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A PROPOSAL ON NEGOTIATION METHODOLOGY IN VIRTUAL ENTERPRISE

Toshiya KAIHARA and Susumu FUJII***
** Graduate School of Science and Technology, Kobe University, kaihara@ms.cs.kobe-u.ac.jp*
*** Department of Computer and Systems Engineering, Kobe University, fujii@cs.kobe-u.ac.jp*
JAPAN

The selection of business partners is a very important and critical activity in the operation of a company in VE. In this paper, we focus on the negotiation process in VE formulation as a basic research to clarify its effective management. Each enterprise in VE is defined as agent with multi-utilities and contract-net protocol (CNP) is applied as a negotiation algorithm amongst the agents. The effectiveness of the proposed concept in the agile manufacturing is discussed with several simulation experiments.

1. INTRODUCTION

Nowadays, Virtual Enterprise (VE) is a crucial paradigm of business management in agile environment [1]. VE exists in both service and manufacturing organizations, although the complexity of the each enterprise in VE may vary greatly from industry to industry and firm to firm. Realistic VE handles multiple end products with shared components, facilities and capacities. Since the flow of materials in VE is not always along an arborescent network, various modes of transportation may be considered, and the bill of materials for the end items may be both deep and large.
Although cooperation is the fundamental characteristic of VE concept, due to its distributed environment and the autonomous and heterogeneous nature of the VE members, cooperation can only be succeed if a proper management of dependencies between activities is in place just like SCM [2],[3].
In this paper, we focus on negotiation process in VE formulation as a basic research to clarify its effective management. Each enterprise in VE is defined as agent with multi-utilities [4] and a framework of multi-agent programming, called contract-net protocol (CNP) [5], is applied as negotiation algorithm amongst the agents. We develop a computer simulation model to form VE through multiple negotiations amongst several potential members in the negotiation domain, and finally clarify the formulation dynamism with the negotiation process.

2. ENTERPRISE AGENT

2.1 Basic assumption

A large number of diversified networked organisations of enterprises fall under the general definition of VE [1]. We assumed our VE model in the possible simplest definition as a basic research, as follows:

i) Duration: Single business
ii) Topology: Fixed structure
iii) Participation: Single alliance
iv) Coordination: Democratic alliance

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L. M. Camarinha-Matos (ed.), *Collaborative Business Ecosystems and Virtual Enterprises*

v) Visibility scope: Single level

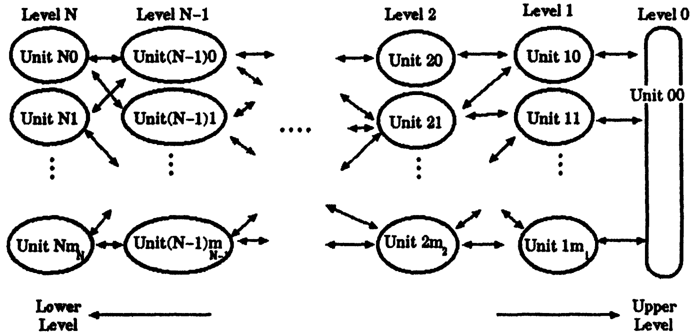

Figure 1 - An example of virtual enterprise model

Figure 1 shows the assumed VE model in this paper. We call an enterprise as *unit*, and there exist *N* layers, which have m_N units in the VE model. Level 0 corresponds to consumers who can create original task requests to the VE. As the Level number increases, we describe it lower based on the information flow order in this paper.
At first, Unit 00 dispatches new order to all the units in Level 1, and then several units, which are satisfied with the order, responds and circulates the order toward lower units in the VE model. Finally a single supply chain will be established for the order as a consequence of their negotiations through all the layers.

2.2 Unit structure

Each unit is defined as agent in our VE model, and its structure is described in figure 2. We adopt CNP as the coordination and negotiation mechanism amongst the units. Nodes generally represent the distributed computing resources to be managed, correspond to "units" in this paper.
An agent (=unit) can act both as a manager and a contractor of a delivery sets. When a unit receives new order (= task announcement) *i*, it creates a contractor / manager set (Manager *i* / Contractor *i*) for the task inside. Manager *i* creates a new order towards the lower units to secure the contract with the upper layer.

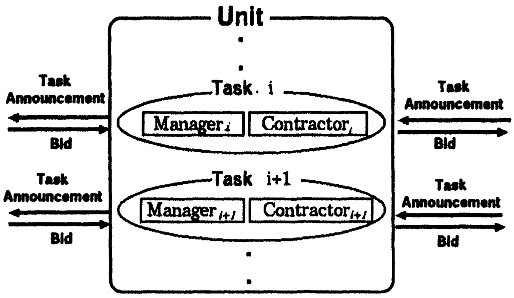

Figure 2 - Unit structure

2.3 Negotiation mechanism

The timeline of the proposed negotiation mechanism in this paper is shown in figure

3. Negotiation steps according to agent roles are described as follows:

<u>Manager</u>

Step M1: Create a new task based on the received bid information.

Step M2: Task announcement (TA) to the lower units.

Step M3: After the bidding period expired, check all the acquired bids according to its standard. If there exists no bid to select, go to M4. Otherwise go to M5.

Step M4: Modify the task and go to M2.

Step M5: Select the task and send award (Award) to the corresponding unit.

<u>Contractor</u>

Step C1: Create an estimated bid.

Step C2.a: Send the bid.

Step C2.b: Request task announcement to the manager.

At first, a task announcement $TA_{(n-1)l}^{k1}$ is sent from manager k in $Unit_{(n-1)l}$ to $Unit_{nm}$ in figure 3 (where $k1$ means the initial announcement from manager k on the task i). $Unit_{nm}$ creates a contractor(i) / manager(i) set against the task announcement. Contractor i creates an estimated bid information (C1), and requests the manager i to announce a task to lower layer (C2.b). Contractor i send a bid to $Unit_{(n-1)l}$ (C2.a) at the same time.

There exist two types of timings to send a bid, such as Bid(a) and Bid(b), in this figure. We will describe the difference later in detail.

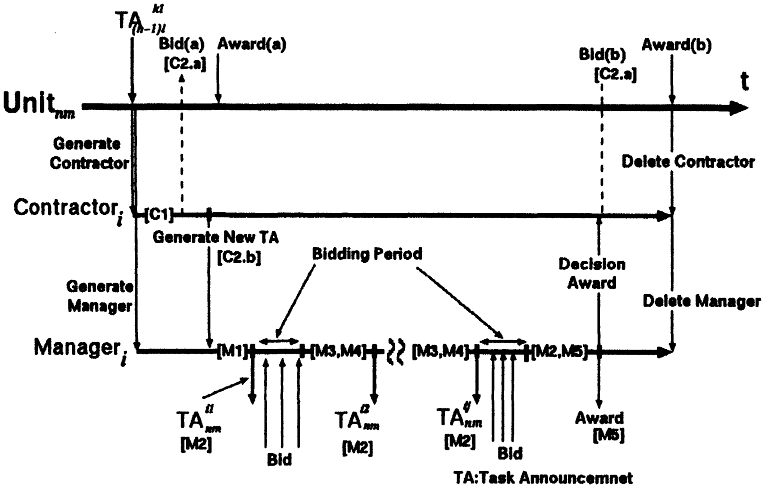

Figure 3 - Negotiation process flow

2.4 Bidding timing and bidding criteria in contractor agent

After creating a task, contractors in units send a bid to the upper units. We assume two types in terms of bidding timing, shown as Bid(a) and Bid(b) in figure 3. Generally the bidding timing is defined as preconditioned precept in VE negotiation.

Bid(a): After the contract conclusion with the upper units, the unit starts to issue TA to the lower unit. It creates the task announcement decisively based on the acquired contract with the upper units.

Bid(b): After the contract conclusion with the lower units, the unit starts to send bid to the upper units. The contrast conclusions with the lower units are provisional basis in this case.

As bidding criteria to select single task from multiple TAs to be received, we adopt turnover and bidding volume in this paper. Contract agents try to maximise their criteria in the negotiation process.

2.5 Bid creation

Contractors show their willingness and ability to perform the task by sending the bid to managers, and if the task is uninteresting, they neglect the task announcements. We measure their utility by two major indexes of trading products in the enterprise negotiation, price and quantity. We assumed two types of contractor agents, price-oriented and volume-oriented, in terms of bid creation algorithm. The price-oriented contractors prefer to supply higher quality products with higher prices, while the volume-oriented contractors aim at lower selling price with mass production. Their behaviours are defined as follows:

Price-oriented contractor

$$p_{nm}^{ij} = P_{(n-1)l}^{kj} * (1+plus_p) \quad (1)$$

$$v_{nm}^{ij} = P_{(n-1)l}^{kj} * V_{(n-1)l}^{kj} / p_{nm}^{ij} \quad (2)$$

Volume-oriented contractor

$$v_{nm}^{ij} = V_{(n-1)l}^{kj} * (1+plus_v) \quad (3)$$

$$p_{nm}^{ij} = P_{(n-1)l}^{kj} - cost * (1/V_{(n-1)l}^{kj} - 1/v_{nm}^{ij}) * \alpha \quad (4)$$

where

p_{nm}^{ij} : bidding price of $Contractor_i$ in $Unit_{nm}$ at j times

v_{nm}^{ij} : bidding volume of $Contractor_i$ in $Unit_{nm}$ at j times

$P_{(n-1)l}^{kj}$: announcing price of $Manager_k$ in $Unit_{(n-1)l}$ at j times

$V_{(n-1)l}^{kj}$: announcing volume of $Manager_k$ in $Unit_{(n-1)l}$ at j times

$plus_p$: price increasing rate in negotiation ($0 \leq plus_p \leq 1$)

$plus_v$: volume increasing rate in negotiation ($0 \leq plus_v \leq 1$)

$cost$: manufacturing cost in unit time

$1-\alpha$: profit margin by mass production

In Bid(b) negotiation process, there occurs some difference in volume between the task announcement from upper units and the provisional contract from lower units. Therefore the contractor decides final volume in bid ($v'_{nm}{}^{ij}$) followed by equation (5) to reduce its stock size caused by the difference.

$$v'_{nm}{}^{ij} = v_{nm}^{ij} + (v_{(n+1)m}^{i} - v_{nm}^{ij})/2 \quad (5)$$

where $v_{(n+1)m}^{i}$: contracted volume of $Manager_i$ in $Unit_{nm}$

2.6 Task creation

According to the request from Contractor i, Manager i creates a task to be done, and sends an offer to perform the task in $Unit_{nm}$.

$$V_{nm}^{il} = v_{nm}^{il} * (1+\beta) \quad (6)$$

$$P_{nm}^{il} = \{(1-profit)*p_{nm}^{il} * v_{nm}^{il} - cost\}/V_{nm}^{il} \quad (7)$$

where

V_{nm}^{i1}	: initial volume in TA_{nm}^{i1} of $Manager_i$ in $Unit_{nm}$
P_{nm}^{i1}	: initial price in TA_{nm}^{i1} of $Manager_i$ in $Unit_{nm}$
profit	: profit rate ($0 \leq profit \leq 1$)
β	: stock increasing rate: ($0 \leq \beta \leq 1$) in Bid(b), β=0 in Bid(a)

2.7 Contract criteria and re-announcement in manager agent

Manager agents show their willingness to accept the bid by sending the award to the successful contractors. Their behaviour is described as following steps:

Step1: Sorting bids based on the following equations.

$$v_{(n+1)h} > v_{nm} \tag{8}$$

$$p_{(n+1)h} < P_{nm} * (1+ permit) \tag{9}$$

where

$v_{(n+1)h}$	: bidding volume of $Unit_{(n+1)h}$
$p_{(n+1)h}$	: bidding price of $Unit_{(n+1)h}$
v_{nm}	: estimated bidding volume of $Unit_{nm}$
P_{nm}	: TA price of $Unit_{nm}$
permit	: bidding price tolerance ($0 \leq permit \leq 1$)

Step2: Select the successful bid according to the following heuristic rules.

- minimum cost rule
- minimum bidding volume rule

If there is no bid to satisfy both equation (8) and (9), the manager agent needs to re-announce a new task offer into the lower units. The manager's algorithm is described as follows:

Step1: Investigate the difficulties of the previous task, in terms of either bidding price or bidding volume.

Step2: Modify the task based on the difficulty. Equation (10) and (11) are adopted against price difficulty and volume difficulty, respectively.

$$P_{nm}^{i(j+1)} = P_{nm}^{ij} - \frac{\sum_{x=1}^{num_{ij}} \left| p^x - P_{nm}^{ij} \right|}{num_{ij}} \tag{10}$$

$$V_{nm}^{i(j+1)} = V_{nm}^{ij} + \frac{\sum_{x=1}^{num_{ij}} \left| V_{nm}^{ij} - v^x \right|}{num_{ij}} \tag{11}$$

where

P_{nm}^{ij}	: price in TA_{nm}^{ij}
p^x	: x th bidding price for TA_{nm}^{ij}
num_{ij}	: the number of bids for TA_{nm}^{ij}
V_{nm}^{ij}	: volume in TA_{nm}^{ij}
v^x	: x th bidding volume for TA_{nm}^{ij}

Manager agents repeat the re-announce process until they receive the bids to satisfy their standards in terms of both price and volume.

3. EXPERIMENTAL RESULTS

3.1 Simulation model

We have developed a computer simulation model to form a virtual enterprise through multiple negotiations amongst several potential members in the negotiation domain. The simulation model is shown in figure 4. There exists 5 unit layers in the VE hierarchy, and 3 units are included in layer 1 – 4. Each unit can communicate to all the units in the next layers.

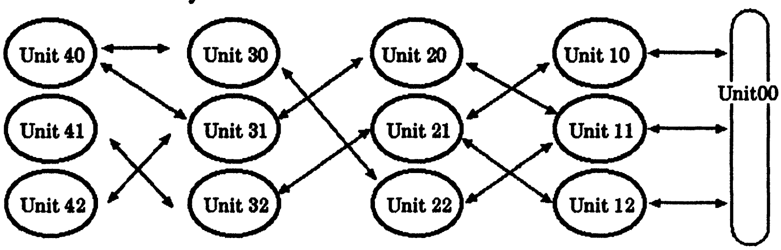

Figure 4 - Simulation model

Experimental parameters defined in equation (1) – (9) are listed in table 1. Initial task order, which is created in Unit 00 at time=0, is (average cost=1,000, average volume=1,000, and standard deviation=0.25 followed by normal distribution). All the simulation results illustrated afterwards are the average of 100 simulation trials.

Table 1 Experimental parameters

	mean	variance
profit	0.3	0.025
$plus_p$	0.025	0.015
$plus_v$	0.05	0.015
permit	0.9	0.015
α	0.45	0.075
β	0.05	0.075

3.2 Unit type and appraisal standards

We defined two types of unit strategies in our VE model.

Type 1: profit-oriented

  Bid creation: price-oriented
  Bidding criterion: turnover
  Contract criterion: minimum cost rule

Type 2: stockless-oriented

  Bid creation: volume-oriented
  Bidding criterion: maximum bidding volume
  Contract criterion: minimum bidding volume rule

Each unit type in the simulation model (figure 4) was randomly set as follows:
Additionally, three types of VE negotiation precept were assumed in as follows:

Type A: Based on Bid(a) in 2.5
Type B: Based on Bid(b) in 2.5
Type C: Contracts are carried out independently

Table 2 Unit type

	Layer			
Number	1	2	3	4
0	1	1	2	1
1	2	2	1	1
2	1	2	2	2

We introduced the following four types of appraisal standards so as to evaluate the acquired VE characteristics, i) total profit of entire VE, ii)ROA (Return on assets), iii)averaged profit / layer, iv)averaged stock volume / layer.
Generally ROA is calculated by the following equation in this paper:

$$ROA = (\text{Throughput} - \text{Operational cost}) / \text{Stock assets} \qquad (12)$$

3.3 Experimental results

We evaluated our experimental VE model at every negotiation precept by computer simulation. Total profit and ROA results are shown in table 3.

Table 3 VE performance

Type	Profit	ROA
A	485,620	12.17
B	509,965	4.64
C	465,951	7.07

Figure 5(a) and 5(b) illustrate the results on average profit and stock volume, respectively. Additionally unit type proportional rate in the finally formed supply chain is shown in Table 4. Table 5 shows the number of TAs, contracts, and cancellations.

Table 4 Unit type proportion

Type	1	2
A	0.00	1.00
B	0.75	0.25
C	0.75	0.25

Table 5 Contract and cancellation

Type	TA	Contract	Cancellation
A	4	4	0
B	140	6	2
C	40	40	36

We clarified the finally formed VE characteristics in each negotiation precept.

Type A: It has been confirmed that type A conducts the supply chain in higher ROA with minimum stock volume. All the unit types involved in the formed supply chain were type 2. No cancellation occurs in table 5, because each contract concludes definitively in this type.

Type B: The contracts are naturally determined upward in Type B. The contrast conclusions with the lower units are provisional basis in this case, and that means cancellation should occur several times. TAs include some offsets in volume (equation (6)), and as the consequence, unit type 1 can be included in he supply chain beyond the volume constraint.

Type C: The contracts are carried out independently, and several cancellations are occurred during the negotiation process.

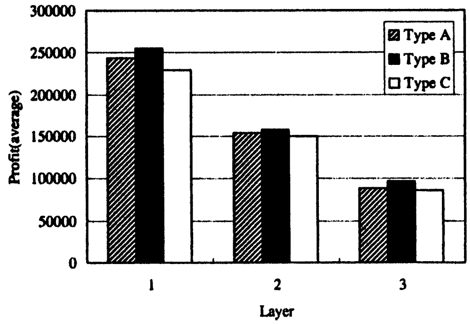

Figure 5(a) - Average profit in layer

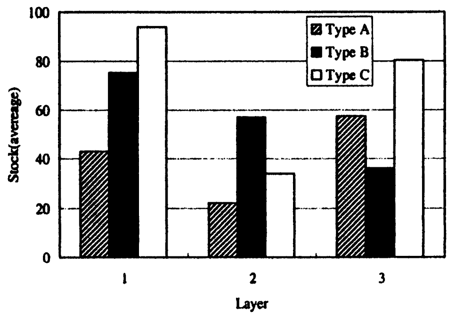

Figure 5(b) - Average stock in layer

4. CONCLUSIONS

In this paper, we focused on the negotiation process in VE formulation to clarify its effective management. We defined each enterprise in VE as agent and applied a framework of multi-agent programming, CNP, as the negotiation mechanism. Negotiation algorithm was proposed and formulated in detail with reality. We developed a computer simulation model to form VE through multiple negotiations, and finally clarified the formulation dynamism with the negotiation process. The effectiveness of the proposed concept in the agile manufacturing has been demonstrated with several simulation experiments.

Acknowledgments

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