A SAREF Extension for Semantic Interoperability in the Industry and Manufacturing Domain

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This chapter builds on the success achieved in the past years with SAREF, a reference ontology for IoT created in close interaction with the industry during a study requested by the European Commission in 2015. SAREF is published as an ETSI Technical Specification series that also includes dedicated extensions to specific domains. A proof-of-concept solution based on SAREF and implemented on existing commercial products has been demonstrated in 2017. This chapter introduces a specialists task force that was recently requested by ETSI and the European Commission to further extend SAREF to the industry and manufacturing domain.

25.1. Introduction

SAREF (https://w3id.org/saref) is a reference ontology developed in close interaction with industry during a study requested by the European Commission in 2015 (https://sites.google.com/site/smartappliancesproject/home). The motivation behind this study was that the market would continue to be too fragmented and powerless without a (protocol-independent) semantic layer that could enable interoperability among the various smart appliances from different manufacturers that co-exist in our homes, from lamps and consumer electronics to white goods, such as washing machines and ovens. To that end, SAREF was created with the intention to interconnect data from different protocols and platforms, for instance

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ZigBee (http://www.zigbee.org), UPnP (now OCF, https://openconnectivity.org/) and Z-Wave (http://www.z-wave.com), enabling the communication between in-home devices that use different protocols and standards. SAREF is not about the actual communication with devices and has not been set up to replace existing communication protocols, but it lays the base for enabling the translation of information coming from existing (and future) protocols to and from all other protocols that are referenced to SAREF. As confirmed in the EC's "Rolling Plan for ICT standardization 2017", SAREF is the first ontology standard in the Internet of Things (IoT) ecosystem, and sets a template and a base for the development of similar standards for the other verticals to unlock the full potential of IoT.

Following the momentum gained during the smart appliances study, SAREF was published by the European Telecommunication Standards Institute (ETSI, http://www.etsi.org/) as a Technical Specification (TS 103 264 V1.1.1). In 2016, ETSI further requested a Specialists Task Force (STF) to provide input on the management of SAREF and create dedicated extensions for specific domains. The STF 513 was consequently established and developed extensions of SAREF in the energy, environment and building domains (TS 103 410-1, TS 103 410-2 and TS 103 410-3, respectively). The STF 513 additionally developed an updated, more modular and flexible SAREF specification (TS 103 264 V2.1.1), using the feedback received from the industrial stakeholders since the first release of SAREF in 2015.

Over time, the SAREF initiative has been welcomed by smart appliances manufactures and IoT industry, which clearly indicated the intention to adopt SAREF and its related communication framework. Other standards organizations and initiatives, such as CEN/CENELEC (https://www.cencenelec.eu), AIOTI (https://aioti.eu) and IERC (http://www.internet-of-things-research.eu), have also acknowledged SAREF and its position in the current IoT landscape [VER 17]. Moreover, a proof-of-concept solution has been recently demonstrated in a follow up study on SAREF for the European Commission [DAN 18] that shows how to integrate different standards for demand response [CLC 17, IEC 17] and the oneM2M standard for machine-to-machine communication (http://onem2m.org/), using SAREF and its extension to the energy domain (SAREF4ENER) as basis for interoperability. This proof-of-concept demonstrates how commercial appliances from different manufacturers (such as washing machines, dish washers, smart meters, electric vehicle charging stations and photovoltaic inverter for solar panels) can communicate their capabilities and needs (e.g. who they are, what model, from which maker, if they are already running or ready to run, how much they are consuming, when they will finish their current activity, and more) with a Consumer Energy Manager (CEM). The CEM is a logical function that aggregates and process information from several devices, and can indicate to the individual appliances when to start, stop, pause, decrease or increase their consumption and so on, according to user preferences, production forecasts (e.g. by solar panels available in the home), smart grid conditions and price incentives at different times during the day. The CEM can be implemented in a component that physically resides in the home or runs remotely in the cloud.

25.2. SAREF extension to industry and manufacturing

A number of industrial sectors expressed their interest to extend SAREF into their domains in order to fill the gaps of the semantics not yet covered by their communication protocols nor by the existing SAREF extensions. To that end, the STF 534 (https://portal.etsi.org/STF/STFs/STFHomePages/STF534.aspx) has been recently launched by ETSI with the goal to create SAREF extensions to the domains of smart cities, smart industry and manufacturing, and smart agri-food, turning SAREF into the umbrella that enables better integration of semantic data from and across various vertical domains in the IoT. The STF 534 consists of two main tasks: (1) gather requirements, collect use cases and identify existing sources (e.g. standards, data models, ontologies, etc.) from the domains of interest (i.e. smart cities, smart industry and manufacturing, and smart agri-food); and (2) produce extensions of SAREF for each domain based on these requirements. This paper focuses on the extension of SAREF to the smart industry and manufacturing domain, which will result in a new ontology, called SAREF4INMA, to be published as part of the SAREF series in a new ETSI Technical Specification. The paper describes our approach and presents some initial requirements for the SAREF4INMA ontology.

SAREF contains core concepts that are common to several domains. To be able to handle specific data elements for a certain domain, dedicated extensions of SAREF can be created. Each domain can have one or more extensions, depending on the complexity of the domain. As a reference ontology, SAREF serves as the means to connect the extensions in different domains. Domain specific extensions should reuse and specialize core concepts from SAREF, and can also reuse concepts from other extensions. Extensions can be created by any interested stakeholder, but for an extension to be standardized, it needs to be submitted, discussed and approved by the SmartM2M Technical Committee in ETSI. Extensions have to be created following some best practices, such as: (1) be designed according to the criteria for ontology development specified by [GRU 95], that is clarity, coherence, extendibility, minimal encoding bias and minimal ontological commitment; (2) relevant stakeholders in the domain of interest should be involved in the creation process; (3) the group/community that creates the extension should be committed to contribute to its maintenance; (4) SAREF should be properly re-used and the extension should not add concepts that are already present in SAREF or other extensions; (5) the extension needs to be properly documented and published. More details on the extension and maintenance guidelines can be found in the corresponding ETSI Technical Report (TR 103 411 V1.1.1).

In order to create the SAREF4INMA extension, we follow an interactive and iterative approach, based on the experience gained in the past years with SAREF, which was created in a very transparent manner to allow all stakeholders to provide input and follow the evolution of the work [DAN 15]. The first step of the approach consists of collecting the requirements that can guide the implementation and validation of the ontology. To that end, we need to acquire the necessary information (i.e. specifications, datasets, standards, API specifications, data formats, etc.) from domain experts and existing initiatives in the industry and manufacturing domain. The second step is to collect the use cases for which the ontology has to be used. We specify these use cases in natural language. The third step is to define the purpose and scope of the ontology for the identified use cases. Based on the information acquired from the domain experts, the related initiatives, the use cases and the identified purpose and scope, it is then possible to generate a first version of the requirements. We write these requirements in the form of Competency Questions [GRU 95]. An interactive validation with domain experts and stakeholders should follow, in order to assess whether the requirements are correct and complete. The requirements are then finalized and used to guide the creation of the SAREF4INMA ontology, which should also be iteratively validated with the stakeholders and domain experts in an interactive manner.

25.3. Related initiatives, standards and use cases

There are various member states initiatives aimed to support the digitization of European industry and manufacturing [DEI 17], such as platform Industrie 4.0 in Germany, Industria 4.0 in Italy, Industrie du futur in France and the Smart Industry initiative in the Netherlands. These initiatives focus on aspects such as: (1) cyberphysical systems, that is the usage of robots and advanced IT-capabilities (sensors, data analytics) in a production environment; (2) digital manufacturing technologies, i.e., new manufacturing technologies, such as 3D printing, requiring a high level of digital input; and (3) new business models and propositions, that is lot size one-manufacturing, servitization of manufacturing, maintenance, and other new business propositions leading to changes in the way businesses and their networks are structured. The various Industry 4.0 initiatives are used to provide input to the SAREF4INMA extension in terms of key use cases and standards. In particular, we have collected 24 relevant standards from these initiatives and grouped them based on their scope (e.g. digitization, communication, engineering, life cycle, etc.) and the topic they cover (i.e. factory, product, process). We have further distinguished the standards in the scope of the SAREF4INMA extension from those that are out of scope. These standards in scope include **IEC 62794**, which is a reference model for automation assets and structural and operational relationships; **IEC 62832**, which identifies the general principles of the Digital Factory framework (i.e. a set of model elements and rules for modeling production systems); **IEC 62264**, which describes the manufacturing operations management domain and its activities; **IEC 61512 Batch control**, which is a reference model for batch control as used in the process industries; **IEC 62541 OPC UA**, which describes the OPC-UA architecture, machine to machine communication protocol for industrial automation; **IEC 62890**, which describes the lifecycle management for systems and products used in industrial process measurement, control and automation; **IEC 61360/ ISO 13584**, which specifies a general purpose dictionary covering the field of electro technology, electronics and related domains; **IEC 62424 Topology**, which specifies procedures and specifications for the exchange of process control engineering relevant data provided by the Piping and Instrumentation Diagram (P&ID) tool; and **IEC 62714 AutomationML**, which defines a data exchange solution based on an XML schema for the domain of automation engineering and integrates **IEC 61131**, **IEC 62424** and **ISO/PAS 17506**.

Concerning the use cases, we have selected the **zero-defect manufacturing** use case as basis for the SAREF4INMA ontology. The competitiveness of a manufacturing process is often defined by its ability to be flexible (i.e. quickly change from one product to the other) and have a manufacturing process with as little yield loss as possible. Zero-defect manufacturing focuses on reducing the yield loss to zero, often combined with an increase in flexibility. To that end, a combination of precision manufacturing technology, data collection and process control is needed. Two cycles are especially needed in the zero defect manufacturing use case: (1) the first cycle is a **real-time loop** that focuses on the immediate collection of data from sensors in or around a production equipment (e.g. a stamping machine that takes a metal sheet as raw material and produces a certain metal object as a result). This data consists of the machine settings and states, its measurements (e.g. temperature, pressure, force measured by the machine during production) and units of measure, but also characteristics of the resulting product (e.g. properties of the metal object produced by the machine). Based on this data, a controller component can decide to change the settings of the production equipment in real-time to avoid errors that could possibly lead to defects in the final product; (2) the second cycle is a **data collection and analysis loop** needed to achieve a continuous process analysis and improvement. This loop also includes smart sensors, but it has a longer time span compared to the real-time loop. It can measure the characteristics of the incoming (raw) material to update the production settings accordingly in a later moment. Similarly, it can detect feedback parameters to predict the quality of the end-product and provide feedback to the production process. Over a longer period of time, these parameters are fed to a self-learning framework which can be used to detect patterns leading to errors and/or areas for further improvement. In the zero-defect manufacturing use case, interoperability is especially required between sensors, production equipment and the data collection environment for the data collection and analysis loop (second cycle). The Productive 4.0 innovation and lighthouse program (https://productive40.eu/) provides us with several concrete examples of this use case relating to the stamping of metal objects and chatter control in milling. Competency questions that we have extracted from this use case as basis to create SAREF4INMA include the following: (1) What type of production equipment is used in the factory? (2) What is the incoming (raw) material to the production process? (3) What is the resulting product? (4) What parts is this product made from? (5) Which sensors are used in the production process? (6) Which actuators are used in the production process? (7) Which properties need to be observed and/or controlled by the production equipment? (8) What are the properties of the final product? (9) Which units of measure are these properties measured in?

25.4. Conclusions

This paper introduced the initial work carried out in a dedicated ETSI specialists task force to extend SAREF to the industry and manufacturing domain. This work is done in close collaboration with industry experts, who expect to adopt this extension in specific applications. The paper presented our approach, related initiatives and standards. The paper further described the zero defect manufacturing use case chosen as basis to create SAREF4INMA, formulating some initial requirements extracted from this use case. Future work is focused on finalizing the formalization of these requirements and align them with the semantics extracted from the standards in section 25.3. The final version of these requirements is expected for June 2018. These requirements will be subsequently validated with stakeholders and used to create the SAREF4INMA ontology. A stable version of the SAREF4INMA is expected in November 2018, while the final version is planned for February 2019.

25.5. References

[CLC 17] CENELEC, “B5 50631-1 Household appliances network and grid connectivity – Part 1: General requirements, generic data modelling and neutral messages”, available at https://standards.globalspec.com/standards/detail/?docid=10196921, 2017.

[DAN 18] DANIELE L., STRABBING W. *et al.*, “Study on ensuring interoperability for enabling Demand Side Flexibility”, European Commission, 2018 (forthcoming).

[DAN 15] DANIELE L., DEN HARTOG F., ROES J., “Created in close interaction with the industry: the Smart Appliances REFerence (SAREF) ontology”, in CUEL R., YOUNG R. (eds), *Proceedings of Formal Ontologies Meet Industry*, Springer, pp. 100–112, 2015.

[DEI 17] DG GROW, DG CONNECT, Standardisation to Support Digitisation – Report from the Workshop on Standardisation to Support Digitising European Industry, Report, available at https://ec.europa.eu/digital-single-market/en/news/workshop-standardisation-support-digitising-european-industry, 2017.

[GRU 95] GRUBER T., "Toward principles for the design of ontologies used for knowledge sharing", *International Journal of Human-Computer Studies*, vol. 43, nos 5–6, pp. 907–928, 1995.

[IEC 17] IEC, "62056-6-2 Electricity metering data exchange - The DLMS/COSEM suite - Part 6-2: COSEM interface classes", International Standard, available at https://webstore.iec.ch/publication/34317, 2017.

[VER 17] VERMESAN O., BACQUET J. (eds)., *Cognitive Hyperconnected Digital Transformation: Internet of Things Intelligence Evolution*, River Publishers, Gistrup, Denmark, 2017.