A Semantic Policy Sharing and Adaptation Infrastructure for Pervasive Communities

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ABSTRACT

Rule based information processing has traditionally been vital in many aspects of business, process manufacturing and information science. The need for rules gets even more magnified when limitations of ontology development in OWL are taken into account. In conjunction, the potent combination of ontology and rule based applications could be the future of information processing and knowledge representation on the web. However, semantic rules tend to be very dependent on multitudes of parameters and context data making it less flexible for use in applications where users could benefit from each other by socially sharing intelligence in the form of policies. This work aims to address this issue arising in rule based semantic applications in the use cases of smart home communities and privacy aware m-commerce setting for mobile users. In this paper, we propose a semantic policy sharing and adaptation infrastructure that enables a semantic rule created in one set of environmental, physical and contextual settings to be adapted for use in a situation when those settings/parameters/context variables change. The focus will mainly be on behavioural policies in the smart home use case and privacy enforcing and data filtering policies in the m-commerce scenario. Finally, we look into the possibility of making this solution application independent so that the benefits of such a policy adaptation infrastructure could be exploited in other application settings as well.

Categories and Subject Descriptors

I.2.4 [**Knowledge Representation Formalisms and Methods**]: Representations (procedural and rule-based), Semantic networks

Keywords

Semantic Web, Rules, Semantic Policy, Rule Interchange, Policy Sharing and Adaptation, Policy Transformation, Smart Home, m-Commerce

1. INTRODUCTION

This section elaborates on the general topic of the thesis and identifies specific questions that will be answered during the course of this thesis.

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1.1 Problem Description

Rules are increasingly being used in semantic applications as well as in traditional IT systems to provide a formal and powerful way of representing information like individual preferences, privacy constraints etc [20, 12, 13]. To make such systems more versatile, there have been many initiatives that aim to transform a rule created in one semantic format to one created in another [8, 7, 14, 16]. However, in all these cases there is no provision for a rule or a policy[1] to be shared or reused among applications where its semantic meaning is preserved even while the context and other parameters of respective application environments change. Besides providing a way of sharing of intelligence, this would also save any extra effort needed by the users in creating same/similar rules from scratch. This thesis elaborates on a solution for an intelligent semantic policy sharing and adaptation infrastructure that enables the agents of an application across different settings, context, environments, etc. to share and reuse semantic policies amongst themselves. For this we identify variables that affect the definition of a policy at different usage sites of the application and provide them as input to an underlying transformation engine. The investigations are carried out primarily in the use case of a smart home community as well as in an m-commerce setting.

Smart Meters are increasingly being adopted by various countries, installation of which leads to a better energy optimization both by users and distributors while simultaneously providing a more customized control of home appliances and environments to the user. Several projects and initiatives [5, 15, 18] aim to further unify these advantages and improve the usability of these tools for the common user. At the same time, we observe that in the current urban landscape of most modern cities, there is an increasing tendency of people to reside in living communities like apartments in a large building rather than stand alone houses prevalent in the past [2]. In such a scenario, a natural next step would be to further harness the advantages of information and communication technologies (ICT) in creating connected urban environments which promote increased partnerships among residents of a living community through better information sharing and transparency. A part of such information sharing and exchange of ideas can be in the form of policies that the resident of a building creates for energy saving in his/her respective home. Such an endeavour would aim at providing an enhanced user experience while at the same time reducing their carbon footprint through collaborative efforts.

[1] A policy consists of one or more rules

Several projects have explored the use of mobile specific enablers for providing privacy aware services based on semantic rules for mobile users [11, 19]. We follow up on this trend by including an m-commerce based use case to test the feasibility of our approach. Our aim here is to use telecommunications (telco) specific information like identity, location, etc. in providing personalized advertisements to users based on their own preferences set in the form of policies. These preferences could be anything from user interests and habits to the level of privacy they intend to enforce by deciding on the kind of context data they agree to expose to various services. The policy adaptation infrastructure would enable these users in getting even better recommendations by sharing very effective *preference policies* among contacts and acquaintances in a Web 3.0 environment.

The main research question to be investigated in this thesis is: *For the same application, can a semantic policy created for one set of physical, environmental and contextual conditions and settings be effectively adapted and applied into another different set of settings while preserving its core idea?* To answer it, this thesis will elaborate a semantic policy sharing and adaptation infrastructure in the use cases of energy efficient smart homes as well as a m-commerce based setting. Along the way, this work will also show how to translate the benefits achieved (in terms of cost/energy savings etc.) by application of a policy from one environment to another.

1.2 Motivation

The incentives for having such a system from the perspective of various stakeholders in the mentioned use cases can be summarized in the following paragraphs:

The suppliers of smart home equipment can benefit from such a policy sharing and adaptation model by being able to suggest default policies at new installation sites where the policies are automatically adapted according to the new environment variables of the site. The policies can therefore be packaged with the smart home system saving them effort in defining new set of personalized default policies for every home they want to install the system in.

With a shared policy infrastructure in place, residents of a smart home community can compare the settings of their own predefined "modes" against those of others to assess their efficiency and possibly adopt the more efficient policies from the community. For example, party, sleeping, cooking, etc. modes of one resident can be adapted against the conditions and environments of another resident to check whose corresponding *modes* are more efficient.

Using the context information like mood, location, weather, etc. and other conditions remaining same, the resident may be suggested a policy like *"Last time under these weather conditions on a working day, you switched on the water heater in your house 15 minutes before reaching home"*. Such a policy may also be suggested to other residents in the same community and/or in the friend list of the initial user. eg. *"Under similar weather conditions, when other residents are around 5 kms from their home on a working day, they switch on the heater of their bathroom"* (implying people returning home in cold weather tend to want a hot shower immediately).

In the m-commerce scenario, telco operators could encourage the subscribers of their personalized advertisement based services to implement recommended interesting policies that help them in receiving only the most relevant advertisements matching their interests. The transformation of these *interesting policies* from one subscriber's profile to another can be taken care of by this policy adaptation infrastructure. The policies in this use case will focus mostly on user privacy and data filtering.

The general motivation for developers of various semantic systems to adopt this infrastructure would be the application independence of the proposed solution allowing them flexibility in implementing policies without worrying about adaptation for miscellaneous agents using it.

2. RELATED WORK

There has been considerable interest in the areas of rule interchange and profile matching in the semantic web community. This work takes inspiration from the techniques used in all these areas.

The RuleML[4] (Rule Markup Language) was the first initiative aimed at creating a unifying family of XML-serialized rule languages that includes all the web rules. The idea is to create inter operation bridges between the common web rule languages. In [8], a Web 3.0 case study of Wellness-Rules is described where rules about wellness opportunities are created by users in a community and translated for interchange within other community members using participants' profiles, activities, nutrition, context etc. The rules, originally created in languages like Prolog and N3 are translated using RuleML/XML for interchange with other community members. For this purpose, an extension of FOAF profiles of users with additional vocabulary and rules about Wellness group networking is used by a *Rule Responder* to organize communication between participants. The Rule Responder creates a translation of the rule created in any language into a common format which is reused by other rule engines in the network. OO jDREW and Euler rule engines connected via the Rule Responder are deployed for implementing the rule languages.

W3C launched the Rule Interchange Format(RIF) [16, 3] working group in 2005 tasked with producing a core rule language using which rules can be represented across all systems. The RIF framework for rule-based languages consists of a set of *dialects* which formally describes information about the syntax, semantics and XML serialization for each language. Existing and upcoming rule languages can be mapped into this format which serves as an interlingua for mapping rules from one application to be shared, published and re-used in other applications.

A discussion about the importance of rule languages on the web and the problems and opportunities of exchanging rules in a common standardized format is described in [7]. It also provides interesting discussions into the works of the W3C working group on the Rule Interchange Format, its results, use cases and future work directions.

An interesting related work on semantics-enabled layered policy architecture ("policy layer cake") has been proposed in [14]. This architecture is aimed at facilitating the exchange and management of policies created in multiple languages across the web. The proposed architecture consists of four layers: Unifying Logic layer, Policy Interchange Format (PIF) layer, Privacy Protection/DRM layer and Domain Specific applications layer. The architecture has been proposed as an extension of W3C's Semantic Web architecture to enable the reuse of existing work.

Most of the state of the art Recommender Systems use either a collaborative filtering approach, sometimes using a Multi Criteria Decision Analysis (MCDA) for making recommendations to users/clients of a technology. A detailed survey of such Recommender Systems in [6] gives us an insight of the state-of-art in such technologies and will serve as a good starting point reference for our future developments in the direction of policy recommendation.

While this thesis will take inspirations from the existing works in the direction of rule interchange and sharing, the focus will be more on *application independence* of such a solution rather than *language independence* (as done by other approaches discussed). Moreover, the unique feature of the proposed infrastructure will be the *transformation and adaptation* of a policy created in one set of conditions into that in another set of conditions for the "same" application.

3. APPROACH

In order to re-use the ideas and best practices of different users, the first requirement would be to serialize their preferences and policies in a common format which could easily be adapted from one array of settings to another. The common representation format could be the *Basic Logic Dialect (BLD)* proposed by the Rule Interchange Format (RIF) working group in [16]. On the other hand, for easy adaptation we need to first identify the static and dynamic variables in a rule and then replace the dynamic ones with those matching the new set of environmental conditions. For example in the most simplistic of cases, a rule *Turn off the heater when temperature rises above* $\underline{30\,^{\circ}\mathrm{C}}$ may be transformed to *Turn off the heater when temperature rises above* $\underline{28\,^{\circ}\mathrm{C}}$ with the italicized and underlined parts representing the static and dynamic contents of the rule respectively.

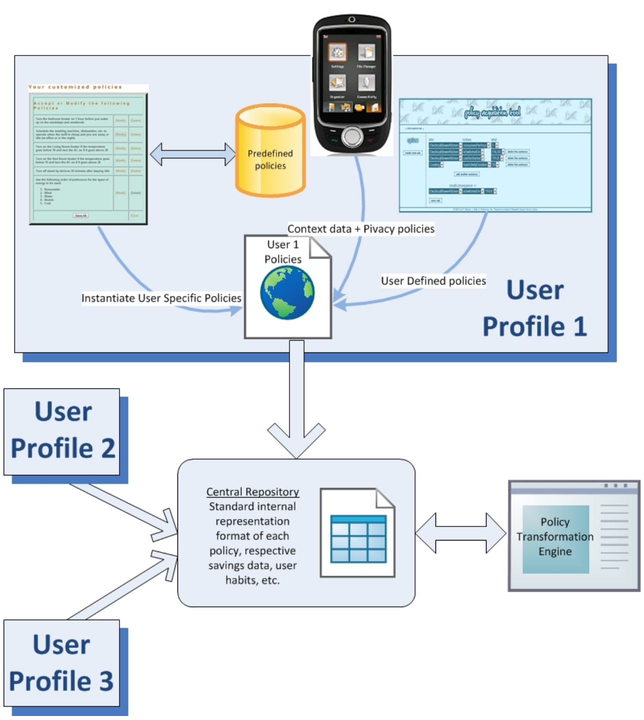

Figure 1: The policy sharing and adaptation infrastructure

Taking a cue from earlier efforts in the direction of Building Information Models [9, 10], we realize the necessity of the availability of a local Building Information Model (BIM) during the lifetime of buildings. The central repository and policy transformation engine (Figure 1) will form a core component of our local BIM infrastructure in the Smart Home use case. Using a similar analogy in the telco use case, these components would reside on the telco service provider's server respectively.

The central repository will collect all the user policies annotated with their respective metadata containing information about their static and dynamic parameters, the perceived quantifiable advantage(s) achieved by their application, etc. It will also contain user and environment data like profile, preferences, temperature, etc. that will substitute the dynamic parameters of a rule.

The Policy Transformation Engine performs the actual transformation of individual rules in a policy from one setting to another using data available in the repository. It also computes the perceived savings attained by the application of the policy in both the settings. The adapted policy along with projected savings is then recommended to the second user as a system suggestion or actively recommended by his/her friends through social media and other forums. For example in the smart home use case, if *Resident A* creates a policy that switches on the heating of his/her bedroom 1 hour before waking up in the morning (instead of keeping it ON for the whole night) and saves around 10 Euro per month by this, then this policy could be suggested to *Resident B* as well. However, to correctly inform *Resident B* about the amount of possible savings by the policy, a recalculation based on his/her habit (waking up time, etc.) and home conditions (heater's power consumption, etc.) needs to be done. To enable this adaptation, necessary mappings between various concepts are required. For example, the concept "Heating" should be mapped through some relation to the requisite appliances that are used in *Resident B's* house for heating and the concept "Habit" to the waking up time for *Resident B*. A formula then calculates the savings made by the same policy with different parameters and presents it to *Resident B*.

4. METHODOLOGY

The overall research is planned in various phases described below.

4.1 Preliminary Study and Analysis

A study of state of the art in various aspects of this project will be taken up. This would start with a survey of existing rule based enablers for semantic systems in general. In particular, efforts in the direction of rule based building enablers and user context management in mobile setting will be focussed upon. This would be followed by an analysis of efforts leading to the creation of existing rule interchange standards.

A general study into existing smart home systems would reveal what kind of *actions* could be represented by semantic rules in our use case. A survey of existing semantic rules interchange standards and semantic profile matching will provide valuable inputs on the technological approaches that need to be taken to answer the core question of this thesis. Effort will be made to find and reuse any publicly available ontology for our semantic applications. A state of the art study of existing technologies for semantic intelligent context enablers for mobile devices will also be undertaken.

In all the above analyses, special attention will be given to potential shortcomings in the existing approaches that might be fixed by the research carried out in this thesis.

4.2 Specification of the Infrastructure

Based on the above inputs, a specification of the proposed semantic policy sharing and adaptation infrastructure will be laid out. This would include a formal specification of each of the components in the infrastructure.

4.3 Prototype Implementation

The prototype implementation will be done in several stages comprising of development of each module of the system followed by an integration phase. Individual modules are described in the coming sections.

4.3.1 Policy creation tool

A tool that enables the user to create, edit, save and delete policies will be developed. Ideally, the interface would allow a user to create these policies in natural language commands (or resembling closely to it). There could be multiple interfaces targeted at expert and naive users separately.

4.3.2 Ontology development

An Ontology that clearly defines all the variables used for policy creation like environmental conditions, context, human actions, etc. will be developed. The structural part of a smart home will be represented in a separate ontology while the behavioural part will be represented by policies. There will be separate ontologies for advertising campaigns and user profile information in the m-commerce use case. User preferences with respect to data filtering and privacy policy will be partially represented by semantic policies. In all these cases either an existing ontology resembling similar definitions will be reused or a new one developed from scratch.

4.3.3 An intelligent context manager & recommendation engine

This module is added to the infrastructure due to our interest in utilizing the context data available through various sources for adaptation of policies. Context information constitutes an important part of the set of dynamic variables that affect the adaptation of a policy. This module manages the context of the user gathering data available through heterogeneous resources like online weather information, various sensors as well as through the user's mobile device. In both our use cases, a strong case is made for the situation where the central system recommends useful policies to its subscribers. A recommendation system will be developed for this purpose.

4.3.4 An underlying policy adaptation module

The adaptation module will be developed in conjunction with the policy creation tool. A policy saved by the user will be stored in the standard semantic format used by the original application as well as in the RIF-BLD format that allows for the transformation of the policy into a different array of settings. The ontologies developed in the earlier section will be used for the purpose.

4.3.5 Integration

Finally, all the modules of the system will be integrated to complete the prototype for testing in the evaluation phase.

4.4 Prototype Evaluation

A separate user evaluation will be conducted for each module individually, and at the end for the prototype as a whole. The final evaluation of the semantic policy adaptation infrastructure will be done on the basis of ease of policy transformation, its effectiveness, user acceptance, ease of use and various other criterion mentioned in the problem description phase.

5. RESULTS

At the end of this thesis, we expect to have a working prototype of the policy adaptation infrastructure in the smart home and m-commerce use cases. The focus of smart home use case would be to allow sharing of effective energy saving policies in a resident community and the evaluations would investigate the semantic similarity of the transformed policy along with preciseness of calculated savings data. Currently, we have a working prototype of an Energy Policy Recommender (EPR) tool that first gets the relevant habit/preference data of the residents by way of a questionnaire and accordingly suggests policies that might be useful for the resident in reducing his/her carbon footprint. The residents can either fully accept or reject the policy or make modifications to them before accepting. For each policy, we show the real time information on the savings possible by the application of that policy in the respective home. After being saved, the policies are translated from natural language and stored in N3 format for use by backend reasoners. The questions and policies appearing in this tool is based on a study for smart homes carried out in [17]. Another standalone policy creation tool enables an expert user to create a policy from scratch using various concepts representing appliances, actions and locations [21]. All the concepts used are derived from an N3 Ontology and the policies are stored in the same format.

Presently the SESAME smart home system is being installed in three computer rooms and hallways of a school in Kirchdorf, Austria. The EPR and school specific shareable policies will be tested in this installation.

The m-commerce use case will primarily aim at using shareable policies as a tool for preserving user privacy while still being able to infer useful information from their publicly shared data for ad recommendations. Evaluations in this case will be based on the difference in the relevance of ads served by effect of manual and machine adapted policies respectively. So far we have implemented a semantic rule based location aware campaigning infrastructure that uses server and client side privacy rules for providing location based ad campaigns matching the user's interests.

6. CONCLUSIONS

In this paper we introduced the idea of a semantic policy sharing and adaptation infrastructure and described some related work which would form a starting point of the research carried out in this thesis. Thereafter, we also mentioned some preliminary results of the work so far. According to the methodology shown in Section 4, the next major steps are to complete the policy transformation engine, context management system as well as the policy recommendation tool. Finally, we intend to test our hypothesis through extensive user tests of the infrastructure proposed in this paper.

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