Task Allocation for Undependable Multiagent Systems in Social Networks

Yichuan Jiang, *Senior Member*, *IEEE*, Yifeng Zhou, and Wanyuan Wang

Abstract—Task execution of multiagent systems in social networks (MAS-SN) can be described through agents' operations when accessing necessary resources distributed in the social networks; thus, task allocation can be implemented based on the agents' access to the resources required for each task and aimed to minimize this resource access time. Currently, in undependable MAS-SN, there are deceptive agents that may fabricate their resource status information during task allocation but not really contribute resources to task execution; although there are some game theory-based solutions for undependable MAS, but which do not consider minimizing resource access time that is crucial to the performance of task execution in social networks. To achieve dependable resources with the least access time to execute tasks in undependable MAS-SN, this paper presents a novel task allocation model based on the negotiation reputation mechanism, where an agent's past behaviors in the resource negotiation of task execution can influence its probability to be allocated new tasks in the future. In this model, the agent that contributes more dependable resources with less access time during task execution is rewarded with a higher negotiation reputation, and may receive preferential allocation of new tasks. Through experiments, we determine that our task allocation model is superior to the traditional resources-based allocation approaches and game theory-based allocation approaches in terms of both the task allocation success rate and task execution time and that it usually performs close to the ideal approach (in which deceptive agents are fully detected) in terms of task execution time.

Index Terms—Social networks, multiagent systems, task allocation, load balancing, undependable, deceptive agents

1 INTRODUCTION

dependable

undependable

guarantee dependable resource access as well as minimize resource access time.

negotiation reputation

achieving dependable resource access and minimizing the tasks' necessary resource access time.

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2 Related Work

2.1 Task Allocation Based on Resources

dependable

2.2 Task Allocation Based on Game Theory and Mechanism Design

2.3 Task Allocation in Networked Multiagent Systems (N-MASs)

satisfying

adjusting

3 Problem Description

3.1 Formalization of Task Allocation in MAS-SN

Definition 1. *Given a MAS-SN, $<A, E>$, where A is the set of agents, and $\forall <a_i, a_j> \in E$ indicates the existence of a social relation between agent a_i and a_j. It is assumed that the set of resources in agent a_i is R_{ai}, and the set of resources required by task t_j is R_{tj}. If the set of tasks is $T = \{t_1, t_2, \ldots, t_m\}$, the task allocation in MAS-SN can be defined as the mapping of task $\forall t_j \in T$, $1 \leq j \leq m$, to a set of agents, A_{tj}, which can satisfy the following situations:*

1. *The resource requirements of t_j can be satisfied, i.e., $R_{tj} \subseteq \cup_{\forall a_x \in A_{tj}} R_{ax}$;*
2. *The predefined objective can be achieved by the task execution of A_{tj}.*

3. *The agents in A_{tj} can execute the allocated tasks under the constraint of social network, for example, $\forall a_x, a_y \in A_{tj}$, $N_{xy} \subseteq E$, where N_{xy} denotes the negotiation path between a_x and a_y.*

3.2 Objective of Task Allocation in MAS-SN

[illegible] *, to reduce the execution time of a task, one of the key problems is to reduce the time used accessing the resources necessary for the task.* [illegible] *, o reduce the execution time of a task, we can reduce the utilities of resource access time that include two factors: the communication time between the manager agent and contractor agents in the social network, and the task's waiting time for resources at the agents* [illegible]

[illegible] t [illegible] a_t [illegible] t [illegible] A_t [illegible]

2.

5.2 Task Allocation Mechanism

5.2.1 Introduction of Manager/Contractor Architecture

manager agent).

contractor agents),

5.2.2 Allocation to Manager Agent

Definition 8. *Let $n_j(k)$ denote the amount of resource r_k owned by agent a_j.* ... *a_i for resource r_k is then defined as follows:*

$$\Phi_i(k) = \sum_{\forall a_j \in (A-\{a_i\})} \left(\lambda_j \cdot n_j(k) \cdot \left(cn_{ij} \Big/ \sum_{\forall a_j \in (A-\{a_i\})} cn_{ij} \right) \right) + \lambda_i \cdot n_i(k), \tag{4}$$

where λ_j is used to denote that the negotiation reputation of agent a_j (which is determined by the negotiation history between a_i and a_j and the negotiation histories between all other agents and a_j) can influence the probability that a_i will obtain dependable resources from a_j. Thus, even if there are few negotiation histories showing that a_i received resource from a_j (i.e., the negotiation strength from a_i to a_j is low), the probability that a_i can dependably obtain resources from a_j may be high when λ_j is high. Therefore, it is more likely to obtain dependable resources from the agent with the highest negotiation reputation.

Theorem 1. *It is assumed that task t requires resource r_k, and the reputation values are correct. Let there be two agents, a_1 and a_2; $P_i(t-k)$ denotes the probability that task t can obtain dependable resource r_k from agent a_i. Therefore, $\Phi_1(k) > \Phi_2(k) \Rightarrow P_1(t-k) > P_2(t-k)$.*

Proof. □

$\Phi_i(k)$ ... a_i ... r_k ... *So our allocation of manager agent satisfies Objective 1 of task allocation.*

5.2.3 Allocation to Contractor Agents

Definition 9. *Let a_t be the manager agent for task t. It is assumed that a_j will be negotiated by a_t for resource assistance.* ... *a_j* ... *t is as follows:*

$$V_j(t) = \alpha \cdot (1/d_{tj}) + (1-\alpha) \cdot \left(\lambda_j (|R_{a_j} \cap \overline{R_t}| / |\overline{R_t}|) \right), \tag{5}$$

where α is a parameter, λ_j is the negotiation reputation of a_j, d_{tj} is the communication distance between a_t and a_j, $\overline{R_t}$ is the set of resources for t that are currently lacking. The difference between λ_j and $V_j(t)$ is as follows: λ_j is the opinion of all other agents toward a_j, but $V_j(t)$ is only the opinion of a_t to a_j for task t; λ_j can influence $V_j(t)$ to some degree.

... d_{tj}, ... $|R_{a_j} \cap \overline{R_t}| / |\overline{R_t}|$, ... λ_j, ... *Thus, the negotiation value is designed by considering Objectives 1 and 2 of task allocation.*

Algorithm 2.

/* a_t ... A ... R_{at} ... a_t R_t ... t ... $\overline{R_t}$ ... t */

) $\overline{R_t} = R_t - R_{at}$; $A' = A - \{a_t\}$; $A_t = \{a_t\}$; $b1 = 0$; $b2 = 0$

) **If** $\overline{R_t} == \{\}$, **then** $b1 = 1$

) **While** $((b1 == 0)$ $(b2 == 0))$ **do**

) $maxvalue = 0$ $b2 = 1$

) $\forall a_j \in A'$

) $V_j(t) = \alpha \cdot (1/d_{tj}) + (1-\alpha) \cdot (\lambda_j(|R_{a_j} \cap \overline{R_t}| / |\overline{R_t}|))$

) **If** $V_j(t) > maxvalue$, **then**

$maxvalue = V_j(t)$ $sa = a_j$ $b2 = 0$

) **If** $(b2 == 0)$, **then**

$A_t = A_t \cup \{sa\}$ $\overline{R_t} = \overline{R_t} - R_{sa}$ $A' = A' - \{sa\}$

) **If** $\overline{R_t} == \{\}$, **then** $b1 = 1$

) **If** $(b1 == 1)$, **then Return** (A_t)

else Return ( )

) **End**.

Theorem 2. *Let the manager agent for task t be a_t and the set of allocated agents using Algorithm 2 be A_t. It is, then, assumed that there is another agent set, A^*, that can also satisfy all the resources in $\overline{R_t}$. Thus, we have*

$$\left(\forall A^* \wedge \left(\overline{R_t} - \bigcup_{\forall a_j \in (A^* - \{a_t\})} R_{a_j} = \phi\right)\right)$$
$$\Rightarrow \left(\sum_{\forall a_j \in (A_t - \{a_t\})} V_j(t) \geq \sum_{\forall a_j \in (A^* - \{a_t\})} V_j(t)\right).$$

Proof. [illegible] □

From Theorem 2, Algorithm 2 can find the contractor agents with the maximum negotiation values, satisfying Objectives 1 and 2 of task allocation.

5.2.4 Load Balancing

[illegible] t [illegible] A_t [illegible] t [illegible] R_t [illegible] r_k [illegible] a_i [illegible] Q_{ik}, [illegible] a_t [illegible] v_i [illegible] Q_{ik} [illegible] s_{ik}. [illegible] stimated resource enrichment factor ( ) [illegible]

$$\Phi_i^*(k) = \psi(s_{ik}/(v_i \cdot \lambda_i$$

Let $R^t_{a_j}$ be the set of real resources that a_j contributed to task t which can be achieved by a centralized heuristic; $R_{a_j} \cap R_t$ is the set of resources that a_j can contribute to task t. We will now punish a_j according to its degree of nonfeasance to resource contribution during task execution.

$$\forall a_j \in A_t : p_{tj} = (1-\omega) r_t \cdot \big(1 - \big(|R^t_{a_j}| / |R_t \cap R_{a_j}|\big)\big), \quad (10)$$

where p_{tj} is the penalty that agent a_j should pay for its nonfeasance to resource contribution in executing task t.

a_t

$(\omega r_t + p_{tt})$

a_k p_{tk}

A_t

. $\forall a_j \in A_t$ a_j

λ_j λ_j

$$a_t : \lambda_t = \lambda_t \cdot (1 - \omega r_t - p_{tt})$$
$$= \lambda_t \cdot \big(1 - \omega r_t - (1-\omega) r_t \big(1 - |R^t_{a_t}| / |R_t \cap R_{a_t}|\big)\big),$$
$$\forall a_k \in (A_t - \{a_t\}) : \lambda_k = \lambda_k \cdot (1 - p_{tk})$$

$= \lambda$ i4.61519042041nna203m0510.819136.333422a0in33.914n i 91:6134.7.3.917n1maa227an222234915.2491510.97191m519.2

- *Ideal task allocation model in which all deceptive agents can be detected (Transparent model).*

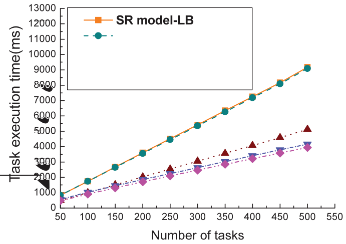
1. (*primarily for Objective 1*)
2. (*primarily for Objective 2, partly for Objective 1*)
3. (*primarily for Objective 3*)
4. (*to test the generality of our model*)
5. (*to test the robustness of our model*).

6.1 Tests of the Success Rate of Tasks

n $1/n$.

1.
2.
3. ( )
4.
5.

In conclusion,



6.2 Tests of the Execution Time of Tasks

1.

2.

3.

4.

In conclusion,

6.3 Tests of the Load Balancing of Tasks

1.

2.

In conclusion,

7 Conclusions and Discussion

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