ABSTRACT

Single convention convergence across different types of networks is a challenging multi-agent task. Our central hypothesis in this paper is that no simple distributed mechanism (such as the state-of-the-art Generalized Simple Majority (GSM) rule) can achieve this. We augment the agents with “network thinking” capability to solve this single convention convergence problem. Topological features such as node degree is used to design the accumulated coupling strength (ACS) convention selection algorithm. However, ACS does not perform as well in random networks as GSM does. Hence we propose a topology aware convention selection (TACS) algorithm that enables the agents to predict their local neighborhood topology and then to select a suitable convention selection algorithm. We have performed an extensive simulation study on random and SF networks showing that the majority of the agents correctly recognize their topology and use the appropriate convention mechanism leading to the convergence into a single convention.

Categories and Subject Descriptors
I.2.11 [Distributed Artificial Intelligence]: Multiagent Systems

General Terms
Algorithms, Design, Experimentation

Keywords
Multi-agent systems, Scale-free network, Random network, Convention Selection Algorithm, Network Thinking

1. INTRODUCTION

Reaching an agreement, a convention, or a consensus, is a fundamental coordination problem in multi-agent systems [3]. In such a problem, each agent is faced with a number of plausible alternatives to choose from, and the goal is for all the agents to agree on the same alternative.

Several simple mechanisms for reaching a convention were proposed, such as social learning [2] and Generalized Simple Majority (GSM) rule [1]. GSM used a non-deterministic approach where an agent chooses a convention with a probability proportional to dominance of the convention among the agent’s neighbors. It was shown experimentally and argued theoretically that agents using GSM converge into a single convention in a variety of complex networks, including Scale-Free (SF) and Small-World (SW) networks [1].

The central hypothesis in this paper is that no simple distributed mechanism (such as GSM) works well across different types of complex networks. In Section 3, we empirically show that GSM does not work in sparse SF networks (a clear contradiction with the previous work [1]). In response, we propose another simple convention selection mechanism that works well for SF networks. Our proposed mechanism is called Accumulated Coupling Strength (ACS) that only requires the agents’ knowledge about their immediate local neighborhood and encodes all past interactions in agents’ state to create a social pressure that expedites the convergence. We empirically confirm, in congruence with our hypothesis, that ACS does not work as well in Random Networks as GSM does. We then propose a topology-aware convention selection (TACS) mechanism that enables agents to predict the underlying network topology and to choose a suitable mechanism accordingly. TACS is fully distributed and uses information only from immediate neighbors to predict the underlying topology based on the maximum likelihood principle.

2. PROPOSED SOLUTION

We propose a convention selection algorithm (ACS) that is best suited for SF networks. However, ACS does not work as well in random networks as GSM does (we experimentally verify this in Section 3). Therefore, we propose a topology aware convention selection algorithm (TACS) that works across both SF and random networks.

Accumulated Coupling Strength: The ACS convention selection algorithm is based on a simple intuition that agents might find it beneficial to adopt the conventions of their socially influential neighbors. During initialization of the game, this social influence of an agent is captured by its Coupling Strength (CS) that is represented by its degree [4]. Therefore, initially agents with higher-degree bear large CS and are in a position to induce greater influence over their neighbors to adopt its convention. We require that the CS of each agent gets accumulated by adding the degree of its neighbor node from which it has adopted the convention. In other words, whenever a new node i adopts its neigh-
to a single convention. In contrast, the performance of the ACS and the TACS differs significantly in these random networks with p-values always less than 0.05.

In SF networks the performance of the TACS is good. The difference in the performance between the TACS and the ACS is not significant for smaller networks (size less than 2000) with p-values greater than 0.05. However, GSM performs poorly in SF networks (p-values always less than 0.05). Therefore, TACS enables the large majority of the agents to correctly predict their topology and use either GSM (for random networks) or ACS (for SF networks) that lead to the convergence into a single convention.

3. EXPERIMENTAL RESULTS

We conducted extensive simulations to evaluate the performance of our proposed topology aware convention selection algorithm (TACS) on random and SF networks.

Table 1 shows the performance of the TACS in comparison with the performance of the GSM and the ACS for various size random and SF networks. We conduct 50 simulations by creating distinct instances of the networks. Each simulation consists of 1000 time steps where a time step is a single run of the program. For random networks we notice that the TACS performs as well as the GSM. Overall the difference in the performance between the TACS and the GSM in random networks is not significantly different with p-value greater than 0.05. The exceptions are the 100, 1000 and 2000 size networks where the p-values are less than 0.05. However, even in these networks both the TACS and the GSM always lead to a single convention. In contrast, the performance of the ACS and the TACS differs significantly in these random networks with p-values always less than 0.05.

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4. REFERENCES