Ontology Based Policy Mobility for Pervasive Computing

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1. Introduction

The array of devices, networks and resources available in pervasive computing environments, or smart spaces, will require effective self-management systems controlled via user-level policies. However, the local nature of smart spaces means that they present a potentially huge increase in the number of and nature of management domains, e.g. representing individual homes, shops, businesses, schools, hospitals etc. Differences in local domain models and local resource models means that policies relevant to one smart space will often use different semantics for subject and target objects compared to other pervasive computing domains. To allow users to capture personal preferences in terms of policies that can be consistently applied as they roam between smart spaces, the semantic interoperability problem resulting from different models for policy subjects and targets must be overcome. In this paper we present a framework where the use of ontology-based semantics for policy elements allows dynamic ontology mapping capabilities to support policy mobility. Ontology-based semantics are used to support run-time semantic interoperability. Autonmated runtime semantic interoperability is beyond current reasoning techniques [klein], but the proposed framework guide the development of semantic models to maximize their ameanability to runtime interoperability. We demonstrate its operation with a case study showing policy mobility in a policy-driven smart space management system.

2. Policy Mobility

We have realized a technical environment based on mobile and cellular IP [barratt] and integrated an hierarchical policy-based management (PBM) system [ghamri-doudane]. The integrated system and the enforcement of policies are shown in Fig 1.

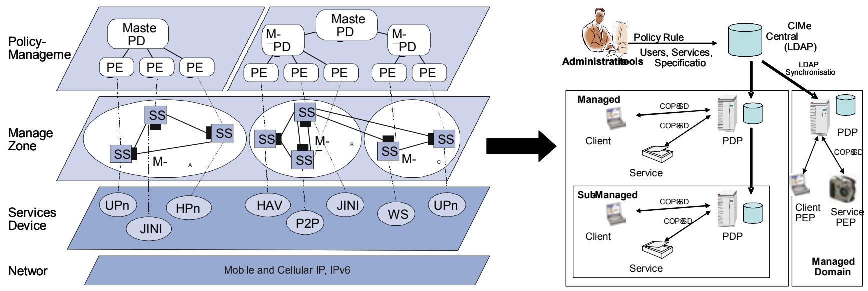

Figure 1. Policy Based Management and Smart Space Integrated System

Where a policy is related to the smart space behaviour preferences of a specific user, it must be enforced in different zones as the user roams.. Our aim is the seamless roaming of a device or a user between managed zones (inter managed zones). Seamless means that the device or the user can instantly enjoy similar services with similar access rights and behavioural preferences, without manual re-configuration as a user's personal policies are applied in differnet zones. We focus here not on differing semantic in policy languages, e.g. roles, domains, expression of deonic concepts etc, but on the semantics of the information models used to express the subjects and targets of policy rules and the actions that are performed between them.
To outline this complexity in practise we use the following example. A smart space provider is managing different smart spaces for Small to Medium Size Enterpises (SMEs). Some of the SMEs require sophisticated managed zones using the CIM based PBM system introduced above, others are satisfied with a small and simple managed zone using the printer MIB and standard PBM system. Mobile policies could be access control polcies if they related to resource that the user carries with them, e.g. access to a laptops GPRS Internet link. However, we expect mobile policies will more likely be obligation policies related to the users preference to using a resource (e.g. if document length is over 30 page set printer to 2up mode), or policies guideing the selection of services in the current smart space (e.g. always use the printer with the highest output capacity) However, the semantic interoperability of a mobile policy and the specified profiles for users and services remains a problem.
In the CIM model, a user and a group are managed entities associated to access rules for services, in our example for a printer service. In the second model, users are categorized by means of system manger (configurator), printer operator (printer manager), asset manager, user (printer browser) and user (printing application). To move a policy from one domain to the other, these relationships have to be semantically translated and the pre-defined access rights have to be adapted to the given specifications. Thus, the CIM model can have any kind of configuration, including different natural languages, which are (semantically) not compatible to the second model.

3. Semantic Interoperability for Policies

In this context, we have been investigating ontology processing techniques to dynamically bridge between the terminology of two different pervasive computing environments which we assume have been developed using different ontologies. In [osullivan] we have shown how such dynamic bridges can be automatically generated given a set of ontology mappings.

The key challenge in our work has been to identify an integrated software and process framework which will minimise the amount of design time work involved and devolve as much work as possible to a runtime algorithm. Minimising design time work and devolving as much as possible to runtime processing is crucial for the uptake of this approach in pervasive computing environments. Equally important is maximising the applicability of human generated ontology mappings by ensuring it is sufficient to maximise chances of a successful runtime mapping between information conforming to concepts from the two ontologies concerned.

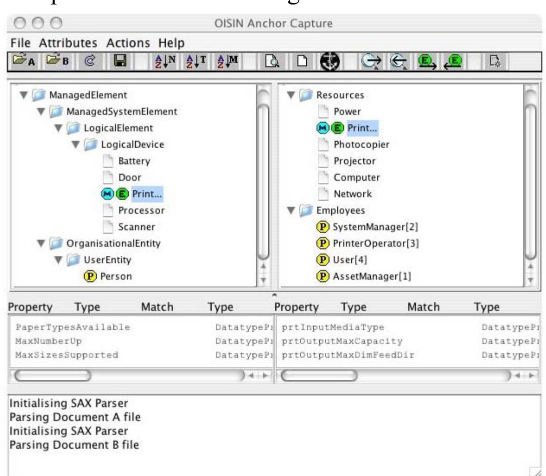

Figure 2: Example of OISIN anchor capture process

The resultant OISIN (**O**ntology **I**nteroperability for **S**emantic **IN**teroperability) framework is being used to help identify mappings.

The software and process elements of the OISIN framework:

- Determines the quality and dimensions of the ontologies referenced by the policies from each party;
- Highlights (see Figure 2) potential candidate mappings between the ontologies based on lexical matching of classes and properties;
- Allows the user determine and document candidate mappings.

A key differentiation of our approach from others (e.g. PROMPT/Anchor tool [noy]) is our belief that the determination of what is or is not considered an actual mapping can only be undertaken in the context of the applications involved in using the mappings and what they are trying to achieve. Thus our graphical tool helps the user identify candidate mappings. For this reason the original matching information as well as the potential mapping candidates provided by the user are made available to the application. This set of information is then used at runtime to transform terms used in a policy by party A into terms used in a policy by party B.

Our approach aims to address the more open corpus of management information that can be expected in pervasive computing environments, with the aim of minimising manual model mapping and maximising automatic runtime mapping, which then have the potential to take into account the context of the mapping operation. The application to policy mobility is chosed specifically because it can only be achieved for pervasive computing by runtime mappings.

In future work we also aim to show that such minimal human generated mapping allows automated mappings to be made that are most appropriate to the runtime context. This avoids the problem caused when human generated mappings are based on decisions that prejudge the problem domain in which the mapping is required. More broadly, we need to deepen our understanding of the role which ontologies can play in the modelling of management information, the maintenance of multiple models (including versioning), the binding to concrete management interfaces and software functionality and the use of mappings for guiding conceptual convergence between models.

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