Interconnect Semantic Interoperability Framework in support of CERF for energy in data exchange and aggregation in semantic interoperable manner towards alignment with European Energy Data Spaces

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Semantic interoperability is a main enabler for realizing data spaces. When it comes to energy data spaces, they need to span different domains – from grids, over IoT (smart homes and buildings) to mobility and more. The European Commission is proposing a Common European Reference Framework (CERF)[1] as a mean for establishing interoperability at scale as needed by the European energy system. The H2020 project InterConnect[2] was tasked with delivering the first blueprint and the first implementation of the CERF for the energy domain. The goal was to utilize InterConnect Semantic Interoperability Framework (SIF) and SAREF ontology to establish a pool of interoperable services and data sources which can be used by service and application developers to bring forth energy saving applications. We also claim that this work can support the upcoming European Data Space on Energy to fulfill its objectives.

1 INTRODUCTION

This paper offers a birds-eye-view over the first version of the Common European Reference Framework (CERF) and scopes how the Semantic Interoperability Framework of H2020 project InterConnect – the SIF – became a structural part of the solution. The InterConnect project demonstrated how the CERF[3] can act as a semantically interoperable knowledge/data and service pool which can be used by developers of customer facing energy management applications. It was the gear for innovative solutions capable of addressing immediate and forecasted needs of grid operators while ensuring proper end user engagement. This paper scopes how the regular flow of the SIF is used with a CERF key exploitable result, the Interoperable Recommender, and how it shares interoperable recommendations that abide by a graph pattern semantic representation.

Given the importance of data to deliver better services, increase efficiency and implement new solutions in many sectors, this paper also aims to pave the way to connect, through the InterConnect SIF, the CERF with the upcoming European Data Space on Energy[4], as well as to support the connection between European Data Spaces, and provide recommendations for the upcoming revision of the CERF.

2 BACKGROUND

CERF: Common European Reference Framework

The CERF for energy enables EU member states to be better prepared for energy crises by empowering consumers to actively participate in solving the energy challenges thus improving grid stability in both

[1] https://digital-strategy.ec.europa.eu/en/news/delivering-our-promise-deploy-common-european-reference-framework-energy-saving-applications
[2] https://interconnectproject.eu/
[3] https://digital-strategy.ec.europa.eu/en/news/delivering-our-promise-deploy-common-european-reference-framework-energy-saving-applications
[4] https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/digital-2024-cloud-ai-06-enerspace

proactive and reactive manners. Building on the outcomes of a comprehensive landscape analysis led by ETRA [1] and the outcomes of the work of Expert Group 3 of the Smart Grids Task Force (SGTF) [2], the InterConnect project delivered the **first-generation blueprint of the CERF** in May 2023 [3]. The overarching goal of CERF demonstrates that EU is ready to capitalize on innovative technologies to mitigate the impact of energy crisis. End consumers are viewed as critical stakeholders in achieving this objective. The key technological advancement required to support this mission is the **achievement of inter and intra domain data interoperability on all levels** (from syntactic over semantic to business/policy levels).

CERF presents as a digital ecosystem where data driven services and data sources can be chained for each instance of a CERF. This allows creation of highly customized and specialized customer facing apps which tap into the same semantically interoperable pool of data sources and services.

SIF: Semantic Interoperability Framework

Cross-domain semantic interoperability is the transversal and core innovation of the H2020 InterConnect project, which is embodied through the Semantic Interoperability Framework (SIF)[5]. The main features of the SIF are:

- The SIF enables cross-domain semantic interoperability to be established in a distributed manner with existing digital platforms – no need for centrally hosted facilitating platform.
- Interoperability originates at stakeholder's end, and it does not disrupt existing practices – this is achieved with the Service Adapters.
- Semantic interoperability within the InterConnect project is based on SAREF ontology. However, the developed enablers are ontology agnostic.
- The achieved semantic interoperability enhances security and privacy protection measures by securing communication interfaces and providing integrators with improve their best practices as well as to customize knowledge flows through selecting how and with whom to share data.
- The SIF can be deployed on all system levels from devices over the edge to the cloud.
- Finally, semantic interoperability provides federated knowledge spaces, with answers to complex stakeholder's queries. This is key for establishing intra and inter-domain data spaces.

The SIF departs from a proven concept of distributed connectors or gateways, i.e., Service Adapters, but considers SAREF [4] to bring transversal meaning to data in favor of considering a fixed data model as the interoperability agreement between stakeholders. Becoming semantically interoperable goes beyond the ability of systems to exchange information with correct syntax (syntactic interoperability) to the automatic, correct interpretation of the meaning of information. The SIF unlocks a semantically interoperable interface that allows stakeholders' services to share and query knowledge represented according to SAREF instead of using syntactic interfaces with strict integration and querying options limited by the chosen data model. Thus, any question that fits the knowledge can be used to interact with a component. The SIF bundles a set of tools to enable interoperability up to the semantic level, namely:

1. service adapters comprise a generic component (Generic Adapter – GA) with unified semantically interoperable interface and a service specific component (Service Specific Adapter – SSA) where mapping of existing/legacy communication interfaces (protocols and data models) onto the SAREF ontology and knowledge dissemination protocol is performed.
2. the distributed Semantic interoperability layer, handling knowledge exchange and querying between adapters. It is called Knowledge Engine (KE).

[5] https://gitlab.inesctec.pt/groups/interconnect-public/-/wikis/home#interconnect-interoperability-framework

3. the Service Store providing a catalog of interoperable services, knowledge explorer and certification of services; the peer-to-peer marketplace for the instantiation of services devoted to fully distributed applications.
4. a set of tools to ensure security, privacy, and governance transversal capabilities.

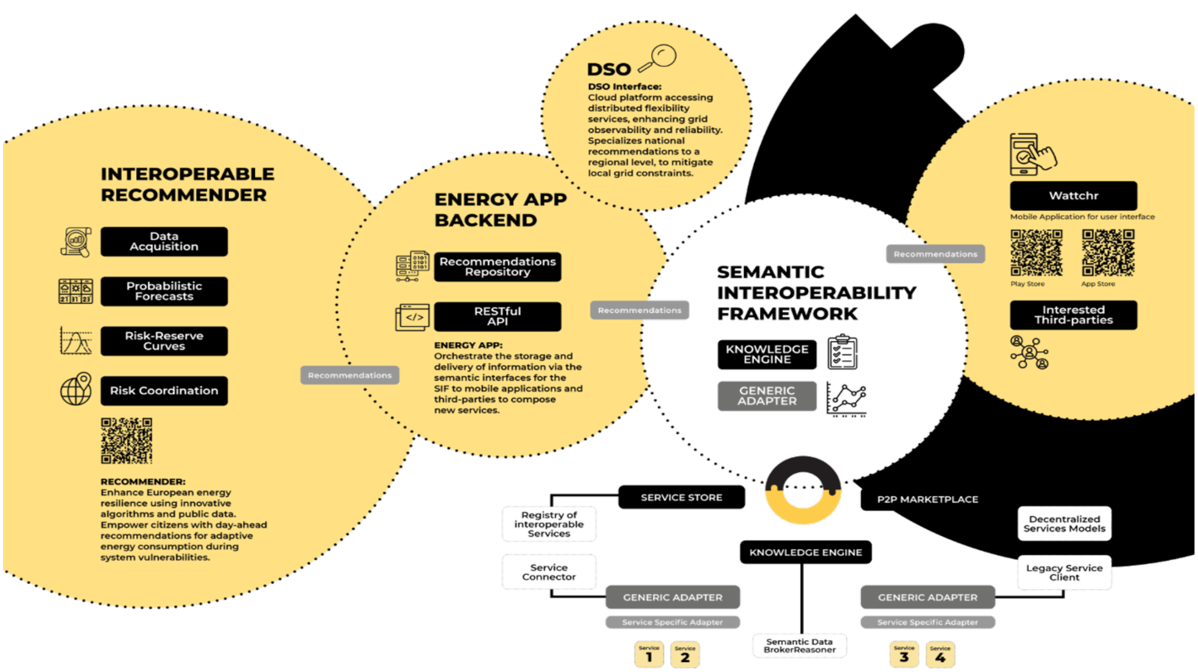
European Data Space on Energy

European Data Spaces is considered in the European Data Strategy by the EC as main enablers to break data silos and support data exchange in Europe on a cross border and cross sector basis. The European Data Space for Energy addresses challenges in the energy sector where interoperability plays a crucial role. Many of the objectives of this new data space are relate to this paper and the SIF (and the connection with the CERF) can support the data space on achieving them:

- Access to data to develop innovative energy services.
- Achieve interoperability with other sector data spaces, enabling actors from various sectors to participate in the energy market and deliver services.
- Provide interoperability mechanisms to achieve interoperability of data, systems and services between the key players of the energy value chain, considering semantic standards as SAREF.
- Build on actions from Horizon Europe programme and existing national or regional efforts.

3 PROPOSED SOLUTION: SIF ENABLED CERF

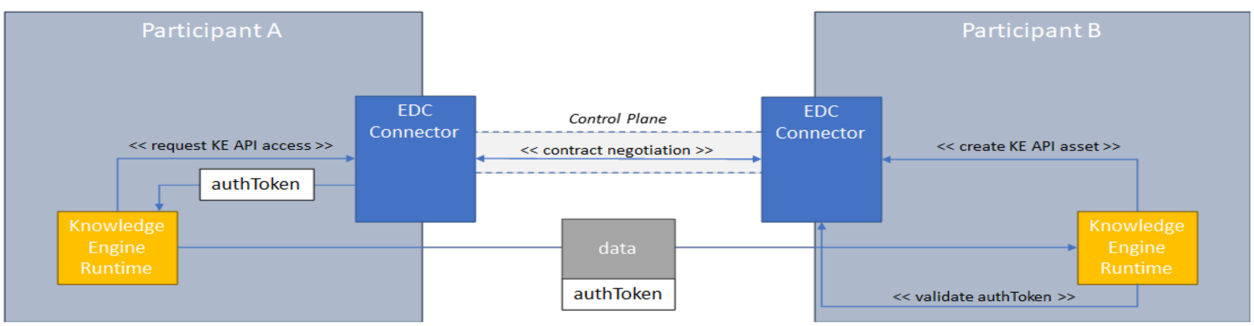
The core rationale of the SIF splits information metadata into knowledge interactions, representing data querying options, namely: Asking and Answering, Posting and Reacting to data. Interaction pairs paved the way for InterConnnect use cases demonstrated in 7 EU Member states and across their borders. For the CERF, the SIF vocabulary hub of knowledge interactions was extended with an ASK-ANSWER pair to deliver national wide recommendations on how to steer energy consumption to increase grid resilience. Geared by a pipeline based on open data, primarily obtained from the ENTSO-E transparency platform, the Interoperable Recommender system uses the SIF to distribute recommendations along with their generation metadata context.



The SIF acts as the key enabler within the CERF, providing a solid basis for implementing new and enhancing existing applications that face end-users and provide them with actionable recommendations. The SIF allows third parties to access the recommendations with the full semantic context of their representation but also allows for specializations to be included back in the knowledge base of the recommender system. This architecture allows services to be easily composable to produce new processing pipelines and added value.

Specifically, the Knowledge Engine (KE) improves semantic interoperability by using AI technologies like reasoning and ontologies to orchestrate the exchange of scattered knowledge between parties or components. It assumes trust between these actors within a knowledge network, but this assumption is often not true for real world use cases. Seeking intrinsic trust integration experiments between the KE's advanced semantic capabilities and the trust enabled by data space connectors. The figure scopes the integration where participant A wants to send data to participant B and both parties use an Eclipse Dataspace Connector (EDC) and a Knowledge Engine Runtime (KER). In our working proof-of-concept[6] both participants expose their Knowledge Engine API as an asset in the EDC catalogue which allows the other party to request access to this KE API. After ensuring the needed trust level by negotiating a contract, they receive an authentication token that is used when sending data. After a KER receives data with such an authentication token, it will ask the EDC connector to validate it and the KER accepts or rejects the data accordingly.

The proof-of-concept can evolve, namely by merging the discovery mechanisms and gearing new participants to join existing data sharing networks. A future version it would be possible to replace KE's Knowledge Directory with the Federated Catalogue when running in "data space"-mode. Additionally, the data space concept of a Vocabulary Hub[7], which stores the relevant vocabularies/ontologies within a data space, fits the ontology-based functionality of the KE, allowing the KE to retrieve the relevant domain knowledge within a data space from the Vocabulary Hub and use it for validation and reasoning purposes. Moreover, the current EDC asset and policy management would be capable to bind to knowledge interactions as the data asset and move to the data space protocol message stack.



The first-generation CERF blueprint included the definition of the data sources, the targeted end-users, the recommendations for action, the intervention and implementation strategies, and the approach to field piloting to be conducted as part of the InterConnect project. A three-stage process was followed for the testing of the first CERF blueprint consisting of (a) the delivery of a Minimum Viable Product (MVP) (b) the deployment of large-scale demonstrations, and (c) the launching of an open call that requested the adoption and demonstration of CERF by SMEs in a 6 months' time.

To this end, the InterConnect project reused its key exploitable results: the SIF and interoperable DSO interface (DSOi) to realizing the CERF.

Finally, this work can contribute to the European Data Space for Energy as follows:

[6] The proof-of-concept is available here: https://github.com/TNO/knowledge-engine/tree/add-authorization-header/examples/edc-example

[7] https://www.semantic-treehouse.nl/vocabulary-hub

- The SIF enabled CERF provides a semantically interoperable pool of data sources (public and private ones) and data access/processing services (interoperability originating at the data sources) used through unified interface (SAREF compliant).
- The SIF addressed cross-domain interoperability challenges from the grid and IoT (smart homes/buildings) domains and with use cases focused on electric mobility. The goal is to align the SIF (and the CERF) with data space connectors and enable semantical interoperability.
- The SIF provides semantic interoperability on all system levels (from device, over edge, fog to private and public clouds). During the project, 25 different digital platforms have achieved semantic interoperability and 63 different services have reached semantic interoperability. Different white goods manufacturers achieved semantic interoperability by relying on the SIF enablers. This was one of the primary motivators for the Code of Conduct version 1[5].
- The SIF and SIF based CERF utilizes SAREF ontology for achieving semantic interoperability.
- The SIF is a key exploitable result of the InterConnect project. The CERF version 1 is built by the InterConnect project leveraging its key exploitable results like the SIF, DSO interface and interoperable recommender for energy consumption.

4 SUSTAINABILITY AND SCALABILITY

Based on the success of CERF solution in more than 10 EU Member States, the InterConnect project recommends **adopting standardized data exchange protocols through CERF.** This adoption significantly streamlines the development process, leading to faster end user application delivery. Moreover, the application's scalability within the different countries relies on its ability to adapt to local data formats and exchange methods while adhering to standardized solutions. This flexibility is crucial for expanding the applications' reach to heterogeneous audiences and accommodating unique data management and infrastructure needs across different regions.

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