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Subject
Position paper IAB Semantic Interoperability Workshop: "Towards semantic interoperability in the IoT using the Smart Appliances REFerence ontology (SAREF) and its extensions"

1 Introduction

On request of the European Commission (EC), TNO has developed the Smart Appliances Reference ontology (SAREF)[1], which has been published by ETSI as a Technical Specification in November 2015 (TS 103 264 - V1.1.1). The request from the EC to develop SAREF originated from the interaction of the EC in several workshops with manufacturers of Smart Appliances - inside and outside Europe - on the topics of Energy Efficiency of devices, and how these devices could be controlled in a home or building environment. One of the conclusions of these workshops was that to be able to control devices in a home, a common model was necessary that would allow information and data from different standards to be connected and translated. Therefore, we created SAREF which has the intention to interconnect data and information from different protocols (for instance ZigBee, UPnP and Z-Wave) to enable the communication between 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 [1], SAREF is a first ontology standard in the Internet of Things (IoT) ecosystem and sets a template and a base for development of similar standards for the other verticals to unlock the full potential of IoT.

Now that the first version of SAREF has been standardized, ETSI and TNO are well underway in defining an extension to the SAREF ontology (called SAREF4EE) to be able to fully support demand/response use cases in the Energy domain. For this activity TNO works with the Italy- and Germany-based Energy@Home[2] and EEBus[3] industry associations to use SAREF as a means to interconnect their data models, so that in the near future it will become possible to easily combine smart appliances from manufacturers that support the Energy@Home or EEBus standards.

2 Background

As explained in [2], to develop SAREF we took an approach divided in the following three main tasks: 1) Take stock of the so-called *assets* in the smart appliances domain, in order to relate SAREF to the existing work from industry and academia. The assets we analysed were mostly published in the form of a

[1] http://ontology.tno.nl/saref, http://ontology.tno.nl/saref.ttl
[2] http://www.energy-home.it
[3] http://www.eebus.org/en

specification, a standard, a project deliverable, an UML data model, an XML schema, in a few cases a scientific paper, or sometimes just a PowerPoint presentation. In the end, we processed 47 assets as they were published in June 2014 or before, and created a short list of 23 assets; 2) Extract the semantics, often implicit, from the 23 assets in the short list and create a corresponding formal representation in RDF/OWL. The resulting RDF/OWL representations can be downloaded at the project website[4], which also provides natural language descriptions of their main classes and properties; and 3) Create SAREF as a shared model of consensus to facilitate the matching of existing assets in the smart appliances domain.

The study to create SAREF was performed in a very transparent manner to allow all stakeholders to provide input and follow the work. We took a multi-channel approach to solicit for review comments: within the span of a year we organized four workshops for stakeholders together with the EC and ETSI, in which we presented the deliverables and work done, and provided an opportunity for stakeholders to provide us with feedback. Besides this quarterly interactive heartbeat of face-to-face gatherings, we had continuous interaction with all involved parties by email, LinkedIn, and the projects' websites, and by attending additional related events such as ETSI and Home Gateway Initiative (HGI) meetings. This interactive and iterative approach was a key factor of success in the creation of SAREF and its subsequent adoption by the industrial stakeholders. Although this approach created a lot of overhead work, it also guaranteed a higher practical quality of the outcome, reflecting the wishes and intentions of the community in an optimal way, and above all creating the necessary trust into our work, increasing the likelihood of a strong acceptance of the results. In this line, TNO was asked by Energy@Home and EEBus to create the SAREF4EE extension.

3 Reference ontology

SAREF is a reference ontology that describes the core concepts for the stakeholders in the smart appliances domain and provides a mechanism to map different existing solutions (i.e., data models, protocols, specifications) to each other. SAREF is expressed in OWL-DL, which provides formal semantics and allows reasoning, being supported by a large number of software reasoning and consistency checking tools. As SAREF is represented at a conceptual level, independent of any specific implementations or protocols used to transport the data, it can be considered as an information model according to the definition in [3]. As acknowledged by the IoT Semantic Interoperability Workshop 2016[5], an important problem in the IoT is "the lack of an encoding-independent standardization of the information, the so-called *information model*". Therefore not only SAREF responds to the existing need of information models, but also provides a concrete example of how an information model that enables semantic interoperability in the IoT should look like.

[4] https://sites.google.com/site/smartappliancesproject/ontologies
[5] https://www.iab.org/activities/workshops/iotsi/

As a reference ontology, SAREF is intended to be used as basis to create more specialized ontologies, such as SAREF4EE that we created for the interoperability between specific Energy@Home and EEbus devices. The main advantage is that specialized ontologies based on a reference ontology are (semantically) interoperable by construction with other ontologies that use the same reference ontology. For example, specializing SAREF concepts using subsumption relations provides a way to map related concepts from ontologies developed by different organizations. When querying for general SAREF devices, it is thus possible to retrieve more specific devices, such as SAREF4EE devices, but also devices defined elsewhere in other ontologies based on SAREF.

A problem of reference ontologies is that sometimes they can be large models. However, this does not mean that all stakeholders and third-party developers should use the whole ontology for their developments, in fact they may need only a subset that is of interest for their specific application. For example, when creating SAREF4EE we focused on the subset of energy-related concepts defined in SAREF, such “Device”,” Profile”, “Energy” and “Power”.

4 Conclusions

We conclude that reference ontologies (such as SAREF) and the network of extended ontologies possibly sprouting from them (such as SAREF4EE) are a powerful means to enable semantic interoperability in the IoT and should be used more systematically to map existing data models and protocols to each other. In particular, SAREF and its network of ontologies should evolve in the future to cover other verticals that are relevant to the IoT and the Smart Home, such as e-health, security and entertainment. We expect that more extensions of SAREF will be created in the future to support use cases in different domains, and we foresee that these extensions will provide input to modify SAREF to ensure that new relevant concepts are included, so that SAREF can be used as a mechanisms to translate between domains. In this way, each domain can have an ontology that perfectly fits its needs, while the core concepts that are shared with other domains are reused from the SAREF core model, allowing easy interconnections between different domains.

References

[1] European Commission, Directorate-General for Internal Market, Industry, *Enterpreneurship and SMEs, GROW - Rolling Plan for ICT Standardisation 2016*, http://ec.europa.eu/DocsRoom/documents/14681/attachments/1/translations/en/renditions/native

[2] L. Daniele, F. den Hartog, J. Roes, *Created in Close Interaction with the Industry: The Smart Appliances REFerence (SAREF) Ontology*, Proceedings of the Formal Ontology Meets Industry workshop (FOMI2015), August 2015, Springer 2015.

[3] Network Working Group, RFC 3444, *On the Difference between Information Models and Data Models*, 2003, https://tools.ietf.org/html/rfc3444