Decentralized Service Management based on Homophily for Self-Adaptive SOMAS

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***Abstract*—Humans create efficient social structures in a self-organized way based on a feature called homophily. This paper proposes the use of homophily in Service-Oriented Multiagent Systems to create efficient self-organized structures and provide a decentralized service management.**

***Keywords*-Service management; self-adaptive systems**

I. Introduction

Nowadays, there is a trend towards large-scale and highly-dynamic systems. Peer-to-peer technologies (P2P), cloud computing systems or Service-Oriented Multiagent Systems (SOMAS) are more and more populated by entities that change frequently and look for other entities to collaborate in order to get a resource or to deal with a complex goal. Therefore, the system should provide mechanisms to manage the available resources and to adapt themselves to the changes in the environment.

Human beings are able to create efficient social structures, in a self-organized way, without the supervision of a central authority.These structures allow individuals to locate others in a few steps taking only local information into account. One of most salient properties present in these social networks is *homophily* [1]. The idea behind this concept is that individuals tend to interact and establish links with similar individuals along a set of social dimensions.

In this paper, we propose a decentralized service management system for SOMAS based on two types of homophily: *choice* and *structural*. *Choice homophily* is considered to build the system structure and to guide the search of services. *Structural homophily* is used in the system for self-adaptation of the agents to the system demand.

II. System Model

The system is defined as $MAS = (A, L)$, where $A = \{a_1, ..., a_n\}$ is the a finite set of autonomous agents that are part of the system and $L \subseteq A \times A$ is the set of links. It is assumed that the knowledge relationship among agents is symmetric, so the network is an undirected graph. An agent $a_i \in A$ is characterized by a tuple (R_i, N_i) where: $R_i = \{r_1, \ldots r_m\}$ is the set of roles played by the agent; N_i is the set of neighbors of the agent, $N_i = \{a_p, ..., a_q\} : \forall a_j \in N_i, \exists(a_i, a_j) \in L$, and $|N_i| > 0$. It is assumed that $|N_i| \ll |A|$. A role $r_i \in R_i$ is defined by the tuple (ϕ_i, S_i), where: ϕ_i is a semantic concept for the role; $S_i = \{s_1, \ldots, s_l\}$ is the set of semantic services offered by the agent.

III. Using Homophily For Community Creation

Homophily is introduced to create self-organized structure in which agents are linked to similar ones. *Choice homophily* ($CH(a_i, a_j)$) is the factor that allows the agents to establish links with other agents and to redirect queries about services that they cannot offer. Choice homophily is subdivided into two types: (i) *status homophily*, which is related to the formal or informal status similarity of the individuals, in the case of agents this is identified with the semantic description of the role; and (ii) the *value homophily*, which is based on the similarity of shared attributes, in the case of agents is the semantic description of the services it offers ($CH(a_i, a_j) = \varphi * H_s(R_i, R_j) + (1 - \varphi) * H_v(S_i, S_j)$). The link between two agents is established taking into account the *choice homophily* between the agents. The system structure can be considered to be a preferential attachment network, which grows according to a simple self-organized process. Because the homophily condition is a probability function, it allows new agents not only to establish 'direct connections' between agents with similar attributes, but also between agents that are not similar. These connections are responsible for the small-world characteristics of the system, which allow agents to locate other agents efficiently by using only local information. The selected algorithm for service discovery in the system is an extension of the EVN algorithm [2], which is a greedy, mixed algorithm that uses degree and similarity. It has been modified to use the choice homophily as similarity measure that integrates role information with the service description (see Figure 1) [3].

IV. Structural Homophily For Self-Adaption

Structural homophily reflects how similar the services it offers are to the services demanded in the system. In the system, each agent controls the queries that pass through it. Each agent classifies each query into one category by calculating the degree of matching between the required service and one of its services that it uses as reference for the query classification. With this information each agent periodically analyzes its structural homophily. With this

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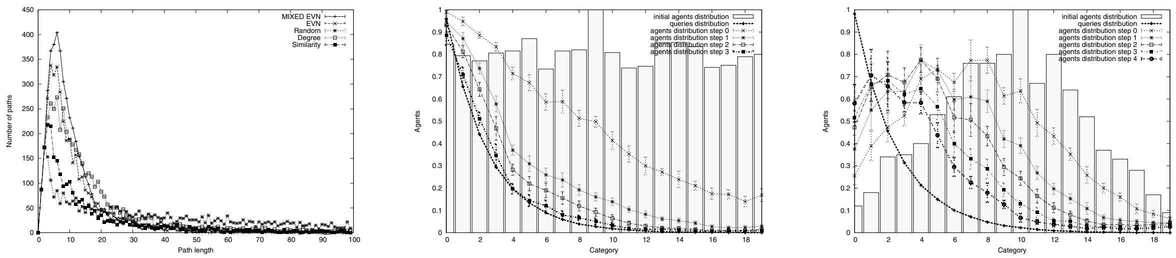

Figure 1: Performance of the service search. Frequency of path length in successful searches using different search strategies (left). Adaptation process for different initial agent distribution: uniform (middle), and normal (right). It is assumed that the request distribution in the system follows an exponential function. After the adaptation of each agent in the system, the agent distribution should follow the same exponential distribution. The results are normalized to compare the size of the network with the distribution of the queries. Bars show the initial distribution, lines show the agent distribution obtained after each adaptation step, and the query distribution. The final adaptation step and the query distribution are stressed in bold.

local information, the agent decides whether to continue in the system because its services are demanded, or leave it.

We assume that the traffic is modeled as an exponential distribution. Then, using a least squares method, the agent fits the distribution of the data to an exponential curve $y = a \cdot e^{b \cdot x}$. With this function, the agent evaluates whether or not the services demanded in the system correspond to the services it offers. The agent substitutes the categories c_i of each one of the services it provides in the exponential function to get the estimation of the demand. The structural homophily of the agent is the maximum value obtained among its services ($SH(a_i) = a \cdot e^{bc_i}$ where $c_i = \underset{x}{\operatorname{argmax}}\, a \cdot e^{b\ x}$).

Each agent is able to decide autonomously to stay in the network or to drop because it is not useful. The probability of both facts depends on the structural homophily calculated, so $P_\psi(\text{stay}) = SH(a_i)$ and $P_\psi(\text{drop}) = 1 - SH(a_i)$. But if an agent decides to leave the network, a service can become eventually unavailable. To avoid that, if the agent is the last member of one category in its neighborhood, it will hold with a probability that depends on the similarity with its neighbors $P_\psi(\text{hold}) = 1 - g(x) = 1 - \frac{\sum_{j \in N_i} CH(a_i, a_j)}{N_i}$. On the other hand, agents can be saturated if they number of queries that it receives increases, so agents that decide to stay, can be 'cloned' with a probability that depends on the increment of the traffic Δt managed by the agent $P_\psi(\text{clone}) = 1 - f(x) = 1 - \frac{1}{1+e^{\Delta t}}$. By combining these behaviors, the possible actions an agent can take are the result of the adapting function are $\Psi = \{leave, continue, replicate\}$, with probabilities:

$$
\begin{aligned}
P_\psi(\text{leave}) &= P_\psi(\text{drop} \cap \overline{\text{hold}}) = (1 - SH(a_i))g(x) \\
P_\psi(\text{continue}) &= P_\psi(\text{stay} \cap \overline{\text{clone}}) + P_\psi(\text{drop} \cap \text{hold}) = \\
&= SH(a_i)f(x) + (1-SH(a_i))(1-g(x)) \\
P_\psi(\text{replicate}) &= P_\psi(\text{stay} \cap \text{clone}) = SH(a_i)(1-f(x))
\end{aligned}
$$

In Figure 1, the agents analyze their $SH(a_i)$ in 4 steps (middle) and 5 steps (right). Each step consists of 20,000 search requests. It can be observed that the most important adaptation occurs in the first step, where the agents with services that are less demanded disappear and only a few of them remain in the system.

The aim of this work is to investigate how the integration of different areas such as SOMAS and social networks provide the necessary tools to build a decentralized and self-adaptive service management system. This system is based on homophily: a sociological concept that is present in many human networks created in a decentralized way. For this reason, homophily has been introduced in the system. Choice homophily is used to create a preferential attachment system based that facilitates the search process. Moreover, the system is able to adapt itself to the service demand in a completely decentralized way analyzing its structural homophily.

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