verifiable Credential should be rejected).

The mechanisms can be combined and are not exclusive or all-or-nothing in an ecosystem. Depending on the requirements/complexity of a domain in an ecosystem, one domain can use just Trusted Issuers List while another domain can use a chained mechanism. It is even possible to start with only a Trusted Issuers List and transition seamlessly to the chained mechanism if the domain complexity grows beyond some limit, decided by the governance rules of the domain.

4.2.4 Onboarding of Data Space participants

In this context, onboarding refers to a process which precedes entering into a business relationship with a new participant, which has to be a legal entity (we do not address onboarding of natural persons, except as employees of a legal person). If the onboarding process is done electronically and at a distance (e.g. online), it is referred to as digital onboarding.

In general, the onboarding process is one of the less digitized and with diverse implementations depending on the sector of activity and geography. Even within the same sector the actual implementation of onboarding processes for different companies can vary considerably.

Onboarding of participants in a Data Space may also present differences depending on the specific Data Space. This chapter presents an approach based on eIDAS digital certificates that can facilitate in the EU area a fully digital and automated cross-border onboarding processes and compliance with KYC (Know Your Customer) requirements. For other regions of the world, some of the principles can be generalized if there are equivalent mechanisms.

The onboarding process presented in this chapter is just one of the many different onboarding processes that can be implemented, but we think it should be the main one supported in the EU region given its advantages.

The eIDAS Regulation (EU) 910/2014 (hereafter denoted as 'eIDAS') is a major step towards building the EU Digital Single Market (DSM) as it provides a predictable regulatory environment for the cross-border recognition of electronic identification (eID) and electronic trust services by Trust service Providers (TSPs). eIDAS may facilitate to meet the legal obligations, concerning security, know-your-customer, strong authentication of parties and interoperability.

For the purposes of this chapter, the onboarding process consists of the following logical phases (which can be combined in a single step when performing them in a digital way):

- **Application**. Pre-on-boarding phase, addressing the act of applying to become a participant. In this phase, the applicant provides the required identity and KYC attributes for verification and collection.
- **Verification**. The verification phase determines whether the expected requirements and mechanisms used to perform verification of attributes are met. It can be divided into 3 steps:
  - Authenticity check of documents (to determine that the document can be considered a trustworthy source of information such as for identity attributes).
  - Identity check of the applicant (comparison of the bearer of the document against the owner of the document).
  - Anti-fraud check (to determine the document is not used in fraud-related activities and it belongs to a living person; and that the applicant is not involved in fraud activities, not under sanctions or considered a PEP)

4.2.4.1 Scope of the onboarding process

Depending on the sector of activity and its legal and regulatory requirements (e.g., banking) a complete onboarding process requires the following common due diligence measures:

- **Identification of legal person** on the basis of documents and data submitted; and verification of the submitted information on the basis of information obtained from a reliable and independent source;
- **Identification and verification of the legal representative** and the right of representation;
- Identification of the beneficial owner, based on information provided for onboarding or obtained from another reliable and independent source; and
- Obtaining information on the purpose and nature of the business relationship or transaction.

In this chapter we focus only on the **first and second** steps, and assume that once the legal entity and the person acting as its legal representative have been properly identified, the remaining documentation can be provided in a trusted way to complete all required steps in the specific onboarding process for the data space.

4.2.4.2 Legal Person and Natural Person as Legal Entity Representative

The objective of the onboarding process in a Data Space is to identify and register a legal entity as a new participant. However, in most cases the process is initiated and driven by a natural person.

To ensure legal validity and reduce legal uncertainty, the onboarding process requires that the natural person driving the process should be either a legal representative of the participant or a natural person that has been delegated by a legal representative at least the powers required to perform the onboarding process on behalf of the legal entity.

Article 3(1) of eIDAS allows the case of representation, in particular "natural person representing a legal person".

Based on the regulation, the TSPs (Trust Service Providers) in the EU provide several types of digital certificates for digital signature/seals:

- Natural Person (for signature)
- Legal Person (for seals)
- Natural Person as Legal Entity Representative (for signature)

Not all Member States implement at this moment the Natural Person as Legal Entity Representative digital certificate, but the onboarding process described below takes advantage of it when it is available for a participant initiating the onboarding.

In this way, the onboarding process is prepared for the future, because given that there are different cases of representation, the eIDAS Technical subgroup has been requested by the eIDAS Cooperation Network to amend the technical specifications to include all the cases of representation (see section 2.8. NATURAL AND LEGAL PERSON REPRESENTATIVE from eIDAS SAML Attribute Profile V1.2., 31 August 2019). It is expected that in the near future most TSPs will start issuing those digital certificates that simplify and streamline enormously the onboarding processes, not just for Data Spaces but for any type of use case.

To facilitate the explanation below, we will use the following terminology:

- **NP**: Natural Person with a certificate for electronic seal.
- **LE**: the Legal Entity that is being onboarded, with a certificate for electronic seal.
- **LER**: the Natural Person as Legal Entity Representative with a certificate for electronic signature when acting as legal representative of a legal entity.

In addition to the above, we use the term **LEAR** (Legal Entity Appointed Representative) to denote a natural person that has been issued a VerifiableID (a special type of Verifiable Credential) with proof that the person has the power to represent the legal person.

4.2.4.3 The VerifiableID

The onboarding process is based on a special type of Verifiable Credential that we will call VerifiableID, given its purpose. We require that the user driving the process is a LEAR holding and controlling a VerifiableID.

The VerifiableID can be generated in different ways from one or more of the above digital certificates.

1. The easiest case is when there is already a LER. In big companies there may be more than one LER depending on the company structure. In this case, the LER issues a Verifiable Credential to a natural person (typically an employee of a department in charge of managing the relationship with a given Data Space). The Verifiable Credential includes a description of the actual powers that are being delegated (the required ones have to be defined by the Data Space). The Verifiable Credential is signed with the digital certificate of the LER. This VC is then called a VerifiableID and the person controlling it can use it to authenticate in the onboarding process and act as LEAR.

   As a special case, the LER can issue a VerifiableID to herself and then become a LEAR. This can be used when the LER wants to be the one performing the onboarding process.

2. The above process is almost the same when a natural person controlling a LE certificate is used to digitally seal the VerifiableID.
3. In the case where a NP person represents the legal person and neither LE nor LER digital certificates are available, an explicit separate power/mandate is required. To verify the legal power/mandate of the presented legal person, the Verifiable Credential should be signed with the NP electronic signature and a trusted entity different from the legal entity (e.g., a notary or business registry). If those trusted entities are already TSPs, the verification of the VerifiableID is almost the same as with the mechanisms above. The main difference being that the VerifiableID is signed by a trusted entity instead of by an existing representative of the legal entity, making the process somewhat more cumbersome.

4.2.4.4 The actual onboarding process

The onboarding service of a Data Space can use the mechanisms described in 4.3 Identification and Authorisation and the above VerifiableID to properly identify the legal person involved, the natural person performing the onboarding and that the natural person has the powers of representation.

This can be done without requiring a previous relationship among the entities, and in a totally digital and automated way to allow self-onboarding.

Once this step is performed, the LEAR can provide additional documents (ideally as Verifiable Credentials) to complete the onboarding process or perform other required validations.

4.3 Identification and Authorisation

For **authentication** we propose to use the same mechanism as in EBSI and the EUDI Wallet for online flows, namely using OpenID Connect for Verifiable Presentations (OID4VP) and Self-Issued OpenID Provider v2 (SIOPv2), which leverages the proven, robust and secure standards of OpenID Connect protocols to:

- Transport Verifiable Credentials/Presentations in the flows of OpenID Connect, so Relying Parties can use well known mechanisms to issue and receive Verifiable Credentials.
- Enable all participants (via SIOPv2) to send identity data and Verifiable Credentials to other participants without the requirement for big and centralized Identity Providers as it is unfortunately common in implementations of standard OpenID Connect.

The authentication phase corresponds to interactions (1) to (4) in Figure 4.1. The detailed descriptions with a concrete example can be found in section 6 Detailed workflows based on a common reference use case.

This way we implement a distributed, fault-tolerant, trustful and efficient IAM system avoiding the existence of centralized Identity Providers (IdPs). Using widely implemented standards like OIDC and W3C Verifiable Credentials provides a very low barrier of entry to participants implementing IAM.

Using OIDC for transporting Verifiable Credentials enables integration of the attested data inside the credential for sophisticated and flexible **Authorization** schemes. Participants implementing this **Decentralized Identity and Access Management Framework** can use credential data for advanced RBAC/ABAC access control and policy enforcement.

The authorization phase corresponds to interactions (5) to (8) in Figure 4.1. The detailed descriptions with a concrete example can be found in section 6 Detailed workflows based on a common reference use case.

Furthermore, the IAM Framework can be used by participants not just to interact with the data space and marketplaces but they can adopt it and use it for peer-to-peer interactions between participants in the ecosystem without the involvement of central entities (except for initial onboarding and certification processes).

4.4 Usage/Access Control

4.4.1 Policy negotiation

A policy or contract negotiation (CN) involves two parties, a provider that offers one or more assets under a usage contract and consumer that requests assets. A CN is uniquely identified through an IRI. Each CN requires a newly generated IRI, which may not be used in a CN after a terminal state has been reached. A CN progresses through a series of states, which are tracked by the provider and consumer using messages. A CN transitions to a state in response to an acknowledged message from the counter-party. Both parties have the same state of the CN. In case the states differ, the CN is terminated and a new CN has to be initiated.

The detailled description of the Policy negotiation are subject to the Dataspace Protocol for Contract Negotiation including message definitions, a state machine and a binding to the HTTPS Protocol.

4.4.2 Policy enforcement

The trust in the capacity for a rule engine to properly compute and enforce policy is directly related to the level of control and measurability that the parties can have on that rule engine.

Nowadays, there are mainly two categories of control:

- Legal via a binding document between the parties and the operator of the rule engine.
- Technical via a workload remote attestation[4] of the rule engine by the parties.

The XACML architecture described below can be used in any of the two categories mentioned above.

Once the authentication phase has been performed based on Verifiable Credentials, the system generates an access token which can be used to access protected resources and allows efficient enforcement of usage policies. This phase corresponds to interactions (5) to (8) in Figure 4.1. The details of how this can be done is described with concrete examples in section 6 Detailed workflows based on a common reference use case.

[4] Example of workload remote attestation https://keylime.dev/

In the description we use concepts from the standard XACML architecture, and the most relevant ones are explained below, using a simplified diagram of the main logical components. To be clear, we are not limited to an XACML implementation, but use some of their architectural concepts for our explanation.

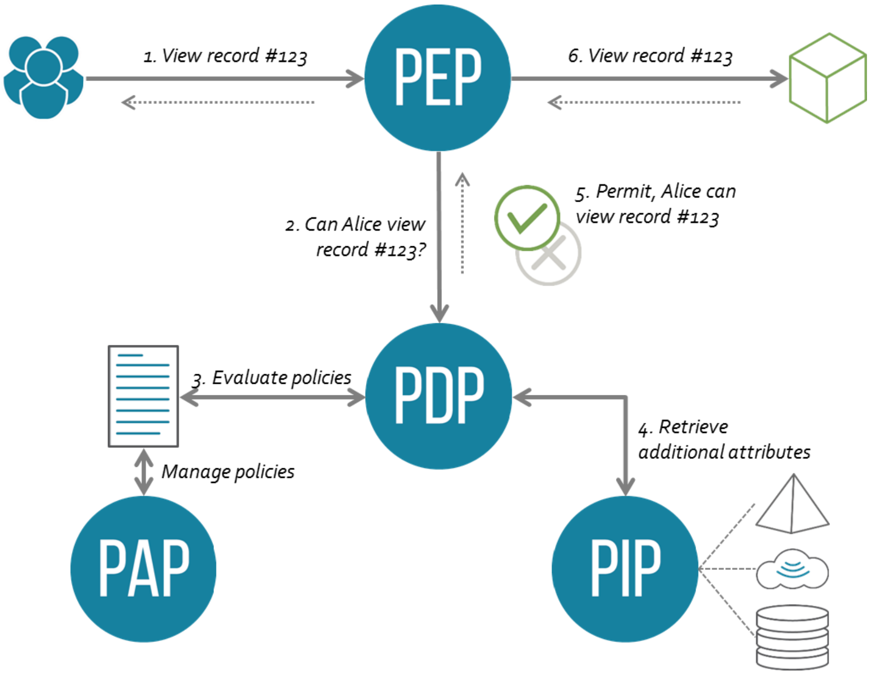

PEP
1. View record #123
6. View record #123
2. Can Alice view record #123?
5. Permit, Alice can view record #123
PDP
3. Evaluate policies
Manage policies
4. Retrieve additional attributes
PAP
PIP

Figure 4.3. Logical architecture for policy enforcement.

As explained above, we assume that the authentication phase has been already performed, and that an access token has been derived from the VerifiableID that was used for authentication. Without entering into details, we can assume that the access token contains the essential information from the credential (e.g., claims) so the policy enforcement can be performed. An example of concrete access tokens can be found in section 6 Detailed workflows based on a common reference use case.

The general flow is the following:

1. A user sends a request which is intercepted by the **Policy Enforcement Point** (PEP). If the request is authenticated (contains the access token), the flow continues.
2. The PEP converts the request (including data from the access token) into an authorization request in a given format.
3. The PEP forwards the authorization request to the **Policy Decision Point** (PDP).
4. The PDP evaluates the authorization request against the policies it is configured with. The policies are acquired via the **Policy Retrieval Point** (PRP) and managed by the **Policy Administration Point** (PAP). If needed it also retrieves attribute values from underlying **Policy Information Points** (PIP).

5. The PDP reaches a decision (Permit / Deny / NotApplicable / Indeterminate) and returns it to the PEP.

4.4.3 Policy Definition Language

A Policy Definition Language is required to define and agree access and usage policies. The defined and agreed policies can be used directly or translated into an executable language, e.g. Rego.

We propose to use ODRL as an interoperable standard for the negotiation and acceptance of Access and Usage Policies including the policy negotiation sequence as defined by IDSA in the IDS-RAM. ODRL is used in some well-known contexts, like VP/VC or DCAT, also.

We propose to work on well-defined ODRL Profiles, focussed on given requirements. Those profiles will be understood and used by all parties the same way. Those profiles will be mentioned in given ODRL-Policies and are a fundamental building block for senseful enforcements and the operationalisation of cross-dataspace interoperability.

The association of ODRL and VP/VC is at the core of the Gaia-X ontology to have integrity and authentication checks of semantically interoperable policies.

The enforcement of those policies can be realized as described in the previous section.

To be noted that under the condition that the various grammars allow it, the semantic interoperability between different executable policy engines could be achieved only if common controlled vocabularies (here: ODRL Profiles) are adopted.

5 Data Value Creation

5.1 Overview

Creating value out of data based on the sharing and usage of data is the ultimate goal in data-driven business-ecosystems.This follows basically the steps to:

- Describe data, services and data products in an interoperable manner
- Including data and service publication services to discover offerings and connect providers and consumers
- Add value–adding services such as marketplaces for commercialization

Those steps are covered by the DSBA technical convergence framework as described below. Providing access to services and data and providing usage policies, as well as required steps for interoperability are described in sections above.

5.2 Data, Services and Offerings descriptions

5.2.1 Self Descriptions and DCAT

A Participant who wants to offer data products in a data space needs to conduct several steps to make it available to potential Consumers of those data products. In typical data spaces use cases, a Data Service Provider does not know which other Participant is interested in the provided data offering, or even does not know about the existence of the later Data Service Consumer at the time when the data service is published. In such cases, the proper description and advertisement at the right locations is critical to enable a business transaction.

A data space should define manners to tackle these challenges by specifying a technology-agnostic language for data Self-Descriptions as well as the necessary infrastructure components to host and search through these Self-Descriptions. In all cases, the original Data Provider stays the sovereign origin of any information, and any involved component acts on behalf of it. Therefore, it is in general not allowed for any intermediate player to change or manipulate the content of the received Self-Descriptions, apart from obviously wrong data or to protect the operability of the data space.

The Data Space Information Model (see section 2.3.2) provides the schema for Self-Descriptions and their basic building blocks, like for instance Usage Contracts, endpoint descriptions, or the internal structure of data assets.

During the creation of a Data Product Offering the Data Service Provider may reuse, as described above, existing standards for the (semantic) description of the data itself or create a (semantic) description of the data. These Vocabularies can be published to a Vocabulary Hub and linked to the self-description (see section on domain-specific vocabularies and application profiles). This Design-time step supports the semantic interoperability in Data Spaces. While semantic models for the description of data in data spaces are in general a good practice, Vocabularies can also make use of other concepts.

The first step in a typical data product publication process is therefore the proper creation of a data product Self-Description. Data Space Connectors may provide the technical manners to create and maintain them. After reaching a syntactically and semantically correct Self-Description, they are then registered in Product Catalogs deployed at the Data Providers Data Space Connector. These Catalogs would be accessible via endpoints in the Connector exporting TM Forum APIs and also by making use of the Dataspace Protocol Catalog functionality which implements DCAT V3. Self-Descriptions may also include elements of domain specific ontologies or generic key/values depending on the domain of the ecosystem.

5.3 Publication and Discovery services

5.3.1 Meta-Data-Broker and Vocabulary Hub

The Data Service Provider may want to announce the created Self-Descriptions at a remote component of a data space instead of just offering it in its own Data Space

Connector instance. One of the options would be that the Data Provider sends the Self-Descriptions to a Metadata Broker. Specifications of the IDS Metadata Broker are the baseline for this kind of system.

A Meta-Data Broker is a component in a data space that allows the publication of Self-Descriptions for Data Products and Data Space Connectors. Data Service Consumers can find suitable data product offerings while not knowing the existence or the location of the Data Service Providers.

The selection of the appropriate Metadata Broker is in the responsibility of each data space Participant. The Metadata Broker then stores the received Self-Descriptions and makes them available for search requests from Data Space Connectors. Potential Data Consumers can search through the Self-Descriptions registered in the Metadata Broker, filter for relevant offers, negotiate with a given Data Service Provider and start interacting with the data service that is accessible through the corresponding Data Space Connector.

It should be clear, however, that no Data Service Provider is obliged to publish any data product at any Metadata Broker. Neither is a Data Service Consumer forced to start its integration process at an Metadata Broker, if it has other options to find and locate its data exchange partners. Still, both have the opportunity to interact with an Metadata Broker using the following main interaction patterns.

5.4 Marketplace and Accounting services

Data spaces should provide support for the creation of multi-sided markets where participants can generate value out of sharing data. This requires the adoption of common mechanisms enabling the description of services for accessing data or linked to applications processing data, the description of offerings associated with those services, the publication and discovery of both services and service offerings, and the management of all the necessary steps supporting the lifecycle of contracts that are established when a given participant acquires the rights to use a service, according to certain service offering.

The proposed approach will take the form of a Decentralized Open Marketplace Ecosystem (DOME) based on the federation of marketplaces, all of them connected to a commonly shared digital catalogue of cloud and edge services and service offering descriptions.

Cloud and edge services can be further classified as:

- data services, providing access to data

- application (app) services, which gather and process data, and typically deliver data results
- cloud or edge infrastructure services, supporting the deployment and execution of data/app services

Cloud and edge infrastructure service providers, in turn, can be classified as cloud/edge IaaS providers or cloud/edge Platform service providers (in this latter case, providing a platform targeted to solve either the integration of several data/app services linked to a given application domain, like smart cities or smart farming, or the integration of certain type of data/app services, e.g., AI services)

Each of the federated marketplaces in the referred DOME will be a marketplace provided by an independent marketplace provider or a marketplace connected to the offering of a given cloud / edge infrastructure service provider (IaaS or platform provider). Besides these marketplaces, A DOME global portal would implement functions through which cloud/edge service providers may register their product offerings and end customers can discover offered products.

DOME will rely on the adoption of common open standards for the description of cloud and edge services and service offerings as well as their access through a shared catalogue.

Following subsections elaborate on the roles that organizations can play with respect to DOME as well as some details of the technical architecture. Further clarification might be required, please visit the outlook section for this.

5.4.1 Roles of organizations in the ecosystem

Six different roles can be played by organizations involved in the ecosystem linked to DOME as illustrated in figure 5.1: cloud and edge service providers, marketplace providers, customers, the operators of the DOME technical infrastructure, third parties capable of integrating and offering their services complementing those implemented in the DOME technical infrastructure, and members of governance and supervisory bodies. The following subsections will introduce the mentioned roles.

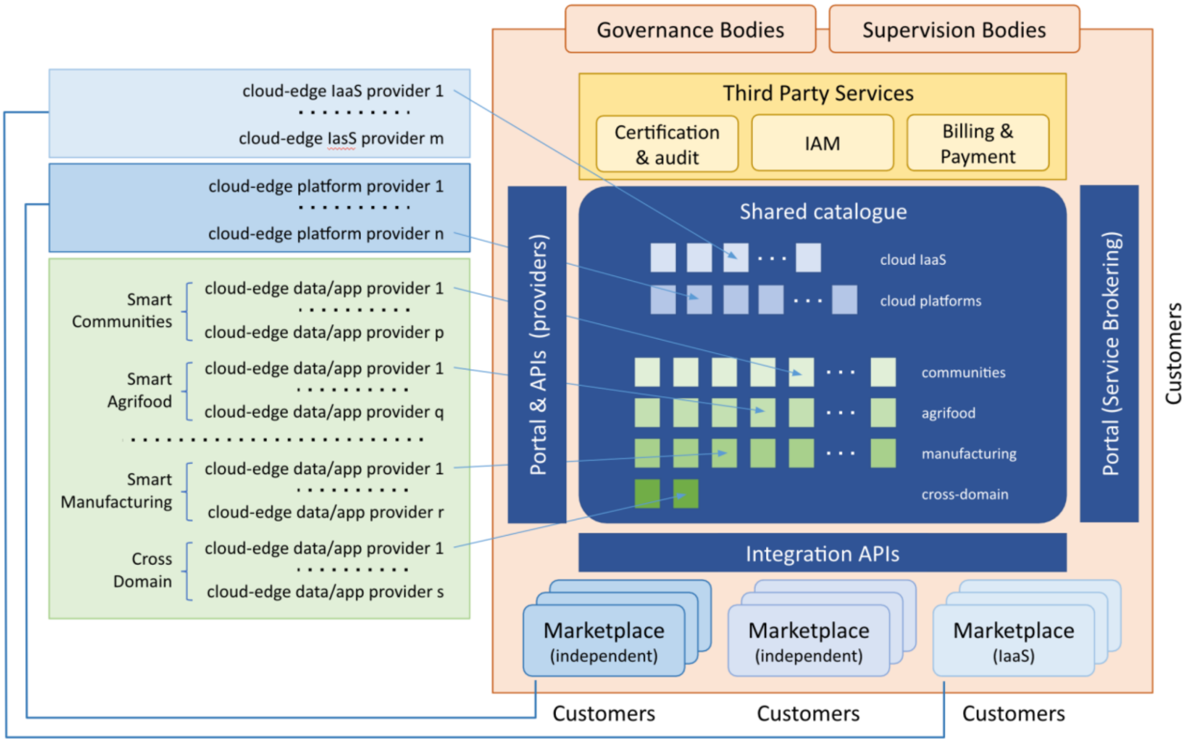

Governance Bodies
Supervision Bodies
Third Party Services
Certification & audit
IAM
Billing & Payment
cloud-edge IaaS provider 1
cloud-edge IasS provider m
cloud-edge platform provider 1
cloud-edge platform provider n
Smart Communities
cloud-edge data/app provider 1
cloud-edge data/app provider p
Smart Agrifood
cloud-edge data/app provider 1
cloud-edge data/app provider q
Smart Manufacturing
cloud-edge data/app provider 1
cloud-edge data/app provider r
Cross Domain
cloud-edge data/app provider 1
cloud-edge data/app provider s
Portal & APIs (providers)
Shared catalogue
cloud IaaS
cloud platforms
communities
agrifood
manufacturing
cross-domain
Portal (Service Brokering)
Customers
Integration APIs
Marketplace (independent)
Marketplace (independent)
Marketplace (IaaS)
Customers
Customers
Customers

Figure 5.1: High-level vision of DOME architecture, operating model and roles

5.4.1.1 Cloud and edge service providers

Cloud and edge service providers (IaaS, platform and app/data service providers) are organizations (public institutions or private companies) that offer service products that can be consumed by customers, such as other organizations or individuals. They access a DOME global portal where they can register and manage the description of specifications and offerings linked to their products. Product Specifications and Product Offerings associated with a given service from a service provider are stored in the Shared Service Catalogue that is the central part of DOME. A Product comprises a number Services and supporting Resources (e.g., an Air Quality monitoring product for a giving City may consist in an application offered as a Service from the Cloud and a number of computing resources on the Cloud plus a number of IoT devices for monitoring air quality deployed in the field).

The description of each Product Specification and Product Offering will be provided in a standard-based format prescribed in DOME. The description of a Product Specification will comprise information like the unique identifier of the product, its name, version, associated documentation, description of software services implementing the product functionality, description of resources required for execution of such software services (e.g., computing capacity, including disk storage, to be provisioned for serving each customer, or devices to be deployed on the edge), status within the lifecycle of the product (under testing, validated, active, obsolete, retired, ...), etc. On the other hand, the description of a Product Offering will comprise an unique identifier, a reference to the specification of the product being offered, lifecycle status, terms and conditions associated to its use, pricing model, associated agreements (e.g., list of Service Level Agreements that users can choose from), target market segment, kind of marketplaces through which the product can be offered, etc. Both, Product Specifications and Product Offering descriptions, will comprise a number of labels issued by certification agencies in connection with the service offered that certifies compliance with defined EU regulations or rules established by supervision authorities (e.g., GDPR regulations, established regulations for specific sectors like health, energy, finance, regulations for cloud services to be established in the EU Cloud Rulebook, ...), relevant standards (e.g., standards for interoperability) or best practices (e.g., Open Source Security Foundation Best Practices).

A Cloud and edge Data/App service provider could receive Product Orders from end customers directly or from those marketplaces federated in DOME which have incorporated the given Data/App service as part of their catalogue (see description of the role of Federated Marketplaces below). Similarly, a given Data/App service provider may receive payments through third-party payment service providers that have integrated their services directly with DOME and it has decided to rely on for direct processing of orders, but they can receive such payments also from the payment services implemented by the federated marketplaces through which service orders for the Data/App service were issued.

Through specific pages for providers of the DOME global portal, cloud and edge IaaS, Platform and data/app service providers can also monitor the evolution of their contracts for particular end users and generate different kinds of reports. In order to be able to access these specific pages for providers under the DOME global portal, each cloud and edge IaaS, Platform and data/app service provider has to be registered in the eIDAS service.

5.4.1.2 Federated Marketplaces

As illustrated in figure 1, different kind of marketplaces can be federated to DOME:

- Marketplace connected to an IaaS provider, which comprises a catalogue of cloud and edge data/app services which customers can pick and then easily deploy on top of the computing infrastructure supported by the given IaaS provider
- Marketplace connected to a Platform provider which comprises a catalogue of cloud and edge data/app services which customers can pick and easily activate, integrated with the rest of applications on top of the provided Platform.

- Independent Marketplace, which comprises a catalogue of cloud and edge data/app services which are not tied to any particular IaaS or Platform provider

Examples of Marketplaces connected to Platform providers would be marketplaces connected to specific application domains, like Smart Cities or a Smart Farming, or marketplaces connected to specific technology frameworks, like a Spark-based platform for development of AI apps, or a Grafana-based platform for development of dashboard apps. In the case of a marketplace connected to a specific Smart City platform, the catalogue may comprise apps for Smart Parking, Smart Air Monitoring or Smart Waste Management, for example. Note that each data/app service may be hosted on a different IaaS cloud or servers and it does not need to be the same where the Platform is hosted. In the case of a Smart Farming Platform, the catalogue may comprise apps for Smart Field Watering, Smart Pesticide Spreading or Smart Silo. Similarly, a marketplace connected to a Spark-based platform may comprise applications for predictive maintenance of vehicles, or Weather predictions. Some of the data/app services can be provided by the Platform provider (e.g., Integrated Command and Control system in connection with Smart City Platforms, or Smart Farm Management system in connection with Smart Farming). Some of them may be already active by default for all customers, otherwise may require acquisition through the marketplace.

Note that a given cloud/edge service may be visible in multiple marketplaces. On the other hand, a given marketplace may only comprise a subset of the cloud and edge services listed in the DOME shared catalogue (e.g., the Marketplace connected to a concrete Smart City platform based on FIWARE will only include data/app services relevant for cities that implement the NGSI-LD standard for integration).

Also note that cloud and edge data/app services will always be visible and could be directly procured once discovered through the DOME global portal. However, federated Marketplaces will typically bring a personalized user experience to their target customers, and also a different implementation of their own rating, billing and payment processes, even though they may rely on payment and billing services offered by third parties through DOME.

5.4.1.3 Customers

European public and private customers looking for trusted cloud and edge services will interact with DOME following one of the two following paths:

- In a very first step, accessing the DOME global portal and leveraging service brokering functions of the DOME technical infrastructure to discover IaaS or platform providers which, together with their associated marketplaces can bring to them the best personalized experience. Afterwards, interacting directly through the marketplace associated with the IaaS and platform of their choice, picking the concrete cloud and edge data/app services offerings that are published through the marketplace catalogue which therefore can be seamlessly integrated with their selected IaaS/Platform to support processes of their organization.

- Accessing the DOME global portal to find cloud and edge services directly, placing and managing orders of selected services via mechanisms those services expose through the DOME infrastructure, and conducting payments via payment systems which are supported directly by the service provider or are offered by third parties integrated with the DOME infrastructure that have been accepted by the selected service provider.

While the second path will be feasible, it is envisaged that the first path will be more optimal, since the consumer will benefit from a more rich and comprehensive service that IaaS/Platform providers can offer.

5.4.1.4 Operators of the DOME technical infrastructure

For a given data space or federated set of data spaces, a number of companies will act as operators of the DOME technical infrastructure, ensuring the proper functioning of DOME, including security aspects.

5.4.1.5 Third parties integrating/offering complementary services

DOME will provide means for integration of Third-party services, like for example:

- Services from certification and audit agencies which will help to validate the reliability, security, and sovereignty of certain cloud services by checking/verifying their compliance with predetermined market-wide certifications.
- IAM service providers offering services aligned with open standards for IAM adopted in DOME, bringing participants the ability to securely manage identities and access to specific cloud and edge data/app services.
- Billing and Payment service providers working as gateways that rely on transaction logs registered in the federated blockchain network infrastructure underlying DOME to provide secure, transparent and trustful billing to consumers and payment to providers.

For all these three kinds of third-party services, or additional ones, DOME represents a new source of revenue, as it gives them access to a new market (the cloud and edge service providers and the customers). On the other hand, they may represent potential sources of revenue for securing the sustainability of DOME.

5.4.1.6 Members of governance and supervisory bodies

Last but not least, DOME will define suitable governance and supervisory bodies that will oversee development of the ecosystem around DOME ensuring fulfillment of its objectives. These bodies will typically incorporate operators of the DOME infrastructure, representatives of the organizations using DOME, and other relevant stakeholders including, when relevant, representatives of public bodies.

5.4.2 Shared Catalogue and Transactions Ledger (Distributed Persistent Layer)

At the heart of the technical architecture of DOME is the DOME Distributed Persistent Layer which manages storage of, and access to, information associated with:

- the Shared Catalogue of Product Specifications (including the specifications of associated services and supporting resources) and Product Offerings defined by cloud and edge service providers
- Product Orders and Product instances along their lifecycle, as well as information about actual Usage of Products

The DOME Distributed Persistent Layer can be implemented on top of a number of interconnected national blockchains (like Alastria or HashNet) compatible with the European Blockchain Service Infrastructure (EBSI). As illustrated in Figure 5.2, each cloud and edge service provider, federated marketplace, and the DOME Global Portal backend itself implements an access node to the DOME Distributed Persistent Layer that implements the standard TM Forum APIs defined for the implementation of Marketplace functions.

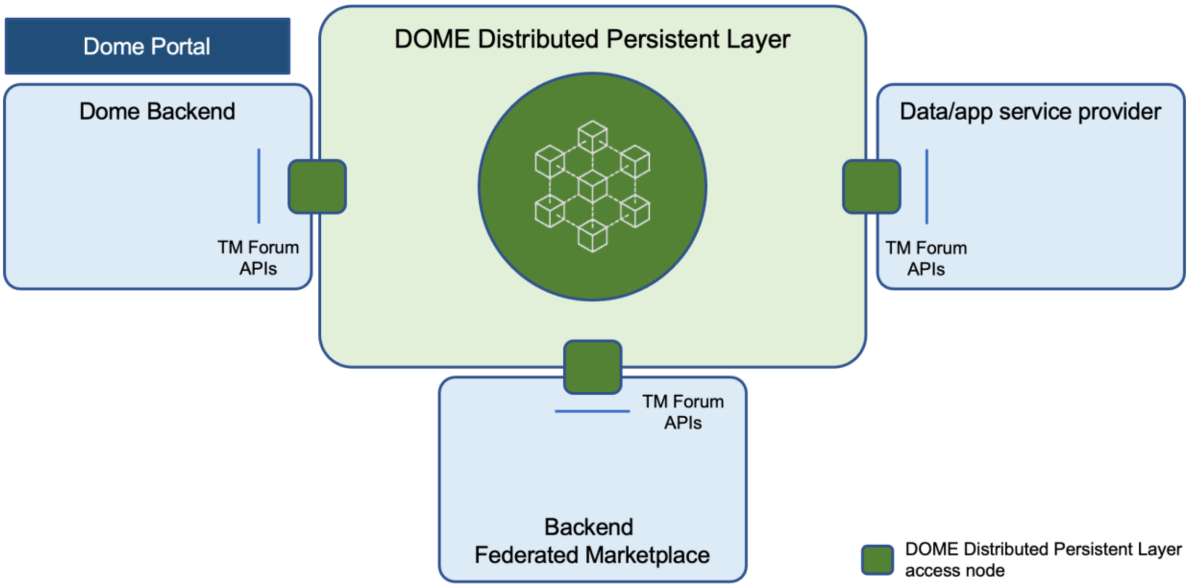

Dome Portal
Dome Backend
TM Forum APIs
DOME Distributed Persistent Layer
Data/app service provider
TM Forum APIs
TM Forum APIs
Backend
Federated Marketplace
DOME Distributed Persistent Layer access node

Figure 5.2 - High-level architecture of the DOME Distributed Persistent Layer

When a Product Offering is created through the DOME Global Portal, for example, information about it has to be stored in the DOME Distributed Persistent Layer. This is achieved by invoking the specific operation for creating a Product Offering entity of the TM Forum Catalog Management API (TMF620 recommendation) that the Distributed Persistent Layer access node implemented in the DOME Global Portal backend supports. Part of this information is stored in the blockchain and, consequently, becomes replicated in all other nodes connected to the DOME Distributed Persistent Layer while rest of the information will be stored "off-chain" within the access node, which will typically also store a local copy of the information stored in the blockchain to support local queries in a more efficient manner. What part of the information will be stored in the blockchain and what part of information will be stored only "off-chain" is still to be decided. In any case, any access node will be able to access information stored "off-chain" based on information stored in the blockchain, provided it owns the necessary credentials that grant them access to the nodes where such "off-chain" data is stored.

Aligned with Gaia-X specifications, the description of Product Specifications and Product Offerings will be represented in the form of Verifiable Credentials/Presentations (VC/VP) compliant with W3C standard specifications[5], some of which will take the form

[5] W3C Verifiable Credentials Data Model v1.1, W3C Decentralized Identifiers (DIDs) v1.0

of labeled certifications (verifiable credentials issued by certification and audit agencies). These VC/VPs are also stored in the DOME Distributed Persistent Layer.

The DOME Distributed Persistent Layer brings transparency and trust to all participants since all transactions linked to the creation of Product Specifications, Product Offerings, Product Orders and Product Instances as well as their evolution over time or the generation of Usage Logs will be stored in a blockchain. This allows, for example, cloud data/app service providers to audit when their services have been procured and through which marketplace (any of the federated ones or directly DOME). Similarly, it will allow a given marketplace provider to audit when a given data/app service that was procured through its marketplace has been used. Last but not least, Usage Logs can be used by third party Charging/Billing/Payment gateways integrated with DOME which may be offered to cloud and edge service providers which do not want to implement a charging/billing/payment system on their own. They can also be used to generate verifiable credentials regarding operations of a service provider which can later be used as "passport" in front of investors or funding agencies.

5.4.3 Services providers journey

Figure 5.3 describes the journey that cloud and edge service providers will go through when interacting with DOME.

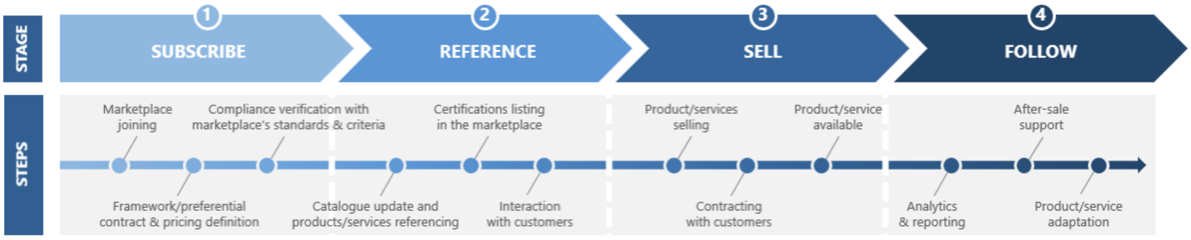

STAGE
1
SUBSCRIBE
2
REFERENCE
3
SELL
4
FOLLOW
STEPS
Marketplace joining
Compliance verification with marketplace's standards & criteria
Certifications listing in the marketplace
Product/services selling
Product/service available
After-sale support
Framework/preferential contract & pricing definition
Catalogue update and products/services referencing
Interaction with customers
Contracting with customers
Analytics & reporting
Product/service adaptation

Figure 5.3 - Service providers journey in DOME

Next we explain each of the stages, providing some details about what goes on within each stage from a technical perspective:

5.4.3.1 Stage 1 - Subscribe

The 'subscription' stage comprises all the steps followed by any given cloud and edge service provider since it joins DOME until it publishes its Product Offerings. This consists of three steps that the provider performs via DOME (either through APIs or the Portal) – 1) registration as a cloud/edge service (product) provider, 2) registration of the specifications of products it offers (defined as combination of services and associated resources) as well as definition of the basic characteristics of product offerings around registered product specifications like market segments the offering is targeted to (useful later on to fine tune discovery services), sale channels through which the offering will be visible (e.g., type of federated marketplaces in addition DOME), or terms and conditions, including information about the different pricing models supported, and 3) verification of the compliance with DOME's basic standards and criteria.

All these steps will imply registration and management of information linked to entities described in the information model previously described in Figure 2 using TM Forum APIs that the DOME Distributed Persistent Layer supports. As an example, registration of a given cloud/edge service provider would mean creation of a Party playing the role of Provider using the TM Forum Party Management API (TMF632 recommendation). Similarly, registration of Product Specifications and Product Offerings will be performed using the TM Forum Product Catalog Management API (TMF620 recommendation) which in turn will rely on the the TM Forum Service Catalog Management API (TMF633 recommendation) and the TM Forum Resource Catalog Management API (TMF634 recommendation) since products are made out of the combination of services and supporting resources. Cloud and edge service providers can perform these operations programmatically using the TM Forum APIs that their access nodes to the DOME Distributed Persistent Layer support or via de DOME Global Portal (whose backend, on the other hand, uses TM Forum APIs supported by the DOME Distributed Persistent Layer). Compliance verification of a given Product Specification or Product Offering will imply the transition of their status (one of the attributes these kinds of entities export) into "active" status.

An IaaS or Platform service provider that has implemented a marketplace connected to its services also relies on the TM Forum Party Management, Product Catalog Management, Service Catalog Management and Resource Catalog Management APIs (TMF632, TMF620, TMF633 and TMF634 recommendations) that their access nodes to the DOME Persistent Layer offer in order to register data/app service providers, as well as Product Specifications and Product Offerings of those data/app service providers that have been registered through their marketplaces instead of directly through DOME. This is why we say that these marketplaces connected to IaaS or Platform service providers are federated to DOME: no matter how a data/app service provider registers, directly or through a federated marketplace, its Product Specifications or Product Offerings will end up registered in the DOME Share Catalogue (part of the DOME Distributed Persistent Layer).

Cloud and edge service providers get notified when information relevant to them is stored in the DOME Persistent Layer. Such notifications are received through their access nodes to the DOME Persistent Layer. Thus, for example, when a specific data/app service provider registers a given product offering (associated with a given product specification defined as combination of services and resources) in DOME, it will be offered the possibility of register the product offering just in DOME or in DOME as well as any of the marketplaces connected to IaaS or Platform service providers federated with DOME. In the latter case, these IaaS or Platform service providers will receive a notification through the access node to the DOME Persistent Layer they implement. This way, a provider has only to register a data/app service once in DOME and get visible through the catalogue of all federated marketplaces it allows to work as sales channels. Note that additional compliance verification may be performed at the level of each of the federated marketplaces. For example, support of a NGSI-LD interface by the data/app service being registered may be verified by marketplaces associated with Platform services that are based on FIWARE.

Figure 5.4 illustrates interactions that take place during the Subscribe stage.

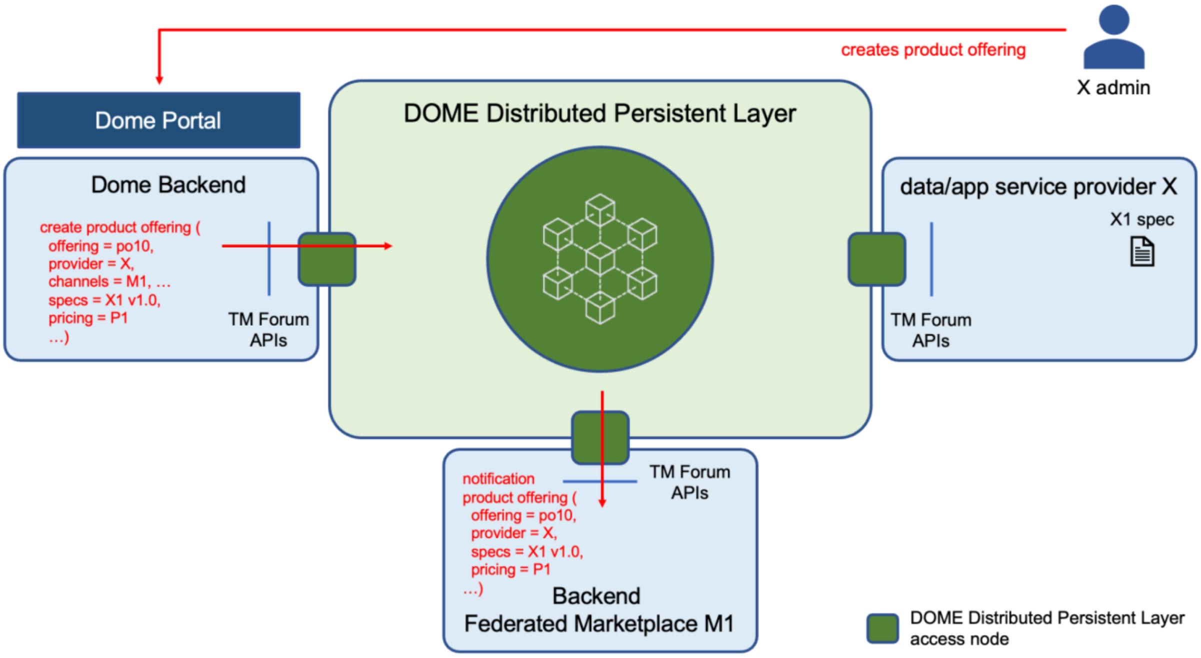


Figure 5.4 - interactions among components during subscribe stage

5.4.3.2 Stage 2 - Reference

Once a Product Offering becomes "active" it becomes visible to other users of DOME (typically end customers as well as IaaS and Platform service providers in the case of data/app services, since they may be interested to incorporate those data/app services in their respective catalogs). The provider of the Product Offering may establish visibility rules that determine who can get access to the offering.

Cloud and edge service providers may refer to web pages of the DOME global portal describing their product offerings once incorporated in the DOME Catalog. This way being able to promote them in front of potential customers.

A Cloud and edge service provider is able to update characteristics of its Product Offerings as well as corresponding Product Specifications (or specifications of associated services and resources). Those updates can be formulated through TM

Forum APIs supported by the access nodes to the DOME Distributed Persistent Layer or via the DOME global portal. These updates will not only get registered in the DOME Product Catalog (becoming then visible through the DOME Global Portal to other direct users) but will be propagated to federated marketplaces in which the given Product Offerings / Specifications that got updated were also registered. This propagation will take place through notifications that federated marketplaces will receive through the access nodes to the DOME Distributed Persistent Layer they implement.

Through search and browsing capabilities that the DOME Global Portal will implement, customers will be able to easily find the specific product they are looking for. In its most basic format, the DOME global portal will allow customers to launch product offerings and product specifications searches, leveraging category filters and tagging functions, some tags connected to Verifiable Credentials (VCs) describing them. These functions will also be accessible via API enabling integration of more sophisticated customer applications.

Beyond basic search functions, DOME will implement more advanced features with the goal of connecting consumers with relevant services as quickly as possible. As an example, it will be possible to implement a search algorithm which would match customer search queries with keywords from relevant product listings. Even more advanced search functions may leverage additional information (such as product ratings or click-through rates) to prioritise/rank the results of search queries and improve the customer experience. Finally, search algorithms could also be specific to the customer’s sector to provide results that take into account the customer’s particularities.

Figure 5.5 illustrates interactions that take place during the Reference stage.

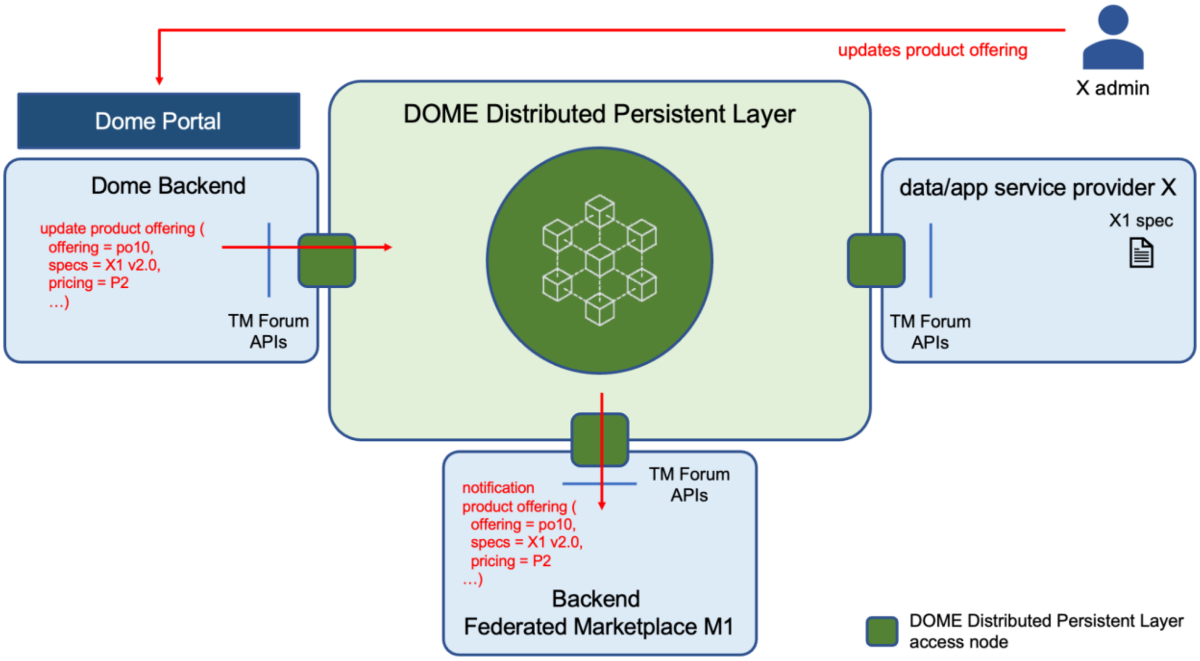


Figure 5.5 - interactions among components during reference stage

5.4.3.3 Stage 3 - Sell

There are two ways in which a given Product offered by a cloud/edge service provider can be procured: either directly after discovery through DOME or through marketplaces associated with IaaS or Platform service providers where the corresponding Product Offering has also been registered. When a given customer discovers a cloud/edge service Product Offering it is interested in, both possibilities are offered.

In the first case, procurement may be performed either via the DOME Global Portal or programmatically. In both cases, the creation of a Product Order will be ultimately requested using the TM Forum Product Ordering Management API (TMF622 recommendation) that the Distributed Persistent Layer access node implemented in the DOME Global Portal backend supports.

In the second case, typically associated with procurement of data/app services, the customer will be redirected to the marketplace of its choice, through which the procurement process will be handled. At a given moment, the creation of a Product Order will be performed via invocation of the TM Forum Product Ordering API supported by the DOME Distributed Persistent Layer access node linked to the selected marketplace. Note that this Product Order will also become visible not only in the federated marketplace but also at the DOME Global Portal.

In any of the two cases, a Product Order is created within the DOME Distributed Persistent Layer and the given cloud/edge provider will receive a notification about creation of the Product Order it should handle. This notification will be received through their corresponding DOME Distributed Persistent Layer access node.

Note that many customers will end up consuming services through the portals of federated marketplaces the DOME global portal will guide them to. This is because these portals are expected to provide a better tailored user experience (UX). However, the federation of marketplaces with DOME will mean that all relevant transactions will be registered in the DOME Distributed Persistent Layer and therefore become visible at the DOME Global Portal, this way ensuring transparency and giving higher trust to both customers and data/app service providers.

Figure 5.6 illustrates interactions that take place during Product Ordering.

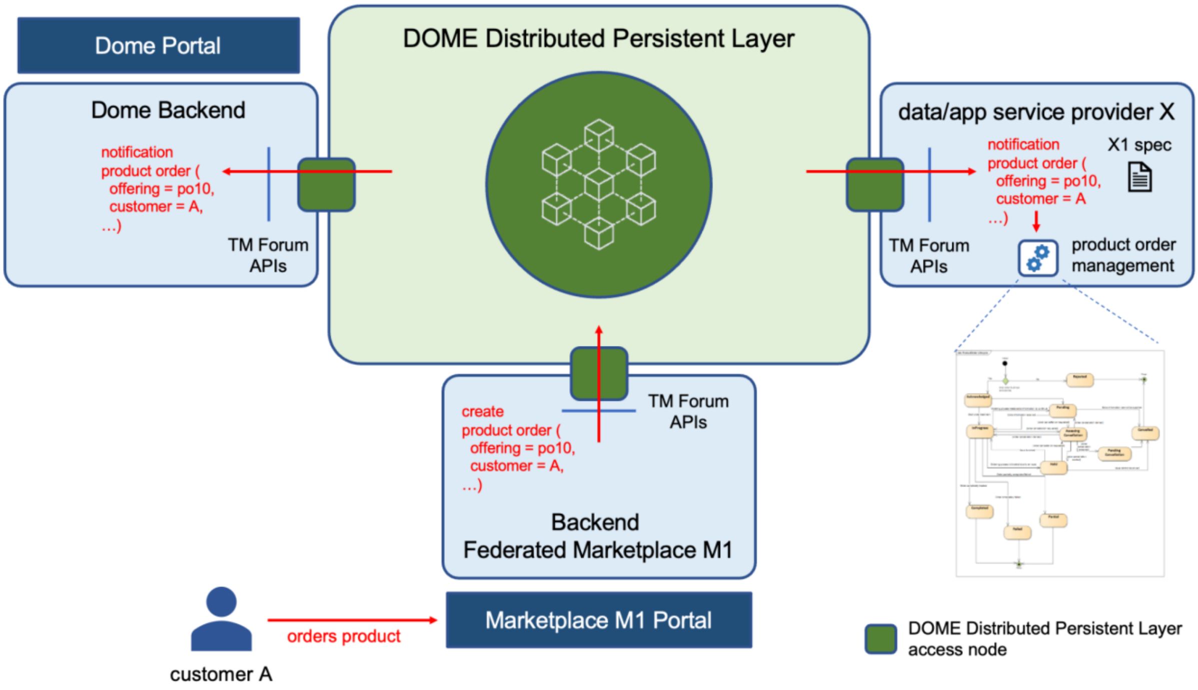


Figure 5.6 - interactions among components during Product Ordering

Figure 5.7 illustrates the different states a Product Order will go through since it is issued by a given customer and it gets completed. Such states will be reflected as values of the attribute “state” that any Product Order will support. The defined lifecycle complies with TM Forum specifications but will be revised based on feedback from first deployment and pilots of DOME.

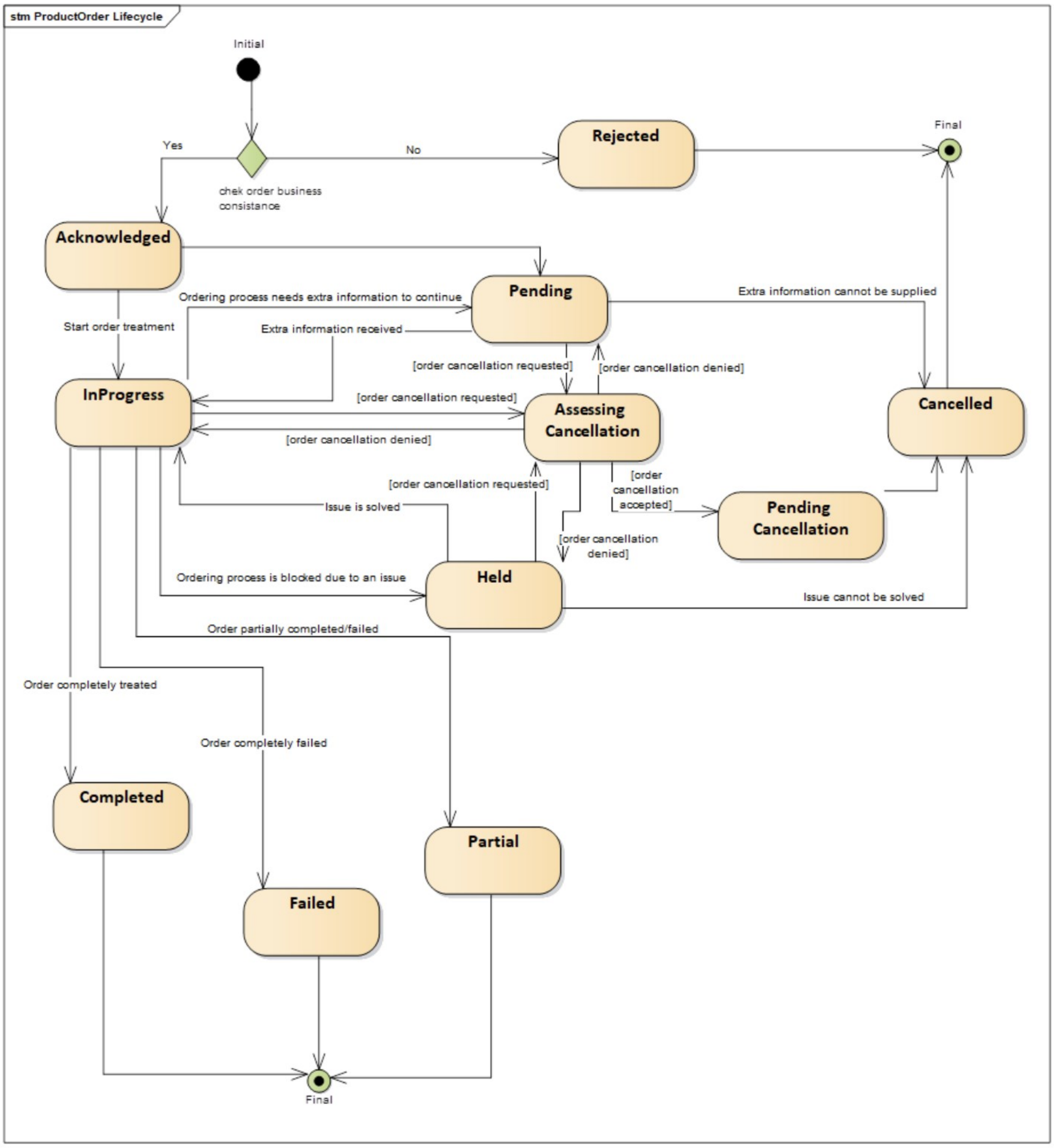

stm ProductOrder Lifecycle
Initial
Yes
No
Rejected
Final
chek order business consistance
Acknowledged
Pending
Ordering process needs extra information to continue
Extra information cannot be supplied
Start order treatment
Extra information received
[order cancellation requested]
[order cancellation denied]
InProgress
[order cancellation requested]
Assessing Cancellation
Cancelled
[order cancellation denied]
[order cancellation requested]
[order cancellation accepted]
Issue is solved
Pending Cancellation
[order cancellation denied]
Ordering process is blocked due to an issue
Held
Issue cannot be solved
Order partially completed/failed
Order completely treated
Order completely failed
Completed
Partial
Failed
Final

Figure 5.7 - Lifecycle of Product Orders

Once a Product Order is completed, a contract between the customer and the service provider is established so that terms and conditions defined in the Product Offering start to apply. As a result, the customer becomes a Trusted Issuer of Verifiable Credentials relevant to the product business logic (see section on “Trust Anchor and Decentralized Identity and Access Management (IAM) Framework” below). The service provider will then create a Product instance using the TM Forum Product Inventory Management API (TMF637 recommendation) that its access node to the DOME Distributed Persistent Layer supports. As a result, the Product instance will become visible to the customer, either through the DOME global portal or the federated marketplace through which the originating Product Order was issued.

Figure 5.8 illustrates the different states a Product instance will go through since it is created, right after the originating Product Order was completed, until it is terminated. Such states will be reflected as values of the attribute “state” that any Product instance will support. The defined lifecycle complies with TM Forum specifications but will be revised based on feedback from first deployment and pilots of DOME.

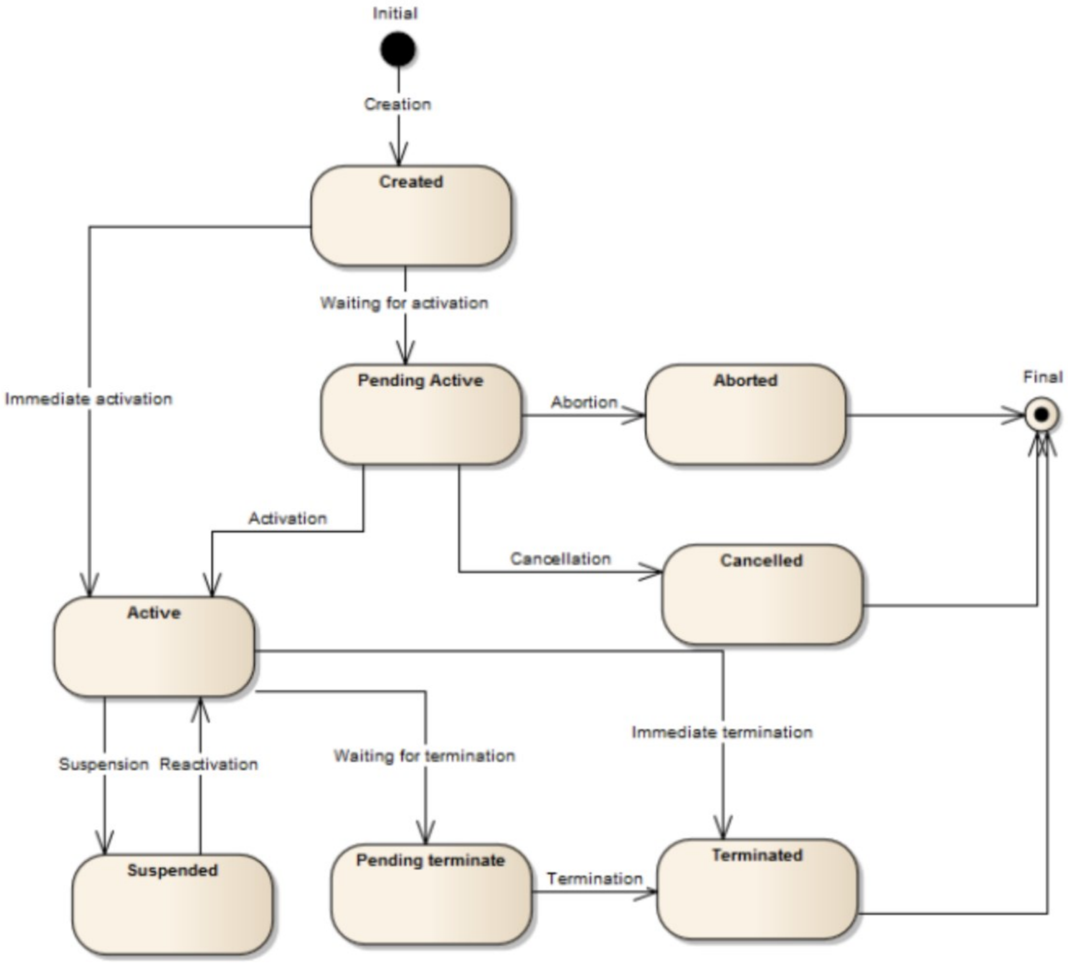


Figure 5.8 - Lifecycle of a Product (instance)

Note that the creation of a Product instance does not necessarily mean that its component services and required resources get automatically provisioned and activated. There may exist a period from the time at which a Product is created until it actually can be used by the customer that ordered it. This is for example the case in connection to products which require deployment of resources in the field (e.g., an app for air quality monitoring which requires deployment of several IoT devices in the field).

It is also the case when manual configuration and/or integration testing with products from third parties is required. Once everything is ready for actual usage, the state of the Product becomes “Active”. This will be the point at which access to the service will be permitted, or logs for the initial charging will be generated in connection to one-payment or subscription fee pricing models. It will also be the point at which Usage logs will start to be generated, bringing the basis for the monitoring of services as well as the support to pay-per-use pricing models.

Cloud and edge service providers registered in DOME will commit to register Usage logs in the DOME Distributed Persistent Layer, using the TM Forum Usage Management API (TMF635 recommendation) that its access node to the DOME Distributed Persistent Layer supports. Those Usage logs will ultimately be recorded in the blockchain associated with the DOME Distributed Persistent Layer but multiple logs will be condensed into a block for performance reasons.

Figure 5.9 illustrates interactions that will take place during the lifecycle of a Product instance, particularly at the time of its creation as the result of completing a Product Order by a particular customer, and its activation for that customer.

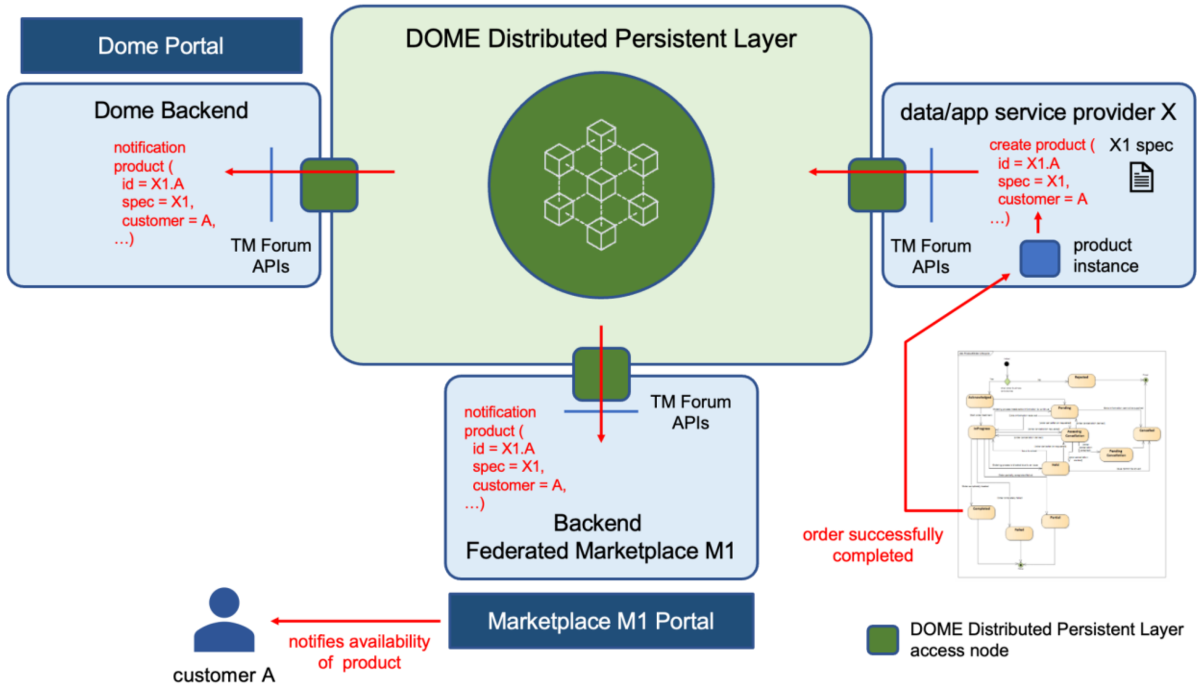


Figure 5.9 - Interactions during the lifecycle of Product instances

5.4.3.4 Stage 4 - Follow

Once providers have sold their service, they will need to be able to monitor consumption, provide after-sale support and leverage the experience to innovate and continuously strengthen their service offering.

Reporting and analytics features will be offered via the DOME Global Portal that providers and customers can consume. Notably, the marketplace can provide users the option to personalize their reports or to export data to outside platforms via connectors and APIs. Since relevant information for fueling these reporting and analytic tools is accessible through the DOME Distributed Persistent Layer, more advanced versions can be offered as Third-Party services that get access to the APIs that the DOME Distributed Persistent Layer offers.

Note that customers will mostly end up consuming services through the portals of federated marketplaces the DOME global portal will guide them to. These portals are expected to incorporate their own reporting and analytic functions meeting the needs of customers (particularly to support the different stages of their journey).

5.4.4 Customers journey

Figure 5.10 describes the journey that consumers of cloud and edge services offered through DOME will go through when interacting with DOME.

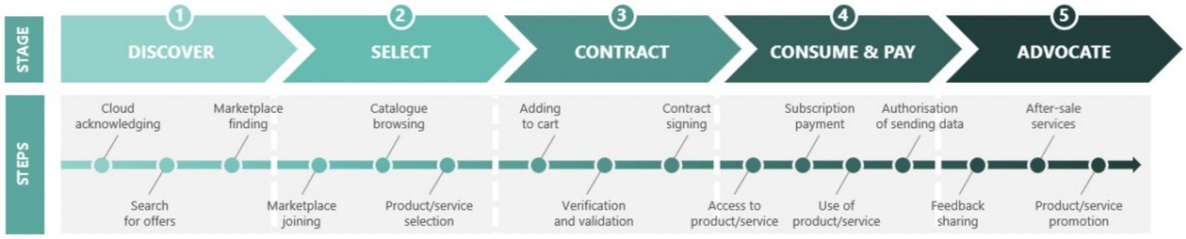


Figure 5.10 - Consumers journey in DOME

Those customers who approach the DOME ecosystem for the first time or wish to check other marketplaces different than the one they are already using, will connect to the DOME global portal searching for offerings. They may end selecting and contracting individual data/app cloud or edge services directly through DOME which may require use of third party payment services integrated with DOME. However, in other cases they will look for the marketplaces, connected or not to an IaaS, Platform provider or Individual Marketplace Provider that may better solve their overall needs. When a customer selects a given marketplace then they will further interact with its corresponding portal, which will typically mean they will enjoy a more personalized user experience through that portal interface, including the payment of services. Note that, despite further interactions will then be bilateral with the marketplace, DOME will bring trust to the relationships established between customers and app/data cloud and edge services, because both can audit transactions as they are logged in the DOME Distributed Persistent Layer. Satisfied customers will become the best ambassador of DOME and federated marketplaces based on a satisfactory experience.

5.4.5 Interoperability with Data Publication Platforms

Some of the cloud or edge data services registered in DOME may bring access to static data or near real-time data resources available through RESTful APIs (e.g., IoT data). DOME will integrate data publication functions enabling the exposure of such data resources in compliance with DCAT specifications defined by W3C and DCAT-AP recommendation by the EC. This way, data resources linked to data services offered through DOME can be harvested through external Data Publication platforms (e.g., the European Data Portal) .

6 Detailed workflows based on a common reference use case

6.1 Overall description of the reference use case

In order to better visualize and understand the details of the descriptions in the previous chapters, we define a highly detailed reference use case with technical descriptions that can be generalized to other use cases, always taking into account the different nature of different use cases. This section brings an overall description of the reference use case through which we will specify how the different technical building blocks for supporting data spaces will be integrated and be used together.

The reference use case implements a scenario where a data service provider offers a service on a public marketplace, so that service consuming parties can acquire access to this offering. Furthermore, these consuming parties can delegate the access to the acquired service offering to their users (e.g., customers).

In this use case, the provider is a packet delivery company, supporting creation and management of packet delivery orders and offering a service to view and change specific attributes of a packet delivery order. The consuming parties will be different retailers providing shop systems to their customers. These retailers will acquire access to services of the packet delivery company through the Data Space Marketplace, and delegate the access to its customers.

In the reference use case, several parties are involved, each hosting its own infrastructure. Namely:

- Data Space Marketplace: Public marketplace for creating service offerings and acquiring access to them

- Trust Anchor: fulfills the role of a scheme administrator which holds information about each participating party (including a global UID called EORI) and allows it to check for the admittance of each party.
- Packet Delivery Company: Provider which offers a service for retrieving and updating data of packet delivery orders
- Happy Pets: Premium pets retailer. Additionally there are two human actors involved: Happy Pets employee (actor working on behalf of Happy Pets company) and Happy Pets Customer (Customer of the pets shop system)
- No Cheaper: Retailer offering products at big discounts. Additionally there are two human actors: No Cheaper employee (actor working on behalf of No Cheaper company) and No Cheaper Customer (Customer of the No Cheaper shop system)

The following figure depicts the overall architecture of the reference use case. The packet delivery company and the shop system provider each have their own identity provider and authorization registry. In addition, the packet delivery company hosts a portal which allows users to view and modify attributes of packet delivery orders. The order entities are stored in an instance of the Context Broker. Read and write access to the packet delivery order entities is controlled by a PEP Proxy and PDP according to the described roles in section 4.2 Parties involved.

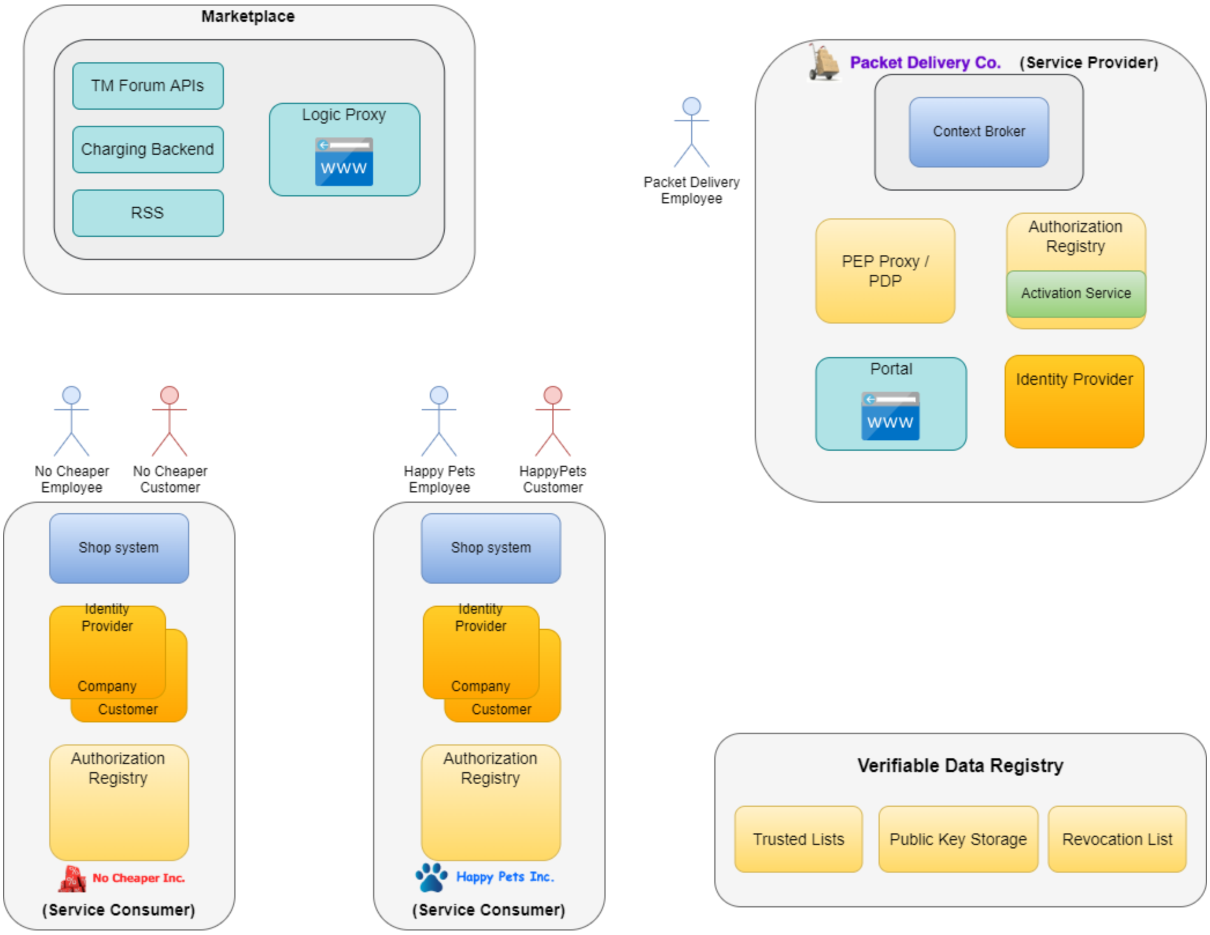


Figure 6.1: Overall architecture

6.2 Parties involved

6.2.1 Data Service Provider: Packet Delivery Company

Packet Delivery Company (PacketDelivery for short) is a parcel service provider delivering packets all over the world. It offers two kind of Packet Delivery services:

- A “Standard Packet Delivery" service for which the customer simply is given the opportunity to specify the issuer (sender) of the packet, the address, date and time at which the packet to be delivered is ready for collection, and the name and address of the destinee to whom the package has to be delivered. When the PacketDelivery receives a packet delivery order from a given customer, it returns the target date at which the packet is planned to be delivered. Under defined terms and conditions (e.g., there are no problems with customs, addresses are valid, etc), it commits to deliver the packet in 48 hours within the same country and 5-6 days if it requires international shipping. However, customers are not allowed to adjust the concrete date of delivery (e.g., delaying it to a more suitable date) nor fine-tune the concrete time of delivery within the selected date of delivery.

- A "Gold Packet Delivery" service for which the customer enjoys all the benefits of the "Standard Packet Delivery" but also is allowed to adjust the concrete address of delivery, date of delivery within an offered period, as well as concrete time of delivery within the selected date of delivery, provided such adjustments are feasible (e.g., are requested enough time in advance and do not imply additional costs).

PacketDelivery offers its services electronically to different retailers, bringing them access to its Packet Delivery Info system (P.Info) via a REST API in order to allow them to issue packet delivery orders, trace location of orders and allow their customers to perform requests for adjustments on address, date and time of planned delivery when their clients are entitled to.

This is implemented because the P.Info system offers access to data about DELIVERYORDER entities through a Context Broker using NGSI-LD. A DELIVERYORDER is an entity with attributes like:

- issuer
- pickingAddress
- pickingDate
- pickingTime
- destinee
- deliveryAddress
- PDA (planned date of arrival)
- PTA (planned time of arrival)
- EDA (expected date of arrival)
- ETA (expected time of arrival)

PacketDelivery has defined two roles "P.Info.standard" and "P.Info.gold" for the P.Info system based on which the operations that can be requested on the above attributes through the Context Broker service it publishes have been defined. To simplify the description of the scenario, we will focus on attributes *deliveryAddress*, *PDA* and *PTA* since we could assume that the other ones will be assigned values at the time an order is created, will be always readable but will not be able to be changed by users with the defined roles. In that sense, the following policies apply for the defined roles regarding modification of these three attributes (deliveryAddress, PDA, PTA) once an order has been created:

Path:	Verb

/ngsi-ld/v1/entities/{entityID}/attrs/{attrName}	GET	PATCH
deliveryAddress	P.Info.standard/gold	P.Info.gold
EDA	P.Info.standard/gold	---
ETA	P.Info.standard/gold	---
PDA	P.Info.standard/gold	P.Info.gold
PTA	P.Info.standard/gold	P.Info.gold

Note that orders will be created using POST but with a different path (/ngsi-ld/v1/entities/). For issuing such requests an additional role "P.Create" is defined which will be assigned to the retailers Happy Pets and No Cheaper only.

PacketDelivery has decided to publish two different Packet Delivery offerings targeted to potential retailers and other kind of companies:

- Basic Delivery: which allows the company which acquires the offer to provide just a Standard Packet Delivery Services to its customers
- Premium Delivery: which allows the company which acquires the offer to provide Standard and Gold Delivery Services to its customers

Both have different pricing assigned.

Note that PacketDelivery should not know about the identity of users of applications of any Retailer company. It simply should be able, when it receives a request, to a) recognize that such request comes from a user linked to an application that belongs to a Retailer company that acquired one of its offerings in the Marketplace, b) find out what is the role within the P.Info application that such user has been assigned by the given Retailer company (i.e., either "P.Info.standard" or "P.Info.gold"), and c) check that such a role is a role that the given Retailer company could assign, considering the offering in the Marketplace it had acquired. After such steps, PacketDelivery will simply check whether a user with the given role can perform the operation requested.

An application created by organization NoCheaper, no matter if it defines users whom it assigns role "P.Info.gold" to, is unable to successfully change the value of the PTA attribute of a given order because it has acquired the Standard Packet Delivery service which does not allow to change those values.

6.2.2 Data Service Consumer: HappyPets Inc.

HappyPets Inc. (HappyPets for short) is a company that sells products for pets. It will acquire the "Premium Packet Delivery" offering in the Marketplace. This will allow it to offer, in turn, *standard* and *gold* delivery services to its customers through the store application of HappyPets (HappyPetsStore). In addition, there may be certain employees within its own organization, namely supervisors and agents in the phone help-desk service it offers, who may change the deliveryAddress, PDA and PTA of a given order using an internal application (HappyPetsBackOffice).

When a customer signs up in the HappyPetsStore, it can act as "regular" customer or "prime" customer (paying an annual fee). "Regular" customers are provided the standard packet delivery services while "prime" customers are provided the gold packet delivery service. This means they are assigned the "P.Info.standard" role and the "P.Info.gold" role within the HappyPetsStore application, respectively.

On the other hand, different employees are given different roles within the HappyPetsBackOffice application, so certain employees with supervisor roles at physical shops or agents at the central help-desk also have the "P.Info.gold" role assigned.

The Happy Pets employee:

- Acquires the offering "Premium Packet Delivery" at the marketplace

The Happy Pets Customer:

- Signs up at the shop system of Happy Pets and gets assigned the "prime customer" role
  - For simplicity, we will assume that there is already a Happy Pets customer which already registered as "prime customer"
- Makes an order on the shop system, which results in the creation of a packet delivery order
  - For simplicity, we will assume that there is already a delivery order for this customer at the Packet Delivery company system
- Successfully changes the PTA of the order via the packet delivery company portal
  - We will describe later in this document the detailed process to perform this operation

6.2.3 Data Service Consumer: NoCheaper Ltd

NoCheaper Ltd (NoCheaper for short) is a company that sells products of any kind at rather big discounts. It will acquire the "Basic Packet Delivery" offering from the Packet Delivery Service company in the Marketplace.

The No Cheaper employee:

- Acquires the offering “Basic Packet Delivery” at the marketplace

The No Cheaper Customer:

- Signs up at the No Cheaper shop system and gets assigned the “standard customer” role
  - For simplicity, we will assume that there is already a No Cheaper customer which already registered as “standard customer”
- Makes an order on the shop system, which results in the creation of a packet delivery order
  - For simplicity, we will assume that there is already a delivery order for this customer at the Packet Delivery company system
- When trying to change the PTA of the order via the packet delivery company portal, it is denied
- It can be also shown that this request will get denied, even when the No Cheaper employee is assigning the “Prime Customer” role to the No Cheaper customer in its own Identity Provider system

6.2.4 Marketplace

The Marketplace is built based on the FIWARE BAE (Business Application Ecosystem) component that is made up of the combination of the FIWARE Business Framework and a set of APIs provided by the TMForum. It allows the monetization of different kinds of assets during the whole service life cycle, from offering creation to its charging, accounting and revenue settlement required for billing and payment to involved participants.

Figure 6.2 shows the overall Architecture of the FIWARE Marketplace and the interactions between the different components.

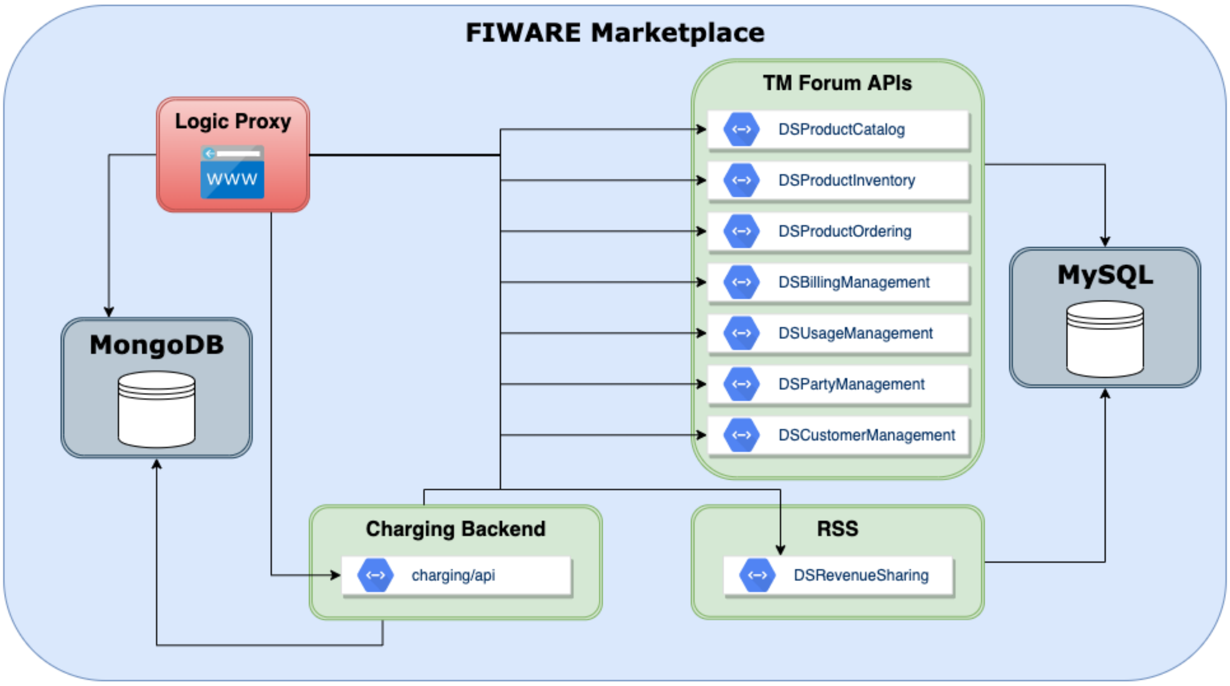


Figure 6.2: FIWARE Marketplace architecture overview

The packet delivery order asset parameters when creating the offer, and implementation of the necessary steps performed by the marketplace during the acquisition and activation phase, are provided by a dedicated plugin to be installed within the Charging Backend component.

A dedicated theme for the Marketplace UI can be found here.

6.2.5 Trust Anchor Framework

The system uses Verifiable Credentials and participants are identified via DIDs (described in "Decentralized Identifiers (DIDs) v1.0"). In order to enable an efficient and decentralized verification of the credentials and identities of participants, a blockchain-based Trust Framework has to be implemented to avoid central entities intermediation in all authentication flows.

The trust framework is basically composed of two things:

1. A list of the identities of trusted organizations stored in the blockchain, together with associated information for each entity.
2. A process to add, modify and delete the trusted entities, implementing a concrete governance model.

The trust framework is designed to be largely decentralized and represents the trust relationships in the real world. Here we describe a possible approach to implementing a blockchain-based trust framework which is very decentralized and at the same time simple, secure and robust.

The identities of the legal persons involved in the ecosystem are registered in a common directory implemented in the blockchain following a hierarchical scheme very similar to the DNS (Domain Name Service) schema in the Internet.

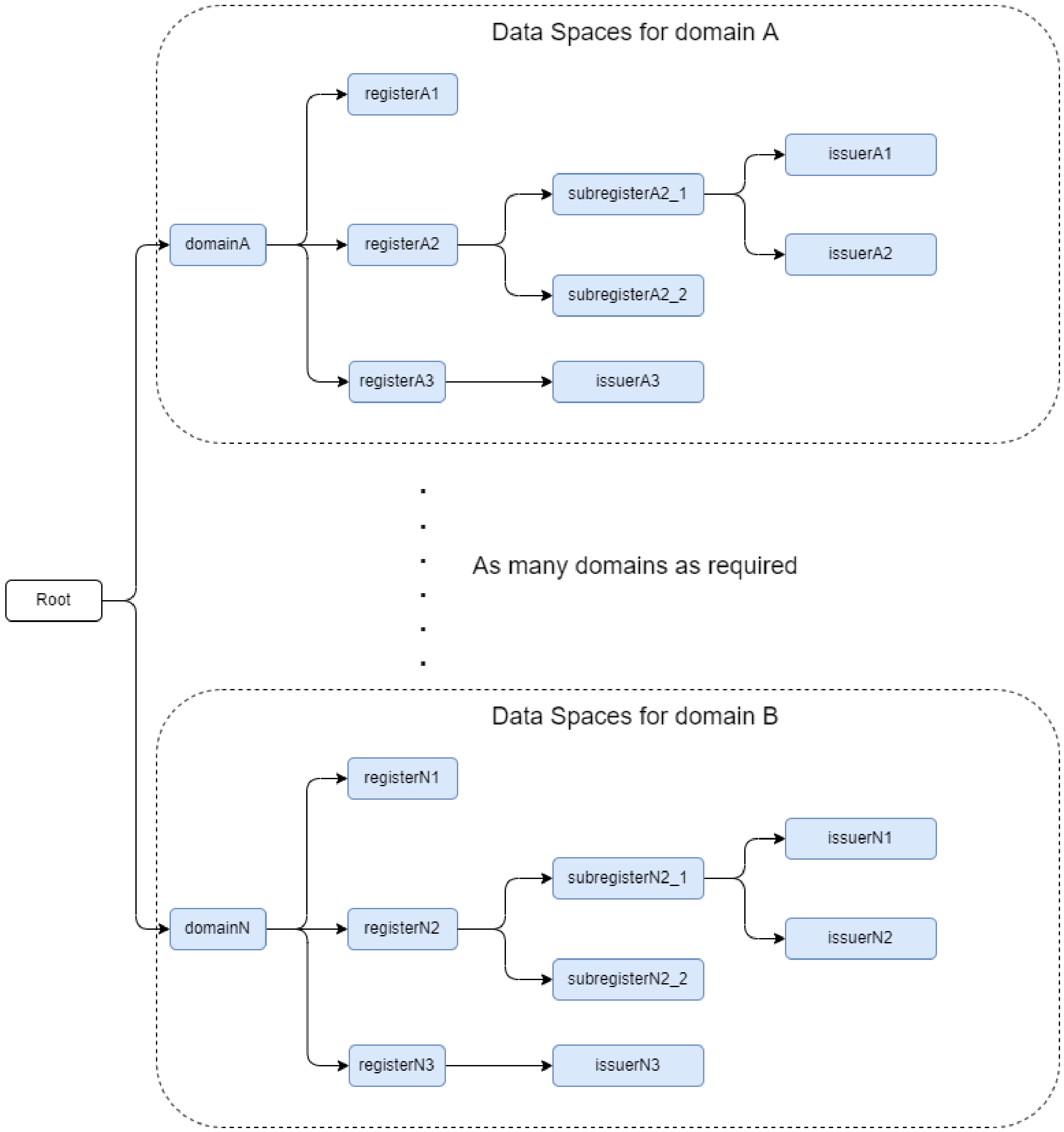
Essentially, once an entity is registered in the system, it is completely autonomous for adding other entities that are managed as child entities.

In this way, trust is delegated according to a well defined, transparent, auditable and public scheme. Any participant can get trusted information about the current trust structure of the ecosystem and also the events that led the system to the current situation. For example, what entity registered another entity, when it was done and what attributes were assigned to the child entity by the parent entity.

The scheme is flexible enough to implement as many levels as required by the actual governance model of the ecosystem. In very simple cases. it can have just two levels, where there is only one entity registering all other participants in the ecosystem.

In general, the system can be made very decentralized. However, there is one centralized element: the root of trust at the top of the hierarchy should be a trusted entity (or federation of entities) in the ecosystem that is the one responsible for bootstrapping the system. Depending on the concrete governance framework of the ecosystem, this may be the only mission of the root entity, possibly including the monitoring and oversight of the ecosystem. Typically it should be a regulatory body, a public administration or a neutral organization which is accepted as fully trusted by all participants in the ecosystem.

The approach for a single blockchain network is described in the following figure (the scheme is easily extensible to different blockchain networks where we want to establish trust across them so entities in one network can interact with entities in another network in a trusted way.



As can be seen in the figure, the Trust Framework in a given blockchain is not really a flat list, but a hierarchical structure, implemented as a Smart Contract:

- There is a special organization (or set of organizations) which is at the root of the hierarchy. This entity is called the Trusted Registration Authority (TRA) in EBSI, or Trusted Anchors in other contexts. We will use the term Trusted Anchors in the following description. The essential characteristic is that this is the most trusted entity/entities in the ecosystem.

- This root entity is responsible for registering the identities of some other trusted entities. For example, in a country with several regions with autonomous competencies to manage universities, the Ministry of Education could register in the blockchain the identities of the regional institutions which are responsible for managing the universities in each of their regions.
- Once this is done, each of the regional institutions can register the identities of dependent entities, like universities.
- The hierarchy can have several levels. For example, a university can be big and have several organizational units with some autonomy, maybe distributed geographically. It can create sub-identities and register them as child nodes in the blockchain.

6.2.5.1 Registering identities in the ecosystem

A new identity can only be registered by an existing identity. The only exception is the Trust Anchors entity which is the one deploying the Smart Contract to the blockchain and so it has special privileges. On deployment, the Smart Contract allows the registering of the Trust Anchor's identity and associated information.

Every legal entity identity in the system has assigned a domain name, in a similar way to what happens with Internet domains. When a new identity is created, it is assigned a name and it is automatically set up as a sub-domain depending on the parent identity. The only exception is that the root domain (Trust Anchors) has an empty name.

For example, the entity ***issuerA1*** in the diagram above has a full domain name of ***domainA.registerA2.subregisterA2_1.issuerA1*** and it is uniquely identified by its full domain name.

In this example, ***domainA*** is a top-level domain which should have been added to the system by the Trust Anchors entity.

It should be clear that an organization can be registered in the blockchain only because its parent entity has registered it. No other entity in the Trust Framework can have performed the registration, not even the parent of the parent entity.

An organization is responsible for all its child entities, represented as child nodes in the Trust Framework.

A third party external to the framework with read access to the blockchain can see the whole trust structure, including the immutable history of events from the initial bootstrapping of the ecosystem that led to the current status. This provides an incredible transparency to the ecosystem.

6.2.5.2 Verifying identities: the Universal Resolver

To be useful to all participants, the Trust Framework requires a component that implements a public API (non-authenticated) which can be used by any participant to verify identities: the Universal Resolver. The Universal Resolver resolves Decentralized Identifiers (DIDs) across many different DID methods, based on the W3C DID Core 1.0 and DID Resolution specifications. A reference implementation of the Universal Resolver is available from the Decentralized Identity Foundation Identifiers & Discovery Working Group.

DID resolution is the process of obtaining a DID Document for a given DID. This is one of four required operations that can be performed on any DID ("Read"; the other operations being "Create", "Update", and "Deactivate"). The details of these operations differ depending on the DID method. Building on top of DID resolution, DID URL dereferencing is the process of retrieving a representation of a resource for a given DID URL. Software and/or hardware that is able to execute these processes is called a DID resolver.

The process of DID resolution is needed during the SIOP flows when we have to obtain the public keys associated with an entity and be able to verify its signature over some data used in the exchange of information. The public key is part of the DID Document that is obtained after performing DID Resolution. See the document Decentralized Identifier Resolution (DID Resolution) for more information.

Ideally, there should be many instances of the Universal Resolver running in the ecosystem, because having just one instance increases the risk of centralisation. In particular, any legal entity that wants to reduce dependencies from third parties as much as possible (to be self-sovereign) would like to operate its own instance of a Universal Resolver on top of its own blockchain node connected directly to the blockchain network. Alternatively, an entity may wish to rely on a third party that they trust to perform DID resolution.

6.3 Verifiable Credentials in the ecosystem

In this section we describe the different types of credentials that are needed for the functionalities in the ecosystem.

6.3.1 Employee of Packet Delivery

Packet Delivery issues credentials to some of its employees, so they can access the Marketplace, either to create offerings or to purchase offerings.

This credential is used by an employee of Packet Delivery to prove to a third party that she is entitled to use some services provided by the third party on behalf of the employed company (Packet Delivery in this case). In other words, the credential is used as a mechanism for Packet Delivery to delegate its access control rights to one or more of its employees.

The essential characteristics of such credential are:

- Nobody has tampered with its contents since it was issued, because the credential is digitally signed by the issuer, Packet Delivery.
- Proves that the issuer is Packet Delivery, because the public key that verifies the signature of the credential is cryptographically associated with the real-world identity of Packet Delivery registered in the Trust Framework.
- Optionally, it can prove that the credential was issued no later than a given time, because the credential was registered (timestamped) in the blockchain when it was issued. The term “notarisation” is commonly used for this action, but it is wrong, because the term is coming from anglo-saxon cultures where notaries are very different from the latin-germanic notary functions in the EU and many other countries in the world. We will use the term “timestamping”.

Please note that the date of timestamping can be greater than the date in the field “Issued at” included inside the credential. For example, the credential is created and signed at one time, but timestamped the next day (maybe to batch the operation with other credentials). The real requirement is that nobody can create a credential and timestamp as if it happened in the past. In other words, nobody can create credentials from the past. The verifiers have to check that the field inside the credential “Issued at” is not later than the timestamp (at least by a small leeway to account for clock synchronisation differences).

Also note that many credentials may not require timestamping, avoiding the overhead of the registration process. It all depends on the type of credential, the intended usage of the credential and the level of risk assumed. The employee credential discussed here is one example of credential that does not require timestamping with the same level of risk. The only thing that the verifier requires is that the holder can prove that at the time of usage of the credential (eg., login), the credential was issued by the employer (Packet Delivery in our case). Obviously, this does not require timestamping, because if the employee can present a credential when performing login, she can do so only if the credential was issued before.

From the above description we can derive the following trust properties for a verifier receiving a credential:

- The level of trust in the identity of the issuer of the credential depends on the level of trust of the verifier in the onboarding process implemented in the Trust Framework. The onboarding process associates the public key of the issuer with its real identity.
- The level of trust in the claims inside the credential depends on the level of trust that the verifier has with the issuer entity. For example, Packet Delivery could issue employee credentials to people who are not real employees. However, if this is the case the verifier has a strong non-repudiable mechanism to prove to third-parties (e.g., a court) that the issuer stated wrong facts.

From the above it follows that Packet Delivery can issue employee credentials which include some employee data (name, surname, etc.) and the verifier can have a given level of trust on those claims.

But this just proves that Packet Delivery attests that the data inside the credential (called claims) is true. It does not say anything about whether the person presenting the credential online is the same that is referred to in the claims. In other words, the person sending the employee credential to the verifier could be a different person from the employee.

This is the reason why the credential includes a public key as one of the claims associated with the employee (inside the "credentialSubject" object.

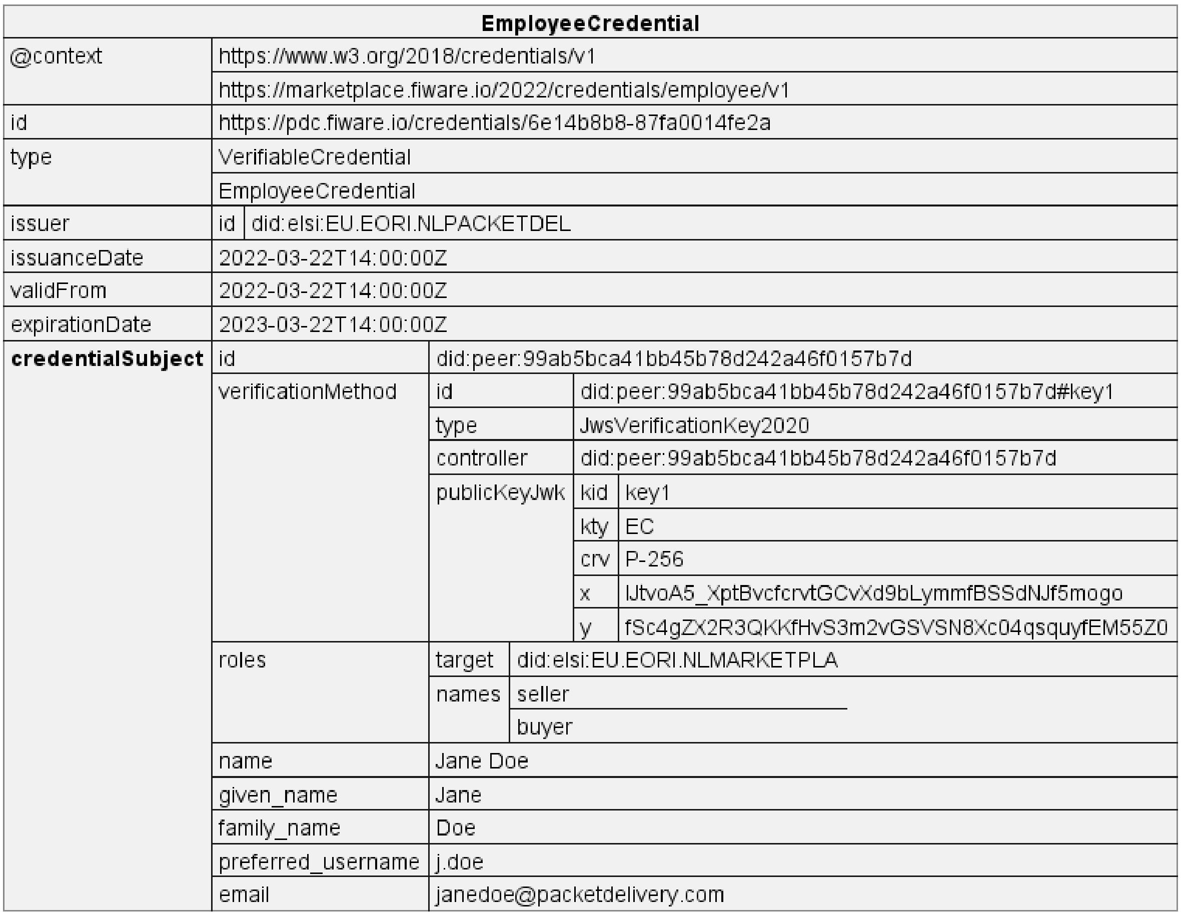
That public key corresponds to a private key that was generated in the employee device (PC or mobile) during the process of credential issuance. The process is explained in more detail later, but essentially:

- The employee generates a pair of public/private keys and sends the public key to the employer via an authenticated and encrypted channel (e.g., HTTPS). This channel can be the usual mechanism that employees use to connect to enterprise applications.
- The employer generates a credential with some employee data and includes the public key.
- The employer signs the credential and sends it to the employee using the same authenticated channel.

Below we present an example employee credential issued by Packet Delivery.

```
// Credential issued by PacketDelivery to its employees, providing access to
// Marketplace, either to create offerings or to purchase offerings.
{
  "@context": [
    "https://www.w3.org/2018/credentials/v1",
    "https://marketplace.fiware.io/2022/credentials/employee/v1"
  ],
  "id": "https://pdc.fiware.io/credentials/6e14b8b8-87fa0014fe2a",
  "type": ["VerifiableCredential", "EmployeeCredential"],
  "issuer": {
    "id": "did:elsi:EU.EORI.NLPACKETDEL"
  },
  "issuanceDate": "2022-03-22T14:00:00Z",
  "validFrom": "2022-03-22T14:00:00Z",
  "expirationDate": "2023-03-22T14:00:00Z",
  "credentialSubject": {
    "id": "did:peer:99ab5bca41bb45b78d242a46f0157b7d",
    "verificationMethod": [
      {
        "id": "did:peer:99ab5bca41bb45b78d242a46f0157b7d#key1",
        "type": "JwsVerificationKey2020",
        "controller": "did:peer:99ab5bca41bb45b78d242a46f0157b7d",
        "publicKeyJwk": {
          "kid": "key1",
          "kty": "EC",
          "crv": "P-256",
          "x": "lJtvoA5_XptBvcfcrvtGCvXd9bLymmfBSSdNJf5mogo",
          "y": "fSc4gZX2R3QKKfHvS3m2vGSVSN8Xc04qsquyfEM55Z0"
        }
      }
    ],
    "roles": [
        {
            "target": "did:elsi:EU.EORI.NLMARKETPLA",
            "names": ["seller", "buyer"]
        }
    ],
    "name": "Jane Doe",
    "given_name": "Jane",
    "family_name": "Doe",
    "preferred_username": "j.doe",
    "email": "janedoe@packetdelivery.com"
  }
}
```

The structure of the above credential can be visualized as follows:



EmployeeCredential				
@context	https://www.w3.org/2018/credentials/v1			
	https://marketplace.fiware.io/2022/credentials/employee/v1			
id	https://pdc.fiware.io/credentials/6e14b8b8-87fa0014fe2a			
type	VerifiableCredential			
	EmployeeCredential			
issuer	id	did:elsi:EU.EORI.NLPACKETDEL		
issuanceDate	2022-03-22T14:00:00Z			
validFrom	2022-03-22T14:00:00Z			
expirationDate	2023-03-22T14:00:00Z			
credentialSubject	id	did:peer:99ab5bca41bb45b78d242a46f0157b7d		
	verificationMethod	id	did:peer:99ab5bca41bb45b78d242a46f0157b7d#key1	
		type	JwsVerificationKey2020	
		controller	did:peer:99ab5bca41bb45b78d242a46f0157b7d	
		publicKeyJwk	kid	key1
			kty	EC
			crv	P-256
			x	lJtvoA5_XptBvcfcrvtGCvXd9bLymmfBSSdNJf5mogo
			y	fSc4gZX2R3QKKfHvS3m2vGSVSN8Xc04qsquyfEM55Z0
	roles	target	did:elsi:EU.EORI.NLMARKETPLA	
		names	seller	
			buyer	
	name	Jane Doe		
	given_name	Jane		
	family_name	Doe		
	preferred_username	j.doe		
	email	janedoe@packetdelivery.com		

The credential is of type "*EmployeeCredential*" and to enable access to the Marketplace the roles embedded in it can be "buyer", "seller" or both. The URL in the "@context" field points to the marketplace (https://pdc.fiware.io/2022/credentials/employee/v1), which defines the general requirements for an Employee Credential. However, participants in the ecosystem can extend it and of course use the roles and role names that they need for their own purposes.

The "*credentialSubject*" section in the credential has the following objects:

- "**id**", specified as a DID. For privacy reasons and given that this is a natural person, the DID used is the Peer Method as specified in the W3C Peer DID Method Specification. The method can be used independent of any central source of truth, and is intended to be cheap, fast, scalable, and secure. It is suitable for most private relationships between people, organizations, and things.

- “**verificationMethod**”, which is a standard W3C VC object that specifies the Public Key associated with the DID of the employee. The binding between the DID of the employee and the Public Key was performed at the moment of credential issuance by Packet delivery.
- “**roles**” is an array with one or more role specifications. Each specification defines a potential target entity that will receive the credential, and one or more names of roles defined by that target entity.
    - “**target**” is the DID of the entity that will receive the credential.
    - “**names**” is an array with one or more roles that the target entity recognizes and that will be used by the target entity to apply its own access control policies. In the example, we have used both “*buyer*” and “*seller*” roles as defined by the Marketplace. Other entities can define their own roles for their specific purposes. Names are made unique in the ecosystem thanks to the *target* property.
- The rest of the fields in the credential have the usual meaning in the standard W3C Verifiable Credential Data Model.

The “id” field at the top level is the identification of the credential, which can be used for revocation if that functionality is required. The basic requirements for the “id” field are that:

- It is unique in the scope where it is going to be used
- It is based on a cryptographically secure random number generator and so is difficult to “guess” by a potential attacker who could try to revoke a given credential. Using such Ids reduces the probability of an attacker guessing the id to the same level than an attacker guessing a private key,
- It is not related in any way with the personal data included in the credential, to minimise the risk of correlation

A UUID Version 4 complies with all those requirements but other schemas can be used.

6.3.2 Employee of Happy Pets (or No Cheaper)

The employee credential issued by Happy Pets and No Cheaper companies to its employees are virtually identical to the employee credential from Packet Delivery described above. The main difference is the set of roles assigned to the employee and specified in the “roles” claim.

```
// Credential issued by HappyPets to its employees, providing access
// to order creation in PacketDelivery.
{
  "@context": [
    "https://www.w3.org/2018/credentials/v1",
    "https://happypets.fiware.io/2022/credentials/employee/v1"
  ],
  "id": "https://happypets.fiware.io/credentials/25159389-8dd17b796ac0",
  "type": ["VerifiableCredential", "EmployeeCredential"],
  "issuer": {
    "id": "did:elsi:EU.EORI.NLHAPPYPETS"
  },
  "issuanceDate": "2022-03-22T14:00:00Z",
  "validFrom": "2022-03-22T14:00:00Z",
  "expirationDate": "2023-03-22T14:00:00Z",
  "credentialSubject": {
    "id": "did:peer:99ab5bca41bb45b78d242a46f0157b7d",
    "verificationMethod": [
      {
        "id": "did:peer:99ab5bca41bb45b78d242a46f0157b7d#key1",
        "type": "JwsVerificationKey2020",
        "controller": "did:peer:99ab5bca41bb45b78d242a46f0157b7d",
        "publicKeyJwk": {
          "kid": "key1",
          "kty": "EC",
          "crv": "P-256",
          "x": "lJtvoA5_XptBvcfcrvtGCvXd9bLymmfBSSdNJf5mogo",
          "y": "fSc4gZX2R3QKKfHvS3m2vGSVSN8Xc04qsquyfEM55Z0"
        }
      }
    ],
    "roles": [
        {
            "target": "did:elsi:EU.EORI.NLPACKETDEL",
            "names": ["P.Create"]
        }
    ],
    "name": "Jane Doe",
    "given_name": "Jane",
    "family_name": "Doe",
    "preferred_username": "j.doe",
    "email": "janedoe@packetdelivery.com"
  }
}
```

6.3.3 Customer of Happy Pets (or No Cheaper)

This credential is used by Happy Pets to delegate access control to customers that want access to services provided by Packet Delivery and that were purchased by Happy Pets in the past.

It follows the same model as with employee credentials except that:

- The credential should be issued by Happy Pets to customers using a secure and authenticated channel created as part of a previous customer onboarding process (KYC).
- The role included in the credential corresponds to the type of customer, with the role name defined and understood by the service provider, in this case Packet Delivery.

```
// Credential issued by HappyPets to a customer,
// providing access to Gold services at PacketDelivery.
{
  "@context": [
    "https://www.w3.org/2018/credentials/v1",
    "https://happypets.fiware.io/2022/credentials/employee/v1"
  ],
  "id": "https://happypets.fiware.io/credentials/25159389-8dd17b796ac0",
  "type": ["VerifiableCredential", "CustomerCredential"],
  "issuer": {
    "id": "did:elsi:EU.EORI.NLHAPPYPETS"
  },
  "issuanceDate": "2022-03-22T14:00:00Z",
  "validFrom": "2022-03-22T14:00:00Z",
  "expirationDate": "2023-03-22T14:00:00Z",
  "credentialSubject": {
    "id": "did:peer:99ab5bca41bb45b78d242a46f0157b7d",
    "verificationMethod": [
      {
        "id": "did:peer:99ab5bca41bb45b78d242a46f0157b7d#key1",
        "type": "JwsVerificationKey2020",
        "controller": "did:peer:99ab5bca41bb45b78d242a46f0157b7d",
        "publicKeyJwk": {
          "kid": "key1",
          "kty": "EC",
          "crv": "P-256",
          "x": "lJtvoA5_XptBvcfcrvtGCvXd9bLymmfBSSdNJf5mogo",
          "y": "fSc4gZX2R3QKKfHvS3m2vGSVSN8Xc04qsquyfEM55Z0"
        }
      }
    ],
    "roles": [
        {
            "target": "did:elsi:EU.EORI.NLPACKETDEL",
            "names": ["P.Info.gold"]    // Or P.Info.standard
        }
    ],
    "name": "Jane Doe",
    "given_name": "Jane",
    "family_name": "Doe",
    "preferred_username": "j.doe",
    "email": "janedoe@packetdelivery.com"
  }
}
```

6.3.4 Role-based access

As can be seen in the above credentials, they contain claims specifying roles. The roles are not defined by the issuer of the credential, but by the provider (i.e.: the relying party) that is going to receive the credential and perform authentication and authorization.

The provider defines a role having a certain name, and this role is mapped to a certain policy set representing the policies that the provider wants to enforce. An offering on the marketplace then just represents a certain role (or several roles). When acquiring access to an offering on the marketplace, these roles then get issued to the acquiring organization within the Authorisation Registry of the provider. Furthermore, the acquiring organization then can just assign these roles to their users by embedding the roles inside the Verifiable Credential issued to its users. When accessing the service, it is up to the PEP proxy/PDP component of the provider to obtain the set of attribute-based policies that belong to the assigned roles and to perform the evaluation of granting access based on the NGSI-LD request.

It is out of scope for this document to describe the actual policy language and engine used to perform the enforcement (ODRL, Rego, etc).

6.3.5 Deployment of components

In addition to the components described in section 4.2 Parties involved the following components are needed.

Verifiable Data Registry

In the form of a blockchain network that is used to implement the core technology of the Trust Framework for the ecosystem. Some entities participating in the ecosystem (not necessarily all of them) should operate blockchain nodes in order to create and operate collaboratively a suitable blockchain network that can implement the backbone of the Trust Framework.

Universal Resolver

The Universal Resolver resolves Decentralized Identifiers (DIDs) across many different DID methods, based on the W3C DID Core 1.0 and DID Resolution specifications. See 2.4.2.2 Verifying identities: the Universal Resolver for more details. In this context we refer to one or more production-level instances of a service implementing the same API as the one deployed for testing purposes by the DIF.

Credential Issuer and Verifier components

These components are normally implemented as extensions to existing components implementing the OIDC flows.

End-User wallet

The wallet component that the End-User employs to receive, hold and present Verifiable Credentials that have been issued to her. This component can be implemented as a native mobile application, a PWA application or even as a web app hosted by one or more highly trusted entities in the ecosystem.

6.4 Detailed workflows

6.4.1 Create Offering

We now describe the process of creating an offer. In the reference use case, Packet Delivery needs to perform it twice for creating the offerings for “Basic Delivery” and “Premium Delivery”, providing a different set of offering information. The process will be performed by an employee of the Packet Delivery company.

When using the SIOP flows with Verifiable Credentials it can be observed that the Marketplace does not have to query any other entity in the ecosystem to verify the credential because all the information needed is in the Verifiable Credential presented by the employee and in the Decentralized Verifiable Registry (implemented in our case using a blockchain network), accessed via the Universal Resolver.

In other words, the flows are essentially peer-to-peer and do not require any centralized IdP to be queried, providing an efficient, scalable, private and resilient framework.

6.4.1.1 Sequence description (Packet Delivery Co.)

The following gives a detailed description of the offer creation process. Figure 6.3.a presents the different interactions in an architectural overview, whereas Figure 6.3.b shows a detailed sequence diagram of the whole process.

In the following, a description is given for each of the sequence steps.

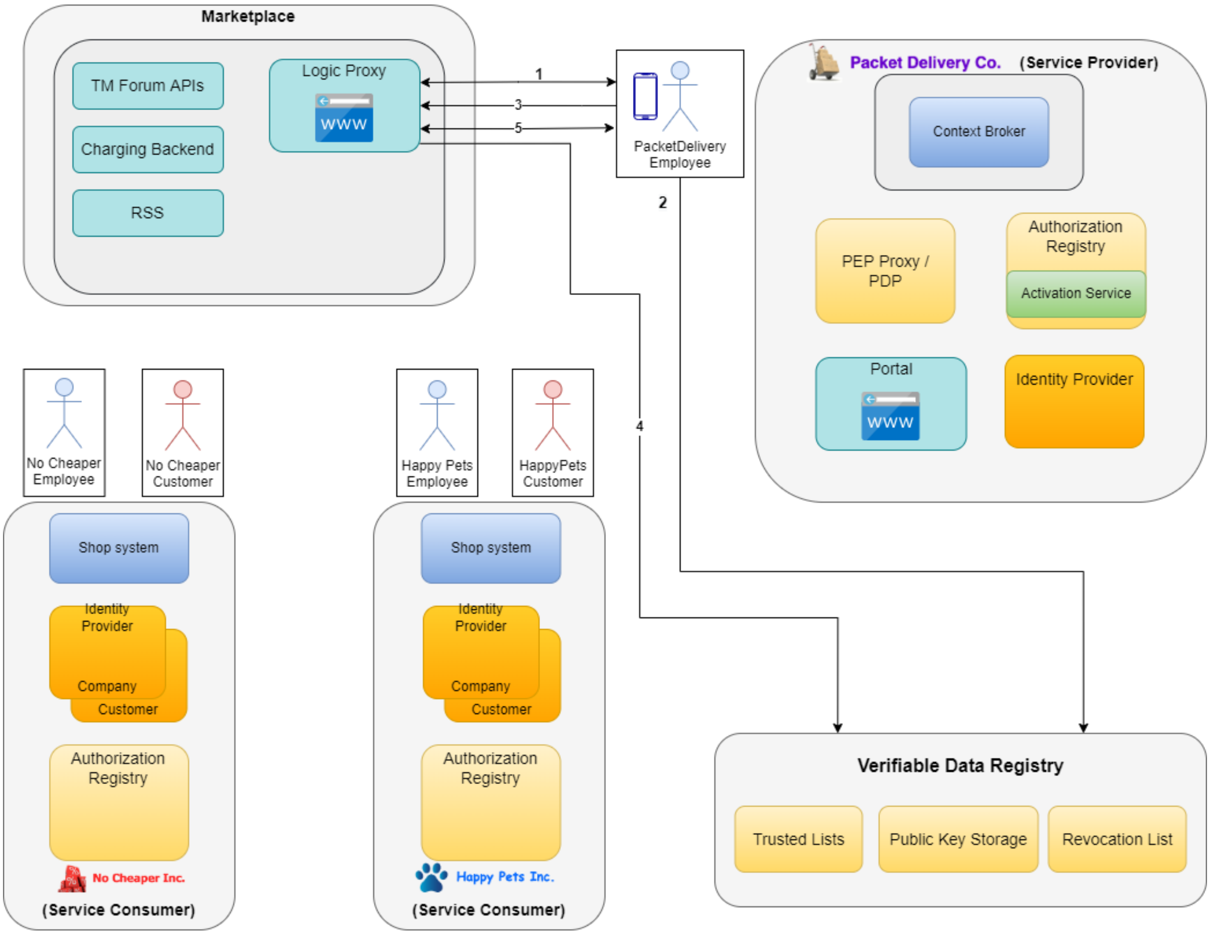
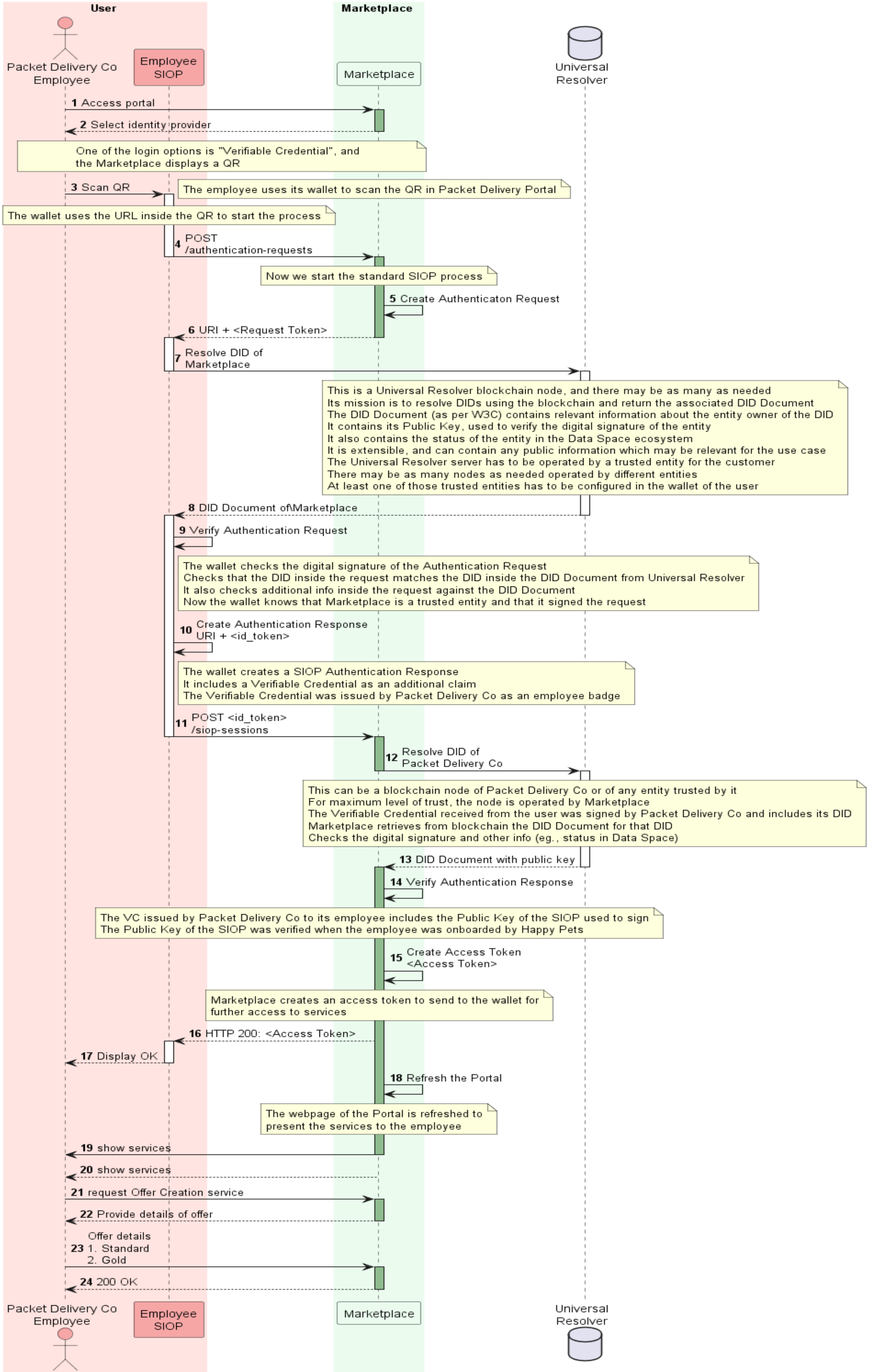


Figure 6.3.a: Architecture diagram for step "Create Offering"

Packet Delivery - Offer creation



1 Access portal

2 Select identity provider

One of the login options is "Verifiable Credential", and the Marketplace displays a QR

3 Scan QR

The employee uses its wallet to scan the QR in Packet Delivery Portal

The wallet uses the URL inside the QR to start the process

4 POST /authentication-requests

Now we start the standard SIOP process

5 Create Authenticaton Request

6 URI + <Request Token>

7 Resolve DID of Marketplace

This is a Universal Resolver blockchain node, and there may be as many as needed
Its mission is to resolve DIDs using the blockchain and return the associated DID Document
The DID Document (as per W3C) contains relevant information about the entity owner of the DID
It contains its Public Key, used to verify the digital signature of the entity
It also contains the status of the entity in the Data Space ecosystem
It is extensible, and can contain any public information which may be relevant for the use case
The Universal Resolver server has to be operated by a trusted entity for the customer
There may be as many nodes as needed operated by different entities
At least one of those trusted entities has to be configured in the wallet of the user

8 DID Document of\Marketplace

9 Verify Authentication Request

The wallet checks the digital signature of the Authentication Request
Checks that the DID inside the request matches the DID inside the DID Document from Universal Resolver
It also checks additional info inside the request against the DID Document
Now the wallet knows that Marketplace is a trusted entity and that it signed the request

10 Create Authentication Response URI + <id_token>

The wallet creates a SIOP Authentication Response
It includes a Verifiable Credential as an additional claim
The Verifiable Credential was issued by Packet Delivery Co as an employee badge

11 POST <id_token> /siop-sessions

12 Resolve DID of Packet Delivery Co

This can be a blockchain node of Packet Delivery Co or of any entity trusted by it
For maximum level of trust, the node is operated by Marketplace
The Verifiable Credential received from the user was signed by Packet Delivery Co and includes its DID
Marketplace retrieves from blockchain the DID Document for that DID
Checks the digital signature and other info (eg., status in Data Space)

13 DID Document with public key

14 Verify Authentication Response

The VC issued by Packet Delivery Co to its employee includes the Public Key of the SIOP used to sign
The Public Key of the SIOP was verified when the employee was onboarded by Happy Pets

15 Create Access Token <Access Token>

Marketplace creates an access token to send to the wallet for further access to services

16 HTTP 200: <Access Token>

17 Display OK

18 Refresh the Portal

The webpage of the Portal is refreshed to present the services to the employee

19 show services

20 show services

21 request Offer Creation service

22 Provide details of offer

23 Offer details
1. Standard
2. Gold

24 200 OK

Figure 6.3.b: Sequence diagram for step “Create Offering”

1. Packet Delivery employee accesses the Marketplace portal (provided by the BAE Logic Proxy), in order to login.
2. The Marketplace portal displays a list of Identity Providers for selecting the desired Identity Provider for login. One of the login options is “Login with Verifiable Credentials”.
3. Packet Delivery Co employee selects the “Verifiable Credentials” login method, which causes the Marketplace portal to generate a QR containing the URL of the /authentication-requests endpoint of the Marketplace server.
4. The employee scans the QR with her mobile and the mobile calls the /authentication-requests endpoint.
5. This starts a standard SIOP (Self-Issued OpenID Provider) flow, where the Marketplace plays the role of Relying Party (RP in Open ID Connect terminology) and the mobile device of the employee as a Self-Issued IDP. In this step, Marketplace creates a SIOP Authentication Request. As a Self-Issued OP may be running as a native application or progressive web application (PWA), the RP may not have a network-addressable endpoint to communicate directly with the OP. We have to leverage the implicit flow of OpenID Connect to communicate with such locally-running OPs, as described in https://openid.net/specs/openid-connect-self-issued-v2-1_0.html.

   The Authentication Request travels in the response to the HTTP GET request performed in the previous point, as a JWT signed by Marketplace. The decoded contents of the JWT may be:

```
openid://?
   scope=openid
   &response_type=id_token
   &response_mode=post
   &client_id=did:elsi:EU.EORI.NLMARKETPLA
   &redirect_uri=https://marketplace.fiware.io/siop_sessions
   &claims=... //the Marketplace would specify here what type of claims it wants
the employee to provide.  Those claims should be connected to roles of users in the
application, documented in the marketplace
   &registration={
      "subject_syntax_types_supported": ["did:key",
      "urn:ietf:params:oauth:jwk-thumbprint"]
   }
   &nonce=n-0S6_WzA2Mj
```

6. The Authentication Request is returned to the employee wallet acting as SIOP. The SIOP flow uses a new response mode **post** which is used to request the SIOP to deliver the result of the authentication process to a certain endpoint. The parameter **response_mode** is used to carry this value.

   This endpoint where the SIOP shall deliver the authentication result is defined in the standard parameter **redirect_uri**.

7. In this step the employee verifies that the Marketplace is a trusted entity belonging to the ecosystem, by resolving the DID of the Marketplace which is received in the **client_id** parameter of the Authentication Request.

   To resolve a DID, the wallet sends a GET request to the **/api/did/v1/identifiers/did:elsi:EU.EORI.NLMARKETPLA** endpoint of one of several trusted servers implementing the Universal Resolver functionality. The Universal Resolver includes a blockchain node, and there may be as many as needed. Its mission is to resolve DIDs using the blockchain and return the associated DID Document. The DID Document (as per W3C) contains relevant information about the entity owner of the DID. It contains its Public Key, used to verify the digital signature of the entity. It also contains the status of the entity in the Data Space ecosystem. It is extensible and can contain any public information which may be relevant for the use case. The Universal Resolver server must be operated by a trusted entity for the customer. There may be as many nodes as needed operated by different entities. At least one of those trusted entities has to be configured in the wallet of the employee.

8. The wallet receives the DID Document of Marketplace, with trusted information about the entity, including the Public Key associated with the Private Key that Marketplace uses to digitally sign tokens. For example:

```
{
  "payload": {
    "@context": [
      "https://www.w3.org/ns/did/v1",
      "https://w3id.org/security/v1"
    ],
    "id": "did:elsi:EU.EORI.NLMARKETPLA",
    "verificationMethod": [
      {
        "id": "did:elsi:EU.EORI.NLMARKETPLA#key-verification",
        "type": "JwsVerificationKey2020",
        "controller": "did:elsi:EU.EORI.NLMARKETPLA",
        "publicKeyJwk": {
          "kid": "key-verification",
          "kty": "EC",
          "crv": "secp256k1",
          "x": "V8XptJkb5wplYkExcTF4nkyYVp7t5H5d5C4UPqCCM9c",
          "y": "kn3nSPxIIvd9iaG0N4v14ceuo8E4PcLXhhGeDzCE7VM"
        }
      }
    ],
    "service": [
      {
        "id": "did:elsi:EU.EORI.NLMARKETPLA#info",
        "type": "EntityCommercialInfo",
        "serviceEndpoint": "https://marketplace.fiware.io/info",
        "name": "Packet Delivery co."
      },
      {
        "id": "did:elsi:EU.EORI.NLMARKETPLA#sms",
        "type": "SecureMessagingService",
        "serviceEndpoint": "https://marketplace.fiware.io/api/sms"
      }
    ],
    "anchors": [
      {
        "id": "redt.alastria",
        "resolution": "UniversalResolver",
        "domain": "marketplace.dataspace",
        "ethereumAddress": "0xbcB9b29eeb28f36fd84f1CfF98C3F1887D831d78"
      }
    ],
    "created": "2021-11-14T13:02:37Z",
    "updated": "2021-11-14T13:02:37Z"
  }
}
```

9. The DID Document includes one or more public keys inside the “verificationMethod” array. The keys are identified by the “id” field in each element of the array. The employee wallet uses the **kid** field that was received in the Authentication Request (in the protected header of the JWT) to select the corresponding Public Key and verify the signature of the JWT. It also verifies that the top-level “**id**” field in the DID Document ("did:elsi:EU.EORI.NLMARKETPLA") is equal to the **client_id** parameter of the Authentication Request.
10. The employee wallet creates an Authentication Response to be posted in the **redirect_uri** specified by Marketplace in step 5. The contents of the Authentication Response are described below.
11. The SIOP sends the authentication response to the endpoint passed in the **redirect_uri** authentication request parameter using a HTTP POST request using "application/x-www-form-urlencoded" encoding. The response contains an ID Token and a VP (Verifiable Presentation) token as defined in OpenID for Verifiable Presentations.

```
POST /siop_sessions HTTP/1.1
Host: marketplace.fiware.io
Content-Type: application/x-www-form-urlencoded

id_token=eyJ0 ... NiJ9.eyJ1c ... I6IjIifX0.DeWt4Qu ... ZXso
&vp_token=...
&state=af0ifjsldkj
```

The decoded **id_token** would be:

```
{
  "iss": "https://self-issued.me/v2",
  "aud": "did:elsi:EU.EORI.NLMARKETPLA",
  "iat": 1615910538,
  "exp": 1615911138,
  "sub": "did:peer:99ab5bca41bb45b78d242a46f0157b7d",
  "auth_time": 1615910535,
  "nonce": "n-0S6_WzA2Mj"
}
```

The **sub** claim is *did:peer:99ab5bca41bb45b78d242a46f0157b7d* which is the DID of the user and for privacy reasons it is not registered in any blockchain or centralized repository. It must be the same as the DID included in the Verifiable Credential that was issued by the Packet Delivery company when onboarding the employee and which travels in the authentication response.

The **vp_token** includes the Verifiable Presentation, which can be in two formats: **jwt_vp** (JWT encoded) or **ldp_vp** (JSON-LD encoded). The following example is using the JWT encoding:

```
{
   "format": "jwt_vp",
   "presentation":
   "eyJhbGciOiJSUzI1NiIsInR5cCI6IkpXVCIsImtpZCI6ImRpZDpleGFtcGxlOmFiZmUxM2Y3MTIxMjA0
   MzFjMjc2ZTEyZWNhYiNrZXlzLTEifQ.eyJzdWIiOiJkaWQ6ZXhhbXBsZTplYmZlYjFmNzEyZWJjNmYxY
   zI3NmUxMmVjMjEiLCJqdGkiOiJodHRwOi8vZXhhbXBsZS5lZHUvY3JlZGVudGlhbHMvMzczMiIsImlzc
   yI6Imh0dHBzOi8vZXhhbXBsZS5jb20va2V5cy9mb28uandrIiwibmJmIjoxNTQxNDkzNzI0LCJpYXQiO
   jE1NDE0OTM3MjQsImV4cCI6MTU3MzAyOTcyMywibm9uY2UiOiI2NjAhNjM0NUZTZXIiLCJ2YyI6eyJAY
   29udGV4dCI6WyJodHRwczovL3d3dy53My5vcmcvMjAxOC9jcmVkZW50aWFscy92MSIsImh0dHBzOi8vd
   3d3LnczLm9yZy8yMDE4L2NyZWRlbnRpYWxzL2V4YW1wbGVzL3YxIl0sInR5cGUiOlsiVmVyaWZpYWJsZ
   UNyZWRlbnRpYWwiLCJVbml2ZXJzaXR5RGVncmVlQ3JlZGVudGlhbCJdLCJjcmVkZW50aWFsU3ViamVjd
   CI6eyJkZWdyZWUiOnsidHlwZSI6IkJhY2hlbG9yRGVncmVlIiwibmFtZSI6IjxzcGFuIGxhbmc9J2ZyL
   UNBJz5CYWNjYWxhdXLDqWF0IGVuIG11c2lxdWVzIG51bcOpcmlxdWVzPC9zcGFuPiJ9fX19.KLJo5GAy
   BND3LDTn9H7FQokEsUEi8jKwXhGvoN3JtRa51xrNDgXDb0cq1UTYB-rK4Ft9YVmR1NI_ZOF8oGc_7wAp
   8PHbF2HaWodQIoOBxxT-4WNqAxft7ET6lkH-4S6Ux3rSGAmczMohEEf8eCeN-jC8WekdPl6zKZQj0YPB
   1rx6X0-xlFBs7cl6Wt8rfBP_tZ9YgVWrQmUWypSioc0MUyiphmyEbLZagTyPlUyflGlEdqrZAv6eSe6R
   txJy6M1-lD7a5HTzanYTWBPAUHDZGyGKXdJw-W_x0IWChBzI8t3kpG253fg6V3tPgHeKXE94fz_QpYfg
   --7kLsyBAfQGbg"
}
```

Which decoded would be:

```
{
  "@context": ["https://www.w3.org/2018/credentials/v1"],
  "type": ["VerifiablePresentation"],
  "verifiableCredential": [
    {
      "@context": [
        "https://www.w3.org/2018/credentials/v1",
        "https://marketplace.fiware.io/2022/credentials/employee/v1"
      ],
      "id": "https://pdc.fiware.io/credentials/6e14b8b8-87fa0014fe2a",
      "type": ["VerifiableCredential", "EmployeeCredential"],
      "issuer": {
        "id": "did:elsi:EU.EORI.NLPACKETDEL"
      },
      "issuanceDate": "2022-03-22T14:00:00Z",
      "validFrom": "2022-03-22T14:00:00Z",
      "expirationDate": "2023-03-22T14:00:00Z",
      "credentialSubject": {
        "id": "did:peer:99ab5bca41bb45b78d242a46f0157b7d",
        "verificationMethod": [
          {
            "id": "did:peer:99ab5bca41bb45b78d242a46f0157b7d#key1",
            "type": "JwsVerificationKey2020",
            "controller": "did:peer:99ab5bca41bb45b78d242a46f0157b7d",
            "publicKeyJwk": {
              "kid": "key1",
              "kty": "EC",
              "crv": "P-256",
              "x": "lJtvoA5_XptBvcfcrvtGCvXd9bLymmfBSSdNJf5mogo",
              "y": "fSc4gZX2R3QKKfHvS3m2vGSVSN8Xc04qsquyfEM55Z0"
            }
          }
        ],
        "roles": [
          {
            "target": "did:elsi:EU.EORI.NLMARKETPLA",
            "names": ["seller", "buyer"]
          }
        ],
        "name": "Jane Doe",
        "given_name": "Jane",
        "family_name": "Doe",
        "preferred_username": "j.doe",
        "email": "janedoe@packetdelivery.com"
      }
    }
  ]
}
```

12. Marketplace uses its own blockchain node or the one from a trusted entity implementing the Universal Resolver functionality to resolve the DID of Packet Delivery Co, which is inside the Verifiable Credential received in the Verifiable Presentation. This DID can be found in the “issuer” field of the “verifiableCredential” structure above.

    Resolution is performed sending a GET request to the Universal Resolver: **/api/did/v1/identifiers/did:elsi:EU.EORI.NLPACKETDEL**

    Marketplace could use a Universal Resolver operated by a different entity, but this would reduce the level of trust compared to using its own server directly connected to the blockchain network.

13. Marketplace receives the DID Document of Packet Delivery Co with trusted information about the company, including the Public Key associated with the

Private Key that Packet Delivery Co used to digitally sign the Verifiable Credential that the employee has just sent inside a Verifiable Presentation as part of the authentication flow. **Using the Public Key and the DID inside the DID Document, it can verify the signature of the Verifiable Credential and that Packet Delivery Co is a trusted entity in the ecosystem and that it is active.**

14. The above is just for verification of the Verifiable Credential. In addition, Marketplace can also verify that the Verifiable Presentation including the Verifiable Credential is sent by the employee and not by a malicious agent. To do so, it uses the Public Key of the employee in the "verificationMethod" of the "credentialSubject" structure. That public key is cryptographically bound to the employee DID during the onboarding process that Packet Delivery Co performed with its employee.
15. Once all verifications have been performed, Marketplace creates an Access Token for the employee so she can use it to access services in the Marketplace server in the future.
16. The wallet (SIOP) receives the access token and saves it temporarily to be able to request services from Marketplace.
17. The wallet displays a success message to the employee.
18. The Marketplace server refreshes the page (it was the login page before) and displays the services available to the employee of Packet Delivery Co.

At this point the Packet Delivery Co employee is logged in on the Marketplace application. The user is now able to create catalogues, products and offerings.

At this moment, the Marketplace knows the following:

- That Packet Delivery Co belongs to the Data Space and can issue credentials of the type EmployeeCredential because it is included in the Trusted Issuers List and is active, because this info is in the DID Document retrieved in step 13.
- That Packet Delivery Co says that the user is one of its employees. This info is inside the Verifiable Credential that is digitally signed by Packet Delivery Co.

From this point on, the Marketplace can display to the user the services available to her and execute them if the user is entitled to do so. The Marketplace can use all the claims inside the credential to perform RBAC/ABAC access control and policy enforcement.

6.4.2 Acquisition of Rights / Activation

The process of acquiring access to the packet delivery service is displayed. It is performed by employees of both parties separately, Happy Pets and No Cheaper, where the former one acquires access to the “Premium Delivery” offering and the latter acquires the “Basic Delivery” offering.

6.4.2.1 Sequence description (Happy Pets Inc.)

The flows are exactly the same as the ones described in 2.3.4 Acquisition of Rights / Activation with the exception that the initial authentication of the Happy Pets or No Cheaper employees with regard to the Marketplace is performed using a Verifiable Credential issued to its employees by those companies. In the same way as described in 2.4.3 Create Offering, the policies delegated to its employees by Happy Pets and No Cheaper are embedded into the Verifiable Credentials. In this sense, the flows for authentication of the employees for Acquisition of Rights / Activation are exactly the same as described in 2.4.3.1 Sequence description (Packet Delivery Co.) with the appropriate company name changes and specific content of the policies.

For those reasons, we describe only the authentication process which replaces steps 1-14 in 2.3.4.1 Sequence description (Happy Pets Inc.) with steps 1-19 in the sequence diagram below.

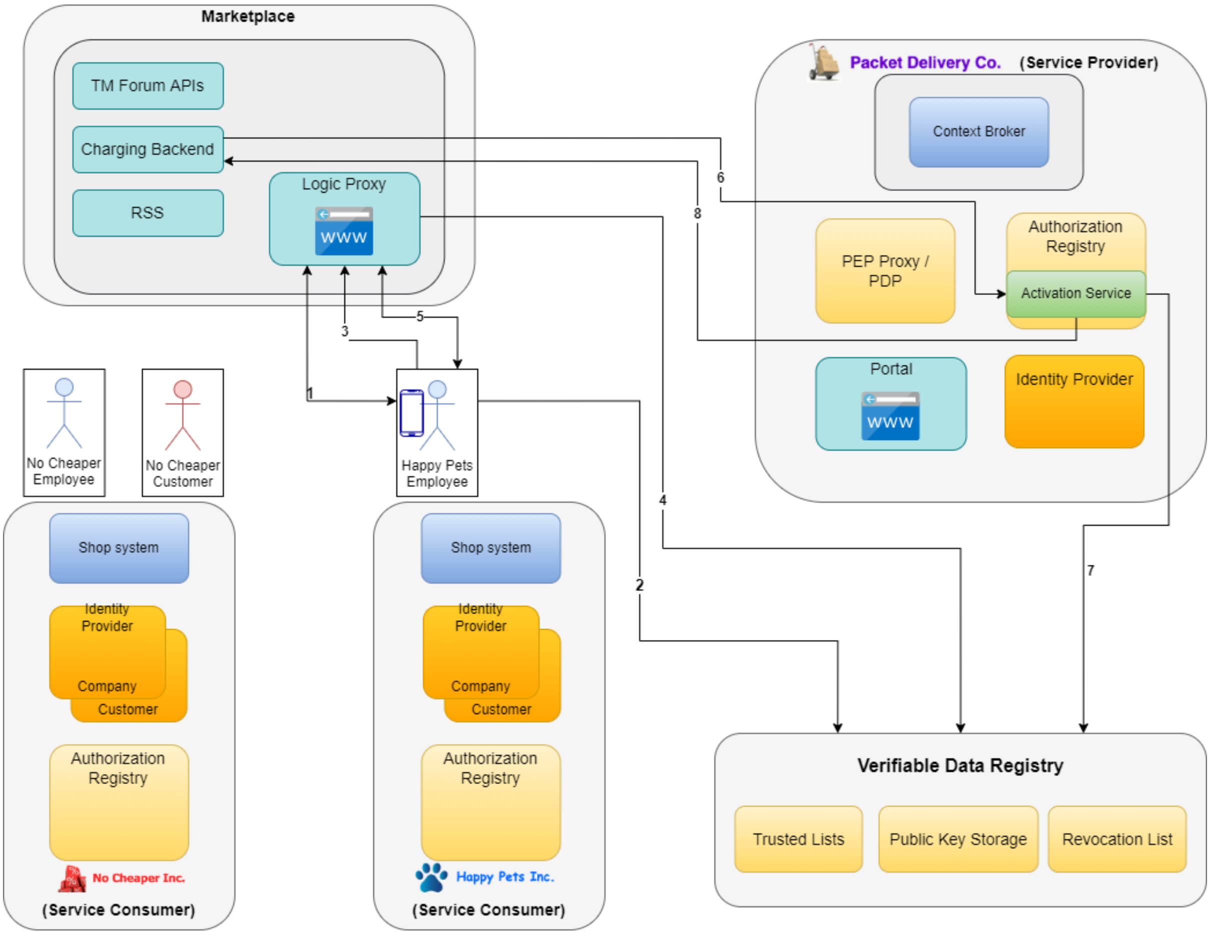
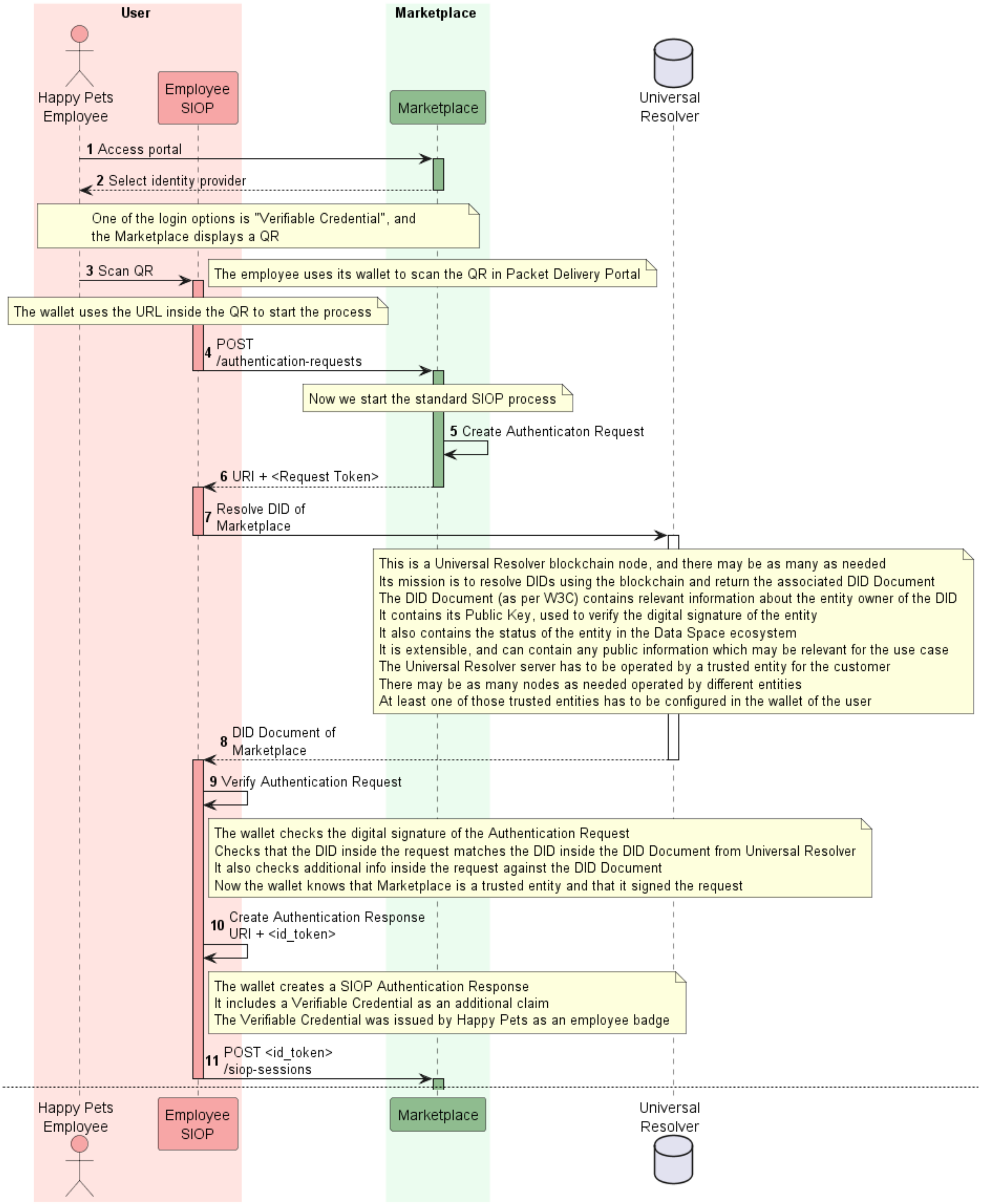


Figure 6.4: Sequence diagram for step “Acquisition of Rights / Activation”

Packet Delivery - Acquisition of rights


User
Marketplace
Happy Pets Employee
Employee SIOP
Marketplace
Universal Resolver
1 Access portal
2 Select identity provider
3 Scan QR
4 POST /authentication-requests
5 Create Authenticaton Request
6 URI + <Request Token>
7 Resolve DID of Marketplace
8 DID Document of Marketplace
9 Verify Authentication Request
10 Create Authentication Response URI + <id_token>
11 POST <id_token> /siop-sessions
Happy Pets Employee
Employee SIOP
Marketplace
Universal Resolver

One of the login options is "Verifiable Credential", and the Marketplace displays a QR

The employee uses its wallet to scan the QR in Packet Delivery Portal

The wallet uses the URL inside the QR to start the process

Now we start the standard SIOP process

This is a Universal Resolver blockchain node, and there may be as many as needed
Its mission is to resolve DIDs using the blockchain and return the associated DID Document
The DID Document (as per W3C) contains relevant information about the entity owner of the DID
It contains its Public Key, used to verify the digital signature of the entity
It also contains the status of the entity in the Data Space ecosystem
It is extensible, and can contain any public information which may be relevant for the use case
The Universal Resolver server has to be operated by a trusted entity for the customer
There may be as many nodes as needed operated by different entities
At least one of those trusted entities has to be configured in the wallet of the user

The wallet checks the digital signature of the Authentication Request
Checks that the DID inside the request matches the DID inside the DID Document from Universal Resolver
It also checks additional info inside the request against the DID Document
Now the wallet knows that Marketplace is a trusted entity and that it signed the request

The wallet creates a SIOP Authentication Response
It includes a Verifiable Credential as an additional claim
The Verifiable Credential was issued by Happy Pets as an employee badge

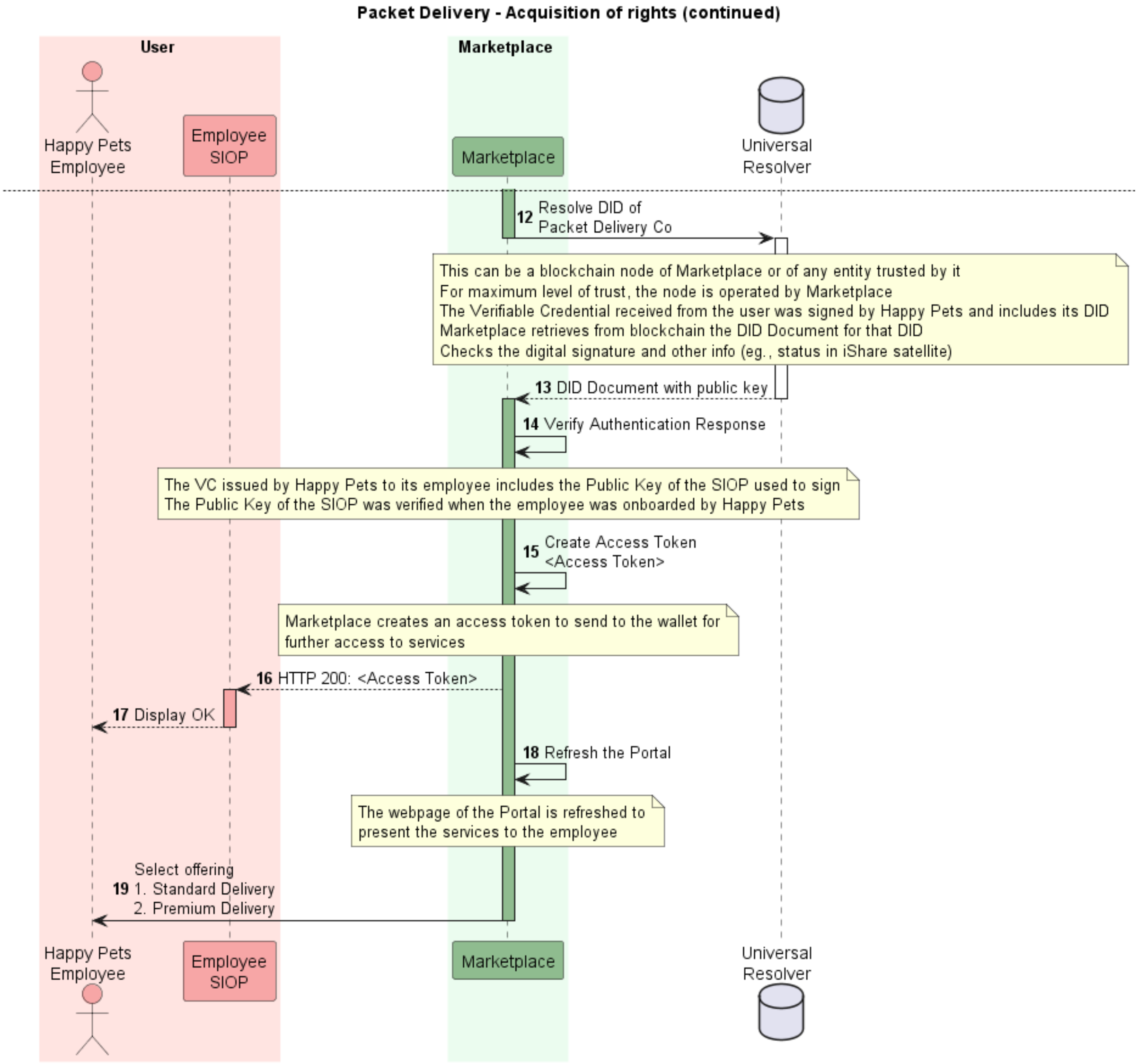

Packet Delivery - Acquisition of rights (continued)
User
Marketplace
Happy Pets Employee
Employee SIOP
Marketplace
Universal Resolver
12 Resolve DID of Packet Delivery Co
This can be a blockchain node of Marketplace or of any entity trusted by it
For maximum level of trust, the node is operated by Marketplace
The Verifiable Credential received from the user was signed by Happy Pets and includes its DID
Marketplace retrieves from blockchain the DID Document for that DID
Checks the digital signature and other info (eg., status in iShare satellite)
13 DID Document with public key
14 Verify Authentication Response
The VC issued by Happy Pets to its employee includes the Public Key of the SIOP used to sign
The Public Key of the SIOP was verified when the employee was onboarded by Happy Pets
15 Create Access Token <Access Token>
Marketplace creates an access token to send to the wallet for further access to services
16 HTTP 200: <Access Token>
17 Display OK
18 Refresh the Portal
The webpage of the Portal is refreshed to present the services to the employee
19 Select offering 1. Standard Delivery 2. Premium Delivery
Happy Pets Employee
Employee SIOP
Marketplace
Universal Resolver

Figure 6.4.b: Sequence diagram for step “Acquisition of Rights / Activation”

1. The Happy Pets employee accesses the Marketplace portal (provided by the BAE Logic Proxy), in order to login.
2. Happy Pets employee is displayed a list of Identity Providers for selecting the desired Identity Provider for login. Happy Pets employee gets forwarded to a page for selecting the desired Identity Provider for login. One of the login options is “Verifiable Credentials” or something similar.
3. Happy Pets employee selects the “Verifiable Credentials” login method, which causes the Marketplace portal to generate a QR containing the URL of the /authentication-requests endpoint of the Marketplace server.

4. The employee scans the QR with her mobile and the mobile calls the /authentication-requests endpoint.
5. This starts a standard SIOP (Self-Issued OpenID Provider) flow, where the Marketplace IDP plays the role of Relying Party (RP in Open ID Connect terminology) and the mobile device of the employee as a Self-Issued IDP. In this step, Marketplace IDP creates a SIOP Authentication Request. As a Self-Issued OP may be running locally as a native application or progressive web application (PWA), the RP may not have a network-addressable endpoint to communicate directly with the OP. We have to leverage the implicit flow of OpenID Connect to communicate with such locally-running OPs, as described in https://openid.net/specs/openid-connect-self-issued-v2-1_0.html.

   The Authentication Request travels in the response to the HTTP GET request performed in the previous point, as a JWT signed by Packet Delivery company. The decoded contents of the JWT may be:

```
openid://?
   scope=openid
   &response_type=id_token
   &response_mode=post
   &client_id=did:elsi:EU.EORI.NLMARKETPLA
   &redirect_uri=https://marketplace.fiware.io/siop_sessions
   &claims=...
   &registration={
      "subject_syntax_types_supported": ["did:key",
      "urn:ietf:params:oauth:jwk-thumbprint"]
   }
   &nonce=n-0S6_WzA2Mj
```

6. The Authentication Request is returned to the employee wallet acting as SIOP. The SIOP flow uses a new response mode **post** which is used to request the SIOP to deliver the result of the authentication process to a certain endpoint. The parameter **response_mode** is used to carry this value.

   This endpoint where the SIOP shall deliver the authentication result is defined in the standard parameter **redirect_uri**.
7. In this step the employee verifies that the Marketplace is a trusted entity belonging to the ecosystem, by resolving the DID of the Marketplace which is received in the **client_id** parameter of the Authentication Request.

   To resolve a DID, the wallet sends a GET request to the **/api/did/v1/identifiers/did:elsi:EU.EORI.NLMARKETPLA** endpoint of one of several trusted servers implementing the Universal Resolver functionality. The Universal Resolver includes a blockchain node, and there may be as many as needed. Its mission is to resolve DIDs using the blockchain and return the associated DID Document. The DID Document (as per W3C) contains relevant information about the entity owner of the DID. It contains its Public Key, used to verify the digital signature of the entity. It also contains the status of the entity in the Data Space ecosystem. It is extensible and can contain any public information which may be relevant for the use case. The Universal Resolver server must be operated by a trusted entity for the customer. There may be as many nodes as needed operated by different entities. At least one of those trusted entities has to be configured in the wallet of the employee.

8. The wallet receives the DID Document of Marketplace, with trusted information about the entity, including the Public Key associated with the Private Key that Marketplace uses to digitally sign tokens. For example:

```
{
  "payload": {
    "@context": [
      "https://www.w3.org/ns/did/v1",
      "https://w3id.org/security/v1"
    ],
    "id": "did:elsi:EU.EORI.NLMARKETPLA",
    "verificationMethod": [
      {
        "id": "did:elsi:EU.EORI.NLMARKETPLA#key-verification",
        "type": "JwsVerificationKey2020",
        "controller": "did:elsi:EU.EORI.NLMARKETPLA",
        "publicKeyJwk": {
          "kid": "key-verification",
          "kty": "EC",
          "crv": "secp256k1",
          "x": "V8XptJkb5wplYkExcTF4nkyYVp7t5H5d5C4UPqCCM9c",
          "y": "kn3nSPxIIvd9iaG0N4v14ceuo8E4PcLXhhGeDzCE7VM"
        }
      }
    ],
    "service": [
      {
        "id": "did:elsi:EU.EORI.NLMARKETPLA#info",
        "type": "EntityCommercialInfo",
        "serviceEndpoint": "https://marketplace.fiware.io/info",
        "name": "Packet Delivery co."
      },
      {
        "id": "did:elsi:EU.EORI.NLMARKETPLA#sms",
        "type": "SecureMessagingService",
        "serviceEndpoint": "https://marketplace.fiware.io/api/sms"
      }
    ],
    "anchors": [
      {
        "id": "redt.alastria",
        "resolution": "UniversalResolver",
        "domain": "marketplace.dataspace",
        "ethereumAddress": "0xbcB9b29eeb28f36fd84f1CfF98C3F1887D831d78"
      }
    ],
    "created": "2021-11-14T13:02:37Z",
    "updated": "2021-11-14T13:02:37Z"
  }
}
```

9. The DID Document includes one or more public keys inside the “verificationMethod” array. The keys are identified by the “id” field in each element of the array. The employee wallet uses the **kid** field that was received in the Authentication Request (in the protected header of the JWT) to select the corresponding Public Key and verify the signature of the JWT. It also verifies that the top-level “**id**” field in the DID Document ("did:elsi:EU.EORI.NLMARKETPLA") is equal to the **client_id** parameter of the Authentication Request.
10. The employee wallet creates an Authentication Response to be posted in the **redirect_uri** specified by Marketplace in step 5. The contents of the Authentication Response are described below.
11. The SIOP sends the authentication response to the endpoint passed in the **redirect_uri** authentication request parameter using a HTTP POST request using "application/x-www-form-urlencoded" encoding. The response contains an ID Token and a VP (Verifiable Presentation) token as defined in https://openid.net/specs/openid-connect-4-verifiable-presentations-1_0.html.

```
POST /siop_sessions HTTP/1.1
Host: marketplace.fiware.io
Content-Type: application/x-www-form-urlencoded

id_token=eyJ0 ... NiJ9.eyJ1c ... I6IjIifX0.DeWt4Qu ... ZXso
&vp_token=...
&state=af0ifjsldkj
```

The decoded **id_token** would be:

```
{
   "iss":"https://self-issued.me/v2",
   "aud":"did:elsi:EU.EORI.NLMARKETPLA",
   "iat":1615910538,
   "exp":1615911138,
   "sub":"did:peer:99ab5bca41bb45b78d242a46f0157b7d",
   "auth_time":1615910535,
   "nonce":"n-0S6_WzA2Mj",
}
```

The **sub** claim is *did:peer:99ab5bca41bb45b78d242a46f0157b7d* which is the DID of the user and for privacy reasons it is not registered in any blockchain or centralized repository. It must be the same as the DID included in the Verifiable Credential that was issued by the Happy Pets company when onboarding the employee and which travels in the authentication response.

The **vp_token** includes the Verifiable Presentation, which can be in two formats: **jwt_vp** (JWT encoded) or **ldp_vp** (JSON-LD encoded). The following example is using the JWT encoding:

```
{
    "format":"jwt_vp",
    "presentation":
    "eyJhbGciOiJSUzI1NiIsInR5cCI6IkpXVCIsImtpZCI6ImRpZDpleGFtcGxlOmFiZmUxM2Y3MTIxMjA0
    MzFjMjc2ZTEyZWNhYiNrZXlzLTEifQ.eyJzdWIiOiJkaWQ6ZXhhbXBsZTplYmZlYjFmNzEyZWJjNmYxY
    zI3NmUxMmVjMjEiLCJqdGkiOiJodHRwOi8vZXhhbXBsZS5lZHUvY3JlZGVudGlhbHMvMzczMiIsImlzc
    yI6Imh0dHBzOi8vZXhhbXBsZS5jb20va2V5cy9mb28uandrIiwibmJmIjoxNTQxNDkzNzI0LCJpYXQiO
    jE1NDE0OTM3MjQsImV4cCI6MTU3MzAyOTcyMywibm9uY2UiOiI2NjAhNjM0NUZTZXIiLCJ2YyI6eyJAY
    29udGV4dCI6WyJodHRwczovL3d3dy53My5vcmcvMjAxOC9jcmVkZW50aWFscy92MSIsImh0dHBzOi8vd
    3d3LnczLm9yZy8yMDE4L2NyZWRlbnRpYWxzL2V4YW1wbGVzL3YxIl0sInR5cGUiOlsiVmVyaWZpYWJsZ
    UNyZWRlbnRpYWwiLCJVbml2ZXJzaXR5RGVncmVlQ3JlZGVudGlhbCJdLCJjcmVkZW50aWFsU3ViamVjd
    CI6eyJkZWdyZWUiOnsidHlwZSI6IkJhY2hlbG9yRGVncmVlIiwibmFtZSI6IjxzcGFuIGxhbmc9J2ZyL
    UNBJz5CYWNjYWxhdXLDqWF0IGVuIG11c2lxdWVzIG51bcOpcmlxdWVzPC9zcGFuPiJ9fX19.KLJo5GAy
    BND3LDTn9H7FQokEsUEi8jKwXhGvoN3JtRa51xrNDgXDb0cq1UTYB-rK4Ft9YVmR1NI_ZOF8oGc_7wAp
    8PHbF2HaWodQIoOBxxT-4WNqAxft7ET6lkH-4S6Ux3rSGAmczMohEEf8eCeN-jC8WekdPl6zKZQj0YPB
    1rx6X0-xlFBs7cl6Wt8rfBP_tZ9YgVWrQmUWypSioc0MUyiphmyEbLZagTyPlUyflGlEdqrZAv6eSe6R
    txJy6M1-lD7a5HTzanYTWBPAUHDZGyGKXdJw-W_x0IWChBzI8t3kpG253fg6V3tPgHeKXE94fz_QpYfg
    --7kLsyBAfQGbg"
}
```

Which decoded could be:

```
{
  "@context": ["https://www.w3.org/2018/credentials/v1"],
  "type": ["VerifiablePresentation"],
  "verifiableCredential": [
    {
      "@context": [
        "https://www.w3.org/2018/credentials/v1",
        "https://happypets.fiware.io/2022/credentials/employee/v1"
      ],
      "id": "https://happypets.fiware.io/credentials/25159389-8dd17b796ac0",
      "type": ["VerifiableCredential", "EmployeeCredential"],
      "issuer": {
        "id": "did:elsi:EU.EORI.NLHAPPYPETS"
      },
      "issuanceDate": "2022-03-22T14:00:00Z",
      "validFrom": "2022-03-22T14:00:00Z",
      "expirationDate": "2023-03-22T14:00:00Z",
      "credentialSubject": {
        "id": "did:peer:99ab5bca41bb45b78d242a46f0157b7d",
        "verificationMethod": [
          {
            "id": "did:peer:99ab5bca41bb45b78d242a46f0157b7d#key1",
            "type": "JwsVerificationKey2020",
            "controller": "did:peer:99ab5bca41bb45b78d242a46f0157b7d",
            "publicKeyJwk": {
              "kid": "key1",
              "kty": "EC",
              "crv": "P-256",
              "x": "lJtvoA5_XptBvcfcrvtGCvXd9bLymmfBSSdNJf5mogo",
              "y": "fSc4gZX2R3QKKfHvS3m2vGSVSN8Xc04qsquyfEM55Z0"
            }
          }
        ],
        "roles": [
          {
            "target": "did:elsi:EU.EORI.NLPACKETDEL",
            "names": ["P.Create"]
          }
        ],
        "name": "Jane Doe",
        "given_name": "Jane",
        "family_name": "Doe",
        "preferred_username": "j.doe",
        "email": "janedoe@packetdelivery.com"
      }
    }
  ]
}
```

12. Marketplace uses its own blockchain node or the one from a trusted entity implementing the Universal Resolver functionality to resolve the DID of Happy Pets, which is inside the Verifiable Credential received in the Verifiable Presentation. This DID can be found in the “issuer” field of the “verifiableCredential” structure above.

    Resolution is performed sending a GET request to the Universal Resolver: **/api/did/v1/identifiers/did:elsi:EU.EORI.NLHAPPYPETS**

    Marketplace could use a Universal Resolver operated by a different entity, but this would reduce the level of trust compared to using its own server directly connected to the blockchain network.

13. Marketplace receives the DID Document of Happy Pets with trusted information about the company, including the Public Key associated with the Private Key that Happy Pets used to digitally sign the Verifiable Credential that the employee has just sent inside a Verifiable Presentation as part of the authentication flow. **Using the Public Key and the DID inside the DID Document, it can verify the signature of the Verifiable Credential and that Happy Pets is a trusted entity in the ecosystem and that it is active.**

14. The above is just for verification of the Verifiable Credential. In addition, Marketplace can also verify that the Verifiable Presentation including the Verifiable Credential is sent by the employee and not by a malicious agent. To do so, it uses the Public Key of the employee in the “verificationMethod” of the “credentialSubject” structure. That public key is cryptographically bound to the employee DID during the onboarding process that Happy Pets performed with its employee.

15. Once all verifications have been performed, Marketplace creates an Access Token for the employee so she can use it to access services in the Marketplace server in the future.

16. The wallet (SIOP) receives the access token and saves it temporarily to be able to request services from Marketplace.

17. The wallet displays a success message to the employee.

18. The Marketplace server refreshes the page (it was the login page before) and displays the services available to the employee of Packet Delivery Co.

At this point the Happy Pets employee is logged in on the Marketplace application. The user is now able to use the services available to her.

At this moment, the Marketplace knows the following:

- That Happy Pets belongs to the Data Space and can issue credentials of the type EmployeeCredential because it is included in the corresponding Trusted Issuers List and is active, because this info is in the DID Document retrieved in step 13. Maintenance of this information is performed by the Trust Anchor entity (or entities) responsible for the Trusted Issuers List.
- That Happy Pets says that the user is one of its employees. This info is inside the Verifiable Credential that is digitally signed by Happy Pets.

From this point on, the Marketplace can display to the user the services available to her and execute them if the user is entitled to do so. The Marketplace can use all the claims inside the credential to perform RBAC/ABAC access control and policy enforcement.

6.4.2.2 Sequence description (No Cheaper Ltd)

The process is exactly the same as for the acquisition process for Happy Pets, except that the entities involved are No Cheaper Ltd and its employees. We do not provide a detailed flow to avoid repetition.

6.4.3 Access to data service

The process of changing the PTA attribute of a packet delivery order via the packet delivery portal is explained. The process would be similar, when trying to change the PDA or delivery address.

In the following the sequences are shown for the scenario of the Happy Pets customer changing the PTA of the delivery order. In the case of the No Cheaper customer, the sequences would be the same with the only difference being that the request for changing the PTA would be denied.

6.4.3.1 Sequence description (Happy Pets Customer)

The following gives a detailed description of the process of changing the PTA attribute by the Happy Pets customer, when using Verifiable Credentials. Figure 4.4.3.1b shows a detailed sequence diagram of the whole process. The numberings in the architectural overview map to the different steps of the sequence diagram.

In the following, a description is given for each of the sequence steps.

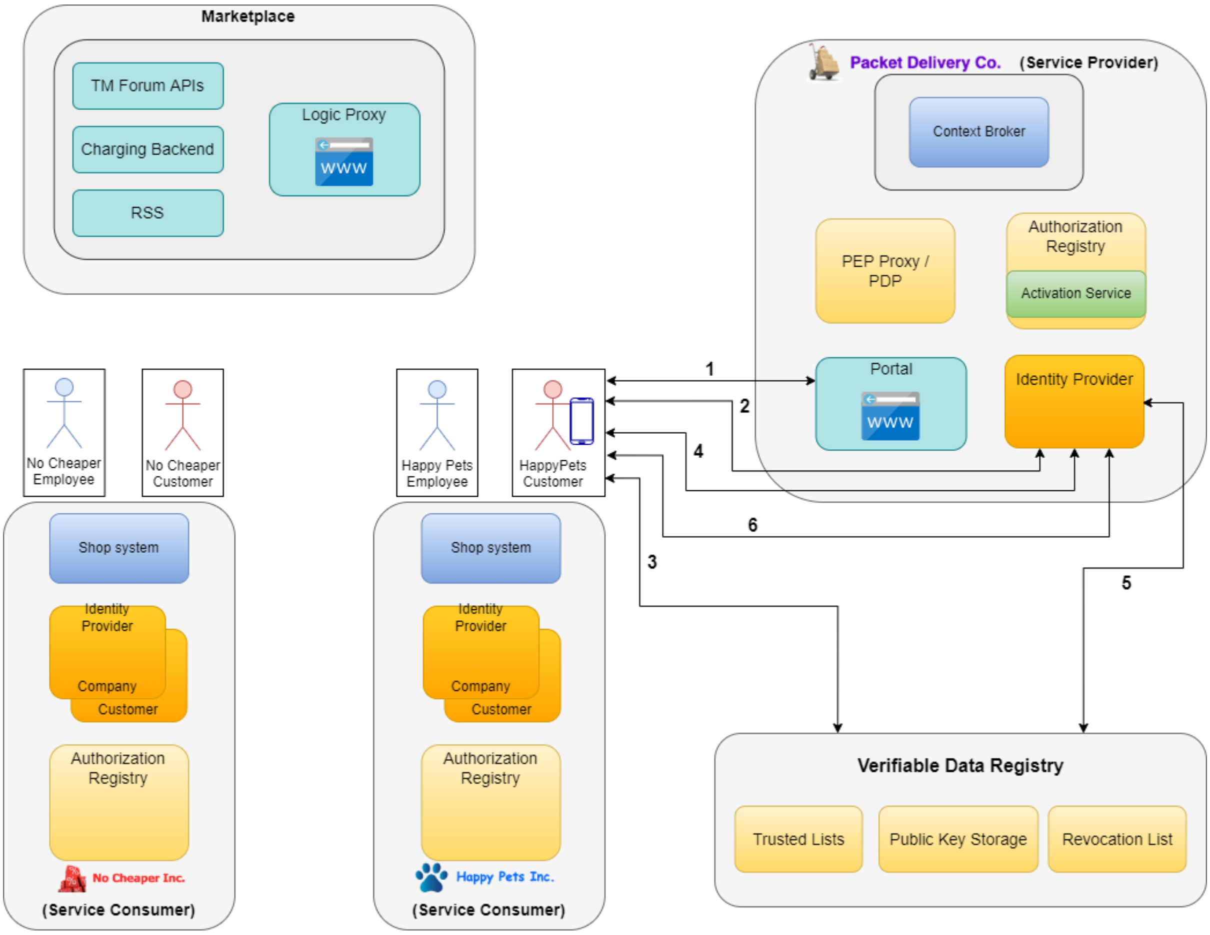
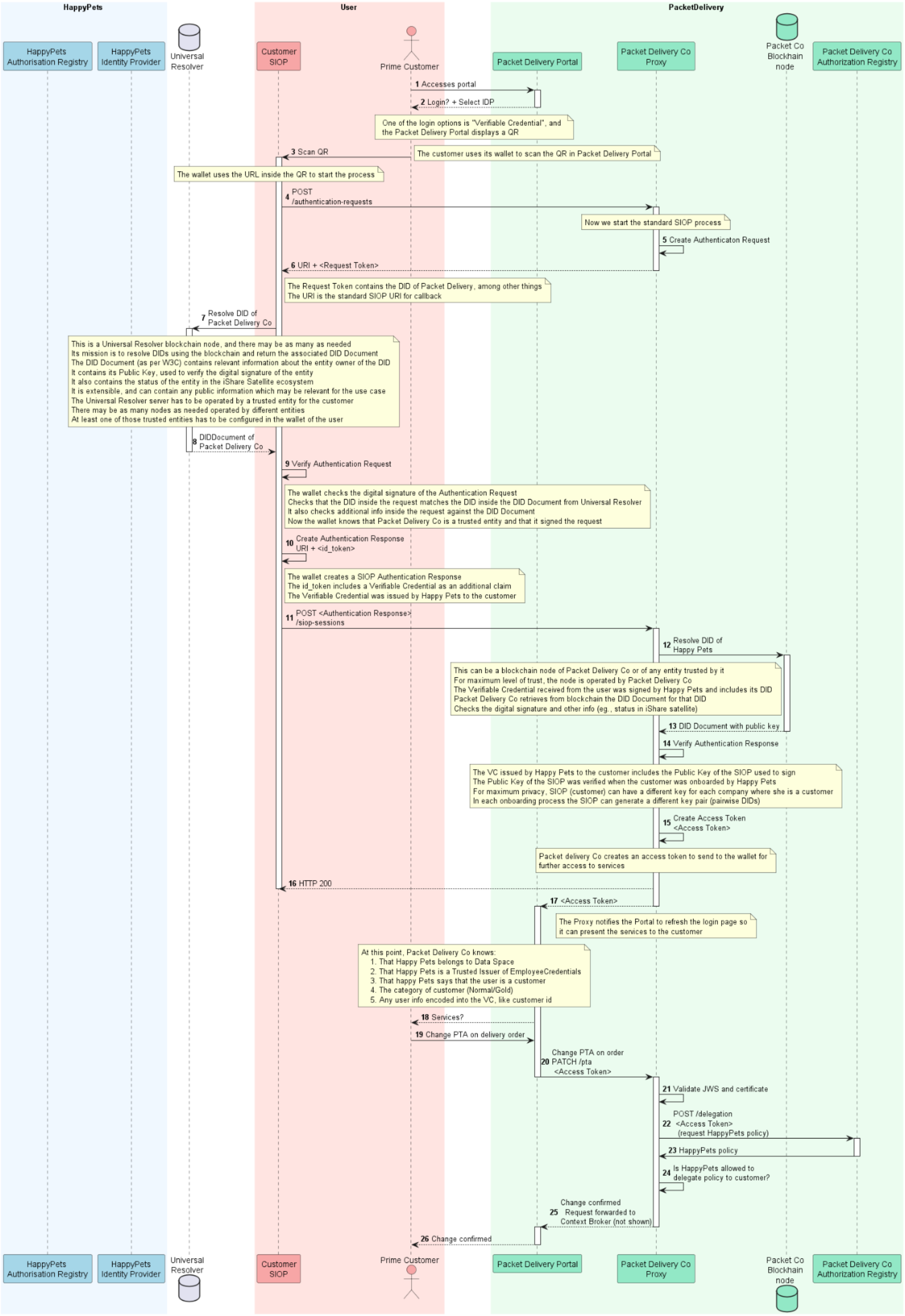


Figure 6.5.a: Architecture diagram for step "Change PTA by Happy Pets customer"

Packet Delivery - HappyPets customer changes PTA - detailed flow


HappyPets
User
PacketDelivery
HappyPets Authorisation Registry
HappyPets Identity Provider
Universal Resolver
Customer SIOP
Prime Customer
Packet Delivery Portal
Packet Delivery Co Proxy
Packet Co Blockhain node
Packet Delivery Co Authorization Registry
1 Accesses portal
2 Login? + Select IDP
3 Scan QR
4 POST /authentication-requests
5 Create Authenticaton Request
6 URI + <Request Token>
7 Resolve DID of Packet Delivery Co
8 DIDDocument of Packet Delivery Co
9 Verify Authentication Request
10 Create Authentication Response URI + <id_token>
11 POST <Authentication Response> /siop-sessions
12 Resolve DID of Happy Pets
13 DID Document with public key
14 Verify Authentication Response
15 Create Access Token <Access Token>
16 HTTP 200
17 <Access Token>
18 Services?
19 Change PTA on delivery order
Change PTA on order
20 PATCH /pta
<Access Token>
21 Validate JWS and certificate
POST /delegation
22 <Access Token>
(request HappyPets policy)
23 HappyPets policy
24 Is HappyPets allowed to delegate policy to customer?
Change confirmed
25 Request forwarded to
Context Broker (not shown)
26 Change confirmed

One of the login options is "Verifiable Credential", and the Packet Delivery Portal displays a QR

The customer uses its wallet to scan the QR in Packet Delivery Portal

The wallet uses the URL inside the QR to start the process

Now we start the standard SIOP process

The Request Token contains the DID of Packet Delivery, among other things
The URI is the standard SIOP URI for callback

This is a Universal Resolver blockchain node, and there may be as many as needed
Its mission is to resolve DIDs using the blockchain and return the associated DID Document
The DID Document (as per W3C) contains relevant information about the entity owner of the DID
It contains its Public Key, used to verify the digital signature of the entity
It also contains the status of the entity in the iShare Satellite ecosystem
It is extensible, and can contain any public information which may be relevant for the use case
The Universal Resolver server has to be operated by a trusted entity for the customer
There may be as many nodes as needed operated by different entities
At least one of those trusted entities has to be configured in the wallet of the user

The wallet checks the digital signature of the Authentication Request
Checks that the DID inside the request matches the DID inside the DID Document from Universal Resolver
It also checks additional info inside the request against the DID Document
Now the wallet knows that Packet Delivery Co is a trusted entity and that it signed the request

The wallet creates a SIOP Authentication Response
The id_token includes a Verifiable Credential as an additional claim
The Verifiable Credential was issued by Happy Pets to the customer

This can be a blockchain node of Packet Delivery Co or of any entity trusted by it
For maximum level of trust, the node is operated by Packet Delivery Co
The Verifiable Credential received from the user was signed by Happy Pets and includes its DID
Packet Delivery Co retrieves from blockchain the DID Document for that DID
Checks the digital signature and other info (eg., status in iShare satellite)

The VC issued by Happy Pets to the customer includes the Public Key of the SIOP used to sign
The Public Key of the SIOP was verified when the customer was onboarded by Happy Pets
For maximum privacy, SIOP (customer) can have a different key for each company where she is a customer
In each onboarding process the SIOP can generate a different key pair (pairwise DIDs)

Packet delivery Co creates an access token to send to the wallet for further access to services

The Proxy notifies the Portal to refresh the login page so it can present the services to the customer

At this point, Packet Delivery Co knows:

1. That Happy Pets belongs to Data Space
2. That Happy Pets is a Trusted Issuer of EmployeeCredentials
3. That happy Pets says that the user is a customer
4. The category of customer (Normal/Gold)
5. Any user info encoded into the VC, like customer id

Figure 6.5.b: Sequence diagram for step “Change PTA by Happy Pets customer”

1. Happy Pets customer accesses the Packet delivery company portal or starts the Packet Delivery company app in its smartphone, to login.
2. Happy Pets customer gets forwarded to a page for selecting the desired Identity Provider for login. One of the login options is “Verifiable Credentials” or something similar.
3. Happy Pets customer selects the “Verifiable Credentials” login method, which causes the Packet delivery company portal to generate a QR containing inside the URL of the /authentication-requests endpoint of the Packet Delivery company IDP.
4. The customer scans the QR with her mobile and the mobile calls the /authentication-requests endpoint.
5. This starts a standard SIOP (Self-Issued OpenID Provider) flow, where the Packet Delivery company IDP plays the role of Relying Party (RP in Open ID Connect terminology) and the mobile device of the customer as a Self-Issued IDP. In this step, Packet Delivery company IDP creates a SIOP Authentication Request. As a Self-Issued OP may be running locally as a native application or progressive web application (PWA), the RP may not have a network-addressable endpoint to communicate directly with the OP. We have to leverage the implicit flow of OpenID Connect to communicate with such locally-running Ops, as described in https://openid.net/specs/openid-connect-self-issued-v2-1_0.html.

   The Authentication Request travels in the response to the HTTP GET request performed in the previous point, as a JWT signed by Packet Delivery company. The decoded contents of the JWT may be:

```
openid://?
  response_type=id_token
  &response_mode=post
  &client_id=did:elsi:EU.EORI.NLPACKETDEL
  &redirect_uri=https%3A%2F%2Fidp-pdc.fiware.io%2Fsiop_sessions
  &scope=openid%20profile
  &state=af0ifjsldkj
  &nonce=n-0S6_WzA2Mj
  &registration=%7B%22subject_syntax_types_supported%22:%5B%22did%22%5D,
    %22id_token_signing_alg_values_supported%22:%5B%22RS256%22%5D%7
```

6. The Authentication Request is returned to the customer wallet acting as SIOP. The SIOP flow uses a new response mode **post** which is used to request the SIOP to deliver the result of the authentication process to a certain endpoint. The parameter **response_mode** is used to carry this value.

   This endpoint where the SIOP shall deliver the authentication result is defined in the standard parameter **redirect_uri**.

7. In this step the customer verifies that the Packet Delivery company is a trusted entity belonging to the ecosystem, by resolving the DID of the Packet Delivery company which is received in the **client_id** parameter of the Authentication Request.

   To resolve a DID, the wallet sends a GET request to the **/api/did/v1/identifiers/did:elsi:EU.EORI.NLPACKETDEL** endpoint of one of several trusted servers implementing the Universal Resolver functionality. The Universal Resolver includes a blockchain node, and there may be as many as needed. Its mission is to resolve DIDs using the blockchain and return the associated DID Document. The DID Document (as per W3C) contains relevant information about the entity owner of the DID. It contains its Public Key, used to verify the digital signature of the entity. It also contains the status of the entity in the Data Space ecosystem. It is extensible and can contain any public information which may be relevant for the use case. The Universal Resolver server must be operated by a trusted entity for the customer. There may be as many nodes as needed operated by different entities. At least one of those trusted entities has to be configured in the wallet of the user.

8. The wallet receives the DID Document of Packet Delivery company, with trusted information about the company, including the Public Key associated with the Private Key that Packet Delivery company uses to digitally sign tokens. For example:

```
{
  "payload": {
    "@context": [
      "https://www.w3.org/ns/did/v1",
      "https://w3id.org/security/v1"
    ],
    "id": "did:elsi:EU.EORI.NLPACKETDEL",
    "verificationMethod": [
      {
        "id": "did:elsi:EU.EORI.NLPACKETDEL#key-verification",
        "type": "JwsVerificationKey2020",
        "controller": "did:elsi:EU.EORI.NLPACKETDEL",
        "publicKeyJwk": {
          "kid": "key-verification",
          "kty": "EC",
          "crv": "secp256k1",
          "x": "V8XptJkb5wplYkExcTF4nkyYVp7t5H5d5C4UPqCCM9c",
          "y": "kn3nSPxIIvd9iaG0N4v14ceuo8E4PcLXhhGeDzCE7VM"
        }
      }
    ],
    "service": [
      {
        "id": "did:elsi:EU.EORI.NLPACKETDEL#info",
        "type": "EntityCommercialInfo",
        "serviceEndpoint": "https://packetdelivery.com/info",
        "name": "Packet Delivery co."
      },
      {
        "id": "did:elsi:EU.EORI.NLPACKETDEL#sms",
        "type": "SecureMessagingService",
        "serviceEndpoint": "https://packetdelivery.com/api"
      }
    ],
    "anchors": [
      {
        "id": "redt.alastria",
        "resolution": "UniversalResolver",
        "domain": "packetdelivery.ala",
        "ethereumAddress": "0xbcB9b29eeb28f36fd84f1CfF98C3F1887D831d78"
      }
    ],
    "created": "2021-11-14T13:02:37Z",
    "updated": "2021-11-14T13:02:37Z"
  }
}
```

9. The DID Document includes one or more public keys inside the “verificationMethod” array. The keys are identified by the “id” field in each element of the array. The customer wallet uses the kid field that was received in the Authentication Request (in the protected header of the JWT) to select the corresponding Public Key and verify the signature of the JWT. It also verifies that the top-level “id” field in the DID Document ("did:elsi:EU.EORI.NLPACKETDEL") is equal to the **client_id** parameter of the Authentication Request.

10. The customer wallet creates an Authentication Response to be posted in the **redirect_uri** specified by Packet Delivery company in step 5. The contents of the Authentication Response are described below.
11. The SIOP sends the authentication response to the endpoint passed in the **redirect_uri** authentication request parameter using a HTTP POST request using "application/x-www-form-urlencoded" encoding. The response contains an ID Token and a VP (Verifiable Presentation) token as defined in https://openid.net/specs/openid-connect-4-verifiable-presentations-1_0.html.

```
POST /siop_sessions HTTP/1.1
Host: client.example.com
Content-Type: application/x-www-form-urlencoded

id_token=eyJ0 ... NiJ9.eyJ1c ... I6IjIifX0.DeWt4Qu ... ZXso
&vp_token=...
&state=af0ifjsldkj
```

The decoded **id_token** would be:

```
{
  "iss": "https://self-issued.me/v2",
  "aud": "did:elsi:EU.EORI.NLPACKETDEL",
  "iat": 1615910538,
  "exp": 1615911138,
  "sub": "did:peer:99ab5bca41bb45b78d242a46f0157b7d",
  "auth_time": 1615910535,
  "nonce": "n-0S6_WzA2Mj"
}
```

The **sub** claim is *did:peer:99ab5bca41bb45b78d242a46f0157b7d* which is the DID of the user and that is not registered in any blockchain or centralized repository. It must be the same as the DID included in the VP that was issued by the Happy Pets company when onboarding the customer and which travels in the authentication response.

The **vp_token** includes the Verifiable Presentation, which can be in two formats: **jwt_vp** (JWT encoded) or **ldp_vp** (JSON-LD encoded). The following example is using the JWT encoding:

```
{
    "format":"jwt_vp",
    "presentation":
    "eyJhbGciOiJSUzI1NiIsInR5cCI6IkpXVCIsImtpZCI6ImRpZDpleGFtcGxlOmFiZmUxM2Y3MTIxMjA0
    MzFjMjc2ZTEyZWNhYiNrZXlzLTEifQ.eyJzdWIiOiJkaWQ6ZXhhbXBsZTplYmZlYjFmNzEyZWJjNmYxY
    zI3NmUxMmVjMjEiLCJqdGkiOiJodHRwOi8vZXhhbXBsZS5lZHUvY3JlZGVudGlhbHMvMzczMiIsImlzc
    yI6Imh0dHBzOi8vZXhhbXBsZS5jb20va2V5cy9mb28uandrIiwibmJmIjoxNTQxNDkzNzI0LCJpYXQiO
    jE1NDE0OTM3MjQsImV4cCI6MTU3MzAyOTcyMywibm9uY2UiOiI2NjAhNjM0NUZTZXIiLCJ2YyI6eyJAY
    29udGV4dCI6WyJodHRwczovL3d3dy53My5vcmcvMjAxOC9jcmVkZW50aWFscy92MSIsImh0dHBzOi8vd
    3d3LnczLm9yZy8yMDE4L2NyZWRlbnRpYWxzL2V4YW1wbGVzL3YxIl0sInR5cGUiOlsiVmVyaWZpYWJsZ
    UNyZWRlbnRpYWwiLCJVbml2ZXJzaXR5RGVncmVlQ3JlZGVudGlhbCJdLCJjcmVkZW50aWFsU3ViamVjd
    CI6eyJkZWdyZWUiOnsidHlwZSI6IkJhY2hlbG9yRGVncmVlIiwibmFtZSI6IjxzcGFuIGxhbmc9J2ZyL
    UNBJz5CYWNjYWxhdXLDqWF0IGVuIG11c2lxdWVzIG51bcOpcmlxdWVzPC9zcGFuPiJ9fX19.KLJo5GAy
    BND3LDTn9H7FQokEsUEi8jKwXhGvoN3JtRa51xrNDgXDb0cq1UTYB-rK4Ft9YVmR1NI_ZOF8oGc_7wAp
    8PHbF2HaWodQIoOBxxT-4WNqAxft7ET6lkH-4S6Ux3rSGAmczMohEEf8eCeN-jC8WekdPl6zKZQj0YPB
    1rx6X0-xlFBs7cl6Wt8rfBP_tZ9YgVWrQmUWypSioc0MUyiphmyEbLZagTyPlUyflGlEdqrZAv6eSe6R
    txJy6M1-lD7a5HTzanYTWBPAUHDZGyGKXdJw-W_x0IWChBzI8t3kpG253fg6V3tPgHeKXE94fz_QpYfg
    --7kLsyBAfQGbg"
}
```

Which decoded could be:

```
{
  "@context": ["https://www.w3.org/2018/credentials/v1"],
  "type": ["VerifiablePresentation"],
  "verifiableCredential": [
    {
      "@context": [
        "https://www.w3.org/2018/credentials/v1",
        "https://happypets.fiware.io/2022/credentials/employee/v1"
      ],
      "id": "https://happypets.fiware.io/credentials/25159389-8dd17b796ac0",
      "type": ["VerifiableCredential", "CustomerCredential"],
      "issuer": {
        "id": "did:elsi:EU.EORI.NLHAPPYPETS"
      },
      "issuanceDate": "2022-03-22T14:00:00Z",
      "validFrom": "2022-03-22T14:00:00Z",
      "expirationDate": "2023-03-22T14:00:00Z",
      "credentialSubject": {
        "id": "did:peer:99ab5bca41bb45b78d242a46f0157b7d",
        "verificationMethod": [
          {
            "id": "did:peer:99ab5bca41bb45b78d242a46f0157b7d#key1",
            "type": "JwsVerificationKey2020",
            "controller": "did:peer:99ab5bca41bb45b78d242a46f0157b7d",
            "publicKeyJwk": {
              "kid": "key1",
              "kty": "EC",
              "crv": "P-256",
              "x": "lJtvoA5_XptBvcfcrvtGCvXd9bLymmfBSSdNJf5mogo",
              "y": "fSc4gZX2R3QKKfHvS3m2vGSVSN8Xc04qsquyfEM55Z0"
            }
          }
        ],
        "roles": [
          {
            "target": "did:elsi:EU.EORI.NLPACKETDEL",
            "names": ["P.Info.gold"] // Or P.Info.standard
          }
        ],
        "name": "Jane Doe",
        "given_name": "Jane",
        "family_name": "Doe",
        "preferred_username": "j.doe",
        "email": "janedoe@packetdelivery.com"
      }
    }
  ]
}
```

12. Packet Delivery company uses its own blockchain node implementing the Universal Resolver functionality to resolve the DID of Happy Pets, which is inside the Verifiable Credential received in the Verifiable Presentation. This DID can be found in the “issuer” field of the “verifiableCredential” structure above.

    Resolution is performed sending a GET request to the Universal Resolver: **/api/did/v1/identifiers/did:elsi:EU.EORI.NLHAPPYPETS**

    Packet Delivery could use a Universal Resolver operated by a different entity, but this would reduce the level of trust compared to using its own server directly connected to the blockchain network.

13. Packet Delivery receives the DID Document of Happy Pets with trusted information about the company, including the Public Key associated to the Private Key that Happy Pets used to digitally sign the Verifiable Credential that the customer has just sent inside a Verifiable Presentation as part of the authentication flow. **Using the Public Key and the DID inside the DID Document, it can verify the signature of the Verifiable Credential and that Happy Pets is a trusted entity in the ecosystem.**

14. The above is just for verification of the Verifiable Credential. In addition, Packet Delivery company can also verify that the Verifiable Presentation including the Verifiable Credential is sent by the customer and not by a malicious agent. To do so, it uses the Public Key of the customer in the "verificationMethod" of the "credentialSubject" structure. That public key is cryptographically bound to the customer DID during the onboarding process that Happy Pets performed with the customer.
15. Once all verifications have been performed, Packet Delivery company creates an Access Token for the customer so she can use it to access services in Packet Delivery company in the future.
16. The wallet (SIOP) receives a successful reply to the POST request.
17. The Packet Delivery company proxy notifies the Packet Delivery portal that the customer is successfully authenticated, and the portal can display the services available to that customer. The browser of the user receives the Access Token created by Packet Delivery to enable it to request services without going through the previous authentication process. The Access Token is a standard OAuth access token that includes the information that Packet Delivery requires for accessing its services.

    At this point the Happy Pets customer is logged in on the Packet Delivery company portal/app and is presented with the possible services provided, including the option to change the PTA of its delivery orders.

    At this moment, the Packet Delivery company knows the following:

    - Happy Pets is a participant in the Data Space and that it is a Trusted Issuer of EmployeeCredentials because this info is in the DID Document retrieved in step 13. Maintenance of this information is performed by the Trusted Anchor entity(or entities) managing the Trusted Participants List and Trusted Issuers List.
    - Happy Pets says that the user is a customer. This info is inside the Verifiable Credential that is digitally signed by Happy Pets.
    - The category of the customer (and associated policies) with regards to the services offered by Packet Delivery company. This information is also in the Verifiable Credential presented by the customer.
18. The Happy Pets customer is presented with the possible services provided by Packet Delivery, including the option to change the PTA of its delivery orders.
19. Happy Pets customer searches for his packet delivery order and is presented its details. He now requests a change of the PTA of this order on the Packet Delivery company portal/app.

20. Packet Delivery company portal/app sends a request to Packet Delivery company proxy, in order to change the PTA of the delivery order. The request contains the Access Token generated in step 15, with information about the authorisation registry to retrieve policies from.

```
> Authorization: Bearer IIeD...NIQ   // Bearer JWT
> Content-Type: application/json

PATCH https://umbrella.fiware.io/ngsi-ld/v1/entities/urn:ngsi-
ld:DELIVERYORDER:001/attrs/pta

> Payload
{
  "value": "<new PTA>",
  "type": "Property"
}

Decoded Bearer JWT payload:
{
  "iss": "EU.EORI.NLHAPPYPETS",  // Issuer: Happy Pets
  "sub": "419404e1-07ce-4d80-9e8a-eca94vde0003de", // Customer pseudonym
  "jti": "d8a7fd7465754a4a9117ee28f5b7fb60",
  "iat": 1591966224,
  "exp": 1591966254,
  "aud": "EU.EORI.NLHAPPYPETS",
  "authorisationRegistry": {  // AR to retrieve policies from
     "url": "https://ar.packetdelivery.com",
     "identifier": "EU.EORI.NLHAPPYPETS",
     "delegation_endpoint": "https://ar.packetdelivery.com/delegation",
   }
}
```

21. Packet Delivery company proxy received the request of step 19 for changing the PTA of a delivery order. The Access Token received from the customer ensures that she was assigned the delegation evidence with a policy for updating the PTA attribute of this specific delivery order (called issuance at **user level**). Furthermore, since in this scenario the required customer policy was issued by a 3rd party (Happy Pets), the proxy has to check whether Happy Pets itself is allowed to delegate this policy. In general, the rule would be that the proxy needs to check the existence of valid policies through the chain of issuers, until itself (in this case the Packet Delivery company) is the issuer. In this scenario, the proxy will check policies at two different levels: issued at

organizational level (from Packet Delivery company to Happy Pets) and issued at **user level** (from Happy Pets to customer). The Verifiable Credential takes care of the user level policies.

At first, the Packet Delivery company proxy validates the JWT which is part of the authorization header of the PATCH request.

22. In order to check whether Happy Pets is allowed to delegate the policy to its customers, the proxy will check at the Packet Delivery company Authorisation Registry whether this policy exists. The proxy sends a request to the `/delegation` endpoint of the Packet Delivery company Authorization Registry.
23. The proxy receives the delegation evidence policy issued from Packet Delivery company to Happy Pets.
24. Having received the delegation information from the Packet Delivery company Authorization Registry, the proxy (or more precisely, the PDP) can now evaluate whether the contained **organizational policy** allows for updating the PTA attribute, and therefore whether Happy Pets is allowed to delegate the access to its customers. If the proxy received a valid policy, access would be granted on an **organizational level**.

    If the requested delegation evidence can not be found or the returned policy contains the `Deny` rule, the change of the PTA would be denied by the Packet Delivery company proxy and an error would be returned to the Packet Delivery company portal/app, also presented to the Happy Pets customer. The following steps would be omitted.
25. As described in the previous steps, the PDP evaluated that a change of the PTA of the specific delivery order is granted, both on **organizational level** and **user level**. As a result, the request for changing the PTA is forwarded by the Packet Delivery company proxy to the Packet Delivery company Context Broker which holds the information of the packet delivery order. The PTA of the packet delivery order is changed and the Context Broker returns a successful response with HTTP code 204. The Context Broker response is returned to the Packet Delivery company portal, in response to the request of step 26.
26. The successful change of the PTA is presented to the Happy Pets customer.

6.4.3.2 Scenario: No Cheaper

This section describes the variations of above steps in the scenario of the No Cheaper customer.

Basically the sequence of steps is the same as for Happy Pets. In contrast to Happy Pets, during the acquisition of rights described in 4.4.2 Acquisition of Rights / Activation, No Cheaper is just acquiring the standard service and therefore its customers will only be able to read attributes of delivery orders. This means that at the Packet Delivery authorisation registry, there is only a policy created allowing No Cheaper to only delegate GET access to delivery orders.

This scenario can be split into two cases to demonstrate the denial of access based on the different policies on organizational level and user level.

1. At No Cheaper Authorisation Registry, a Verifiable Credential is issued to the No Cheaper customer allowing only GET requests to the Packet Delivery service (representing the P.Info.Standard role). When performing the steps for changing the PTA value of a delivery order, as described in the previous section, the process would stop at step 43, where access would be rejected because the No Cheaper customer was not assigned the necessary policy at user level.
2. At No Cheaper Authorisation Registry, a Verifiable Credential is issued to the No Cheaper customer allowing both GET and PATCH requests to the Packet Delivery service (representing the P.Info.Gold role). When performing the steps for changing the PTA value of a delivery order, as described in the previous section, the process would stop at step 62, where access would be rejected because No Cheaper was not assigned the necessary policy at the Packet Delivery company Authorisation Registry to delegate the premium access to its customers. Therefore access would be rejected at organizational level. This is to show that access would be still rejected, even when the No Cheaper organization issues access to the premium service to its customers within its own Authorization Registry.

In general, for both cases the request for changing the PTA should be denied. However, it can be shown that the No Cheaper customer is able to view attributes of its delivery orders.

6.4.3.3 Issuing tokens for Connectors / application context

In addtion to the section described above tokens (DAT Dynamic Access Token) for the application context must be issued containing the referencing connectors and their security profile. The details of issuing the tokens have to be described to act as an alternative to the current IDS-DAPS realization or to include this mechanisms as specified in IDS-G.

The DAPS issues the requested DAT, or an error response, as per RFC 6749. The Access Token ("the DAT") itself is a JWS adhering to RFC 9068, which in turn contains JSON-LD encoded data in addition to the standard claims, subject to the following additional constraints:

Field name	**additional constraints**
@context	Must be https:*//w3id.org/idsa/contexts/context.jsonld*
@type	Must be ids:DatPayload
securityProfile	Must be an instance of the ids:SecurityProfile class

The DAT MUST be signed using a digital signature scheme. It SHOULD be limited to a short time period (Recommendation: 1 hour). The default resource indicator to be used in the DAT includes idsc:IDS_CONNECTORS_ALL, which SHOULD be accepted by all connectors. Future revisions of this document may allow for mechanisms to specify connectors to be listed in the aud claim such as through RFC 8707.

Additional claims may optionally be present. This specification defines the following:

- **referringConnector** An optional URI of the subject. Is used to connect identifier of the connector with the self-description identifier as defined by the IDS Information Model. A receiving connector can use this information to request more information at a Broker or directly by dereferencing this URI.
- **transportCertsSha256** Contains the public keys of the used transport certificates, hashed using SHA256. The identifying X509 certificate should not be used for the communication encryption. Therefore, the receiving party needs to connect the identity of a connector by relating its hostname (from the communication encryption layer) and the used private/public key pair, with its IDS identity claim of the DAT. The public transportation key must be one of the transportCertsSha256 values. Otherwise, the receiving connector must expect that the requesting connector is using a false identity claim. In general, this claim holds an Array of Strings, but it may optionally hold a single String instead if the Array would have exactly one element.
- **extendedGuarantee** In case a connector fulfills a certain security profile but deviates for a subset of attributes, it can inform the receiving connector about its actual security features. This can only happen if a connector reaches a higher

level for a certain security attribute than the actual reached certification asks for. A deviation to lower levels is not possible, as this would directly invalidate the complete certification level. In general, this claim holds an Array of Strings, but it may optionally hold a single String instead if the Array would have exactly one element.

Example

The following is an example of a sucessful response:

```
200 This is fine
Content-Type: application/json

{
   "access_token": "skdj54dkGjnb[...]lsl8723ijsdfuzticby_ch",
   "scope": "idsc:IDS_CONNECTOR_ATTRIBUTES_ALL",
   "token_type": "bearer",
   "expires_in": "3600"
}
```

The decoded DAT, including header and payload is shown below:

```
{
   "typ": "jwt+at",
   "kid": "somekid",
   "alg": "RS256"
}
.
{
   "iss": "https://daps.aisec.fraunhofer.de/v3",
   "sub":
"DD:CB:FD:0B:93:84:33:01:11:EB:5D:94:94:88:BE:78:7D:57:FC:4A:keyid:CB:8C:C7:B6:85:79:A8:23:A6:CB:15:AB:17:50:2F:E6:65:43:5D:E8",
   "nbf": 1516239022,
   "iat": 1516239022,
   "exp": 1516239032,
   "aud": ["idsc:IDS_CONNECTORS_ALL"],
   "scope": "idsc:IDS_CONNECTOR_ATTRIBUTES_ALL",
   "@context": "https://w3id.org/idsa/contexts/context.jsonld",
   "@type": "ids:DatPayload",
   "referringConnector": "http://some-connector-uri.com",
   "securityProfile": "idsc:BASE_SECURITY_PROFILE",
   "extendedGuarantee": "idsc:USAGE_CONTROL_POLICY_ENFORCEMENT",
   "transportCertsSha256": "bacb879575730bb083f283fd5b67a8cb..."
}
.
somesignature
```

Open aspects to be discussed

Currently, the connector is identified by the attributes of an X.509 certificate. The identifier based on DID has to be decribed. This is still open.

In IDS the security profile is validated by an external evaluation facility and provided to a central authority. The workflow of providing the claim directly as VC/VP needs to be described in detail.

7 Outlook and next steps

The Technology Convergence discussions under the umbrella of the Data Space Business Alliance (DSBA) aimed at achieving technical alignment between the members of the alliance and, so far, has came up with the detailed approach described in the sections above. While some aspects are quite clear and should be adopted by the initiatives, e.g. Identity Management mechanisms and the use of DID and VC/VP, other aspects need further clarification. The discussion will be continued in the next months to close existing gaps and provide a common framework for data spaces. It will also work towards development of some of the required components as open source. Results of the DSBA Technology Convergence, aligned with the work initially conducted in the OpenDEI project, will be contributed to the Data Spaces Support Centre project under the Digital Europe program. Furthermore the ongoing alignment on a common framework for data spaces under the DSBA is crucial to provide a robust foundation for all initiatives realizing data spaces.

In conjunction with the detailed description in the sections above, the DSBA has a common understanding on the roles of the members and their scope of work. These roles and scope of work have been described in section 2.4.

The future work of the DSBA will focus on the following aspects. This is not meant to be a complete list, but listing items that have currently high priority.

- It is still not finally described how IDS Connectors fit into the described identity and access management (IAM) solution. Various options are still possible in an integrated approach or in a hybrid approach.
    - In an integrated approach, there will be modules within IDS Connectors which would implement IAM functions making use of DID and VC/VP in a similar manner for individuals and organizations.
    - While in an hybrid approach X.509 certificates and the Dynamic Attribute Provisioning Service (DAPS) would act in parallel to DID and VC/VP for individuals and organizations.
    - Additionally a mixed mode could also be described.
- The understanding of the interaction of Marketplaces with the Federated Catalog and the Metadata Broker is not final, yet. There is a certain amount of overlap, while a clear responsibility of each component is given. In the process of understanding and clarification some aspects are in the current focus:

  - The mapping of TMForum, Gaia-X and IDS RAM models is provided but is not finalized.
  - The relationship of TMForum APIs and IDS contract negotiation sequence needs to be described. TMForum APIs can be used to support bilateral negotiations between two participants on which IDS contract negotiation could be based, but this is not described, yet.
  - Overall, the responsibilities, functionalities and requirements of each must be described clearly and distinguished from each other.
- The use of Policies for Access and Usage Control is well understood and a clear differentiation from the negotiation of policies and their execution is understood. Nevertheless, there is a clear need to describe the controlled vocabularies that realize those different aspects to provide the required reliability for the implementation.

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