Emergence of Cooperation through Structural Changes and Incentives in Service-Oriented MAS

(Extended Abstract)

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ABSTRACT

In distributed environments where entities only have a partial view of the system collaboration plays a key issue. In the case of decentralized service discovery in Service-Oriented MAS (SOMAS), agents only know about the services they provide and their direct neighbors. Therefore, they need the collaboration of their neighbors in order to locate the required services. However, collaboration is not always present in open and distributed systems. Non-collaborating agents pursuing their own goals could reject forwarding queries from other agents; therefore, the efficiency of the decentralized service discovery could be seriously damaged. In this paper we propose the combination of structural changes and incentives based on utility in order to promote the collaboration in the service discovery process.

Categories and Subject Descriptors

H. [**Information Systems**]

General Terms

Management, Performance

Keywords

Incentives, collaboration, service discovery, complex networks

1. SERVICE DISCOVERY SYSTEM

SOMAS are characterized by a finite set of agents $A = \{a_1, ..., a_n\}$, which offer their functionalities through services, and a set of links $L \subseteq A \times A$, which indicates the existence of a direct relationship between two agents. It is assumed that the knowledge relationship among agents is symmetric, so the network is an undirected graph.

In our model, agents are characterized by a tuple of five elements $(S_i, N_i(t), st_i(t), \Omega_i(t))$ where:

- S_i is the set of services provided by the agent
- N_i is the set of neighbors of the agent, $N_i \subseteq A - \{a_i\}$: $\forall a_j \in N_i, \exists (a_i, a_j) \in L$, and $|N_i| > 0$. It is assumed that $|N_i| \ll |A|$. Links between agents are established based on a social feature called homophily which measures the similarity between agents considering the services that the agents offer. For a detailed mathematical treatment of how homophily between agents is calculated, we refer the reader to [4];
- $st_i(t)$ is the internal state of the agent at a given time t. It is defined by a set of $(q, \#fw(t), \#sfw(t), \#rq(t), \#q(t), \#r(t), \varepsilon)$:
  - q represents the query that the agent receives asking for a service,
  - $\#fw(t)$ is the number of queries that the agent forwarded until time t,
  - $\#sfw(t)$ is the number of queries that the agent forwarded in a successful discovery processes until time t,
  - $\#rq(t)$ is the number of queries that the agent refuses to forward until time t,
  - $\#q(t)$ is the number of service requests attended by the agent until a given time t,
  - $\#r(t)$ is the number of service requests sent by an agent until a given time t,
  - ε is the threshold established by the agent to consider a service similar enough to a query.
- $\Omega_i = \{\omega_i(t), \omega_j(t+1), ...\}$: is the set of strategies used by the agent. Each strategy defines its behavior at a given time t.

Service discovery process in our system relies on the collaboration of the agents. The process starts when an agent a_i is looking for an agent a_t that provides a service s_t. The agent redirects the query to the most promising agent in its neighborhood. The most promising neighbor, $a_j \in N_i$, is the neighbor that is most similar to the target agent a_t (higher degree of homophily) that has the highest degree of connection. The selection function that calculates the most promising neighbor a_j of an agent a_i to reach the agent a_t is described with detail in [4].

If a_j does not offer a service that is similar enough, it chooses between two options: to forward the query or to not forward the query. If a_j does not forward the query, it sends a reject message to a_i, and a_i looks for another promising agent in its neighborhood to redirect the query. If a_j accepts forwarding the query, the query is sent to the most promising agent in the neighborhood of a_j. This process is repeated until the agent that offers a service that is 'similar enough' is found or when the TTL (Time To Live) of the query ends.

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2. STRUCTURAL CHANGES AND INCENTIVES

Distributed systems rely on the collaboration of the entities that participate in them. However, in open and heterogeneous environments, a common and more realistic situation is that selfish agents appear [1]. It is important to provide mechanisms to be able to confront the situation where agents that are pursuing their own goals without collaborating are damaging the performance of the overall system [3].

2.1 Structural Mechanism

Through interactions, agents should be able to change their relations taking into account which neighbors provide profitable relationships and which do not. This feature is called social plasticity [2]. In order to evaluate a link's utility, an agent uses a decay function that evaluates the probability of maintaining a link considering the number of queries rejected. This function is a sigmoid that ranges between [0,1],

$$D_{(a_i,a_j)}(\#rq,t) = 1 - \frac{1}{1+b\cdot e^{\frac{-(\#rq-m)}{n}}}, \tag{1}$$

where $\#rq$ is the number of queries that have arrived to neighbor a_j from agent a_i and a_j decides not to forward at a given time t. The parameters b and m are the displacement, and n is the steepness. These parameters are adjusted by the agent. If a query is forwarded through the link (a_i, a_j), $\#rq$ is updated to 0. Otherwise, the $\#rq$ is increased by one unit.

In the case that the agent a_i decides to break the link with neighbor a_j, a_i looks for another agent to establish a new link in order to maintain its degree of connectivity. We assume that any alternative agent always accepts a new partner. There are different criteria for establishing a new link with another agent in the network: establish a link with a neighbor's neighbor [2], look for a similar agent to me in order to keep the homophily of the system, look for an agent similar to the previous neighbor.

2.2 Incentive Mechanism

In our model, the strategies that an agent can choose at a given time $\omega_i(t)$ are : to collaborate or to not collaborate. Collaborating in the service discovery scenario implies that the agent is going to: forward queries, request services, and attend requests about its services. If the agent decides not to collaborate, it means that the agent is going to: request services and offer its services, but it is not going to forward the queries of neighbors. Considering the possible strategies and the actions involved in each strategy, the following utility function is defined:

$$u_i(\omega_i,t) = \begin{cases} \#q(t)\cdot PS - \#r(t) + RS & \text{if } \omega_i = \text{not coll.} \\ -\#fw(t)\cdot Q + \#sfw(t)\cdot SQ + & \text{if } \omega_i = \text{coll.} \\ \#q(t)\cdot PS - \#r(t) + RS & \end{cases} \tag{2}$$

where ω_i is the strategy used by the agent at a given time t, and $\#q(t), \#sfw(t), \#fw(t), and\#r(t)$ is information of the internal state of the agent at a given time t (see Definition 1). In this function each action in the model implies a cost (forwarding queries (Q), and requesting a service (RS)) or a benefit (forwarding queries in a service discovery process that ends successfully (SQ), and providing a service (PS)).

We assume that all the agents have the same payoffs. Agents are rational entities that update their own behavior to maximize their own benefit. They also take into account the utility of their direct neighbors, and update their strategy. If the agent has a neighbor that has obtained a higher payoff in the previous iteration, the agent changes its strategy to the neighbors' strategy.

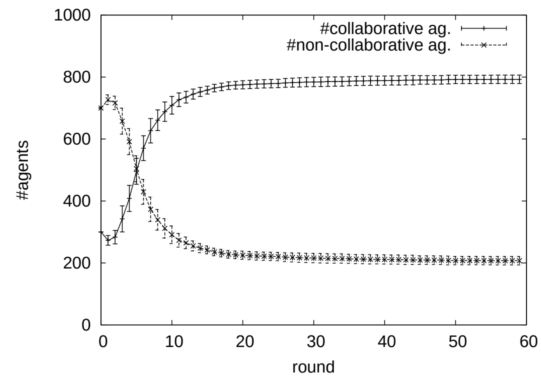

Figure 1: Evolution of collaboration in networks of 1000 agents (300 C and 700 NC). Agents consider utility and plasticity.

2.3 Structural Changes and Incentives

The use of structural mechanisms such as social plasticity or incentives promote the emergence of cooperation. Nevertheless, in scenarios where the predominant behavior is not to collaborate, the separate use of these mechanisms is not enough. Social plasticity could break the network and incentives cannot change the behavior due to the high number of non-collaborators. Therefore, we propose the integration of both mechanisms in order to facilitate the emergence of collaboration.

Basically, each agent evaluates its links considering whether or not its neighbors are collaborating in the forwarding process. This evaluation is done each time an agent receives or generates a query (see Eq. 1). With the result of this evaluation, the agent decides whether or not change its links. Moreover, in each iteration, each agent updates its utility and compares it with the rest of its direct neighbors. Based on this comparison, the agent decides whether or not to change its behavior in order to improve its payoff in future interactions. The results show that, even in scenarios where the predominant behavior is to not collaborate the collaboration emerges.

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4. REFERENCES

[1] B.-G. Chun, R. Fonseca, I. Stoica, and J. Kubiatowicz. Characterizing selfishly constructed overlay routing networks. In *INFOCOM*, 2004.

[2] V. M. Eguiluz, M. G. Zimmermann, C. J. Cela-Conde, and M. S. Miguel. Cooperation and emergence of role differentiation in the dynamics of social networks. *Am. J. Sociol.*, 2006.

[3] J. Kleinberg. Social networks, incentives, and search. In *Proceedings of the 29th ACM SIGIR*, 2006.

[4] E. D. Val, M. Rebollo, and V. Botti. Self-Organized Service Management in Social Systems. In *45 HICCS*, 2012.