Methods and Techniques for Ontology-based Semantic Interoperability in Networked Enterprise Contexts *

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1 Introduction

By exploiting open distributed architectures like Peer-to-Peer (P2P) and Grids, networked organizations can dynamically cooperate and share resources often in response to opportunities or challenges that cannot be anticipated in advance and require a rapid response [1, 7]. One of the major obstacles in the deployment of networked organizations like Virtual and Extended Enterprises is the lack of semantic interoperability techniques, to adequately ensure the effective, coordinated, and virtualized access to distributed and heterogeneous resources, under dynamic and context-dependent requirements. In particular, in order to support the correct and effective sharing and composition of informational resources to provide complex services in virtual organizations, an important requirement is the availability of a semantic description of the resources to be shared, to make them understandable and usable by the target community. In addition, to enable seamless access and retrieval of the right information resources, in the time frame that the users require, while preserving the information representation and management requirements of each single party involved in the networked organization coalition, appropriate matchmaking techniques are required, to dynamically perform the matching of requests for information resources against a multitude of, possibly heterogeneous, ontology descriptions.

In this paper, we address the problem of semantic interoperability in networked, multi-ontology enterprise contexts, where ontologies are employed for representing informational resources that each party provides for dynamic sharing and exchange with other parties. We study the problem of semantic interoperability under the assumption that no agreement exists among the various parties about the way resources are described in each ontology and about the vocabulary to be adopted for semantic description of resources. We propose a reference ontology model and associated semantic matching techniques to enforce dynamic resource discovery, by exploiting semantic resource descriptions available in an ontology

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at different levels of detail and with different degrees of flexibility. Then, we discuss ongoing and future research work on exploiting such techniques for dynamic semantic collaborations in networked organizations based on the P2P paradigm.

2 Ontology model and matchmaking techniques

To support dynamic resource discovery in networked multi-ontology contexts, we have developed a reference ontology model and associated ontology matching techniques to dynamically identify semantic mappings among similar concepts in different ontologies.

Reference ontology model. The advent of the Semantic Web has produced a large body of research around ontology languages, and many standard proposals that can be used for resource description in open networked systems have emerged (e.g., RDF, DAML+OIL, OWL). Different ontologies can describe the same domain using different descriptions of the same resources, also using the same language (e.g., in OWL ontologies, the same real world resources can be described in many different forms, due to the syntactical freedom of RDF). An important requirement of ontology matching techniques is to capture the elements that are relevant for matching purposes in ontology resource descriptions in a language-independent manner, to be applicable in many scenarios. To this end, we have defined a reference ontology model, called H-MODEL, capable of representing the ontology features that are relevant for matching purposes in a language independent way, in terms of concepts, properties, and semantic relations. A node ontology is organized as a two-layer architecture where the upper layer represents the *content knowledge* and the lower layer represents the *network knowledge*, respectively. The content knowledge layer describes the knowledge of a node, namely the knowledge about the resources that a node brings to the networked organization. The network knowledge layer provides a description of other parties of the networked organization providing resources that are semantically related to those described in the content knowledge layer of the considered node. A detailed description of the reference ontology model and of the architecture of a node ontology can be found in [2].

Ontology matchmaking techniques. In open networked contexts, nodes dynamically request to other parties for resources semantically compatible with a target resource (dynamic resource discovery). In this context, each node has to compare incoming requests against its node ontology, in order to discover whether it can provide resources matching the target. In order to address this requirement, appropriate ontology matching techniques are required capable to cope with different levels of detail in concept descriptions. For ontology matching, we note that in a node ontology, the meaning of ontology elements depends basically on the names chosen for their definition and on the relations they have with other elements in the ontology. An important requirement is related to the fact that these features can have a different impact in different ontology structures. We have developed matching techniques capable of performing dynamic matching at different levels of depth, with different degrees of flexibility and accuracy of results by taking into account various metadata elements (i.e., concept name, concept properties, concept relations) separately or in combination. Different *matching models* have been conceived with the goal of providing a wide spectrum of metrics suited for dealing with many different matching scenarios that can be encountered in comparing ontological resource descriptions in real open distributed systems. The choice of the appropriate matching model depends on the level of detail of the ontology description as well as on the expected degree of precision of the results. The shallow model is useful when only concept names are to be considered. It requires few computational resources since neither concepts properties nor their relations are considered. This model is well suited, for example, to perform an initial ontology comparison to decide wether it is worth performing a deeper analysis. If the ontology is constituted mainly by concepts with a few number of properties and hierarchical relation among concepts, the shallow and deep model allow a good degree of precision without requiring great amount of computational resources. In presence of an articulated ontology, with rich resource descriptions and where relations among concepts are described through property values, the intensive model guarantees the most accurate results, but is the most expensive in term of computational resources. A description of the H-Match algorithm and of its matching models is given in [2, 5].

3 Future research work

We are testing the H-Match algorithm on real matching cases, to evaluate and experiment performance and scalability issues posed by ontology-based query resolution considering large ontologies (e.g., Semantic Web ontologies). Furthermore, we will extend our matchmaking techniques to take into account also aspects related to the quality of ontology information. Future research activity will address the application and extension of the ontology-based semantic interoperability methods and techniques presented in this paper in the framework of the Helios (Helios Evolving Interaction-based Ontology knowledge Sharing) system conceived for supporting P2P-based semantic collaboration [3, 6]. The following requirements affect ontology-based semantic interoperability and collaboration in open networked organizations based on the P2P paradigm, and need to be addressed by appropriate methods and techniques: (i) *dynamism of the system*, in that nodes are allowed to join and leave the networked organization at any moment; (ii) *autonomy of nodes*, in that each node is responsible for its own knowledge management and representation and for interacting with other nodes; (iii) *absence of a-priori agreement*, about ontology vocabulary and language to be used for knowledge specification; (iv) *equality of node responsibilities*, in that no centralized nodes with coordinating tasks are recognized and each node enforces interaction facilities with other nodes for knowledge sharing and evolution.

In HELIOS, we are working in the direction of defining a semantic-based query distribution protocol in order to support an effective knowledge discovery process and the spontaneous and dynamic definition of semantic-based communities of interest [4]. We are studying appropriate strategies for the storage of new ontology concepts acquired from the network. The general aim of an evolution strategy is to support the enrichment of the knowledge in a node ontology by adding new concepts or by extending existing concepts with new knowledge acquired by other nodes (learning). Ontology evolution techniques have to support the management of the knowledge acquired from other nodes according to different evolution policies, by enforcing different levels of severity in concept assimilation.

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