Service discovery in open Service-Oriented Multi-Agent Systems

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Abstract. This thesis proposes a model that enhances service discovery in open Service-Oriented Multi-Agent Systems. In this model, agents have a bounded rationality, environment conditions do not remain constant, and not all the agents have a cooperative behavior. Our proposal integrates a network structure and search strategy as well as self-organization mechanisms and strategies for promoting cooperation in open and dynamic environments.

Keywords: Service discovery, complex networks, self-organization, cooperation

1. Introduction

Nowadays, there is a trend towards the design and development of open systems that are populated by a large number of entities that interact with each other in order to share their resources or achieve a complex goal. The integration of Service-Oriented Computing and Multi-Agent Systems is gaining importance due to their suitability for coping with the requirements of this type of systems [1].

In open Service-Oriented Multi-Agent Systems (MAS), agents can represent and act on behalf of real entities (i.e. providers of web services) and offer their functionality through services. Usually, agents only have a local view of their environment. There is no central control on how agents should be connected or disconnected and there is no maintenance of system structure. These features provide more flexibility and adaptability to the system. However, the management of the information about which agents or services are available at a certain moment, as well as how to locate them in an efficient way are considered challenges.

In this thesis, we present a model that facilitates the service discovery in Open Service-Oriented MAS. This model creates a navigable network structure that facilitates the service discovery for agents with bounded rationality. Moreover, the proposed model provides self-organization mechanisms to maintain the performance of the service discovery process when service demand changes and includes strategies that facilitate the promotion and maintenance of cooperation.

2. Decentralized service discovery

The underlying structure has a direct influence in service discovery strategies in distributed environments. In this thesis, we present an underlying structure based on a social self-organizing criterion called *homophily* [6]. Agents establish links with other agents by considering their homophily. In this context, homophily consists of the semantic similarity of two social dimensions: services that agents offer and the organizational roles that agents play. This criterion is also used to guide the service discovery process using local information. Our proposal improves previous approaches for service discovery since it considers all the agents to be equal and they only consider local information. Therefore, the system provides robustness, scalability and adaptability. Second, the system is self-organized based on homophily between agents and does not need an initial period to establish its structure. Third, each agent only maintains a local view of the services it offers and who are its neighbors, and it does not maintain information about routes that could change frequently in highly dynamic environments. Fourth, the service discovery algorithm is based on semantic information and not just keywords or predefined categories.

3. Self-organization

Service discovery systems are deployed in dynamic environments and are expected to perform well un-

der many circumstances (i.e., when the number of available agents changes, or when the service demand varies with time) [5]. However, the majority of the proposals for service discovery in distributed systems are only focused on the location task and do not consider the inclusion of self-organization mechanisms. The structural adaptation plays an important role since structural relations determine the interactions between the agents, their local knowledge, and, therefore, the performance of the service discovery process.

We propose two self-organization mechanisms in the service discovery process [3]. One mechanism focuses on how relations between agents could be rearranged to improve service discovery performance. The other mechanism considers the adaptation of the agent population according to the service demand. The main advantages of this proposal are that the self-organization of the system is a continuous process that is carried out by each agent; each agent is able to reason about when it is most appropriate to make a self-organization decision; agents only require local information; and, dynamics about structural relations and population are taken into account.

4. Cooperation emergence

Cooperation plays an important role for service discovery in open Service-Oriented MAS where agents have a bounded rationality. Agents need the cooperation of their neighbors in order to locate other agents that offer services that they require. Therefore, if selfish agents appear, in the long term, the service discovery process could be seriously compromised. For this reason, our model provides mechanisms that facilitate the emergence and maintenance of cooperation through and adaptive combination of *incentives* and *social plasticity* [4]. *Incentives* influence the behavior of other agents providing a reward to those agents that participate in a service discovery process that ends successfully. Therefore, if there is a high number of cooperators, forwarding queries is considered to be a beneficial action with high probability. However, as the number of non-cooperators increases, this action becomes reckless and less profitable. Incentives are suitable for the emergence of cooperation in scenarios where the number of non-cooperators is not greater than the number of cooperators. Otherwise, social plasticity is used to ostracize selfish agents. *Social plasticity* allows agents to change their structural relations based on the degree of cooperation of their neighbors. As the number of times a neighbor refuses to forward a query increases, the probability of changing this relation increases.

5. Conclusions

This PhD work presents a model to enhance the service discovery in open Service-Oriented MAS. This model integrates: (i) strategies to facilitate the service discovery for agents situated in loosely structured networks; (ii) self-organization mechanisms to maintain the performance of the system when service demand changes; (iii) strategies that facilitate the promotion and maintenance of cooperation in open environments where cooperation is a requirement to carry out the service discovery activity. The whole PhD thesis can be consulted in [2].

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