Semantic Web Technologies' Role in Smart Environments

Faisal Razzak

Department of Control and Computer Engineering
Politecnico di Torino, Italy
faisal.razzak@polito.it

Abstract. Today semantic web technologies and Linked Data principles are providing formalism, standards, shared data semantics and data integration for unstructured data over the web. The result is a transformation from the Web of Interaction to the Web of Data and actionable information. On the crossroad lies our daily lives, containing plethora of unstructured data which is originating from low cost sensors and appliances to every computational element used in our modern lives, including computers, interactive watches, mobile phones, GPS devices etc. These facts accentuate an opportunity for system designers to combine these islands of data into a large actionable information space which can be utilized by automated and intelligent agents. As a result, this phenomenon is likely to institute a space that is smart enough to provide humans with comfort of living and to build an efficient society. Thus, in this context, the focus of my research has been to propose solutions to the problems in the domains of smart environment and energy management, under the umbrella of ambient intelligence. The potential role of semantic web technologies in these proposed solutions has been analyzed and architectures for these solutions were designed, implemented and tested.

Keywords: ambient intelligence, Domotic Effects, LO(D)D, SEIPF, semantic web technologies' role, smart environments.

1 Introduction

The emergence of economically viable and efficient sensor technology has enabled system designers to build smart environments [6] that measure different features across environment, i.e., proximity, temperature, luminosity. Consequently, it gives rise to computational models in which networks of appliances or sensors interact with each other and with their corresponding environments to provide residents, a better living and comfortable experience. The requirement is to model different artifacts of the environment and then processing these models in combination with other computer technologies to reach some environment specific goals, i.e., ubiquitous access to appliances and their information, fulfilling user goals. Semantic web technologies can act as a modeling tool, as they support the representation of structured data, explicit context representation, expressive

P. Herrero et al. (Eds.): OTM 2012 Workshops, LNCS 7567, pp. 54–58, 2012.

context querying, and flexible context reasoning [8]. Since architectural and device modeling deals with the artifacts that are described for each environment and varies across different vendors, their modeling was identified as *Lower Level Modeling (LLM)*. By contrast, the abstract modeling to achieve intelligence and innovative interaction management techniques were identified as *Higher Level Modeling (HLM)* as they deal with generic human centric expression.

This paper very briefly outlines the research contribution and perspective of the author in addressing the issues of ubiquitous access to smart environment, enabling users to program their own environments, achieving user goals, minimizing energy usage in the domains of smart environment and energy management, and the potential role of semantic web technologies. The architectures for these contributions were designed, implemented and tested.

2 Research Methodology

The research methodology was to design, develop and test frameworks addressing different issues related to the fields of smart environments and energy management. These issues tackled were providing a ubiquitous access to smart environment, enabling users to program their own environments, achieving user goals, minimizing energy consumption. In addition, the frameworks were designed to be modular so that they can be integrated with an existing IDE (in our case Dog [1]). The following three steps were iterated to address different problems.

1. The first step was to identify artifacts or concepts and their interrelationships (at LLM or HLM level), and to model them using the ontologies. An ontology represents a specific perspective of the environment that is device modeling, energy modeling, therefore during ontology development the modularity pattern was followed [2,5]. W3C's *Ontology Web Language (OWL)*[1] was chosen to encode the ontology.
2. The second step was to design and develop ontology-powered frameworks. These frameworks build their knowledge base from the ontologies but the processing, reasoning and decisions over the knowledge base depend upon application specific requirements
3. The third step was more like a principle. If a framework intends to share its output on a large-scale or communicate with other frameworks, Linked Data (LD) principles were followed.

Table 1 highlights different frameworks and the combination of ontologies (HLM/LLM) powering them.

3 Research Activities

3.1 Web of Domotics (WoD) [7]

WoD is an amalgam of Smart Environments and the Internet of Things. It represents an Internet architecture enabling mobile users to access information

[1] `www.w3.org/2004/OWL`

Table 1. Development relationship between the ontologies and frameworks

HLM \ LLM	None	Publisher	DogOnt	DogPower
None	X	LO(D)D	Web of Domotics	SEIPF
DogEffects	X	X	Domotic Effects	I.E.O

regarding devices and to operate on those devices in a ubiquitous manner, independent from location constraints. It considers the home and office environments and go beyond the "simple" adoption of real objects as web service proxies [3] by transforming such objects into actionable environment entities. WoD is open and interoperable, network agnostic and location aware. The adoption of standard technologies and protocols, users should be able to interact and operate any smart environment through their "normal" mobile terminals, and without requiring any prior user registration or environment set-up. WoD provides (i) identification of devices by proximity, i.e., through tags (ii) discovery of device access points, through standard DNS aliases (iii) single-sign-on authentication based on OpenID (iv) policy-based authorization for granting different operation possibilities to different users (v) LD information exchange to support interoperability with semantic web technologies. (vi) REST based interaction for querying status and triggering actions on physical devices.

3.2 Domotic Effects

The "Domotic Effects" is a high level modeling approach (Fig. 1), which provides AmI designers with an abstract layer that enables the definition of generic goals in a smart environment, in a declarative way, which can be used to design and develop intelligent applications. The high-level nature of Domotic Effects allows the residents to program their personal space as they see fit: they can define different achievement criteria for a particular generic goal. For example, a user may describe a Domotic Effect (DE) corresponding to the generic goal of lighting up a room, and this goal may be reached by acting, in different ways, on lamps, curtains, and shutters in that room, possibly by taking into account external conditions. Given the state of these devices, the AmI system may determine whether the lighting goal is actually reached (Domotic Effects Evaluation); conversely, if the user asks for this DE to take place, then the AmI system will bring the home devices into a state that satisfies the request (Domotic Effects Enforcement). A "DogEffects" ontology has been developed to provide a formal knowledge base for the modeling framework and is organized in a structure that corresponds to the architecture shown in Fig. 1. The Core layer contains the basic class definitions for expressing DEs. Each DE is expressed as a function of device states or sensor values. Such function is expressed using a set of operators that can be defined by the AmI designer. The AmI layer encodes the set of operators depending on the application domain. Finally, the Instance layer represents the specific DEs being defined in a specific environment.

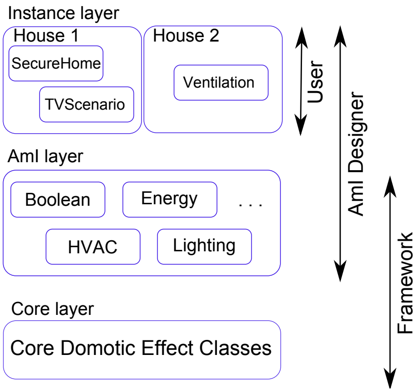

Fig. 1. Domotic Effect Modeling Framework

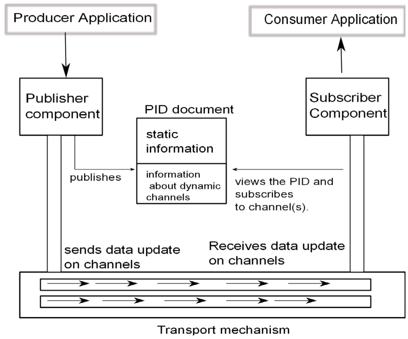

Fig. 2. Architecture of LO(D)D

3.3 Energy Management: SEIPF [2]

A Semantic Energy Information Publishing Framework (SEIPF) was proposed to address the issue of energy management. It publishes, for different appliances in the environment, their power consumption information and other appliance properties, in a machine understandable format following LD principles. While appliance properties are exposed according to the DogOnt ontology [1], power consumption is modeled by introducing a new modular DogPower ontology (previously Energy Profile ontology). The DogPower ontology was designed to model nominal, typical and real power consumptions for each appliance in achievable states. It can be plugged with another ontology (having the notions of device and states), as it follows modularity pattern.

SEIPF is consistent with publication of information at different granularity levels (e.g., by aggregating over device groups) and respecting different authorization levels. The ability to collect and share instantaneous power consumed by different devices in a house can enable the creation of many applications that can lead towards a more energy efficient society. In the future, intelligent negotiation and consumption coordination based on open and semantic representation will allow third-party service providers to build intelligent and automated services that use the energy consumption information to build dynamic services. An example is the optimization of energy inside the smart environment(I.E.O [4]). Based on the Domotic Effects modeling and the power consumption details provided by the DogPower ontology, minimization of energy usage of an environment is achieved along with fulfilling users' goals.

3.4 Publishing Linked Open (Dynamic) Data [5]

It is a distributed framework that provides a systematic way to publish environment data which is being updated continuously; such updates might be issued at specific time intervals or bound to some environment specific event. The framework (Fig. 2) targets smart environments having networks of devices and sensors which are interacting with each other and with their respective environments to gather and generate data and willing to publish this data. It addresses the issues of supporting the data publishers to maintain up-to-date and machine understandable representations, separation of views (static or dynamic data) and delivering up-to-date information to data consumers in real time, helping data consumers to keep track of changes triggered from diverse environments and keeping track of evolution of the smart environment. The framework consists of three components, i.e., a publisher, a subscriber and a transport mechanism. A "Publisher" ontology provides modeling for the different elements of the framework.

4 Conclusion

This paper briefly highlighted the activities undertaken during my research to address problems in the domains of smart environment and energy management. The role of semantic web technologies as a knowledge base was also outlined. In the future, the focus will be to devise developmental guidelines (based on the author's experience) for the use of semantic web technologies, in solving the issues of smart environments.

References

1. Bonino, D., Castellina, E., Corno, F.: The dog gateway: enabling ontology-based intelligent domotic environments. IEEE Transactions on Consumer Electronics 54(4), 1656–1664 (2008)
2. Bonino, D., Corno, F., Razzak, F.: Enabling machine understandable exchange of energy consumption information in intelligent domotic environments. Energy and Buildings 43(6), 1392–1402 (2011)
3. Broll, G., Rukzio, E., Paolucci, M., Wagner, M., Schmidt, A., Hussmann, H.: Perci: Pervasive service interaction with the internet of things. IEEE Internet Computing 13(6), 74–81 (2009)
4. Corno, F., Razzak, F.: Intelligent energy optimization for user intelligible goals in smart environments. IEEE Transactions on Smart Grid (submitted, 2012)
5. Corno, F., Razzak, F.: Publishing LO(D)D: Linked open (dynamic) data for smart sensing and measuring environments. In: The 3rd International Conference on Ambient Systems, Networks and Technologies, Niagara Falls, Ontario, Canada, August 27-29 (accepted, 2012)
6. Diane, C., Sajal, D.: Smart environments: Technology, protocols and applications. Wiley-Interscience (2004)
7. Razzak, F., Bonino, D., Corno, F.: Mobile interaction with smart environments through linked data. In: 2010 IEEE International Conference on Systems Man and Cybernetics (SMC), pp. 2922–2929. IEEE (2010)
8. Wang, X., Dong, J.S., Chin, C.Y., Hettiarachchi, S.R., Zhang, D.: Semantic space: an infrastructure for smart spaces. IEEE Pervasive Computing 3(3), 32–39 (2004)