A Semantic-based Pervasive Computing Approach for Smart Building Automation

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Abstract. The integration of knowledge representation languages and reasoning techniques (originally devised for the Semantic Web) into standard home automation protocols can allow to offer high-level services to users. A semantic-based approach is proposed, able to interface users and devices (whose features are expressed by means of semantically annotated profiles) within an ontology-based service-oriented home appliance infrastructure in a fully automated fashion.

1 Introduction

Problem. Home and Building Automation (HBA) is a growing research and industrial sector attracting efforts from several disciplines, coalescing into a research area known as *Ambient Intelligence* (AmI). A crucial issue for feasible and effective AmI solutions lies in efficient resource/service discovery for ubiquitous and pervasive computing contexts. Current HBA systems and standard technologies are still based on explicit user commands over static sets of operational scenarios, allowing a low degree of dynamism and flexibility. These restrictions can be overcome through the adaptation and integration of Knowledge Representation (KR) formalisms and techniques, originally designed for the Semantic Web. Ontology languages, based on Description Logics (DLs), can be used to describe the application domain and relationships among resources in a way that can support inference procedures and matchmaking processes.
State of the Art. Current service-oriented architectures for AmI, such as [1], lack adequate expressiveness and support only exact match of service attributes. A significant ontology-based framework has been proposed in [2] to overcome such limitations and enhance interoperability. Nevertheless, it uses static rule sets and centralized Knowledge Bases (KBs) for inference. Pervasive environments require a different approach, able to deal with the dynamic and decentralized nature of AmI.

2 Research Outline

Proposed approach. An HBA framework is proposed, supporting semantic characterization of both user requirements and services/resources provided by

devices. The *ubiquitous Knowledge Base* (u-KB) paradigm is applied, *i.e.*, a distributed KB whose individuals are disseminated directly within objects in the environment. Semantic Web languages, such as OWL, provide the KR infrastructure for domotic u-KBs, based on a fully backward-compatible extension of EIB/Konnex protocol stack [4]. New data structures enable devices to (i) store high-level, machine-understandable annotated descriptions of their capabilities; (ii) map them to actual values (set points, operating parameters) that can be activated using standard Konnex mechanisms. New protocol primitives allow devices to expose their annotated service profiles and to request services from peers in the network. Main benefits include: (i) increased interoperability and flexibility compared to domotic standards; (ii) a dynamic service-oriented architecture, which exploits reasoning to characterize environmental conditions (context) and to perform service discovery and matchmaking, while leveraging simple and cost-effective Konnex-based device control for service execution. The reference architecture integrates both semantic-enabled and legacy home devices in a domotic network with an IP backbone. Coordination among user agents and domotic agents (representing devices, rooms and areas) is facilitated by a home central unit. It acts as a service broker within the network and a Decision Support System toward users, embedding a semantic matchmaker.
Methodology and Results. Based on the theoretical framework, the following elements have been defined and are being evaluated: (a) semantic-based Konnex extensions; (b) an HBA ontology able to satisfy requirements of the project; (c) an embedded semantic matchmaking engine, based on [3]. It provides non-standard inference services (Concept Abduction and Covering) allowing to: (i) support non-exact matches and service ranking; (ii) cover a complex request through the union of elementary service units. A fully functional prototypical testbed is under development with off-the-shelf Konnex equipment and a PC-based home central unit. Early experimental results are satisfactory from functional and performance standpoints [4]. Future extensions will include enhancements of the ontological model in order to support service composition according to the IOPE (Inputs, Outputs, Preconditions, Effects) paradigm. Policy-based reasoning will also be considered, *e.g.*, to automate building power management.

References

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