AN AGENT-BASED OPTIMIZATION APPROACH FOR DISTRIBUTED PROJECT SCHEDULING IN SUPPLY CHAIN WITH PARTIAL INFORMATION SHARING

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Abstract: This paper focuses on the optimization problem of distributed project scheduling in the supply chain network which is made up of order manager, service brokers and service suppliers. Based on the initial scheduling by bids of service brokers, we present a heuristic approach with agent negotiation mechanism for the problem. The approach seeks optimal schedule by distributed negotiations, which apply the agent negotiation mechanism and share limited information, between order manager and brokers. Computational experiments show the approach is effective with good optimization performance.

1 INTRODUCTION

With the development of information technology, individual entities can dynamically form project-based alliances, such as virtual enterprise, to meet order demands through effective sharing and applying of resources (Huang et al., 2005). This distributed network structure of the supply chain poses greater challenges on project scheduling, and the research on scheduling problem in this environment getting an increasing concern.

There are many research works about project scheduling in a supply chain and most of them focus on centralized decision making, such as Banaszak & Zaremba (2006), Banaszak et al. (2009), Lecompte et al. (2000), Vairaktarakis & Hosseini (2008). These research works generally assume that the supply chain manager could take decisions by applying a centralized optimization model and could obtain all the information they need. However, some of the information is frequently seemed to be private and won't to share, such as the resource capability and cost structures.

Then, increasing studies about Distributed Project Scheduling Problem (DPSP) in supply chain with incomplete information are emerging. Lau et al. (2006) presented a model base on agent for DPSP, and use a modified contract net protocol to share time window between project agents and contractor agents and to seek a feasible solution of the scheduling. Huang et al. (Huang et al., 2005, 2006) focused on analyzing affected operations rescheduling when the resource condition is changed. Wang et al. (2008) introduce argument negotiation method for scheduling problem of supply chain to promote negotiation efficiency among broker agents. These studies formulated distributed supply chain network with agents, who are intelligent, independent and autonomic, and coordinated conflicts caused by resource constraints through sharing less information to obtain a valid schedule. However, as the studies focused on solving conflicts, the global optimization performance of the scheduling is usually not very good.

As a result, base on a multi-agent architecture, this paper presents a heuristic which is combined with agent negotiation mechanism for performing the optimal project schedule in supply chain with partial information sharing. The information, includes new solution and cost changing of the order manager, and new proposal, concessionary proposal and relevant cost-time changing of broker, is considered for sharing. Taking advantage of the relationship between the new proposals and the concessionary proposals of the brokers, the order manager and the brokers could get the optimal schedule by negotiate each other iteratively.

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2 PROBLEM FOMULATION

A supply chain network like Wang et al. (2008) is considered in this paper. As show in figure 1, the supply chain network consists of an order manager, brokers and service suppliers, and they are described by corresponding agent roles.

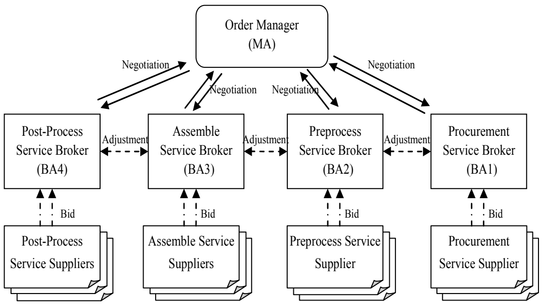

Figure 1: The structure of the supply chain network.

Order Management Agent (MA) analyzes demands of his orders and decomposes them to services. It also chooses the suitable broker for each service by bids and coordinates the relationship of the brokers. Each service could be undertaken by only one Service Broker Agent (BA). And a BA performs the service by himself or chooses a supplier from the available supplier set to do it. Each order has a due date and a high punishment cost will be paid if the delivery is delayed. MA assesses the time requirements and start time of the services according to the due dates of the orders and the relationship of the services.

The relative symbols are shown in following:

I	set of services, a service is indexed by $i \in I$
S_i	set of available suppliers for service i, a supplier is indexed by $j \in S_i$
PT_i	time constraint of service i
st_i	start time of service i
rt_i	service i's redundant time between time constraint of MA and time requirement of BA
$\{mc_i, mt_i\}$	cost and time requirement of a broker to perform service i
$\{pc_{ij}, pt_{ij}\}$	Cost and time requirement of supplier j to perform service i
$\{nc_i, nt_i\}$	cost and time consuming of a new proposal for service i
$\{nfc_i, nft_i\}$	cost decreasing and time increasing of the new proposal relative to present schedule
nv_i	rate of the cost decreasing and the time increasing in a new proposal
$\{dc_i, dt_i\}$	cost and time consuming of a concessionary proposal for service i
$\{dfc_i, dft_i\}$	cost increasing and time saving of the concessionary proposal
dv_i	rate of the cost increasing and the time saving in a concessionary proposal

It is consumed that, brokers bid for the services and an initial global schedule is determined by MA before the interactive optimization process of supply chain scheduling. And a BA always seek to maximize the local profile base on the time constraint and task requirement of MA. Thus the local schedule of BA who takes service i satisfies

$$mc_i = \max(pc_{ij}) \text{, and } mt_i = pt_{ij} \text{;} \quad (1)$$

$$mt_i \le st_{i+1} - st_i \text{.} \quad (2)$$

According to (2), redundant time rt_i satisfies $rt_i = st_{i+1} - st_i - mt_i$.

Based on the initial schedule, the optimal objective of the project scheduling in supply chain is to seek a globally optimal schedule, which is meeting the time constraint of the orders, through adjusting their local time constraint and start time and changing the selection of service suppliers.

3 DISTRIBUTED OPTIMIZATION PROCESS

A distributed optimization process of project scheduling in supply chain base on heuristic and agent negotiation is shown on figure 2.

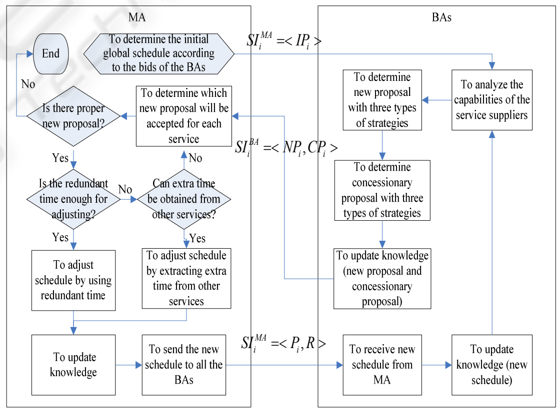

Figure 2: The distributed optimization process.

The knowledge of MA relevant with supply chain scheduling is defined as a quadruple: $K^{MA} =< D, IP, P, R >$, where D represents the set of the services and their assignment; IP and P represent initial and middle schedule respectively, and the content of them is $< st_i, \{mc_i, mt_i\} >$; R represents the amount of total cost decreasing of middle schedule than initial schedule. In the beginning of negotiation, MA provides information $SI_i^{MA} =< IP_i >$ to the BA who charging with service i. In the process of interaction, MA shares the information $SI_i^{MA} =< P_i, R >$ with the BAs.

The knowledge of the BA who charging with service i is defined as a quintuple : $K_i^{BA} =< B_i, st_i, T_i, NT_i, CT_i >$, where $B_i =< S_i, \{pc_{ij}, pt_{ij}\} >$; T_i represents the supplier who is selected in a middle schedule; NT_i represent the supplier correspond to new proposal; CT_i represent the supplier correspond to concessionary proposal. The information that a BA shares with MA is defined as $SI_i^{BA} =< NP_i, CP_i >$, where $NP_i =< \{nc_i, nt_i\}, \{nfc_i, nft_i\}, nv_i >$ represents the new proposal and $CP_i =< \{dc_i, dt_i\}, \{dfc_i, dft_i\}, dv_i >$ represents the concessionary proposal.

3.1 Making New Proposal and Concessionary Proposal by BA

As to the BA who takes service i , if his present schedule is $\{mc_i, mt_i\}$, and the capable of suppliers are $\{pc_{ij}, pt_{ij}\}$, $j \in S_i$, then the algorithm for making the new proposal is shown as

(1) For each supplier $j \in S_i$, if $pc_{ij} < mc_i$, then add supplier j into the supplier set for selection $SetForSel$.

(2) Calculate the following variables for each supplier in $SetForSel$:

$nfc_{ij} = mc_i - pc_{ij}$; $nft_{ij} = pt_{ij} - mt_i$; $nv_{ij} = nfc_{ij} / nft_{ij}$;

(3) Determine a supplier for performing service i from $SetForSel$ according to one of the three strategies:

S1: $nv_{il} = \max(nv_{ik})$, $nv_{il} > 0$, $\forall k \in SetForSel$;
S2: $nfc_{il} = \max(nfc_{ik})$, $nfc_{il} > 0$, $\forall k \in SetForSel$;
S3: $nft_{il} = \min(nft_{ik})$, $nft_{il} > 0$, $\forall k \in SetForSel$;

(4) If a supplier j is meet the condition for a special strategy, then new proposal $NP_i =< \{nc_i, nt_i\}, \{nfc_i, nft_i\}, nv_i >$ satisfies $nc_i = pc_{il}$; $nt_i = pt_{il}$; $nfc_i = nfc_{il}$; $nft_i = nft_{il}$; $nv_i = nv_{il}$. Otherwise, there is no valid new proposal.

The algorithm for making a concessionary proposal is similar to making a new proposal. The differences between them are the variables and the strategies of each supplier. The variables of each supplier of former are

$dfc_{ij} = pc_{ij} - mc_i$; $dft_{ij} = mt_i - pt_{ij}$; $dv_{ij} = dfc_{ij} / dft_{ij}$.

The strategies for determining a supplier for performing service i are

S1: $dv_{il} = \min(dv_{ik})$, $dv_{il} > 0$, $\forall k \in SetForSel$;
S2: $dfc_{il} = \min(dfc_{ik})$, $dfc_{il} > 0$, $\forall k \in SetForSel$;
S3: $dft_{il} = \max(dft_{ik})$, $dft_{il} > 0$, $\forall k \in SetForSel$.

3.2 Schedule Adjusting by MA

Assume that the new proposal of BA who takes service m is selected for optimize the global schedule. Redundant times are firstly considered for meet the demand of adjusting. The algorithm is

(1) if $rt_m \geq nft_m$, then $rt_m = rt_m - nft_m$; update the knowledge of MA to adopt the new proposal of service m ; finish the adjusting process;

(2) if $rt_m < nft_m$ and $\sum_{i \in I} rt_i > nft_m$, then reduce other service's redundant time for i ;

update the knowledge of MA to adopt the new proposal of service m ; finish the adjusting process;

(3) if $rt_m < nft_m$ and $\sum_{i \in I} rt_i < nft_m$, then $nft_m = nft_m - \sum_{i \in I} rt_i$; to continue adjust the global schedule by extracting extra time from other services.

The set of services that can be used to extract time is denoted as B. The set of selected services for extracting time is denoted as C. Then the algorithm for adjusting by extracting extra time form other services is shown as

(1) $dv_n = \min(dv_i)$, $\forall i \in B$;

If $dv_n \neq \phi$ then move service n from B to C , else the adjusting will be finished.

(2) To determine what services in C meet the demand of adjusting:

if $\sum_{n \in C} dfc_n \geq nfc_m$, then the adoption of new proposal is failed and the adjusting will be finished;

If $\sum_{n \in C} dfc_n < nfc_m$ and $\sum_{n \in C} dft_n \geq at_m$, then go to step (3);

If $\sum_{n \in C} dfc_n < nfc_m$ and $\sum_{n \in C} dft_n < at_m$, then go to step (1);

(3) To adjust the global schedule by using the services in set C ; calculate the total cost of the supply chain; and update the knowledge of MA.

4 COMPUTATIONAL RESULTS

We consider an example with 6 continue services for an order and 4 suppliers for each services. The time constraints of the services are generated by random numbers satisfies adequate distribution in [50, 100]. The time consuming and cost for supplier j to perform service i are generated by $P_{ij} = T_i + \alpha$ and $C_{ij} = \beta + (T_i - P_{ij}) \cdot \gamma$, where the coefficients α , β and γ are random numbers satisfies adequate distribution in [-20,20], [250,500] and [0,100] respectively. We create 10 instances by these policies.

A mathematic programming model similar to Lau et al. (Lau et al., 2006) is adopted for centralized optimization and the model is solved by using Lingo. The bid structure and coordination approach of conflict in (Wang et al., 2008) are used and realized with Java. The approach of the heuristic of optimization present in this paper is also realized with Java. The results of solving the instances are shown in figure 3.

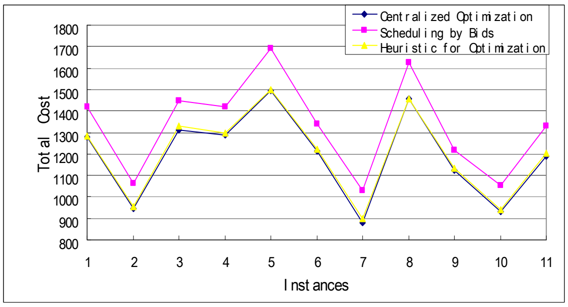

Figure 3: A comparison of the three types of scheduling.

As is shown in the figure, the results of heuristic for optimization are considerably close to the results of centralized optimization, and have relative high cost decreasing than the result of Scheduling by bids.

The comparisons of optimization performance of the three types of scheduling are shown in table 1. There are two indexes of evaluation in the table: the gap between scheduling by bid and centralized optimization $Gap^{Bid} = (TC^{Bid} - TC^{CO}) / TC^{Bid}$, where TC^{Bid} and TC^{CO} represent total cost of schedules obtained by using scheduling by bid and centralized optimization respectively; the gap between heuristic for optimization and centralized optimization $Gap^{HO} = (TC^{HO} - TC^{CO}) / TC^{HO}$ where TC^{HO} represents total cost of schedule obtained by using heuristic for optimization. As is shown in the table, the greatest gap between heuristic for optimization and centralized optimization is just 2.15% and the heuristic for optimization obtains optimal result on instance 8. On the other hand, the gaps between scheduling by bid and centralized optimization are relatively wide. So we can say that the heuristic for optimization has good performance on optimization.

Table 1: Comparisons of optimization performance of the three types of scheduling.

	1	2	3	4	5
Gap^{Bid}	10.06%	11.07%	9.58%	9.16%	11.74%
Gap^{HO}	0.56%	1.07%	1.42%	0.62%	0.47%
	6	7	8	9	10
Gap^{Bid}	9.65%	14.51%	10.44%	7.61%	11.71%
Gap^{HO}	1.03%	2.15%	0.00%	0.81%	1.24%

5 CONCLUSIONS

Base on the description of the structure of a supply chain network, the paper present a heuristic for optimization of distributed project scheduling in supply chain. The approach of scheduling base on a heuristic and an agent negotiation architecture through sharing partial information, including new proposals, concessionary proposals of service brokers and the global schedule of the order manager. Computational experiences show that the approach has good optimization performance by comparing with centralized optimization and scheduling by bids with two evaluation indexes.

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