Evaluating Energy Profiles as Resource of Context and as Added Value in Integrated and Pervasive Socio-Medical Technologies using LinkSmart Middleware

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Abstract. The EU funded project inCASA has brought new insights in the field of socio-medical technology using the context-aware LinkSmart middleware. One of the main concerns that were experienced was whether separate medical devices could aggregate contextual information given by multiple environmental sensors within social care. Energy profiles were hypothesised to be able to substitute many of these in exchange for context information about a patient's behaviour. A small study was conducted to review the energy profiles given by medical devices at dispose. Unluckily, the results showed that the medical devices do not expose relevant information in order to construct such profiles.

Keywords: Energy ontology, Context, Remote Patient Monitoring, AAL, HL7.

1 Introduction

In our everyday lives and environments any computational device that is able to be interwoven or perceptually hidden from us is usually referred to as artefact targeted by pervasive computing. This term is often used in wireless networks, real-time multimedia transmissions over mobile communication protocols, and when working with ubiquitous embedded devices, sensors and actuators. Pervasive computing is prone to get more involved in areas of mHealth and Assisted Ambient Living (AAL) and improve the way healthcare is delivered [1]. Besides changing the way of healthcare delivery, pervasive data gathering opens up for new and more profound approach to how context data can be interpreted.

Solutions that cover eHealth or mHealth alone are generally more directed to raise context-awareness about physiological measurement values and semantics for understanding patient-related information [2][3]. On the other hand, social and elderly care solutions such as what can be found within most European AAL projects [4][5][6] and socio-medical research [7][3] point at the need to contextualise more of the environmental and situational events in order to better understand and anticipate emergencies and social efforts. AAL consequently leads to some kind of Smart Home deployment using sensors and actuators to gather information about and control the environment. The field of Smart Homes is broad and commercially more adopted

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bringing forth AAL as side-effect. Here, devices and appliances are often able to fall into the term of energy efficiency and remote control by exposing relevant information referred to energy profiles. The use of these profiles enables the extraction of valuable contextual information that can be utilized to identify user behaviour and expectancy of energy consumption and cost [8][9].

The fundamental principles behind pervasive computing environment design evolved with distributed systems, wireless networks, LAN, WAN, middleware technologies, and the WWW. The LinkSmart middleware [16] fulfils some key requirements of mobile and pervasive computing by enabling access to critical services and data at any point in time and location by using wireless networking and infrastructure network support. LinkSmart is a successful technology adopted in multiple EU funded projects where energy and control of the environment are essential areas and where context-awareness has a major impact on operating ranges. But it is also used in a socio-medical project addressing AAL [10][11] and this is where this paper has been elaborated to give more knowledge whether medical devices may provide the same type of information on energy profiles leading later to an enhancement of the contextual representation.

2 Energy Semantics and Context-Aware Middleware

While the inCASA project has the mission to help elderly people to handle ageing by using an age calibrated integrated solution that enrols ICT and social and health care resources, LinkSmart, due to its flexible ontology support, has gained wide popularity by the public and at least three EU funded projects to refer to. The SEEMPubS project is about smart energy efficiency for public spaces and uses LinkSmart to develop an intelligent Context Energy Awareness Service Framework capable of managing sensor data and events across different contexts and situations [12]. The Me3Gas project [13] uses almost the same approach to reach its goal of placing the consumers in control of their energy efficiency and appliances at home while the SEAM4US project adopts a isolated solution where models for agent-based distributed and coordinated context-aware and energy resource constrained multi-project scheduling of the different subsystems in the Barcelona subway network [14]. Regardless, the point is that LinkSmart per se offers a stable ground for creating and energy awareness framework that will be reusable in future Smart Home and M2M solutions.

2.1 2.1 Developing with SOA and MDA Middleware

The LinkSmart Middleware was an EU co-funded four years Integrated Project that developed a middleware for Networked Embedded Systems. It ended on 31st December 2010 and due to property rights to its original name "Hydra" the project decided to change it to LinkSmart Middleware and to release it as Open Source reference implementation [15]. By offering a design of a generic semantic model-based architecture that supports model-driven development of applications [16], the middleware allows its developers to easy and quickly incorporate heterogeneous physical devices by using Web Service interfaces for controlling them irrespective underlying communication technology and still present them as semantic entities irrespective network setup.

By describing device related information the LinkSmart device ontology is able to present some basic high level concepts usable during development as well as in run-time processes. A developer is able to use the device ontology to create new instances and detailed data for any device type whereas each of these instances then represents the specific device model. This approach allows the model to be used as the template for the run-time instances so that real devices connected to the middleware can be exposed as virtual devices and accessed on remote.

2.2 Ontology Structure and Modules

The LinkSmart Ontology structure was designed to support and maintain its current setup of ontologies and ensure that future extensions of used concepts could with favour be adopted. Using the OWL language, the LinkSmart developing team differentiated between parts of the device model into separate ontology files from where these can be imported. In LinkSmart the core of device ontology relies on the access to basic device information and as concept the IoTDevice is sub classed by the taxonomy of all device types. This means that it serves as the root ontology concept from which one important property is the deviceId. This represents the unique device URI that is the identifier of the device template assigned to specific run-time instance of that particular device [17].

The semantic device description and structure is divided into three modules 1) device malfunctions, 2) device capabilities, and 3) device services. These are all connected to the core ontology concept from which the initial device ontology structure has been extended (FIPA device ontology specification and AMIGO project vocabularies for device descriptions) and is now covered by the basic device taxonomy and information in the ontology Device.owl that imports all other model parts [16][17].

Basing the semantic service specification on OWL-S standard the LinkSmart service model is able to enable the interoperability between devices and services by exposing the device service capabilities (e.g. device or service states and transitions) as well as tell the developer/end user what the input and output parameters are. As such, the device service ontology component will always present the device's services on a higher and a technically independent level maintaining the service concept. Having the service concept allows each service to be represented whereby the service concept will act as the root concept for all sub classes creating their service taxonomy. On the other hand, a service can respond to several service taxonomies and therefore each taxonomy represents a certain type of categorisation where the ins instance of specific service may be of more rdf:types representing several categories (see below for energy example) [17].

```
<rdf:RDF
    xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-
ns#"
xmlns:property="http://localhost/ontologies/StaticPrope
rtyModel.owl#"
    xmlns:owl="http://www.w3.org/2002/07/owl#"
    xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
    xmlns:unit="http://localhost/ontologies/Unit.owl#"
    xmlns="http://localhost/ontologies/Energy.owl#"
    xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
  xml:base="http://localhost/ontologies/Energy.owl">
</rdf:RDF>
```

The categorisations are implemented as WSDL operations where each service is represented while the property of serviceOperation in the service concept contains the WSDL operation name and works as the service identifier during run-time execution. There is no limit on IoTDevice concept services and this makes the LinkSmart device ontology one of the key components in the middleware being able to store information and knowledge about different devices and device types.

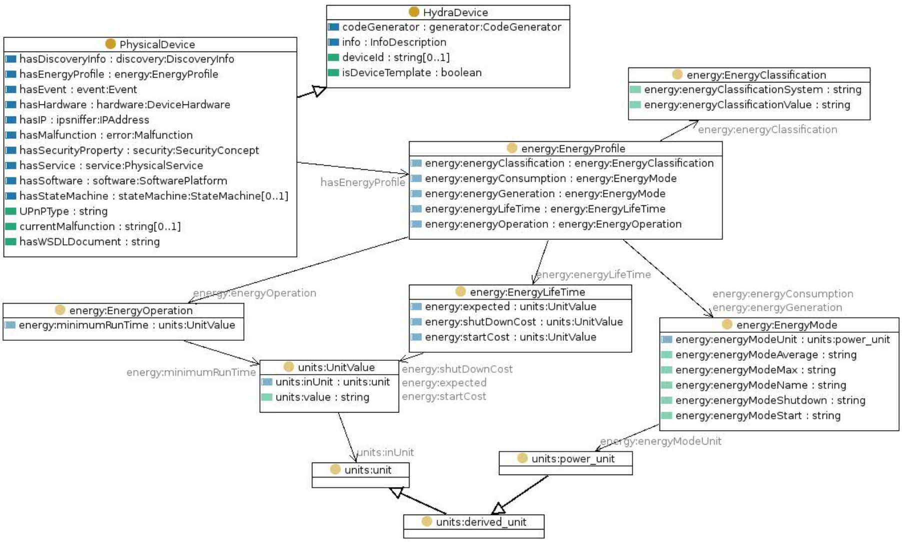

Fig. 1. Model of LinkSmart energy profile ontology

All devices enabled in LinkSmart have automatically attached the model representing their energy profile (Figure 1). This means that every device although not inherently providing the functionality for it will contain the static information related to their device's energy consumption or generation modes; basic energy classification, life-time and operation information. In sum, all ontology properties in LinkSmart that are related to the energy units defining the amount of energy spent, generated, remaining, average, etc. are tied to the power unit instances in LinkSmart QoS ontology [15].

2.3 Context in Socio-Medical Environments

There are two resources for context in the environment where patients and elderly move. One is adopted by the social care and one by the healthcare division. The LinkSmart uses [11] the Continua Guidelines [18] and the HL7 standards [19] as framework for medical data exchange and semantic integration of health services. Most AAL, i.e. Smart Home devices and appliances follow the XML text format for Web-based data exchange [20].

While context for the social care [21][22] will require specific sensors in order to extract enough data to estimate behavioural and social patterns, the medical side and device context is, as stated, rather narrowed down to only include information about physiological and measurement information or the context of medical records, history logs and rules [23][24]. Both have great value to better understand how treatment vs. care is accomplished but few note the fact that a synergy in between would possibly give even greater value in remote monitoring. As medical devices usually do not broadcast environmental data in the way that sensors for assisted living do we need to understand what features are exploitable and what parameters should be accounted for future medical devices.

3 Evaluation Study of Potential Device Energy Services

A first step in evaluating the possibilities to incorporate medical devices as contextual from other perspectives other than what they are originally designed for, i.e. to be used in socio-medical environments, is to eliminate the need to add environmental sensors as IR presence, activity sensor, etc. in order to facilitate recognition of user behaviour parameters for a certain situation. Context information about energy consumption could with ease be translated into activity context and hence behavioural data. An energy profile are therefore hypothesised to be able to substitute plenty of environmental sensors for exchange to context information about a patient's behaviour, e.g. how often is the device used, is the device used, how many times per day does the patient take measurements contra what is actually received at server side.

We have conducted a small study evaluating what energy profiles are available for each field. The idea was to use the experience and knowledge we have using Smart Home devices and appliances and to highlight what features and thereby parameters would be relevant to find in the medical devices. For Smart Home appliances and energy efficiency solutions we mainly use the Plugwise home basic kit and plugs named circles [25] and expose them as Web Services over a P2P network to be monitored and controlled by some end-user. The Plugwise covers many AAL related appliances and is therefore a good example for this comparing study trial.

Table 1. Evaluation of *Smart Home/AAL* IoT device energy service features in LinkSmart using common PlugWise devices. 'A' means that the service is available in LinkSmart while 'C' means that the service is compatible once mapped at application level.

Device description	AVG effect	Current usage	Device energy policy	Energy class	Energy mode	Energy policy status	Energy profile	Max effect	Min effect	RMNG life time	Total usage
PlugWise:: Refrigerator	**C**	**A**		**C**				**A**	**A**		**A**
PlugWise:: Light	**C**	**A**						**A**	**A**		**A**
PlugWise:: Microwave	**C**	**A**		**C**				**A**	**A**		**A**
PlugWise:: SmartTV	**C**	**A**		**C**	**C**	**C**		**A**	**A**		**A**
PlugWise:: Coffeemaker	**C**	**A**						**A**	**A**		**A**
PlugWise:: Cooling fan	**C**	**A**						**A**	**A**		**A**

Table 1 shows the study review of some usual LinkSmart enabled devices. We then continued to review the medical devices (Table 2) we have purchased to see if we could find any embedded services within the devices themselves that could be either exploited and defined on application level through coding or directly consumed by the LinkSmart Energy Profile Ontology.

Table 2. Evaluation of *medical* IoT device energy service features in LinkSmart in conjunction with the LinkSmart enabled medical devices at dispose. 'A' means that the service is available in LinkSmart while 'C' means that the service is compatible once mapped at application level.

Device description	AVG effect	Current usage	Device energy policy	Energy class	Energy mode	Energy policy status	Energy profile	Max effect	Min effect	RMNG life time	Total usage
A&D BPM UA-767PBT-C.					**C**						
A&D WS UC-321PBT-C.					**C**						
Nonin Pulse Oximeter 9560.					**C**					**C**	
Pivotell Pill Dispenser GSM.					**C**					**C**	
Bayer USB Contour.					**C**						
Ambulatory Inc. Actigraph.					**C**						

4 Results and Discussion

Context for social care and context for healthcare does not immediately mean that the two concepts fall under the same area of use. Still, what we now know is that context as resource for added value or additional information about a patient's well-being is subdivided and handled separately for healthcare and social services. Projects such as the inCASA and alike that adopt a socio-medical approach in the remote monitoring of patients are likely to have a consolidation of the two resources and hence realise sustainable solutions for joint social and healthcare delivery. On the other hand, the study showed that our medical devices in general do not possess the ability in expose energy profiles or services and what can be concluded is that they, in their current model versions, will not be able to provide added contextual value as anticipated. We encourage pursuing the topic as it could have great relevance in the forward planning of Internet of Things and socio-medical technologies.

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