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Participant Selection for Short-term Collaboration in Open Multi-agent systems

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ABSTRACT

In multi-agent systems, agents coordinate their behaviour and work together to achieve a shared goal through collaboration. However, in open multi-agent systems, selecting qualified participants to form effective collaboration communities is challenging. In such systems, agents do not have access to complete domain knowledge, they leave and join the systems unpredictably. More importantly, agents are mostly self-interested and have multiple goals and policies that may be even conflicting with others, which makes the participant selection even more challenging.

Many of the current approaches are not applicable in constantly evolving open systems, where their performance will be affected by any unpredictable behaviour, agents' lack of complete domain knowledge and the impossibility of having a central coordinator agent. In open systems, agents require a mechanism that enables them to dynamically change their perception of the environment and observe their neighbouring agents, so that they can identify qualified collaboration participants that have no conflicting goals and to balance their level of cooperation and self-interest.

In this paper, we propose OPSCO, as a solution for On-demand Participant Selection for Short-term Collaboration in Open multi-agent systems. Unlike the existing research, we do not assume any predefined setting for agents' structure in the system and do not have access to complete domain knowledge and allow each agent to build a dynamic dependency model and maintain when there is a change in the system. The model captures the agent's most recent dependency structure of goals and policies with its neighbouring agents. It enables them to identify and select a qualified non-conflicting set of participants.

OPSCO is evaluated in a real world open system smart grid and constrained resource sharing case studies. OPSCO outperforms other methods by selecting a qualified non-conflicting set of agents to collaborate. OPSCO balances the self-interest and level of cooperation and decreases failure in the overall agents' goals (individual/shared).

1. Introduction

Multi-agent collaboration is a coordinated behaviour in which a set of agents will be selected to form a collaboration community and cooperate to fulfil a shared goal [3,12]. A qualified non-conflicting collaboration community is the key to a successful collaboration. This is addressed well in closed multi-agent systems, as complete domain knowledge exists and

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agents are considered to be fully-collaborative. However, an important portion of multi-agent collaboration happens in open distributed systems in real world scenarios. As an example, in congestion management, vehicles may collaborate to achieve better throughput at junctions [5], or in residential energy demand management system, households may collaborate to make better use low cost ene.g. [10]. In such systems, (1) agents leave and join the system frequently and unpredictably, (2) they have different goals and policies which are likely to be conflicting, (3) agents are more likely to be self-interested, (4) acquiring complete domain knowledge is either costly or impossible as agents are not interested to reveal all their internal states, and (5) having a central coordinator to control all the agents is impossible [14].

In many of the existing work in multi-agent cooperative approaches, one or more the above assumptions are violated. Therefore, the existing approaches are not applicable in open systems. In many of the related work, it is assumed that the agents' organizational structure is known [9,11,15,21]. For building such structure in design or run-time, they need to have access to complete domain knowledge including the number of agents in the system, their goals, plans and policies. Moreover they assume all the agents to be fully-cooperative, and they do not consider agents' having multiple goals and policies and their dependencies that affect the cooperative process. These assumptions are not applicable in open systems, first, the number of agents and their dependencies with other agent is highly dynamic as agents behave unpredictably. Second, because agents are self-interested and are not benevolent or willing to share their internal states and cooperate unless there is a good reason for it [2]. Third, selecting a set of agents with conflicting goals for collaboration results in a large number of communication and finally an unsuccessful collaboration community formation process.

To address the issues with existing work, in this paper, we propose OPSCO, a solution for **O**n-demand **P**articipant **S**election for short-term **C**ollaboration in **O**pen multi-agent systems. The solution is designed for open multi-agent systems as characterized in the five points above. We are assuming a community of agents with multiple goals and multiple policies that can be conflicting. Agents do not have access to complete domain knowledge. They join and leave the system frequently and unpredictably. There is no central coordinator agent to manage the participant selection process.

In our approach, instead of sharing the complete domain knowledge (e.g. joining and leaving time, action selection strategy) with every single agent in the system, information exchanges are limited to agents in the neighbour community and only small privacy preserving subset of information is shared. Based on this information, they build and maintain a dynamic dependency model, which will be updated when an agent leaves or a new agent joins the neighbour community. Agents then use this model when there is a need for collaboration to select the qualified set of participants.

We evaluate OPSCO in smart grid, demand response scenario which is a real world example of a multi-agent open system. This scenario includes a community of houses that uses electricity for different devices including electrical vehicles. The reasons why we chose it are as follows: First, it depends on human beings' behaviours which adds some unpredictability and privacy issues to it. This makes it impossible to have access to complete domain knowledge. Second, the electrical vehicles can leave and join the community frequently and the number of electrical vehicles is not fixed. Third, different individual goals and policies and a shared goal can be defined for each electrical vehicles as they use a shared resource to achieve their individual goals. Therefore it can cover both self-interest and cooperative characteristics, when they interact with each other within a neighbour community to use their shared resource. These characteristics allow us to evaluate OPSCO in real world circumstances.

The rest of this paper is organized as follows: Section 2 reviews the related work. Section 3 formally defines OPSCO problem, discusses what data should be shared, specifies when the collaboration need emerges. It also presents a new representation for modelling Neighbouring Agents Relational Network, and introduces an algorithm for participant selection that agents use along with their Neighbouring Agents Relational Networks to select a set of participants. Section 4 presents the experimental design and Section 5 evaluates OPSCO and discusses the results in smart grid and resource sharing scenarios. Finally, the conclusion and future work is discussed in Section 6.

2. Related work

Collaboration participant selection depends on the agents' organization network structure. Such a structure can be defined using agents' individual and collective behavioural and structural characteristics, such as roles, policies, intentions and goals [13]. In cooperative behaviours such as coalition formation and teamwork [15,21], the agent's network structure is not either explicitly modelled or it is considered to be a fully connected network, where agents can communicate with all other agents in the community. These assumptions are valid when the number of agents does not change or it changes in a predicted pattern, so that other agents in the system would know the rest of the agents operating in the system. Other approaches consider a neighbour community network [8], where agents can only communicate with their neighbours. The neighbour communities and agents' dependencies need to be updated and adapted to the changes in their dynamic environment. Such dynamic adaptation has been addressed mostly with performance-based strategies in which agents reconsider their connectivities with their neighbours based on their previous performance [8]. Although this approach helps to find the most helpful agents with single goal, it may not be a practical solution when agents have multiple goals and policies. Therefore, performance cannot be assumed as the sole factor for participant selection in open systems. Another factor that is used to form the agents' organization network is tasks dependencies [8,9,22]. The task-based networks facilitate the participants selection process for either achieving a shared goal (e.g., in teamwork, system level optimality) or an individual goal (e.g., in cooperative process, individual level optimality) [7]. However, they are not helpful solutions for participant selection when agents have simultaneous shared and individual goals and it cannot balance the level of cooperation and self-interest.

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