A Novel Contract Net Negotiation Model based on Trust Mechanism

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***Abstract*—Traditional contract net protocols can simply and flexibly solve the negotiation problem of multi-agent system (MAS). But they can't work very well within the large scale system environment and is ineffective to solve the multi-issue negotiation problem. This paper investigates the reputation contract net protocol (RCNP) and proposes a novel contract net negotiation model based on RCNP. The model synthesizes the previous trust information and the multi-issue negotiation information which can greatly reduce the computational cost introduced by the unnecessary negotiation processes. In order to demonstrate the advantages of the model, a set of experiments were carried out on the JATLite (Java Agent Template Lite) platform. Experimental results indicate that the proposed model improved the performance of the MAS system and the accuracy of the trust evaluation of the negotiation process.**

***Keywords*—Trust mechanism, RCNP, contract net protocol, multi-issue negotiation, MAS**

I. INTRODUCTION

In multi-agent system (MAS), agents are independent to each other, like a society with cooperative and competitive entities. In the manufacturing processes, the classical strategy for dispatching tasks is CNP (Contract Net Protocol) proposed by Reid G.Smith [1]. Contract Net consists of several nodes, each of which is agent. All the agents can be divided into two kinds: the manager agent and the contractor agent. While for each of them, the role is not fixed. Once task arrived, the first one takes its role as manager. If its own task finished, it will announce other agents to bid for sequent process. The manager agent evaluates the responses from agents around it and then chooses the most suitable agent as the contractor one.

Contract Net is often used to solve the complicate dispatch problems in a simple way. It has been successfully applied on many systems. However, there are still some disadvantages of it. Because the traditional CNP protocol neglects the differences of individual agent. In other words, all the agents can bid tasks equally. In fact, many agents are not collaborative agents because they are not trust negotiators [2]. Negotiation risk during the bid process often leads to tremendous communication cost and resource usage. Especially come to the network-based manufacturing process, the dynamical changing of manufacturing environment (such as mechanical fault and shortage of raw materials) will increase the negotiation complexity and execution failure rate.

In practical applications, many schemes are used to improve the CNP protocol for different situation. They are Audience Restrictions, Focused Addressing, and Case-based Reasoning. By considering the historical information, Case-based Reasoning scheme avoids tremendous communication cost and simplifies the decision process during the task dispatching. But in dynamic environment the ability of agent often changes with the outside environment, which significantly limits the effect of the Case-based Reasoning scheme.

Dynamic contract net protocol (DCNP) proposed in [3] is suitable for dynamical changing environment. When announcing the bid, manager would select appropriate contractors to dispatch tasks in a certain probability according to their reputation value. But this protocol hasn't considered the multi-issue scenario, the tasks will not be well implemented and the bid and negotiation process will repeat again and again. The improved DCNP in [4] reduced the communication cost but lack accurate credentials.

A novel contract net negotiation model based on trust mechanism is proposed in this paper. The model describes how locally trusted intermediary parties can provide multiple negotiation to help establish trust between strangers. The rest of the paper is organized as follows. A trust model based on RCNP (Reputation Contract Net Protocol) is presented in Section Ⅱ. The experiments are carried out in Section Ⅲ to demonstrate the advantages of the proposed model. The paper is concluded in Section Ⅳ.

II. CONTRACT NET NEGOTIATION MODEL BASED ON TRUST REPUTATION

A. *Trust model based on RCNP*

According to Gambetta in [5], trust is the reflection of confidence degree from manager to task undertaker. The MAS trust negotiation model can be defined as:

$$NM =< A, actions, deadline, TH, Trust, Sanction >$$

Where, A stands for negotiation participator. A can be defined as $A=<a,r_1,r_2,\ldots r_N>$, a is manager agent who announces the bid, while r_i refers to contractor agents.

actions={*propose, accept, reject*} ∪ {*quit*} [6];

deadline is negotiation deadline time. Negotiation is failing if exceeded the deadline time.

TH means negotiation thread which can be defined as *TH*={$Th_1, Th_2, ..., Th_m$}. In the formula, *m* refers to negotiator number, Th_i is the thread between the manager agent and the contractor agent [7].

Trust is a confidence set which could be defined as follows:

$$Trust=\{R_{aj}^{ri} \mid i=1,2,\cdots N; j=1,\cdots,m\} \quad R_{aj}^{ri} \in [0,1] \quad (1)$$

Where, $R_{aj}^{ri} \in [0,1]$ stands for the r_i reputation value evaluated by a in issue *j*. When announcing bid, the manager agent only selects the trustable contractors which have the comprehensive trust reputation defined by (1).

Sanction is a predefined parameter stands for the penalty to those contractors who are incapable to complete the signed contract. The reputation value of a contractor (such as r_i) would be reduced by the formula defined as $R_{aj}^{ri} \leftarrow R_{aj}^{ri}$ -*Sanction*. The penalty activity will last until a contractor's reputation value is deducted to 0.

B. Trust degree evaluation approach

In this section, we present a novel trust degree evaluation approach to improve the negotiation performance of the model proposed in Section A.

In an open system, there are two kinds of trust reputation: local reputation and global reputation. Based on the traditional local and global reputation, we proposed an improved definition of global reputation. Since the traditional global reputation only considerate the single issue, the improved global reputation proposed in this section can be applied to the multi-issue negotiation. The parameters (such as a, r_i, and R_{aj}^{ri}) used in this section is defined in Section A.

Local reputation is a direct trust. In contract net, when agent *a* transacts with r_i, it will repeatedly evaluate the reputation of agent r_i after several rounds of transaction. Then the trust relationship is established. The degree of trust is described as reputation, which can be calculated as follows: $R_{aj}^{ri} = \frac{s}{s+f}$, where *s* is the successful contract execution number and *f* is the failure contract execution number.

Global reputation defined by (2) synthesizes the direct reputation and its neighbors' recommendation information.

$$\overline{R_{aj}^{ri}} = \zeta R_{aj}^{ri} + (1-\zeta)\overline{R}, \quad \zeta > (1-\zeta) \quad (2)$$

Where R_{aj}^{ri} is the local reputation while $\overline{R}$ is the accumulated recommendation reputation. While the trust degree between unknown agents can be calculated in a transitive way [8], the reputation value defined by our improved global reputation is more accurate than the local one.

Practical contract net negotiation is multi-issue [9-10] negotiation, which means that different issues (such as price, quality, etc.) executed by the same contractor would be gained different reputation. When receiving the bid from a contractor, the manager will evaluate its utility by comprehensively considering its multi-issue reputation. This kind of utility can be addressed as joint utility which is described.

For example, if there are three issues in the negotiation process, v_1^a, v_2^a and v_3^a are the reserved acceptable values set by a (manage agent) for these three issues respectively. Joint utility function is defined as:

$$JU^a(P,t) = \overline{R_{a1}^{ri}} w_1^a (v_1^a - x_1) + \overline{R_{a2}^{ri}} w_2^a (v_2^a - x_2) + \overline{R_{a3}^{ri}} w_3^a (v_3^a - x_3) \quad (3)$$

where *P* means the bid proposed by a contractor at time t, w_1^a, w_2^a, w_3^a refer to the weight of the three issue during the negotiation process, respectively, x_j refer to the three issue values which are discussed at time *t*.

After receiving bid from r_i, *a* will make its decision as follows:

$$\rho^a(t) = \begin{cases} Quit, & t > T^a \\ Accept, & JU^a(P_t^{ri}, t) \geq JU^a(P_{t+1}^a, t+1) \\ update\ P_{t+1}^a & otherwise \end{cases} \quad (4)$$

Which means that *a* evaluates the bid according to the joint utility defined by (3). T^a is the deadline set by *a*. The negotiation must be completed before this time or it will quit the program. $JU^a(P_t^{ri}, t)$ is current bid proposed by r_i at time t, $JU^a(P_{t+1}^a, t+1)$ is the bid which is going to be announced by manager agent at time t+1. If $JU^a(P_t^{ri}, t) \geq JU^a(P_{t+1}^a, t+1)$ which means that the bid proposed by r_i is better than the one going to be proposed by *a*, r_i's bid would be accepted by a and the negotiation is accomplished. Otherwise, a will modify its own bid according to the bid proposed by r_i. Then the updated proposal would be announced to contractor r_i again and a new negotiation would be started.

C. Negotiation process of the contract net negotiation model

In this section, we will demonstrate the negotiation process of the contract net negotiation model proposed in this paper. The process can be described as follows:

1) Manager agent *a* gets a task. If the outside environment is unknown to *a*, so $\sum_i \sum_j R_{aj}^{ri} = 0$, *a* would announce bid to all the agent unconditionally.

Or, *a* would select a contractor in a certain probability defined by

$$p = \frac{\sum_j \overline{R_{aj}^{ri}}}{\sum_i \sum_j \overline{R_a^{ri}}} \quad (5)$$

2) Manager agent announces the bid to the selected contractors. If any selected contractor hasn't responded to the bid, its reputation would be reduced according to the penalty mechanism defined in Section A.

3) Contractor bid;

4) If the bid number=0, goto step 1) for the next task. Or evaluate the bid according to utility, send modified one to contractor, until the bid is accepted.

5) Sign contract

6) Task finished feeds back to manager, reputation will be updated.

III. EXPERIMENT AND RESULTS

Communication cost, running time and trust accuracy are significant factors adopted to investigate the performance of CNP-based negotiation model. In order to evaluate the performance of the proposed model, experiments are carried out within the following software and hardware environment. Software platform: JATLite (Java Agent Template Lite); OS: Windows XP; Hardware: Intel P4 CPU, 1.7GHz, Memory 1GB.

A. *Trust accuracy evaluation*

In multi-issue environment, the reputation value of an agent is given by all the agents around it. Since trust accuracy is influenced by individual opinion, low accuracy will result in frequent deception by contractors. The experiment in this section will simulate a scenario with 20 agents in coalition negotiating to execute 800 tasks. As shown in Figure 1, with the increase of negotiation times, agent gets more knowledge from historical experience, which means that the accuracy is improved. Because there is no reputation consideration in CNP, the accuracy remains unchanged which could be indicated by the blue line. Comparing to the DCNP, the reputation of RCNP proposed in this paper take the multi-issue into accounts, so that its accuracy is better.

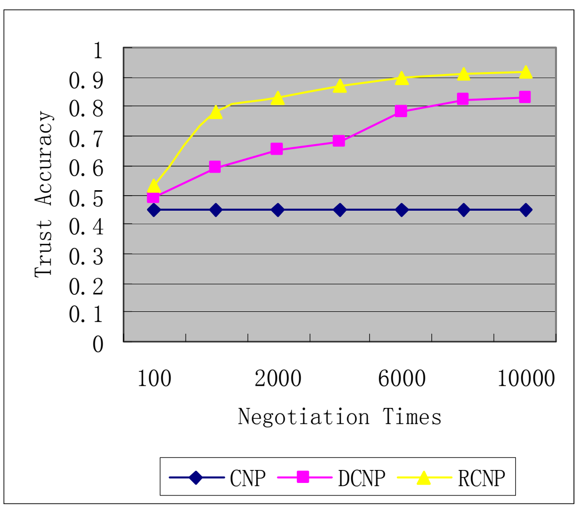

Figure 1. Trust Accuracy Analysis

B. *Comparison of performance*

During the negotiation process, communication cost refers to the total message that agent receives and sends. Running time is time cost of a negotiation process. In this section, we will demonstrate how the tremendous tasks influence the communication cost. The scenario is a MAS system with 20 agents. As shown in Figure 2, along with the increase of tasks, the communication cost of DCNP and IDCNP is larger than RCNP.

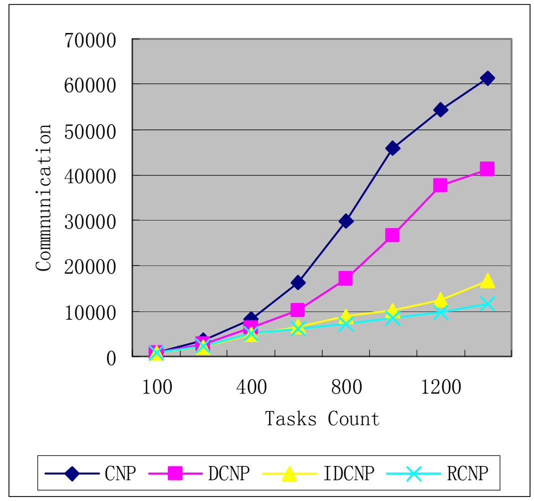

Figure 2. Communication Scale Comparison

When the task amount is fixed (800 tasks in this experiment), the running time would be changed with the system scale. As shown as in figure3, along with the increase of agent amount, the running time of RCNP proposed in this paper is obviously less than other protocols such as CNP, DCNP, and IDCNP. From the figure 3, we could see that when the agent amount is 80, compared with other protocols, more trustless negotiations are avoided in RCNP.

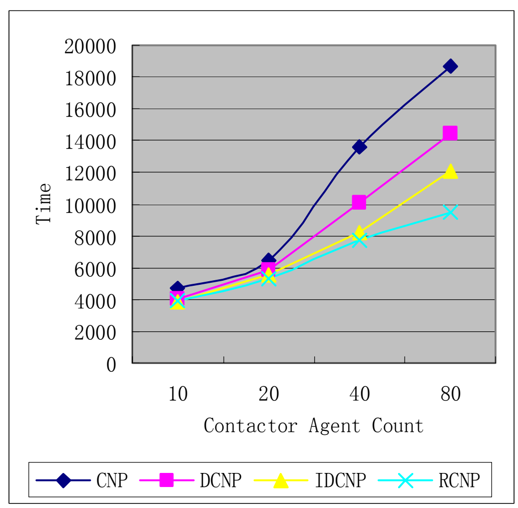

Figure 3. Running time comparison

IV. CONCLUSIONS

A novel contract net negotiation model is proposed and investigated in this paper. The advantages of the proposed model are obvious when comparing with the traditional models, which can be described as follows: 1) the proposed model can avoid the unnecessary negotiation processes, reduce the communication cost, and save the system running time; 2) since the proposed model can easily analyses the local trust information as well as the transitive trust information of the unknown agents, the trust evaluation accuracy of the contract negotiation net can be greatly improved; 3) because the reputation of each agenda is taken into consideration, the accomplishment quality of the task can be ensured and the rebidding problems can be also avoided.

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