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Lightweight data and knowledge exchange for pervasive environments [1]

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On September 21, 2016, Xiang Su defended his PhD dissertation titled “Lightweight Data and Knowledge Exchange for Pervasive Environments" at University of Oulu. Xiang Su presented his dissertation with the assent of the Doctoral Training Committee of Technology and Natural Sciences of the University of Oulu, in a publicly open presentation held in Auditorium IT116, Linnanmaa, University of Oulu, and he was able to comment on every questions raised by opponent professor Johan Lilius. The thesis was supervised by professor Jukka Riekki and reviewed by Doctor Ora Lassila and associate professor Kerry Taylor. Part of the research was carried out during a one-year research visit at Aalto University, supervised by professor Sasu Tarkoma.

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1. Thesis summary

Pervasive environments are physical spaces saturated with devices collecting data, controlling the environment, and interacting with users. These environments support human users in their everyday tasks so that the users can focus on their own tasks and access services and resources whenever and wherever they want. Such environments are also called smart spaces. Knowledge-based systems would enable realizing a variety of intelligent applications for pervasive environments. Generally, such systems recognize the situation in the environment from sensor data and utilize automated reasoning techniques to respond to the situation and the needs of the users.

However, building knowledge-based systems for pervasive environments presents challenges. This dissertation focuses on the challenge of data and knowledge representations. Knowledge-based systems utilize expressive knowledge representations that are verbose and require sufficient resources in order to use them. Most devices in pervasive environments cannot handle these representations as the devices have limited resources for computation, storage, and communication. The main aim of this dissertation is to tackle this challenge. That is, on the one hand, pervasive environments demand data and knowledge representations that do not require many resources from the resource-constrained devices; and on the other hand, the representations should be compatible with the knowledge-based systems. Specifically, a general solution is required that enables many applications to use the same data with minimal effort from application developers.

This dissertation presents a novel representation, Entity Notation (EN), to tackle these challenges. EN

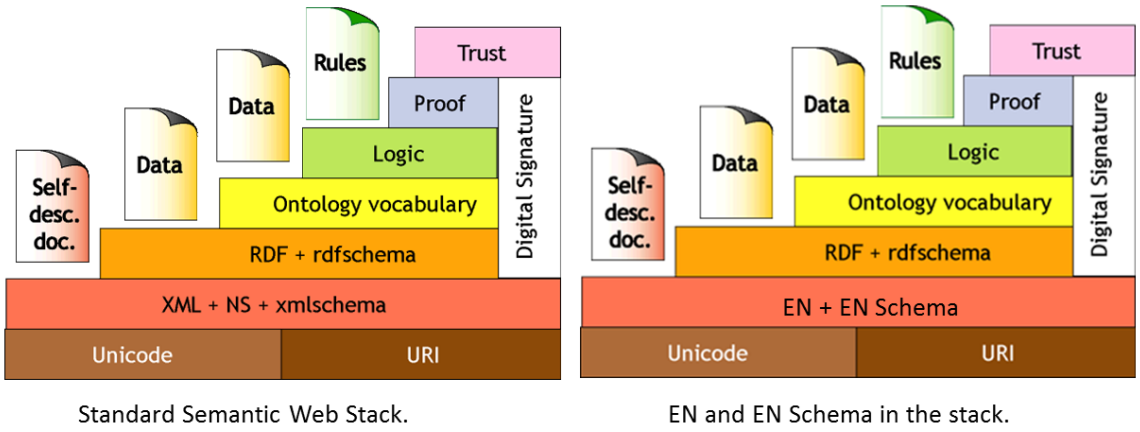

Fig. 1. The roles of EN and EN Schema in standard semantic web stack [4].

is designed as a general lightweight representation for data and knowledge. EN expresses entities, their properties, and property values. This structure resembles the triple structure of Resource Description Framework (RDF) [1] and Web Ontology Language (OWL) [2]. Hence, sensor data in EN syntax can be transformed into common knowledge models in a straightforward manner and utilized with ease by knowledge-based systems. EN Schema is designed for transferring advanced knowledge models. We design EN and EN Schema as a syntax for RDF and OWL and they provide a simple solution for knowledge exchange in pervasive environments. Figure 1 presents the role of EN and EN schema among Semantic Web technologies. The standard Semantic Web stack is adapted from [3]. RDF and RDF Schema are utilized as a description language for resources, then there is an ontology layer on top on them. Ontologies describe relationships between types of resources, but they do not indicate how to compute such relationships. As shown in Figure 1, EN and EN Schema are alternative syntaxes for XML and XML Schema. All entities in EN and EN Schema can be transformed into corresponding resources in RDF and ontologies. Finally, EN also offers an approach to shorten the format with templates and prefixes. This way, EN can be utilized by resource-constrained devices and environments.

Our evaluation verifies that small devices can utilize EN to transfer data and knowledge to devices realizing intelligent functions, such as inference. Moreover, the expressive power of EN is comparable with the alternative representations. Finally, resource consumption is verified by prototypes. Based on the evaluation, we can conclude that EN and EN Schemacan facilitate harnessing the full potential of pervasive environments.

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