Organization and optimization of distributed logistics: estimation and patrolling approach based on multi-agent system

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Abstract: *T*his paper proposes a new method to model supply chains. Distributed systems need continuous and up-to-date information about their products, rooting process and consumption, in order to cover customer's needs and to solve problems emerging during the products rooting. The main goal is the satisfaction of every entity constituting the logistics organization. To achieve this goal, we propose a multi-agent based supply chain management. The supply chain studied presents a variable consumption in some areas; we proposed to use two different methods to solve this problem; the need estimation agent and the patrolling method. Patrolling is a complex multi-agent task, which usually requires agents to coordinate their decision-making in order to achieve optimal performance of the group as a whole. The problems encountered in supply chains and the technique to address these problems is first presented. Multi-agent systems especially need estimation agent and multi-agent patrolling are next used as a potential solution to these problems.

Key-Words: Supply chain management, communication problems, multi-agent systems, need estimation agent, multi-agent patrolling.

1. Introduction

A supply chain is a set of firms acting to design, engineer, market, manufacture, and distribute products and services to end-consumers [8], [4]. In general this set of firms is structured as a network, as illustrated in Fig.1. in which we can see a supply chain with five levels: raw materiel suppliers, tier suppliers, manufactures, distribution centers and retailers.

The management of a supply chain needs a set of approaches used to efficiently integrate suppliers, manufacturers, warehouses, and stores, so that merchandise is produced and distributed in the right quantities, to the right locations, and at the right time, in order to minimize system wide costs, while satisfying service level requirements [9].

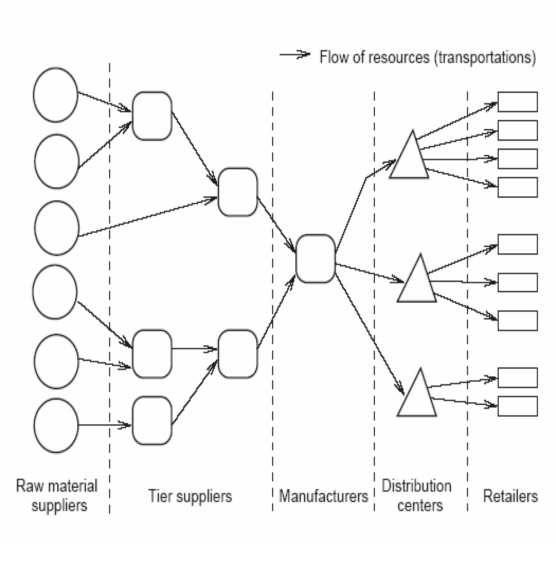

Fig.1. An example of a supply chain

Supply chain planning is a complex process especially the information sharing that must be considered a crucial point for successful business management. The availability of timely information across the different units of the supply chain, and the need to use the information for improved performance are necessary to optimize the performance of the system as a whole.

2. Logistics flow problem

We studied a supply chain composed of different cities: Fig.2. The idea is to route the flows from one city to another. Knowing that the needs in every city are different, and the consumption in the terminal city is variable. This is due to several criteria such as: features of the geographic city, the nature of the stocks, the existing customers in every city. We want to optimize the routing of these flows in order to satisfy the needs in every city. An optimal routing requires a communication between the different units of the system as a whole. Every city is so strongly related with one other, all should collaborate in our supply chain model. As we can see, this system is distributed, and thus, issues of stream fluctuations may appear therein. This is caused by several reasons, such as:

- *Collaboration reason*: an amplification of demand variability in the different units of the supply chain;
- *Collecting information reason*: on each product from the regrouping resources area to the customers or purchase point;
- *Accessing data reason*: from a single point of contact to the city information system ;
- *Analyzing data*: planning activities and making trade-offs based on information from the entire supply chain.

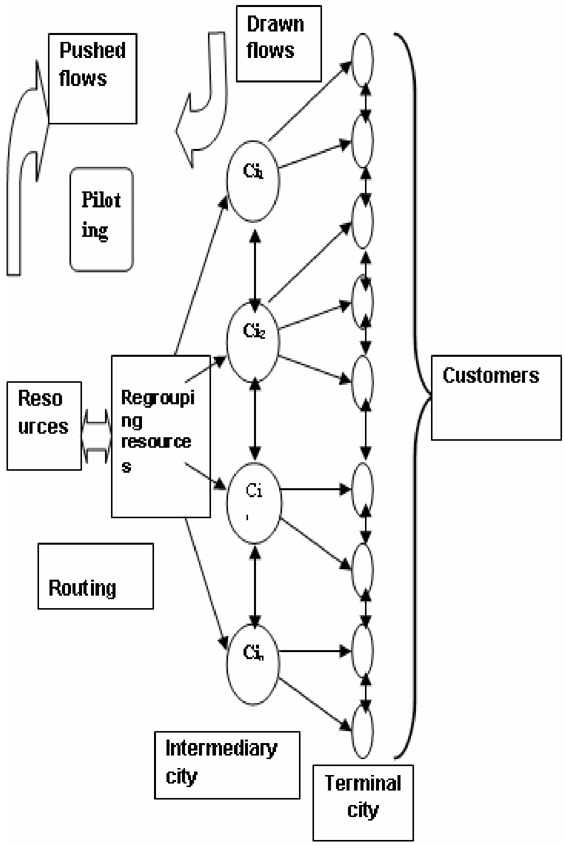

Fig.2. Supply chain studied

3. Problem solution: **A multi-agent architecture for supply chain management.**

3.1. Multi-Agent Systems

The agent paradigm is a natural metaphor for network organizations, since companies prefer maximizing their own profit than the profit of the supply chain [10]. Moreover, multi-agent systems offer a way to elaborate supply chain that are decentralized rather than centralized, emergent rather than planned, and concurrent rather than sequential. Therefore, they allow relaxing the constraints of centralized, planned, sequential control [7].

In this work we use the agent concept which has the same characteristics as a supply chain. The use of such a concept facilitates the conception of the distributed system and makes more flexible the different system's tasks:

- *Autonomy:* a city in the supply chain carries out tasks by itself without external intervention and has some kind of control over its action and internal states;
- *Social ability:* a city in the supply chain interacts with other cities, by placing orders for product routing or services;
- *Reactivity:* a city perceives its environment and the other cities. Each city modifies its behavior to adapt to the environment changes and the evolution of the consumption;
- *Pro-activeness*: a city not only simply acts in response to its environment; it can also initiate new activities.

3.2. Supply chain Modeling

We proposed in a previous paper [11] to model the supply chain as seen in the Fig.3. The Multi-Agent System proposed is composed of four types of agents: piloting Agent Ag_p, regrouping resources agent Ag_R, intermediary city agent Ag_i, and terminal city agent Ag_T [12].

- Ag_p: this agent is the manager; it supervises the different cities in the supply chain. It can cooperate in conflict case with Ag_R, Ag_I and Ag_T.
- Ag_R: responsible of the storage of the resources and flows ready to be routed; it interacts with Ag_p and Ag_I.
- Ag_I: This agent receives resources and flows of the regrouping area and distributes them to the final city, it cooperates interacts with Agp, Ag_T, Ag_I.
- Ag_T: the terminal city agent receives resources from the intermediary city. The terminal city distributes products to the customers.

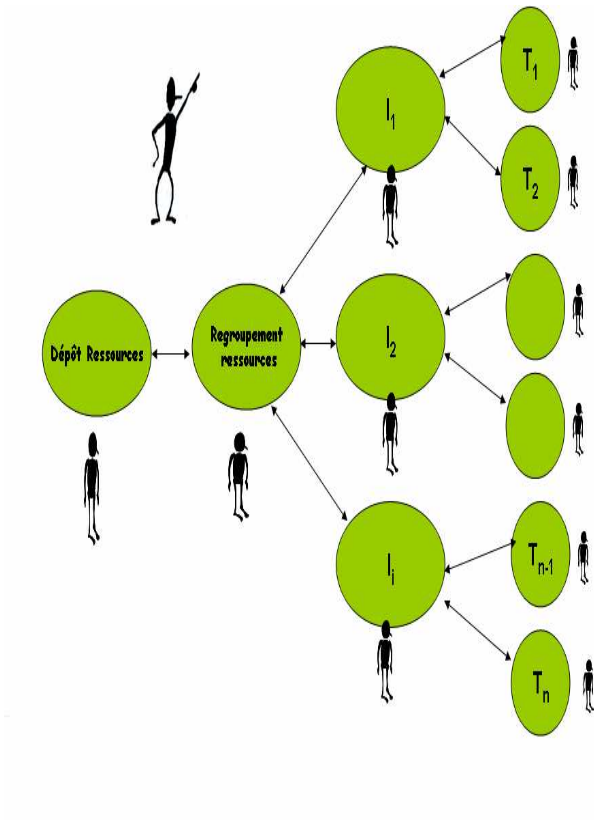

Fig.3. Supply chain modeling

Our focus now is how to control the variable consumption in the terminal city. To achieve this goal, two methods will be proposed, Need Estimation Agent and multi-agent patrolling. In a first time we proposed an estimation agent in the terminal city.

3.3. Need Estimation Agent NEA

In a supply chain, it is important to maintain stocks above a certain critical value. Usually, it is possible to have an idea of the consumption. But in case of modifications of some parameters, this consumption can vary a lot.

The Need Estimation Agent is a multi agent system; it provides an evaluation of the consumption coming from a city.

The NEA is an interface for a whole system; it indicates to a city agent what it will need using all the data provided by this agent.

To evaluate consumption, we achieved an expert system. The idea of this conception is to determine a law of calculation of the consumption, then to optimize it according to the statistical data in our possession.
We decided to treat the case of a demand of clothes. Than a certain number of parameters, that can influence the consumption of clothes, can be determinate. The two parameters used for this simulation are: The ambient temperature and the ambient humidity.
The NEA use fuzzy logic calculation. The city agent provides, to the NEA, the needed data in order to complete the calculation. A human expert is in charge to estimate these data. He has to provide the real data acquired on the city and some estimation in order to create the membership functions and the rule matrix. An optimization process will be able to correct these estimations.
We achieved a test for two linear estimators: Linear regression and Point to point.

week	1	2	3	4	5	6
Humidity	90	90	90	90	90	90
Temperature	20	20	20	20	20	20
Number of persons	5000	15000	20000	30000	25000	25000
Non optimized value	4862,64	14587,93	19450,57	29175	24313	24313
Agent estimator 1	4862,64	14587,93	21995,39	27854	22325	22793
Agent estimator 2	4862,64	14587,93	21000	23000	19000	19000
Optimized value	4862,64	14587,93	21497,7	24618	19831	19758
Corrected value	4500	15500	18000	20000	19000	19000
Weighting agent 1	1	1	1	1	1	1
Weighting agent 2	1	1	2	3	4	5
Non optimized Error	8,06%	5,88%	8,06%	45,88%	27,96%	27,96%
Error Agent 1	8,06%	5,88%	22,20%	39,27%	17,50%	19,96%
Error Agent 2	8,06%	5,88%	16,67%	15,00%	0,00%	0,00%
Total Error	8,06%	5,88%	19,43%	23,09%	4,37%	3,99%

Table 1. Estimation Values

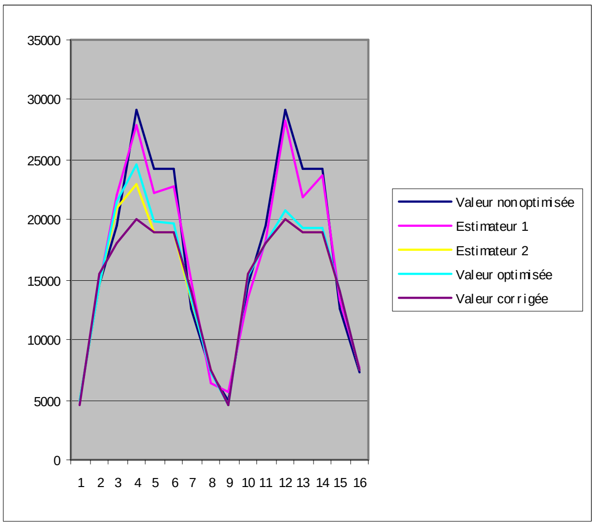

Fig.4. Estimation evolution

We can see in the Fig.4, the estimation evolution in time. The estimator 2, point to point estimator, improves between the first and the second period. In the second period, values given by the estimator 2 are equal to real values, that's means that we can determine the exact needs in these areas.
This method is very efficient in the case of a limited consumption. But it has some restrictions; if the consumption increases in a random way, we will see an overstock. This can affect all the supply chain management.
For this reason we propose another approach, the multi-agent patrolling, this method is recommended in the case of abrupt consumption.

3.4. Multi-agent patrolling

To patrol is literally "the act of walking or traveling around an area, at regular intervals, in order to protect or supervise it" [7]. This task is by nature a multi-agent task and there are a wide variety of problems that may reformulate as particular patrol task [8]. A good patrolling strategy is one that minimizes the time lag between two visits to the same location [1]. Patrolling can be useful for domains where distributed surveillance, inspection or control is required. For instance, patrolling agents can help administrators in the surveillance of failures or specific situations in an Intranet [9] or detect recently modified or new web pages to be indexed by search engines [10].

Patrolling can be performed by multiple agents, requiring coordinated behaviour and decision-making in order to achieve optimal global performance. Despite its high potential utility and scientific interest, only recently multi-agent patrolling has been rigorously studied.

3.4.1. The patrolling task

To define the patrolling task, researchers represent the terrain being patrolled as a graph, where the nodes correspond to specific locations and the edges to possible paths, the main advantage of adopting this abstract representation is that it can be easily mapped to different domains, from terrains to computer networks.

Fig.5. Example of patrolling graph

The graph representing the city will be referred to as G (V, E), where V = {1 . . . n} is the set of nodes and E the set of edges of G. To each edge (i, j) will correspond a weight cij representing the distance between nodes. The time taken by an agent to move across an edge (i, j) will be exactly cij. At time 0, r agents will be positioned on nodes of G. When the patrolling task starts, agents will move simultaneously around the nodes and edges of the graph according to a predetermined strategy [2],[3].

3.4.2. Patrolling strategies

The concept we propose is to apply the patrolling task in the terminal cities, these cities had different criteria, Fig.6. In order to have precious values of the Consumption in These areas. We need to choose the best patrolling strategy.

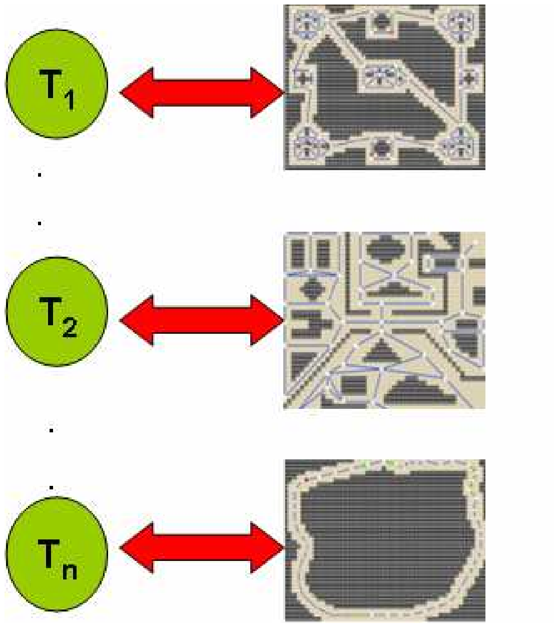

Fig.6. Terminal cites zoom.

To study this approach, we define:

- r: number of agents patrolling the graph nodes of the graph G (V, E);
- $\Pi: N \rightarrow V$; $\Pi(j)$: j^{th} patrolled node;
- $\Pi = \{\Pi_1, \Pi_2, \Pi_3, \ldots, \Pi_r\}$: multi-agent patrolling strategy;
- $\Pi_i(0)$: agent i strategy at t = 0;
- $\Pi_i(j) = \Pi_i(0)\, \Pi_i(1) \ldots \Pi_i(j)$ (1)

The goal of this study is to define the best patrolling strategy of the graph. In order to evaluate the used strategies, we introduce the idleness notion (Idle).The idleness of a city means this city is not patrolled.

- $Idle_t(i)$ = Idleness of the node i at the instant t ;
- t=0 , Idle=0.

From the nodes idleness we can deduce the graph idleness:

- $Max\ Idle_t(G) = \max_{i \in V} dle_t(i)$ (2)

The best patrolling strategy, $\Pi=\{\Pi_1,\Pi_2, \ldots,\Pi_r\}$, is the strategy minimising Max $Idle_t(G)$

Procedure patroll(x, i, patrolledcity, Ag_{Tn})

1. Let $\{AgT1 \ldots AgTn\}$ be a set of n terminal agent
3. Let E be a tree joining all graph regions between them
2. Let $s^i_1 \ldots s^i_{mi}$, a cycle that browses all graph nodes G_i
   $s^i_1 = s^i_{mi} = x$
3. PatrolledCity ← PatrolledCity $\cup \{i\}$
4. **For** k=1…m_i-1 **do**
5. **For** all $(s_k^i, y) \in$ E such us a region j of y $\notin$ PatrolledCity **do**
6. **return** (s_k^i, y)
7. patroll(y, j, patrolledcity, Ag_{Tn})
8. **return** (y, s_k^i)
9. **end for**
10. **return** (s_k^i, s_k^{i+1})
11. **end for**

4. Conclusion

This work presents some original contributions to the problem of supply chain management. The application of multi-agent techniques makes the system more flexible. According to the consumption variation in the city (fluid variation or abrupt and frequent variation), we can use one of the two methods proposed, Need Estimation Agent or multi-agent patrolling. We are in process to implement the multi-agent patrolling approach; our goal is to compare it with the NEA. The hybridization of those two approaches is possible too. It permits to have an open system answering to the requirements of its environment and evolving with every change or possible disruption that can affect it.

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