

COOPERATIVE NEGOTIATION FOR THE PROVISIONS BALANCING IN A MULTI-AGENT SUPPLY CHAIN SYSTEM FOR THE CRISIS MANAGEMENT

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Abstract: Since a few years, logistics has become a performance criterion for the organizations success. So the Supply Chain (SC) study is adopted more and more for the competitiveness of companies development. In previous works we proposed an approach, which aims to reduce an emerging phenomenon of the demand amplification, called the Bullwhip Effect. In this paper, we present a model, based on the proposed approach, for a Cooperative Negotiation for the Provision Balancing in a SC system. The studied SC is a hierarchical system dedicated to the Crisis Management. A Multi-Agent architecture is then proposed to design this distributed chain through interactive software agents. The results of simulation, presented in this paper, prove the importance of the interaction between the SC entities for the Provisions Balancing.

1 INTRODUCTION

A Supply Chain (SC) represents the whole of the links starting from the final customer to the first level supplier. The main objective of such a structure is the final customer satisfaction; it is thus necessary to progress the SC management by optimizing flows going from the supplier to the customer and also from the customer to the supplier (e.g. information and goods flows). In our work, we focus on a special kind of SC: a distributed Crisis Management SC (CMSC) based on a hierarchical structure. In a previous work, we proved that a minimal communication between the different SC links reduce considerably Bullwhip effect. Basing on previous these further verifications, we are interested here to develop a cooperative Multi-Agent System (MAS) negotiation for the ammunition balancing in our CMSC system, in order to balance ammunition in a disturbed mode. The remainder of this paper is organized as follows: initially the CMSC will be described in next paragraph, followed in paragraph 3 by the proposed multi-agent architecture characterized by the communication and the information sharing between the different distributed entities. The negotiation protocol for the provision balancing is presented and detailed in paragraph 4.

Finally, experimentations in paragraph 5 show the contribution of the proposed protocol and its limit.

2 THE CRISIS MANAGEMENT SUPPLY CHAIN

The CMSC is an L-levels SC links; from the provisions warehouse for routing Z_1 (exclusive first level) to several disaster zones Z_L . All other zones are of level i with $1 < i < L$. So for a given zone Z_i , a downstream zone is of Level $i+1$: Z_{i+1} and its upstream zone is of level $i-1$: Z_{i-1} . The retro logistic is not allowed within our CMSC, so the matter flow goes from the upstream to the downstream nodes. However, the data flow can take place in the two directions according to the interaction protocol expressed later. When a crisis takes place (e.g. a natural disaster), the manager affected to a disaster victim zone (Z_L), orders the necessary products from an upstream zone Z_{L-1} , which, in its turn, addresses its request to the zone Z_{L-2} and so on. Each zone has a partial sight of the environment, which results in incomplete data and limited capacities. Thus, we propose to model the CMSC by communicating agents within a distributed MAS which should follow a formal mathematical model (e.g. Least

Square Method and Gaussian Distribution) and pumps data from real case studies. The idea is to prepare a mathematical model package and to instantiate the decided model which can be a single form or a combination of several ones. The decision is done thanks to a strategic level within the reasoning layer of the interaction model presented afterwards in this paper. This feature of the studied CMSC is not detailed in this paper.

3 THE PROPOSED MULTI-AGENT ARCHITECTURE

3.1 Model Representation

As it was previously mentioned, the hierarchical feature between the various entities characterizes the multi-zone logistic system. So there is an agent responsible of each zone representing it, we call this agent: an agent-zone. Each agent-zone can communicate only with another agent-zone that is hierarchically higher to him (an upstream agent-zone) or with another agent of the same hierarchical level. For example, if N, M and P correspond respectively to the zones numbers Z_2 , Z_3 and Z_4 in a 4-levels CMSC, then :

- Ag_{z_1} : the Z_1 agent-zone,
- $Ag_{z_{2i}}$: the Z_{2i} agent-zone ($1 \leq i \leq N$) who can interact with the Ag_{z_1} or with another agent-zone $Ag_{z_{2i'}}$ ($1 \leq i' \leq N$ and $i' \neq i$),
- $Ag_{z_{3ij}}$: the Z_{3ij} agent-zone ($1 \leq i \leq N$ and $1 \leq j \leq M$) who can interact with an agent-zone Z_2 or with another agent-zone $Ag_{z_{3ij'}}$ ($1 \leq j' \leq M$ and $j' \neq j$),
- $Ag_{z_{4ijk}}$: the Z_{4ijk} agent-zone ($1 \leq i \leq N$, $1 \leq j \leq M$ and $1 \leq k \leq P$), who can interact with an agent-zone Z_3 or with another agent-zone $Ag_{z_{4ijk'}}$ ($1 \leq k' \leq P$ and $k' \neq k$).

3.2 Interaction Mode

We adopt the “with agreement” mode, which expresses the collaboration between the agent-zones thanks to an effective communication to make better decisions to the demands. The goal is to find ammunition balancing in our CMSC system thanks to a cooperative negotiation between the disaster sectors and their upstream zones in a disturbed mode.

4 THE NEGOTIATION PROTOCOL MODEL

The cooperative negotiation aims to provide urgent ammunitions to the zones, in case of need, while waiting for the help. We propose a negotiation architecture based on the abstract one presented in (Wooldridge and al., 1995). This architecture is composed of three layers:

- 1- Communication Layer: corresponds to the interaction layer of the architecture, it is responsible for receiving and sending messages between agents;
- 2- Control Layer: corresponds to the negotiating agent behaviours, which will be specified by UML activities diagrams in further works;
- 3- Reasoning Layer: corresponds to the decision-making part of the negotiating agent and interacts with his Knowledge base module. Through this layer, an agent (identified by Ag_Id) can evaluate his own emergency degree for a given resource r_i , according to his mental statements. This emergency degree is called Emergency Index and noted by $E_{index}(r_i, Ag_Id)$. The measurement of this emergency index exceeds the topic of this paper. More details will given in future publications. A negotiation process is decomposed of:

- Initiators of the negotiation who start the process. We focus on the case of a single initiator for hierarchical reasons. This Initiator is noted by *Init*,
- Participants who contribute to this negotiation. An upstream node can command one or several downstream nodes noted by $Part_j$ ($1 \leq j \leq P$),
- Objects of the negotiation: limited resources on which the negotiation members (Initiators end Participants) negotiate. A resource is noted by r_i ($1 \leq i \leq R$).

The decision of which protocol will be used (Communication Layer) depends on the agent-zone Reasoning Layer. In this paper, we focus on an agent-zone Communication Layer; instance of the Help-One-To-Many (HOTM) protocol. In future work, we will compare this proposition to another kind of negotiation protocol: Help-Many-To-Many (HMTM) protocol. The proposed HOTM protocol is described as follows (Figure 1):

- Modification Request: If the Initiator (upstream zone) realizes that he cannot satisfy all his subordinate zones demands before some period of time Δt corresponding to the new supply delay. So, he informs all the subordinate agent-zones about the situation

proposing them to renounce to their demands if they can wait for an additional period of time. In other words, as soon as an upstream agent-zone is not able to response to some resources demands (Reasoning Layer), the Control Layer is activated by a modification demand and an “output event” starts the HOTM protocol,

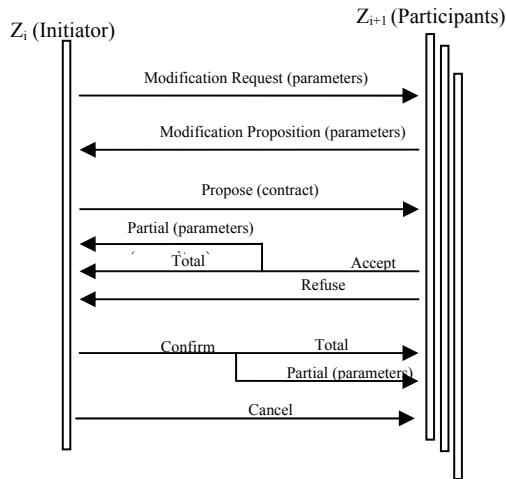


Figure 1: HOTM protocol.

- **Modification Proposition:** each Participant agent-zone sends his emergency degree to the initiator. For example, if an agent-zone intends to desist, he should send a weak emergency degree. This corresponds to an “input event” within the Initiator negotiating Agent Architecture,
- **Propose (contract):** The initiator sends new contract expressing the new provisions quantities balancing evaluated within the Reasoning layer,
- **Accept/Refuse:** After estimation of remaining stocks of all the provisions (water, medicines, clothes, etc.), a participant agent-zone Z_{i+1} realizes that he can accept:
 - All the Initiator propositions (Total Accept),
 - A sub-set of the Initiator propositions (Partial Accept). For example, he can accept the given Initiator proposition for clothes but not for water and medicines,
 - None proposition (Refuse).
- **Confirm:** Since the Initiator receives enough desisting Participant responses for a kind of provisions, he confirms that he can now satisfy:

- All the demands (Total Confirm): there is enough quantities for all kinds of provisions,
- A sub-set of demands (Partial Confirm): there is enough quantities for some kinds of provisions.

Further to a confirmation, the Initiator sends the provisions. In that case, if there are still some downstream agent-zones (Z_{i+1}) who need some provisions in real time and the correspondent upstream agent-zone (Z_i) can't satisfy all the demands, the negotiation process loops (go to Modification Request demand) and so on. Otherwise, the protocol ends.

- **Cancel:** the negotiation process can be cancelled (e.g. at the end of authorized negotiating time).

5 SIMULATION RESULTS

We simulate here a cargo loss between days 35 and 36, checking the HOTM Protocol and we focus on a single resource satisfaction. The experimentation aims to find an effective provisions balancing within the different 4-Levels CMSC zones. The bullwhip effect is not considered here.

5.1 Case 1: Without HOTM

In this case, the upstream agent-zone Z_3 sends all his resources to his subordinates. The problem here is that this agent resides with an out-of-stock condition during 3 days (Figure 2-a). This is a serious problem, because there are no more provisions for his own consumption. We notice here that security stocks of subordinate zones are slightly picked (Figure 2-b). In this context, the principle of the negotiation is to demand to subordinates zones if they agree to pick in their own security stocks in order to avoid emptying totally the upstream zone stock.

5.2 Case 2: With HOTM

In this case, when the upstream agent-zone Z_3 receives subordinate agents demands, he realizes that he cannot satisfy all his subordinate zones demands before the new supply delay. Thus, he informs his subordinates ($Z_{4,1}$ and $Z_{4,2}$) about his situation and proposes them to renounce to their demands if they can wait for an additional period of time. So, each Z_4 agent-zone will estimate if his

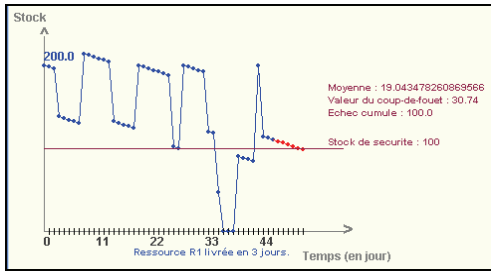


Figure 2-a: Z3.

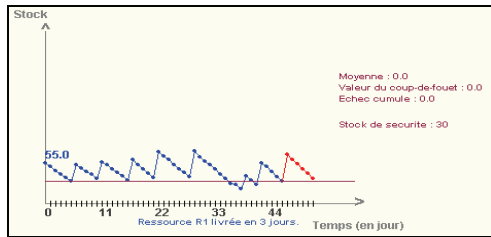


Figure 2-b: Z4,1.

Figure 2: Case without HOTM.

remaining security stock is sufficient to wait the required time. Here, the agent-zone $Z_{4,1}$ was agree to desist giving a weak emergency index in order to avoid the out-of-stock condition of the upstream agent-zone Z_3 (decision through the Reasoning Layer). Thus, Z_3 gives some amount of goods only to $Z_{4,2}$. Consequently, the negotiation allowed to all the zones to survive (Figure 3).

6 CONCLUSIONS

We are interested in our work to a special kind a distributed SC of which the different interactive entities are hierarchically related. We proposed for this SC a multi-agent architecture characterized with independent agent-zones sharing information. In this paper, we focus on the provision balancing thanks to a One-To-Many negotiation protocol (HOTM). We showed within the experimentation results that this protocol allows avoiding the

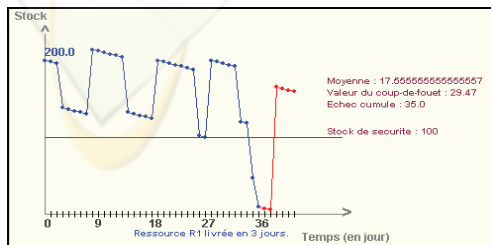


Figure 3: Z4,2.

out-of-stock condition in different cases for a special kind of provisions. The problem is that this protocol is not enough robust when a new disaster crisis overlaps with the current one. So, we propose another variant of the proposed protocol: the Many-To-Many protocol (HMTM) which gives the possibility to an upstream agent-zone to serve a downstream agent-zone who is not necessarily one of his subordinates. This protocol and other kind of interactions models will be proposed, studied and compared to the HOTM in future work in order to find the best near optimal robust solution for the provision balancing and bullwhip effect reduction through an L-levels CMSC.

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