

Data Silos and Interoperability: The Primary Legal Issue in Digital Ecosystems for Data Spaces

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Article Info	ABSTRACT
Article History: Received Apr 08, 2026 Revised May 10, 2026 Accepted Jun 09, 2026 Keywords: Artificial Intelligence (AI), Digital Ecosystems, Central Legal Challenge, Interoperability architecture, DS2 implementations	The modern healthcare system relies on interconnectivity between providers, technology improvements & other players to create complex ecosystems. Ecosystems are dependent on several person-centered models & the need for a high level of interchange & integration for successful care delivery. Leveraging big data to create value relies on data interoperability - or the ability to exchange & use standards-based data across corporate borders. Interoperability is the key to data-driven value creation in the digital economy in terms of administration & oversight, as explored through the lens of the new US health data legislation. The Data Sharing for Data Spaces Interoperability Architecture outlined in this paper is designed to allow for the exchange of data between participants in multiple data spaces by way of different services & platforms. By utilizing common standards by way of collaboratively agreed upon plans, and augmenting federation & participant services, the Data Sharing for Data Spaces Interoperability Architecture builds upon existing levels of trust among data space participants. The Data Sharing for Data Spaces Interoperability Architecture is composed of four components: deployment; data pipeline standards; subsystems for sharing data between data spaces; and an assortment of applications to support those who use them to enter & retrieve data. The Data Sharing for Data Spaces Interoperability Architecture has been tested using v2.x versions of the Data Sharing for Data Spaces reference model 2 and has been compared against multiple other interoperability approaches.
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1. INTRODUCTION

States use interoperability as a tool to reorganize platform marketplaces in response to growing platform concentration and market dominance. In general, interoperability refers to the ability of various technical systems to work together. Interoperability is necessary whether using an ATM across global borders, calling a friend on another phone network, or traveling across the nation on tracks that are owned and operated by various businesses. The U.S. rules that aim to

promote data interoperability in healthcare markets are examined in this opinion [1]. Through this case study, I show how U.S. policymakers aim to use standardization and data accessibility to align healthcare marketplaces with the creation of public value in addition to rearranging the power dynamics between influential market players [2]. I contend that information interoperability is an inadequate instrument for organizing and guaranteeing the creation of public value from data.

In the digital economy, data integration is a necessary infrastructure prerequisite for value creation. Platforms provide value on top of the knowledge flows they shape and mediate by giving outsiders, or "contributors," access to standardized, managed data streams. The main means of achieving this data interchange are "application program interfaces," or APIs. Businesses like Google [3], Facebook, and Amazon provide third parties with access to a regulated dataset about their customers through APIs, allowing those third parties to develop services and products that eventually increase the platform's worth and economic domination. Data that is collected and organized by one platform can be automatically moved to another system for secondary and tertiary value generation processes thanks to APIs, which facilitate data exchange at speed and scale. In this way, without strong, ubiquitous data exchange, there can be no digital business.

Platforms have a great deal of control over how data is exchanged and organized, and consequently on the types of value that may be generated from this information. Platforms such as Facebook, Twitter, Google, and Amazon have strict control over how their APIs are designed and implemented, which benefits the platform firm and makes third-party counterparts dependent on that platform. Platforms have the authority to unilaterally alter what data is exchanged and how when they determine that doing so does not yield enough value for the business. Reddit [4], for example, decided to significantly raise API access fees in 2023 after determining that it was not making enough money from the goods and services provided by third-party supplementary services. Reddit essentially shut down an ecosystem of cherished secondary goods overnight by making access to its APIs so costly. Similar discontent among clubs and users resulted from Twitter's decision to terminate unlimited access to its APIs. Platforms have unilateral control over third parties' access to and capacity to generate revenue from platform information through APIs.

Platforms can use "adversarial interoperable" to challenge and reconfigure market share, even when they have substantial market dominance through their control over APIs. By extracting MySpace's user data and putting it into Facebook, Cory Doctorow shows how Facebook was able to challenge MySpace's market dominance and make it easier for consumers to remove MySpace and switch to a new social media site. Big Tech platforms establish strictly regulated "data enclave [5]" because they are concerned about the possibility of disruption through adversarial connectivity. Businesses might "lock in" potential rivals by controlling these data sanctuaries. This platform economy dynamic, which Katarina Pistor refers to as "the end of markets," occurs when some Big Tech companies hold data sanctuaries in a way that prevents significant competition.

States can impose interoperability of data to dismantle these data enclaves and reorganize platform markets [6], just as platforms can use interoperability to establish secondary marketplaces in ways that provide value for the platform itself. This is an example of platform governance carried out at the infrastructure or protological level. According to Morton et al., compatibility is a "supertool" of platform management that permits "light touch" regulation, which promotes competition without explicitly mandating modalities of worth production.

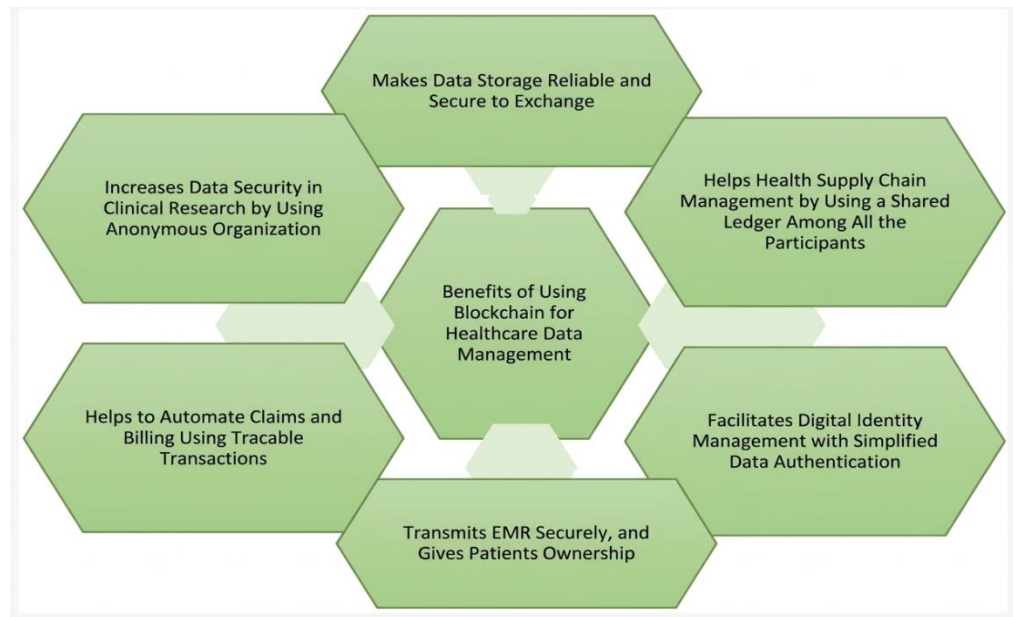


Figure 1. Blockchain for Managing Medical Information

Blockchain offers a great potential to combine medical information from many sources, as seen in Figure 1 [7], as was covered in the research mentioned above. Furthermore, the aforementioned researchers have identified high safety and confidentiality as characteristics of their suggested systems. As a result, blockchain offers a great chance of improving medical systems' security, honesty, and confidentiality. Healthcare systems can benefit from a variety of blockchain features, including immutability, openness, and autonomous distributed data storage. Accessing the patient's health records presents several difficulties. Different procedures are used by authorities and healthcare providers to allow access to a particular medical file. The majority of the blockchain-based healthcare solutions under examination in this proposal are built on a distributed database database on a peer-to-peer (P2P) network made up of blocks that are arranged sequentially. These are dispersed, decentralized systems that rely only on self for regulation rather than outside actors. Blockchain-based systems have no boundaries, such as a singular point of failure, because of globalization. Data is kept in a register that is accessible by every blockchain node.

2. LITERATURE REVIEW

The article offers an analysis of the political economy concept of interoperability, challenging the techno-optimistic stories that frequently underlie this imagination of connectivity. It starts by tracing the evolution of the conceptual relationship between data silos and standardization, where the latter poses a barrier to the former's implementation. Second [8], it expands what we call interoperable capitalism by placing notions of compatibility inside the framework of platform capitalism, emphasizing that existing powerful platform corporations are well-known advocates of interoperable discussions. Finally, it demonstrates how these platform businesses frequently create "digital silos" that allow them to further solidify their dominance by promoting openness through standard desalinization. We end by making the case that political economic issues should continue to be central to research on the techno-political scenarios and interoperable networks.

In the context of ensuring compliance with the General Data Protection Regulation (GDPR), this article offers best practices and lessons gained for an interdisciplinary research effort combining software development and legal [9]. It offers useful resources to assist legal scholars in developing significant multidisciplinary collaboration with software engineering researchers by examining the difficulties and achievements faced in such partnerships. In particular, this article provides examples of ways to bridge the gap between software engineering, which may ignore important regulatory settings, and legal discipline and legal requirements, which frequently lack a sophisticated understanding of technical reality. In particular, the paper addresses linguistic gaps and different methodology assumptions, as well as early-stage research obstacles in finding shared theoretical and practical ground across disciplines.

This article explores these ideas' meanings [10], importance, and real-world applications, emphasizing their vital role in promoting creativity, productivity, and teamwork. Data standardization facilitates smooth data integration and interchange by creating standardized formats, frameworks, and protocols. Compatibility, on the other hand, facilitates effective communication and cooperation between various software systems and applications, dismantling information silos and creating a more interconnected digital environment. Both ideas are essential to realizing data's full potential, which enables businesses to make well-informed decisions, optimize workflows, and bring about revolutionary change in a variety of sectors.

The integration of the FAIR values—Findability [11], Openness, Integration, and Reusability—in CRIS systems is examined in this paper, with a focus on how they enable Open Science. We examine how FAIR concepts are applied in the national SK CRIS and the German CRIS systems using examples from Slovakia and Germany. In order to advance Open Science and guarantee the successful application of FAIR standards at the national level, the article also discusses the crucial significance of data source integration, the adoption of Persistent Identifiers (PIDs), and the implementation of strong data administration practices. This analysis emphasizes how important libraries and CRIS systems are to improving research data access and compatibility, promoting global collaboration, and guaranteeing the long-term viability of scholarly outputs.

Two additions are made in the paper [12]. We start by creating a conceptual structure that views digital ecosystems as lattices of complementarities connecting infrastructure, information, creators, and consumers. The empirical indicators of super modular interactions are scaling laws. Interoperability turns into a lattice reorganization tool that preserves advantages that promote safety, quality, and creativity while selectively undermining those that strengthen market dominance. Second, we combine this economic explanation with a comparison of societal and legal solutions to interconnection. The EU Digital Markets Act and Data Act, telecom connectivity, Microsoft antitrust actions, digital health regulations in the US and EU, and upcoming sector-specific AI and blockchain regulations are a few examples. This contrast makes clear how network complementary features are distributed across layers via horizontal and vertical compatibility responsibilities and how ante and ex post technologies differ in their capacity to transform online ecosystems.

3. METHODS AND MATERIALS

3.1 Architecture for Data Space Interoperability

The foundation of the Data Space Interoperability Architecture (DSIA) described in this work is the existence of a data space mediator that both hosts the network of services required for participants to exchange data among data spaces and offers these services [13]. The goal is to

establish an environment in which data spaces and its members can collaborate and reach consensus on data sharing with different data spaces. Through expandable supporting features, the ecosystem and methodology also assist users in handling the intricacies of data exchanges. System-level architecture is introduced in the present chapter.

3.1.1 The Fundamentals of Data Space Interchange Design

The inter-data space compatibility approach described in this paper is based on the following fundamental ideas:

✚ The establishment of trust between the individuals sharing the data must be predicated on their reliability as users of their respective data areas. Strong and soft trust are complimentary components of trust [14]. Hard trust necessitates the provision of participants' identities and credentials in their data places and cooperation with those data spaces, as well as sufficient interoperability solution trustworthiness for participating data space and their subjects. In order to verify the existence of contracts, accords must exist between data spaces and the interoperable solution provider or providers. Soft trust, which is founded on risk assessment and encourages users to "accept risk based upon favorable expectations of the intents or behavior of another," is an addition to hard trust".

✚ In inter-data area use cases, data autonomy, which is specified in data spaces, must also be honoured [15]. In other words, data sharing takes place directly between individuals, and information transfers are based on the data share agreement between members trusting potential middlemen in the processing and transfer of data, and adhering to legal and regulatory requirements.

It is necessary to facilitate the interoperability system's use with various data space devices. There are several ways to implement information spaces, and different non-compatible systems will result from the use scenarios, technology used, and business objectives. In below figure 2 architecture's (DSIA) functional perspectives are illustrated.

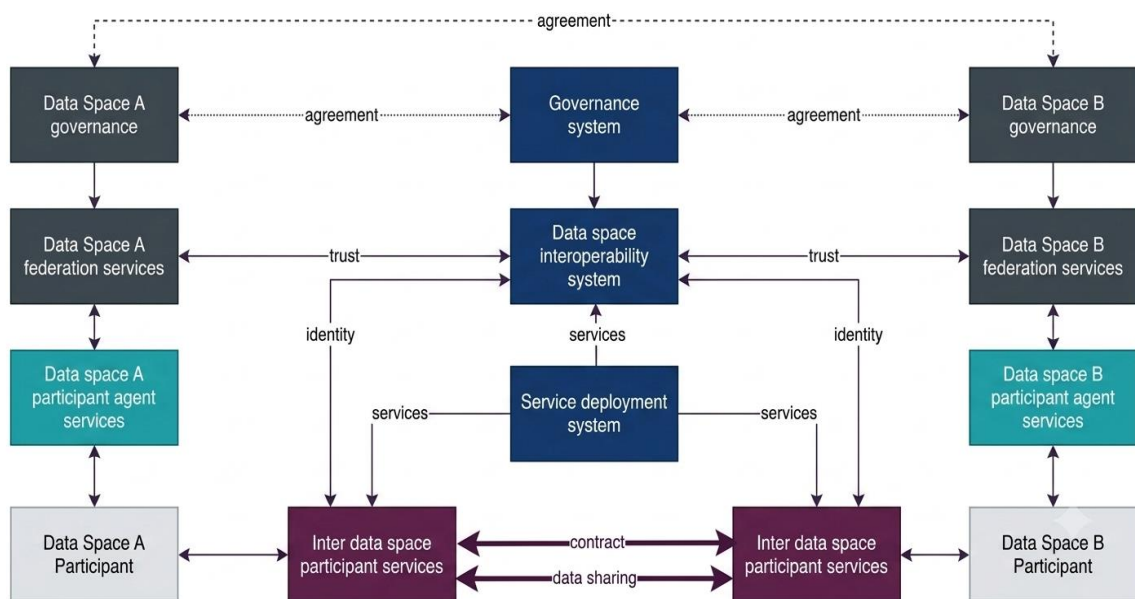


Figure 2. An Overview of the data Space Interoperability Architecture's (DSIA) Functional Perspectives

As a result [16], fundamental services like identity management, publication and finding, sharing information contract administration, and real data transfers have parallel implementations in data spaces. One benefit is that as the number of cooperating data spaces increases, organization and management become less complex.

3.1.2 A Functional Viewpoint

The data space interoperable approach's functional viewpoint is to establish services and systems (green and blue boxes) across data spaces that enable contract-based data sharing between data spaces [17]. Three primary subsystems comprise the approach (yellow and brown rectangles). The management system is in charge of establishing a trustworthy and lawful operating environment for governing authorities, information spaces, and their participants. Implementing the collaboration contracts that allow inter-data space data exchange is the goal rather than developing a new governance system.

The interoperability system of data spaces provides support for trust, identity and access management (IAM), data product visibility, participant information visibility and the operation of other services related to cross-data space interoperability (e.g., data sharing). The system also provides participant inter-data space services through the provision of common solutions for transferring and sharing data, negotiating and executing contracts, and transferring data.

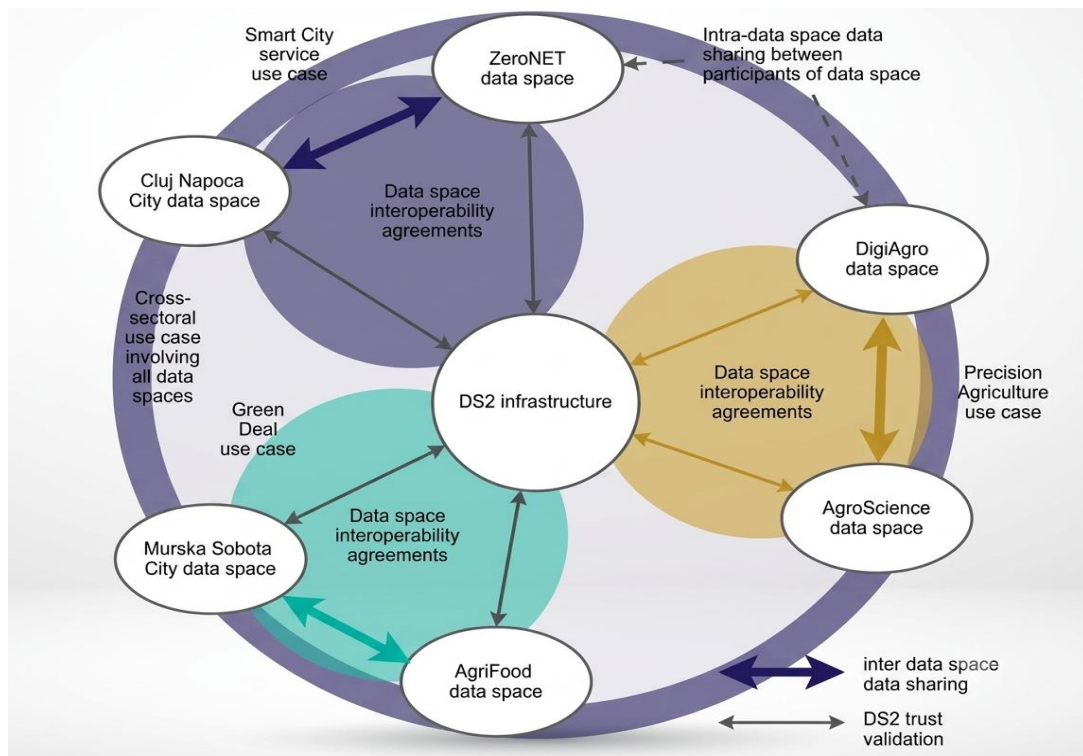


Figure 3. Overall Architecture of Use Cases

These services eliminate most of the challenges associated with possible technical disparities between data spaces. In addition, participant services can provide the full life cycle of contract-based data transactions, to include risk analysis, search support tools, data transformation tools, applications of data, etc. The overall architecture of DS2 use cases is shown in Figure 3 [18]. The DS2 infrastructure services (IDM, CAT, DRM, IDT) and the participant services (IDT) supplied by the DS2 operator provide the means for implementing interoperability of data spaces. Agreement between all the data spaces in all of the piloted data spaces and the DS2 operator to utilize DS2 as an interoperability solution has been established.

4. IMPLEMENTATION AND EXPERIMENTAL RESULTS

4.1 In use scenarios, DS2

There are trials happening with DS2 across multiple data spaces. The DS2 technology is capable of making 6 data spaces interoperable. However, all 6 data spaces are still in the early stages of ramping up. That means that the technical solutions have been defined and implemented, but the governance aspects are mostly manual (not fully defined) processes at this point [19]. DS2 will operate in three physical locations; the data spaces in Greece, Slovenia, and Romania will each be working in a separate industry sector and will have between 3 and 20 participants from various industries during the trial. The data spaces will provide services in the area of precision agriculture and food production, green deals, or smart city services. The key characteristics of the data spaces are included in Table 1.

Table 1. Use Case Data Spaces

Name	Description	Location	Technology
SmartCity (Cluj Napoca)	A data repository that supports multiple uses within a municipality, ranging from government officials to citizens and academics, will ensure that there is an interdisciplinary approach to data sharing for multiple uses of the collected data. The data repo or "data space" will focus on supporting applications for practitioners by looking for ways to analyze emissions and pollutants coming from a municipality.	Romania	IDSA (DSIL connector)
ZeroNET	The goal is to create a common space that allows for easy access to share information on how to use data, including IoT-enabled devices, satellite-based data, agricultural data, and other environmental data.	Romania	IDSA (DSIL connector)
Agrifood data space	By sharing data about environmental assessments, municipalities can increase citizens', small-medium enterprises, industries', and governments' engagement in becoming aware of their local air quality and create more sustainable ways of conducting business.	Slovenia	ITC platform data space
SmartCity (Murska Sobota)	Additionally, municipalities will create a space for farmers to integrate and share their crop data with other environmental data in order to create a recommendation for farmers and the food industry.	Slovenia	IDSA (DSIL connector)
DigiAgro	Lastly, municipalities will create a space for satellite and detailed weather forecasts to support data analysts and agronomists who work in precision agriculture.	Greece	IDSA (TrueConnector)

4.2 Use Case Experiences

Setting up collaboration among data spaces and creating participation services are the main distinctions in data sharing from the user's point of view, since the DS2 approach makes use of dedicated participant services [20].

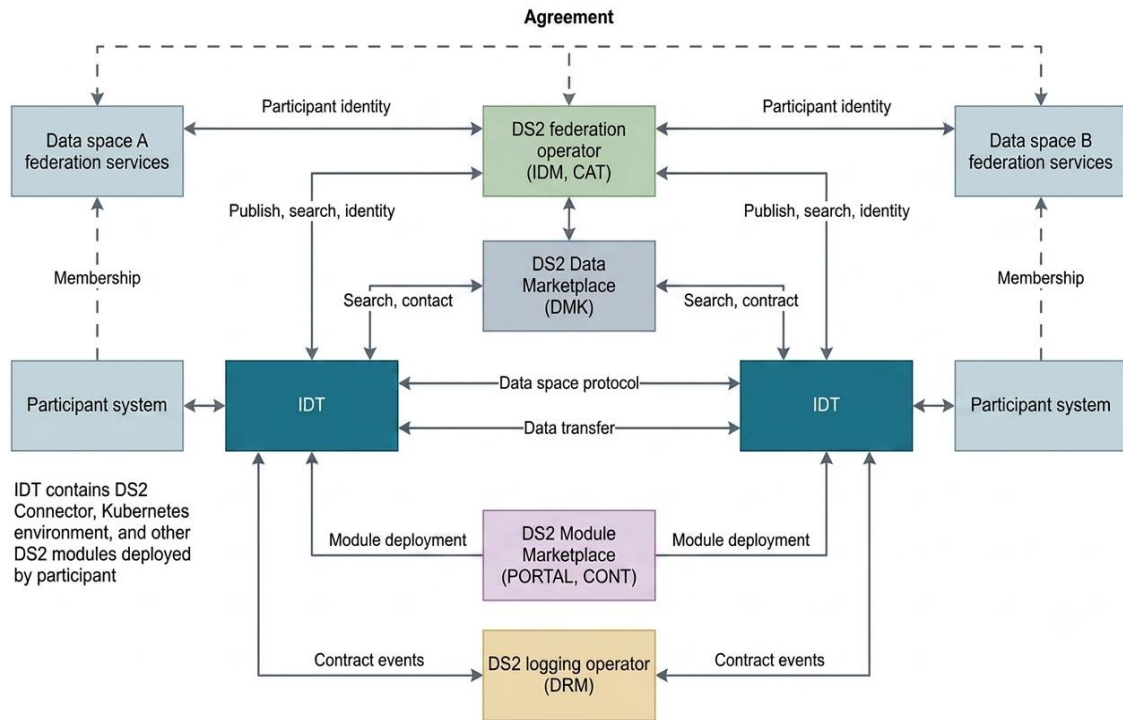


Figure 4. DS2 implementation of DSIA

The procedures that take place inside a data space are quite similar to the real data exchange processes.

4.3 Setting Up IDT for Data Space Participants and Joining DS2

Through an online service [21], participants sign up for DS2 [22]. The DS2 Operator verifies that they are users in their data space, which must have previously been connected to the DS2 Operator service, after they enter basic data. Identities and authorization to upload the IDT module from the DS2 operator module market are provided to participants. Although it naturally relies on the participant system, the installation of IDT [23], which comprises the DS2 connection to the participation system, is a simple and simple procedure in our tests. Although IDT has its own user interface, connecting participating system services to it via the DS2 connector is similar to connecting to any information space.

4.4 Identity Administration

Participant IDs, DS2 elements, and cooperation agreements are issued and verified by the DS2 Operator. In the case of respondents [24], it additionally confirms that they have an active membership from the home information space. Depending on the kind of data space, there are three choices. IDM must have a platform set up for identity validation in data spaces like ZeroNeT and Agrifood that are dedicated to exchanging open data. Verifying identity may be restricted to data space members in cases when the data space is intended for the exchange of private business-to-business information [25]. Access to the service may be provided as part of a DS2-data space agreement if the data space allows identity confirmation for known intermediates. IDM must, of course, facilitate communication over such an interface. In other situations, the DS2 operator can

deploy its data space connection and use it for identity confirmation after joining the data space as a participant. This option is used in VTT DIL data spaces based on IDSA RAM v3 design [26]. It should be noted that the DS2 Operator's connection is only used for identifying and not for actual data transfer, even though this option can be utilized in any data space.

5. CONCLUSION

I started this article by stating that interoperability as a subject of discourse is prominently featured not just in the context of security, migration and border control but also throughout the disciplines of finance, healthcare and telecommunications. The common threads that bind these discourses together are two-fold: in the first instance, the notion that interoperability is about dismantling the boundaries that exist between disparate data 'silos' and secondly, the notion that 'interoperability' is essentially beneficial for the users of digital platforms.

Both DSIA and the implementation of its Digital Service Networks (DS2) rely heavily upon loosely coupled federation services developed utilizing suggested technology from the Digital Services Strategy Council (DSSC). The DSIA has a very low dependency on any technologies adopted by participant data spaces, thus allowing for a greater variety of data space types than usual; however, this means the provision of additional participant services and service intermediaries to facilitate participation, while eliminating the potential complexity and cost of mandating that each data space utilize uniform technical solutions when implementing DS2 participant systems. Implementation and delivery of DS2 to participant systems is accomplished using the "Interoperable Data Toolkit" (IDT) module(s) that contain a Kubernetes based container-run-time environment and dedicated Eclipse-based DS2 participant services and provide the means to install additional containerized participant services/applications from both the DS2 portal and marketplace.

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