ABSTRACT

A major challenge for service-oriented computing is how to discover and compose (Web) services to build complex applications. We present a matchmaking system that exploits both semantics and behavioural information to discover service compositions capable of satisfying a client request.

Keywords: OWL-S ontologies; Petri nets; Web service composition; Web service discovery

INTRODUCTION

The Web is rapidly evolving from being a collection of static information to a collection of services that interoperate through the Internet. Recently, increasing attention is devoted to service-oriented computing (SoC) (Papazoglou, 2003), a new emerging paradigm for distributed computing whose best-known instantiation is represented by Web services. Web services are software components that, thanks to their platform neutral and self-describing nature, should allow to construct complex applications faster and with less programming efforts. The current Web services infrastructure relies on WSDL (W3C, 2001c), SOAP (W3C, 2001a) and UDDI (UDDI, 2000). WSDL is a XML–based language for describing what a service does and how to invoke it. SOAP is a standard protocol for exchanging messages over HTTP between applications. UDDI allows for the definition of global registries where information about services are published. Currently, UDDI is the only universally accepted standard for Web service discovery.

Unfortunately, the current service infrastructure suffers from two main limitations: it does not support service composition and it does not account for semantics information. On the one hand, assuming that for each service request there exists a single Web service that perfectly satisfies it on its own, is rather unrealistic. In many cases, composing functionalities offered by different services may be needed to satisfy a client request. On the other hand, the availability of machine-understandable service descriptions is a must for automatising the processes of ser-
service discovery and composition. Regrettably, available WSDL interfaces provide neither semantics information to describe the service functionality nor behavioural information to describe the service interaction behaviour.

The problem of how to automate the composition of Web services is attracting quite some attention, as witnessed for instance by the definition of BPEL4WS (Andrews, Curbera, et al., 2003) and OWL-S (OWL-S Coalition, 2004), which are two XML-based languages for describing services. Both BPEL4WS and OWL-S allow to describe behavioural information about services, and OWL-S also allows to specify semantics information about them. Generally speaking, most approaches aim at overcoming either of the two above mentioned limitations. Some of them introduce semantics information to improve service discovery (not considering service composition issues), while others focus on composition issues (not considering semantics). We argue that both semantics and behavioural information should be taken into account in order to automate the discovery of service compositions. Semantics information can be fruitfully exploited for discovering (candidate) services, while behavioural information can be fruitfully exploited to compose them in a correct way.

In this perspective, in Brogi, Corfini, & Popescu (2005), we presented an algorithm for the composition-oriented discovery of Web services. Such algorithm performs a flexible matching over a registry of OWL-S service advertisements—considering both semantics and behavioural information—and determines whether there exists a service composition capable of satisfying a client request. The algorithm in Brogi et al. (2005), however, has two drawbacks. The first one is efficiency, as a dependency graph representing the behaviour of each service in the registry must be constructed at query answering time. The second drawback is that the algorithm guarantees neither the deadlock-freedom nor the minimality of the returned service composition.

In this article, we present a Petri net-based matchmaking system that overcomes the above mentioned drawbacks of Brogi et al. (2005). Our system takes advantage of both semantics and behavioural information advertised in OWL-S service descriptions. The main features of the proposed matchmaking system can be summarised as follows:

- Our system is strongly based on behavioural information, as it models services as Petri nets. The expressive power of Petri nets allows to easily model complex service compositions as well.
- Petri net representations of services can be precomputed and stored together with service descriptions, without affecting the efficiency of the matchmaking process.
- The control flow verification of Petri nets allows to determine whether or not the services in a composition terminate correctly.
- Last, but not least, the returned composition does not contain services that are not strictly necessary to satisfy the query.

The rest of the article is organised as follows. In the second section we briefly introduce OWL-S together with a motivating example, that we will use to illustrate our approach throughout the article. In the third section we show how OWL-S behavioural descriptions can be translated into Petri nets. The fourth section is devoted to present the architecture and the behaviour of the matchmaking system for the discovery and composition of services. Related works are discussed in the fifth section, while some concluding remarks are drawn in the sixth section.

**MATCHING SERVICES WITH OWL-S**

The currently adopted standards for Web services UDDI (UDDI, 2000), SOAP (W3C, 2001a) and WSDL (W3C, 2001c) do not deal with semantics information. To overcome the consequent inaccuracy of service discovery, the W3C consortium promotes the adoption of new semantic-based formalisms for describing services. OWL-S (OWL-S Coalition, 2004) is
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