Solid: Enabler of decentralized, digital platforms ecosystems

Melanie Verstraete, Sofie Verbrugge, Didier Colle

June 2022

Abstract

This paper studies the decentralized, digital ecosystem that is enabled by the Solid specification. Solid provides the possibility to break through data silos and simultaneously allows the end-user to regain control. However, research regarding business modelling and economic viability of such ecosystems is still lacking. Therefore, the goal of this paper is to provide first insights for this research area by proposing a value network model for such ecosystems. Though evaluation of existing frameworks and roles proposed by big initiatives like International Data Spaces, a first set of business roles is described. In a second step, these are evaluated with an actual validated use case where Solid is implemented within the HR domain.

1 Introduction

The rise of digital platform ecosystems has created a lot of business opportunities. Both the value creation and innovation that occur on platforms and platform ecosystems are enabled by the large amount of data that is being collected and exchanged. However, this data is often not reusable across platforms due to limited access to the data through API's or data formats. Hence, innovation outside the platform or ecosystem is slowed down or will simply never occur. An additional concern for platform users is the lack of transparency and control over their data. They often do not know which personal data is gathered and analyzed. Even worse, they cannot verify whether there is no illegal secondary usage of data [14].

One solution that provides an answer to this problem is Solid. Solid can be defined as a set of standards that enable a decentralized platform ecosystem [33]. With the use of Solid, a person, company, or entity will be able to store its own data in one or multiple pods (Personal Data Stores) and give - or not - consent to third parties to access and use their data for specified purposes for a specified time range. While researchers are contributing to the technical body of literature concerning Solid and other decentralized ecosystems [8, 27, 9], research from a economic perspective is still very limited.

This article will try to approach decentralized ecosystems, from a techno-economic perspective. The goal is to identify a set of business roles [2] that are applicable to these decentralized ecosystems, the Solid ecosystem in particular.

First, an overview of the state of the art will be provided on the relevant concepts for decentralized and digital ecosystems and the, to our knowledge, limited literature on decentralized ecosystem frameworks. Subsequently, a clear explanation of Solid, from both a technical and an economic perspective is provided. Here a use case will be introduced that is used to validate our intended set of roles. These roles are deducted from the known initiatives by evaluating their applicability for the Solid ecosystem. As a last part of this paper, the proposed set of roles will be mapped on the introduced use case. The result of this analysis will be a first value network mapping for decentralized ecosystems [2].

2 Positioning within state of the art/ Terminology and Concepts

Major organizations as IDSA[1], GAIA-X[2], or My Data Global[3] have started to take interest in data sovereignty and data-sharing ecosystems. However, focus is mostly on industry and sharing of data between organizations while the end-goal of a Solid-based ecosystem is to include and empower all stakeholders. This means, not leaving our the end-user is one of the main goals when implementing Solid.

Not only from industry but also from government, initiatives arise. The European Union has recently provided legislative protection for the data subject through General Data Protection Regulations (GDPR), including the right to access data that has been collected about the data subject and the right to be forgotten [26]. To encourage re-use of public sector data, help individuals exercise their rights under GDPR and data sharing among businesses within the European Union, the EU has published the Data Governance Act[24].

When examining the existing body of literature, many examples of technical implementations for decentralized ecosystems and data sovereignty are present [14, 4, 28]. However, these often remain within a certain domain, for example sensor data, and not much attention has been directed towards the (techno-)economic aspects of the ecosystems. There has already been effort to model data ecosystems but for decentralized ecosystems this is still very limited[23, 21]. For these reasons, this paper will provide a first contribution for techno-economic research regarding decentralized ecosystems including the exchange of personal data.

Additionally, most of the existing body of literature mentioning Solid are of technical nature[27, 8, 9]. Nevertheless, in order to engage adoption of a novel

[1] https://internationaldataspaces.org/
[2] https://www.data-infrastructure.eu/GAIAX/Navigation/EN/Home/home.html
[3] https://www.mydata.org/

technology, the business case also needs to be validated. Therefore and to our knowledge, this paper is to provide one of the first contributions to the more economic oriented literature regarding Solid. In the remainder of this section, several important concepts for these ecosystems will be explained.

2.1 Data sovereignty and decentralization

Sovereignty is defined as the power or authority to rule[4]. In a digital context, data sovereignty refers to the power an individual has over their data. Gaia-X defines digital sovereignty as the power to make decisions about how digital processes, infrastructures and the movement of data are structured, built and managed [10]. Data sovereignty refers then to the self-determination of individuals and organizations with regard to the use of their data [3].

To enable data sovereignty within data ecosystems, a person or organization should be able to control the usage of their data, through e.g. monitoring tools [18, 13]. Transferring this control over data from dominant platforms or governments back to the user, comes down to decentralization of data control [17]. When an individual or an organization has control over its data, this implies that they can choose where this data is stored and who is granted access to it [6]. This decentralization of data control and storage results in breaking through existing data silos [32]. The latter can be enabled with Solid as will be explained in the next section.

2.2 Interoperability and portability

As mentioned in the introduction, data is often stuck within large data silos, not accessible by others and often not stored in an interoperable manner. Interoperability, as defined within the ISO/IEC standard, means the ability of two or more systems or applications to exchange information and to mutually use the information that has been exchanged [12]. While interoperability focuses on the ability to exchange, portability focuses on the actual data flow. Portability is defined as the ability to easily transfer data from one system to another without being required to re-enter data [12].

2.3 Data-sharing ecosystems

When data is kept in big data silos , this results in missed business opportunities and as mentioned in the introduction, less opportunities for innovation. As proposed in literature, data can be shared in open-data ecosystems [15, 13, 25, 10, 32, 11]. In these ecosystems, the focus remains on open data, which can be defined as data that are freely available and accessible to everyone to reuse and republish as they wish without legal restrictions or copyrights, patents or other mechanisms of control. However, not all data can be made freely available, especially personal or sensitive data e.g. your financial information.

[4]https://dictionary.cambridge.org/dictionary/english/sovereignty

2.4 Business roles and value networks

Value network analysis, as defined by Allee [2], offers a way to model value exchanges. Since a company's future depends on the efficiency of value conversion, this analysis can have a significant impact on the business model and future success. A value network is a set of roles, played by people or network participants, and interactions. These interactions result in the exchange of goods, services, knowledge etc. to achieve economic or social good. Two types of exchanges can be identified. Tangible exchanges are contractual transactions involving goods, services, or revenue, while intangible exchanges involve knowledge and information that support the core product but are not contractually defined.

3 Solid

3.1 Brief introduction of Solid

When sir Tim Berners-Lee created the Web, he envisioned it to be an open environment where everyone could exchange information. However, his invention has become, to state his words, an engine of inequality and division [5]. Solid is his answer to the problem. The Solid specification consists of a set of W3C standards and uses the principles of Linked Data Platforms, Web Access Control and other specifications [29]. It enables decentralized exchange of public and private data over the Web [22]. Traditionally, user data is siloed at different service providers, whereas with Solid it is centralized around the individual, stored in one or multiple Solid pods [8]. This way Solid technology enables decoupling data from applications, creating a decentralized Web-ecosystem [27, 29].

A Solid pod, or personal online datastore, is an online storage space. It can be hosted by the individual or business itself or the services of a pod provider can be requested [27]. This way, data sovereignty is achieved with Solid since an entity (for example a person or business) can choose where it stores its data and can grant access to others [6]. The Solid pod is then linked to the entity with the use of a WebID, issued by an identity provider.

Several start ups already noticed the potential of Solid, for example in the media landscape BBC[5] has taken initiative to adopt Solid technology. Not only the private but also public sector engagement is emerging e.g. NHS[6] or the Flemish government[7] show interest.

With the support of communities as Solid World or the Flemish Solid community[8], the interest and adoption of Solid will probably only increase in the near future. For this reason, a framework to capture the Solid ecosystem can be of use to provide insight to those early adopters and potentially help to identify new opportunities and threaths.

[5] https://inrupt.com/solid-enterprise-natwest-bbc

[6] https://solidproject.org/newsletter/2020-10-01

[7] https://www.vlaanderen.be/digitaal-vlaanderen/het-vlaams-datanutsbedrijf/the-flemish-data-utility-company

[8] https://solidcommunity.be/

3.2 Technical implementation of Solid and potential benefits

Multiple stakeholders within a Solid ecosystem could benefit from participating.

The first stakeholders are the individuals, for example end-users of an application. They benefit from several of the capabilities that are included by the shift to decentralization wihtin a Solid ecosystem [6]. First of all they regain control over their data, enabling data sovereignty. The Solid protocol[29] allows access control on a fine grained level.This means that for example, when you as a regular person have your resume stored on you pod and you grant access to your former employer to add a recommendation, you can choose whether your employer sees the whole document or can only add information.

When an individual wants to store its information inside a Solid pod, it must first have a WebID. This is a decentralized and universal identification mechanism and an in-progress open standard within W3C [27]. This WebID refers to the profile document, which describes the entity or business denoted by the WebID [30]. Then with use of Solid OIDC, the individual can identify and authenticate itself with every Solid compliant application. With Solid, an individual can always authenticate itself in a decentralized way and does not need to authenticate with the application provider[27].

After authentication, the application will be granted access to certain data. Due to the fact that the data should always be stored on the pod of the entity it belongs to, there will be no vendor lock-in. From a business and legal perspective, this might not always be the case. Certain contracts and business agreements might require the application to store data for a certain period of time. Think for example about banking apps which are legally required to store your data when they provide a loan. Additionally, there might be other barriers that could potentially create vendor lock-in.

The implementation of Solid is not only beneficial for individuals whose data is collected and used by others, from a business perspective it offers many potential benefits. First of all, since data becomes user-centric instead of platform centric, the data that is available will be more up to date. Organizations do not need to hoard big databases, which are often just static data dumps, when the data is accessible through Solid pods. Instead, they will be able to access - if access is granted- the data that is kept up to date by the individual itself, which in most cases will be the most accurate and complete data. Since they do not store the data, this can potentially reduce efforts regarding lifecycle management of data and legal compliancy (GDPR, DGA and other). Nevertheless, some nuance is required since Solid is still a work -in-progress. Not all data might be in your personal pod, perhaps organizations might host a pod, where they store for example your purchasing behavior and link it with your WebID.

The purpose of Solid, as stated by sir Tim Berners-Lee, is to increase data sharing, preferably in an interoperable manner. Due to the fact that most data will be stored in a machine readable format e.g. RDF format, this can significantly increase interoperability and reduce preprocessing costs for businesses.

3.3 Use case: Human Resources

Nowadays, recruiters and HR platforms collect large amounts of data from their customers, LinkedIn profile's are scraped every minute and resume's are scanned automatically. However, you as an individual are not always aware of what is required to get the job. Karamel.career[9] is a startup that strongly embraces the values behind Solid. They provide a matching between applicants, talent pools and recruiters. The profile of an applicant consists of the standard information such as acquired skills, experience etc. Addionally, Karamel will request other less conventional information, for example, what the interests of a job seeker are in order to provide a more personalized service. Additional to the matching service, they will also provide career guidance and assessment services on their platform.

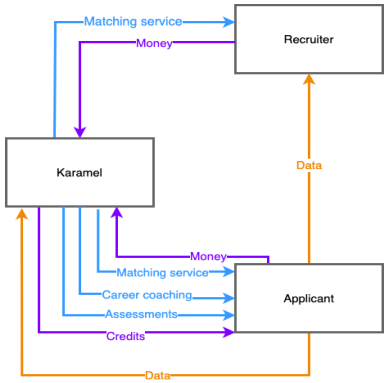

Figure 1: Services provided by Karamel

When a job seeker wants to make use of Karamel's services, he/she has to grant access to Karamel so that their data can be matched to the different talent pools. Talent pools are vacancies, but not for a specific job offering from a company. A talent pool is an extensive description of what is required for a certain position but it also includes how an applicant can gain the required skills e.g. through assessments or additional training. Karamel will also offer assessments and career coaching in an attempt to prepare job seekers for the next step in their career.

Both applicants and recruiters can then be matched to the talent pools. When a match between recruiter and an applicant occurs, the recruiter can request to access the data of the applicant. This request can be accepted or denied by the applicant.

Karamel partners up with Digita [10] who provides pods for their customers and provides the WebID's for those customers through its integrated software offering. When a person does not have a pod, Karamel will direct them to their

[9] https://karamel.career/
[10] https://www.digita.ai/

partners website, where Digita will provide a pod linked to a WebID. Then the applicant will provide initial data through the HR platform, permitting Karamel to write this data to their pod. The data could be for example a diploma which Karamel should be able to verify at the appropriate government institution. No details on this subprocess will be provided in this paper.

In the next section, different proposed frameworks for digital ecosystems will be presented and evaluated for their applicability to a decentralized, digital ecosystem with focus on data sovereignty. From these evaluation, an appropriate set of roles will be proposed and applied to the HR use case as a first validation.

4 Initiatives

4.1 IDSA

The International Data Spaces Association focuses on a global data economy consisting of data spaces across businesses and industry. They propose a set of business roles [3] that are inspired on the basic roles defined in their Reference Architecture Model (RAM) [25]. These roles deem to be suited for different use cases as described in literature [1, 19].

Table 1: Business roles proposed by IDSA

Role	Short description
Data supplier	A data supplier produces/possesses data that may be offered within the IDS ecosystem. Offering data quality, aggregation, completion,...
Service provider	Offers various functions such as data analysis, integration, cleansing or semantic enrichment of data. Offers valuable services, service quality, support, hotline, service availability, service performance and wide range of payment methods.
Data intermediary	Acting as a trusted data broker, the data intermediary manages data exchange in data ecosystems. Offers interface for data suppliers to make their metadata available for data customers. Can play a platform role.
Service intermediary	The service intermediary guarantees the timeliness and allocation of services in the IDS. It provides an interface for data providers to offer metadata about their available services.
Vocabulary publisher and provider	A vocabulary intermediary technically manages and offers vocabularies (i.e. ontologies, reference data models, metadata elements).
Identity authority	An identity authority offers a service to create, maintain, manage, monitor, and validate identity information of and for IDS participants.
Clearing house	Enabler of secure payment, transactional transparency.
Certification body and evaluation facility	The evaluation facility conducts the certification testing and process while the certification body monitors the process, manages quality assurance, and provides guidance throughout the process. These roles ensure that only IDS-compliant organizations are granted access to the trusted business ecosystem.
Software developers	Offering valuable services/apps, service quality, support, hotline, service availability, service performance, wide range of payment methods
Ecosystem orchestrator	Coordinate the development of rules for the data ecosystem, administer the memberships, and audit the proper functioning and adherence to common rules in the data ecosystem

4.2 GAIA-X

Gaia-X is a European project with representatives from business, science and politics that wants to develop a data infrastructure based on the values of openness, transparency, and trust[11]. The GAIA-X ecosystem is based upon different Federations that are interconnected. GAIA-X defines a Federation as "a loose set of interacting actors that directly or indirectly consume, produce, or provide resources" [10]. The organization develops and provides the tools and software

[11] https://www.data-infrastructure.eu

components to develop Federations to enable innovation and data sovereignty.

Table 2: Roles proposed by Gaia-X

Role	**Short description**
Federator	Federators are in charge of the Federation Services and the Federation which are independent of each other. There can be one or more Federators per type of Federation Service.
Provider	Participant who provides Resources in the Gaia-X Ecosystem. The Provider defines the Service Offering including terms and conditions as well as technical Policies.
Consumer	Participant who searches Service Offerings and consumes Service Instances in the Gaia-X Ecosystem to enable digital offerings for End-Users.
End-users	A natural person of process not being a Principal*, using a digital offering from a participant. Participants manage their relations with the End-Users - including identities - outside of the scope of the Gaia-X ecosystem scope. End-users have no credentials within the Gaia-X Ecosystem.

*Principal is either a natural person or digital representation which acts on behalf of a Gaia-X participant.

End-users are not included as participants. This implies a risk that data sovereignty will be enabled within the Gaia-X ecosystem but not outside the boundary of this ecosystem, hence with the end-users. However, additional to the description of the high-level roles in the reference architecture, Gaia-X also provides a more concrete toolbox to create interoperable ecosystems. One proposed implementation of the ecosystem in this toolbox is based on Distributed ledgers in combination with Self-Sovereign Identity [16]. This Whitepaper shows many similarities with the Solid ecosystem including selective disclosure of data (fine grained consent management). Here, as Gaia-X mentions, the focus is no longer solely on the 'Enterprise-Centric Identity' approach but on the 'User-Centric Identity' paradigm.

4.3 MyData

MyData Global is an international non-profit organization and applies "a human-centric approach to personal data management -, which combines industry need for data with digital human rights"[31, 20].

Table 3: Roles proposed by MyData Global

Role	**Short description**
Person	The role of data subject as represented digitally in the ecosystem. Persons manage the use of personal data about themselves for their own purposes and maintain relationships with other persons, services or organizations.
Operator	The role is responsible for operating infrastructure and providing tools for the person in a human-centric system of personal data exchange.
Data source	The role responsible for collecting, storing and controlling personal data which persons, operators and data using services may wish to access and use.
Data using service	The role responsible for processing personal data from one or more data sources to deliver a service. It can be authorised to fetch and use personal data from one or more data sources.
Ecosystem governance	This role is responsible for managing, developing, and enforcing the governance frameworks for the ecosystem.

Different operators can exist and fulfill implement different functional elements, [20] for a detailed description, and at least implement the functionality of Identity Management.

4.4 Comparison between proposed ecosystem roles

From the perspective of Solid, most of these roles are (partially) applicable. However since Solid is invented with the aim to create one big decentralized web-ecosystem including also personal data, hence one large multi-domain ecosystem, some adjustments are necessary. In the next section, the different roles proposed by these initiatives are discussed and a set of roles applicable to the Solid ecosystem (in bold) is suggested.

In order to motivate our comparison and proposed adjustments, an evaluation based on the concepts proposed in section 2 is presented in table 4. Thereby showing how relevant they are for the mapping of a Solid Ecosystem.

Table 4: Comparison of ecosystems

Concept	**IDSA**	**Gaia-X**	**MyData**	**Solid**
Data sharing	Yes	Yes	Yes	Yes
Data sovereignty for businesses	Yes	Yes	Yes	Yes
Data sovereignty for individuals	No	No	Yes	Yes
Decentralization	Yes	Yes	Yes	Yes

It is clear that MyData Global has most similarities with the Solid ecosystem. Since this ecosystem is very user-centric, the description of the person role is action-oriented. The roles are also non-exclusive, an actor that takes up the person role can also be its own operator. This aligns with the vision of Solid to give back control to the end-user. MyData has put its focus more directly on the possible functionalities of a MyData Operator. These functionalities all seem applicable within the Solid ecosystem. However, these are not reflected directly into separate, clear roles that can exchange value. MyData states that these functionalities can be fulfilled (and combined) by different operators.

5 Roles applicable to Solid

For the business roles proposed by IDSA, a first nuance needs to be made for the role of data supplier. In Solid, all stakeholders that control access to their pod and hence the data inside are in fact data suppliers since they possess the data. However, since this can be an average, non-technical person, a distinction needs to be made between who can grant access and the role that can offer for example qualitative data and data processing, cleaning etc. A clear difference in responsibilities needs to be established. This is due to the fact the Solid ecosystem does not stay within an industry vertical but tries to cover all aspects of society. MyData does include the role of data subject - person- in a more active way e.g. permission management.

For this reason, we propose the role of a **data access controller** (DAC) within the Solid ecosystem, this role should be able to control access but not necessarily on a technical level. Since the DAC role only controls the data there is still a need for a role that produces data or introduces it into the ecosystem, this resembles the basic role from the IDSA RAM called the **data creator**.

Access control on a technical level should be the responsibility of the actor that hosts or provides the pod. A **pod provider** relates to the Gaia-X role of a provider that provides data resources and provides the service of decentralized data storage. For MyData, a pod provider relates to the responsibility of a data source that stores personal data which other actors wish to access. Additionally, it also resembles the functionality of a MyData operator that implements personal data storage functionality, permission management and personal data transfer.

What is important is that the software to host pods can be provided by a different role - **software provider** - than the actual provisioning of the pods. One example is Inrupt[12] who provides software components for Solid.

Decoupling data from the applications implies that storage of data no longer lies with the same entity that provides a service based on data. For this reason, a **data consumer** becomes a separate role from the role that provides data storage e.g. pod provider. This corresponds to the data using service (MyData), consumer (Gaia-X) and service provider (IDSA). Since one of the goals of Solid is to unburden the end-user, there should be room for services that realize this

[12] https://inrupt.com/

benefit. In Solid terms, this role should unburden the consent management and access granting process for the DAC. The **access grant provider** should do exactly that, with the authorization of the DAC.

To establish trust within an ecosystem, ISDA proposes the role of certification body and evaluation facility. Although this role is still relevant within the Solid ecosystem since trust needs to be established, this should not increase barriers of entry to the ecosystem. If this would be the case then the vision of Solid - and sir Berners-Lee - would not be guaranteed that Solid would be an enabler for open ecosystems. SOURCE Therefore this paper suggests a **certification authority** and evaluation facility role that issues trust and/or quality certificates to provide trust but simultaneously allows for an open ecosystem.

Within a Solid ecosystem a **WebID provider** needs to be present that can store the WebID within the profile document. Often the WebID provider and the pod provider role will be fulfilled by the same organization. In terms of an identity authority, an **identity provider** (IDP) role remains important when identification with more formal resources is required.

Since data is stored in a decentralized manner, there might be a need for a role that can verify data authenticity and integrity of certain documents. This role will be referred to as the **attestation provider**. One example could be a certification authority and public-private keys. A more decentralized approach could be accomplished with the use of verifiable credentials and Blockchain. The European Union is implementing the latter solution, called the European Blockchain Services Infrastructure[7].

The remaining roles of the IDSA business ecosystem, **clearing house**, **vocabulary publisher** and **ecosystem orchestrator**, are applicable to the Solid ecosystem. These three roles also relate to the functional elements (in the same order) of value exchange, data model management, and governance support defined by MyData. However, these roles should not introduce centralization within the ecosystem. Opening up smaller data silos should not mean merging those into one bigger data silo.

As a final part of this paper, the first validation of these roles through a use case will be presented.

6 Use case validation

The use case of an HR ecosystem enabled by Solid, described in section 3 of this paper, is used to validate our proposed set of roles. Through a set of informal interviews with Karamel[13], we validated the business model and the value network that will be presented within this section. Table 4 provides a brief overview of earlier discussed roles and stakeholders that fulfill those roles. Important to note is that not all roles are included. A first reason for this is that this use case - and Solid in general - is still in implementation phase, as a result not all roles can be validated at the moment. Additionally, some roles

[13]https://karamel.career/

are more overarching and high-level roles that cannot yet be validated through this use case.

Table 5: Roles applicable to Solid use case

Ecosystem role	**Stakeholder**	**Brief description**
Data access controller	Applicant	Controls who can access data within pod.
Pod provider	Digita	Provide technical infrastructure for data sharing and storage
Solid software provider	Digita	Provide software for pod provider and other SDK's
Data consumer	HR platform Recruiter	Requests access to DAC to read, process or perform other actions on data
Data creator	Applicant HR platform	Creates data and request to store in pod of DAC
Access grant provider	HR platform	Authorized by DAC to perform certain actions on behalf of DAC
WebID provider	Digita	Provide WebID and store in profile document, authentication through WebID
Attestation provider	Government institution	Verify authenticity and integrity of data

Value network analysis was used to model the use case on the ecosystem roles as proposed by Allee [2]. As shown in Figure 2, the earlier mentioned stakeholders are represented with squares while the roles are represented with ovals. Within the value network, different value flows can be identified each represented by an arrow. Some arrows are dotted, this indicates that there might be a possible value exchange but that the exchange currently not clear or verifiable since the Solid ecosystem is still in implementation phase. When there is a tangible exchange between roles, a solid arrow is used, while for an intangible exchange this is a dashed arrow. Within the remainder of this chapter, the value network will explained step-by-step.

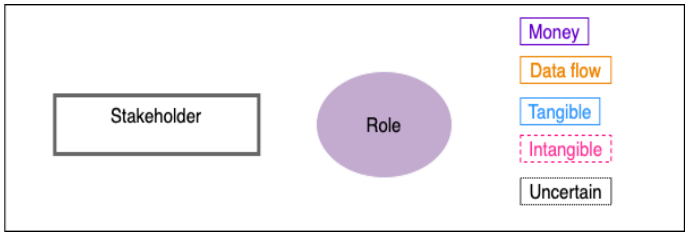

Figure 2: Explanation of used symbols

As mentioned in the introduction of the use case and shown in Figure 2, the applicant will provide data to its data pod. The applicant fulfills both the

role of data creator and data access controller. Karamel acts here as a data consumer by processing the provided applicant data to an interoperable format, for which it needs writing permissions, and will ask for access to the applicant's data as input for the matching algorithm. Here data is exchanged for a service.

The applicant can make use of the assessment services and career coaching provided through the HR platform. If this is the case then all data produced during these services will be stored in the applicant's pod, making also Karamel - assessment expert or career coach - a data creator.[14] Payment for these services happens in the form of credits. The applicant will be rewarded credits for providing data but can also purchase additional credit on the platform. The intangible asset is the trust that is established between both roles due to the use of Solid but also the way Karamel implements and will clearly communicate about Solid to its customers.

The matching algorithm will match applicants and recruiters. If this is the case, the recruiter will ask for permission to access the data on the pod of the applicant. Since no access is granted yet, the recruiter does not see any details of the applicant. On the other side, the applicant can inspect information about the company that is looking for new talent in order to make an informed decision about whether or not information will be shared. Here a trust relationship is established by enabling the applicant first verify if he or she actually trusts the recruiter enough to permit access. Additionally, access can be revoked by the applicant.

Karamel will charge recruiters and businesses a subscription fee for the visibility of their company on the platform. An additional fee for the matching service will only be charged if the applicant grants access to the recruiter. Again, trust is essential here, an applicant will always be able to revoke the access of a recruiter and have the right to demand to be forgotten.

Since Digita takes up three different roles within the ecosystem, there is a strong partnership with Karamel. Through this value exchange Karamel trusts Digita for keeping them up to date with everything Solid-related. This results in the intangible asset of additional knowledge that is exchanged outside of the contractual boundaries. Since the Solid technology is developing at a fast pace, remaining up to date with changes in the technical specifications is identified as a challenge and potential barrier for the Solid ecosystem.

In the business model of Karamel, applicants do not have to pay for their storage space, however, in the future they might want some additional upgrades that can be provided by a pod provider. This would result in an additional money stream from the DAC to the pod provider.

On the value network it is shown how the value exchange with an attestation service provider role could be implemented. During analysis of the use case, this appeared to be one of the challenges. Different roles within the ecosystem will need to be able to verify documents, for example the recruiter might want to verify if an obtained degree issued by an institution is authentic. However, how this will be implemented within this use case is still a work-in-progress.

[14] Simplification: this is not shown on the value network.

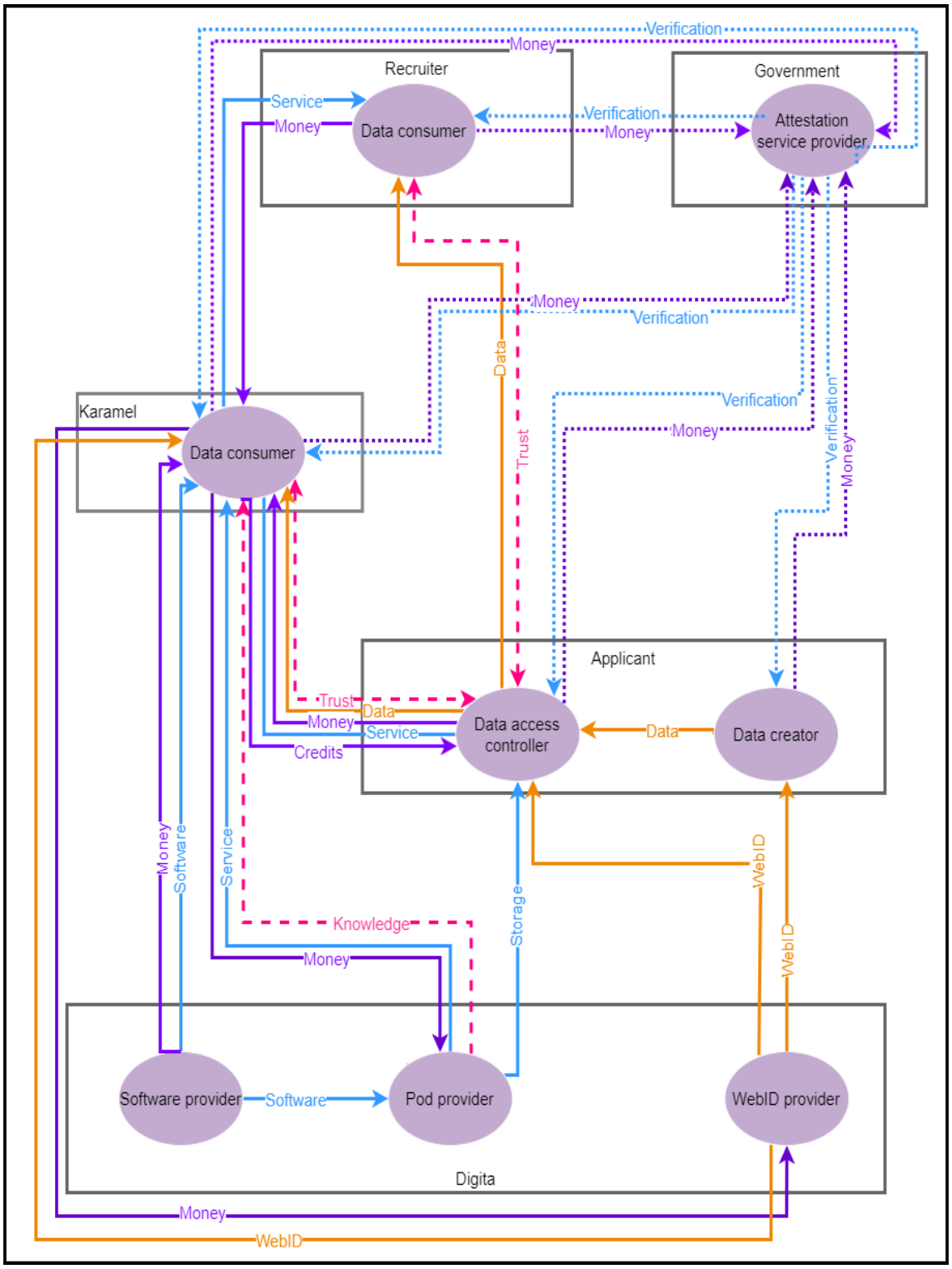

Figure 3: Value network configuration

As shown in figure 2, the stakeholders within the use case can be mapped on the proposed roles. The interviews with Karamel confirm that the value flows between the roles are an accurate representation of how they see the HR ecosystem. This value network is a first validation of the proposed set of roles.

7 Conclusions and future work

From first validation, our proposed value network captured the roles and value flows within the HR-domain use case for Solid. Further validation of these roles and value network analysis is required and the results will further evolve over time. More research into the potential benefits is required in order to assess the impact of these benefits on new and existing business models. The increasing popularity of Solid makes the research within this paper relevant for interested parties and future Solid-driven businesses. This paper is one of the first contributions to a more economic evaluation of a Solid ecosystem. However, a more extensive literature review is recommended, including literature on PIMS and other.

A number of key challenges and questions were identified during the network analysis and validation. Suggestions for future research are listed below.

- Will pod providers use different pricing models and offer different service levels?
- Will end users have one pod per platform or will pods be re-used across platforms? What are the consequences of both options?
- How can data be valuated? What is the impact of the availability of more and dynamically accessible data on value creation?
- Solid is still a work in progress, which means it requires a lot of time and effort for those making use of Solid technology to be compliant to the latest changes in specifications. What is the cost of keeping up to date with a changing specification in it's early stages?
- How to avoid that the technical challenge becomes a barrier to participate within the ecosystem?

Acknowledgement

This research is supported by SolidLab Vlaanderen (Flemish Government, EWI and RRF project VV023/10). We thank Karamel for providing insight and validation of the use case.

References

[1] A. Ahmadian, J. Jürjens, and D. Strüber. "Extending Model-Based Privacy Analysis for the Industrial Data Space by Exploiting Privacy Level Agreements". In: Association for Computing Machinery, 2018, pp. 1142–1149. DOI: https://doi.org/10.1145/3167132.3167256.

[2] V. Allee. "Value network analysis and value conversion of tangible and intangible assets". In: *Journal of Intellectual Capital* 9.1 (2008), pp. 5–24. DOI: https://doi.org/10.1108/14691930810845777.

[3] IDS Association. "New Business Models for Data Spaces Grounded in Data Sovereignty". In: (2021).

[4] A. D. Balmos et al. "ISOBlue Avena: A Framework for Agricultural Edge Computing and Data Sovereignty". In: *IEEE Micro* 42.1 (2022), pp. 78–86. DOI: https://doi.org/10.1109/MM.2021.3134830.

[5] T. Berners-Lee. *One small step for the web...* 2018. URL: https://medium.com/@timberners_lee/one-small-step-for-the-web-87f92217d085.

[6] R. Buyle et al. "Streamlining Governmental Processes by Putting Citizens in Control of Their Personal Data". In: 1135th ed. Springer Nature Switzerland, 2020, pp. 346–359.

[7] European Commission. *The European Blockchain Services Infrastructure*. 2022. URL: https://digital-strategy.ec.europa.eu/en/policies/european-blockchain-services-infrastructure.

[8] G. De Mulder et al. "PROV4ITDaTa: Transparent and direct transfer of personal data to personal stores". In: *Companion Proceedings of the Web Conference 2021*. Association for Computing Machinery, 2021, pp. 695–697. DOI: https://doi.org/10.1145/3442442.3458608.

[9] L. Debackere et al. "A Policy-Oriented Architecture for Enforcing Consent in Solid". In: (2022). DOI: https://doi.org/10.1145/3487553.3524630.

[10] Gaia-X European Association for Data Cloud AISBL. "Gaia-X Architecture Document". In: 2021.

[11] A. Immonen, M. Palviainen, and E. Ovaska. "Requirements of an Open Data Based Business Ecosystem". In: 2. 2014, pp. 88–103. DOI: https://doi.org/10.1109/ACCESS.2014.2302872.

[12] *Information technology — Cloud computing — Overview and vocabulary*. Standard. International Organization for Standardization and International Electrotechnical Commission, 2014.

[13] M. Jarke, O. Boris, and R. Sudha. "Data Sovereignty and Data Space Ecosystems". In: *Business Information Systems Engineering* 61.5 (2019), pp. 549–550. DOI: https://doi.org/10.1007/s12599-019-00614-2.

[14] M. Kang and V. Lemieux. "A Decentralized Identity-Based Blockchain Solution for Privacy-Preserving Licensing of Individual-Controlled Data to Prevent Unauthorized Secondary Data Usage". In: *Ledger* 6 (2021). DOI: https://doi.org/10.5195/ledger.2021.239.

[15] M. Lnenicka and J. Komarkova. "Big and open linked data (BOLD) analytics ecosystem: Theoretical background and essential elements". In: *Government Information Quarterly* 36.1 (2019), pp. 129–144. DOI: https://doi.org/10.1016/j.giq.2018.11.004.

[16] B. Maier and N. Pohlmann. "Gaia-X secure and trustworthy ecosystems with Self Sovereign Identity". In: 2022.

[17] J. Möller and M. Rimscha. "(De)Centralization of the Global Informational Ecosystem". In: *Media and Communication* 5.3 (2017), pp. 37–48. DOI: https://doi.org/10.17645/mac.v5i3.1067.

[18] A. Munoz-Arcentales et al. "An Architecture for Providing Data Usage and Access Control in Data Sharing Ecosystems". In: *Procedia Computer Science* 160 (2019), pp. 590–597. DOI: https://doi.org/10.1016/j.procs.2019.11.042.

[19] A. Munoz-Arcentales et al. "An Architecture for Providing Data Usage and Access Control in Data Sharing Ecosystems". In: *Procedia Computer Science* 160 (2019), pp. 590–597. DOI: https://doi.org/10.1016/j.procs.2019.11.042.

[20] *MyData Declaration*. Version 1. 2017.

[21] M. Oliveira et al. *Towards a Meta-model for Data Ecosystems*. 2018. DOI: https://doi.org/10.1145/3209281.3209333.

[22] *Origin of Solid*. URL: https://solidproject.org/origin.

[23] B Otto and M. Jarke. "Designing a multi-sided data platform: findings from the International Data Spaces case". In: *Electron Markets* 29.4 (2019), pp. 561–580. DOI: https://doi.org/10.1007/s12525-019-00362-x.

[24] *Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on European data governance (Data Governance Act)*. 2020. URL: https://eur-lex.europa.eu.

[25] *Reference Architecture Model*. RAM. International Data Spaces Association, 2019.

[26] "Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation)". In: (2016).

[27] A. Sambra et al. *Solid : A Platform for Decentralized Social Applications Based on Linked Data*. 2016.

[28] Y. Shanmugarasa et al. *Towards Automated Data Sharing in Personal Data Stores*. 2021. DOI: https://doi.org/10.1109/PerComWorkshops51409.2021.9431001.

[29] *Solid protocol*. URL: https://solidproject.org/TR.

[30] *Solid Specification*. URL: https://github.com/solid/solid-spec/.

[31] *Understanding MyData Operators*. Positioning Paper. MyData Global, 2022.

[32] R. Verborgh. *Re-decentralizing the Web, for good this time*. Linking the World's Information: A Collection of Essays on the Work of Sir Tim Berners-Lee. ACM, 2022. URL: https://ruben.verborgh.org/articles/redecentralizing-the-web/.

[33] S. Verbrugge et al. "Towards a personal data vault society: an interplay between technological and business perspectives". In: IEEE, 2021, pp. 1–6. DOI: 10.1109/FITCE53297.2021.9588540.