Trusted Mediator Agents to Better Manage Complex and Competitive Supply Chains

(Extended Abstract)

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ABSTRACT

Competitive markets in supply chains choose not to share their inventory, backlog, and revenue costs and hence global information is not available. In this paper, we propose a new framework for supply chain management based on trusted mediator agents. A mediator agent places an order on behalf of its customer to a corresponding supplier. The agents use local information and apply adaptive heuristic rules in order to enhance the performance of the entire supply chain. We have evaluated our framework through conducting extensive experiments in an agent-based modeling and simulation environment. The results show a consistent improvement in all the cases that were considered in the literature. We show that local information can in fact lead artificial mediator agents to discover effective ordering strategies.

Categories and Subject Descriptors

I.2.11 [**Artificial Intelligence**]: Distributed Artificial Intelligence—*Multiagent systems*; I.6.7 [**Computing Methodologies**]: Simulation and Modeling—*Simulation Support Systems*

Keywords

Supply chain, inventory, backlog, bullwhip effect

1. INTRODUCTION

A supply chain (SC) consists of retailers, distributors, wholesalers, factories, and suppliers who aim to keep a reasonable amount of safety inventory to meet future customers' demands. However, uncertainty in future orders makes it difficult for suppliers to decide on the quantity they should request in order to have a balanced inventory. In most of the successful works that were proposed in literature, sharing of global information is used to achieve good ordering strategies [2, 4, 1]. However, global information sharing is not feasible in real world's competitive markets. Researchers have argued that using global information violates the rules of information sharing and communication permissions [3].

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This paper proposes a new framework based on trusted mediator agents to reduce the total cost of the supply chain and the bullwhip effect. The mediator agents rely only on local information. A mediator agent acts on behalf of its customer in the downstream tier. Hence, a customer does not place an order directly with the supplier, instead it sends the order x to its corresponding mediator agent, which calculates a predicted value y. Then the mediator sends a total order of $(x + y)$ to the supplier. Hence, supply chain entities do not need to be intelligent. We have developed the framework in AnyLogic which is an agent-based modeling and simulation tool. Our simulation experiments show a consistent improvement in all the cases that were studied. We show that local information can in fact lead mediator agents to discover effective ordering strategies while reducing the total accumulated cost of the backlog and inventory.

2. METHODOLOGY

In our framework, a mediator agent coordinates the interaction between a customer and a supplier as shown in Figure 1. This architecture is generic and can be used to study different ordering strategies. A mediator agent employs heuristic adaptive rules to enhance the SC performance. Mediator agents can implement as simple as a one-to-one policy or more sophisticated learning algorithms. If mediator agents are allowed to share their local information, other approaches that require global information (i.e. genetic algorithm and fuzzy logic) can be implemented.

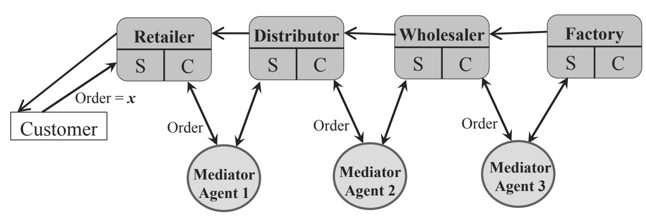
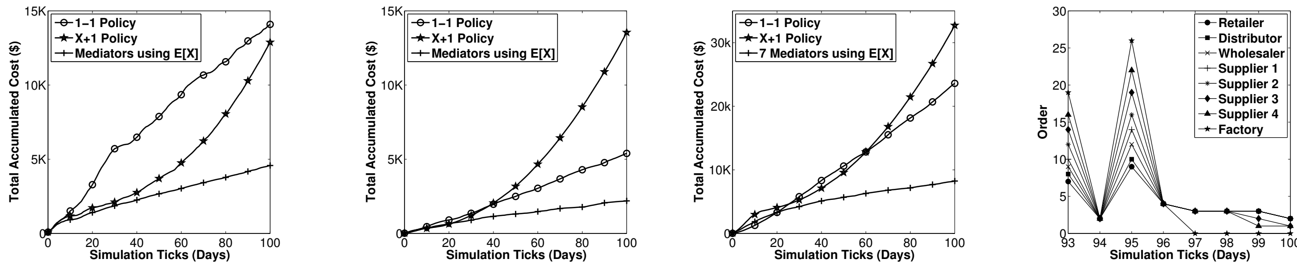


Figure 1: Our proposed framework using mediator agents

The retailer agent to the left of Mediator 1 is its customer; while the distributor is the supplier. The agent on the left sends an order x, its inventory $I(t)$ and backlog $B(t)$ to the mediator. The mediator agent decides whether to pass the order as is, alter it, or not to pass it at all. The supplier on the right sends its inventory $I(t)$ and backlog $B(t)$ to the mediator. The mediator keeps the information confidential.



(a) Demand is $u(0, 15)$, Lead Time is $u(0, 3)$.

(b) Demand is Poisson $\lambda = 3$, Lead Time is $u(0, 3)$.

(c) Large SC, Poisson $\lambda = 3$, Lead Time is $u(0, 3)$.

(d) Orders between days 93 - 100 in the case of large SC.

Figure 2: Total accumulated cost using different demand distributions, (d) shows ordering policies

Mediator 1 in the figure takes into consideration the benefits of both the retailer and the distributor. Mediator 2 takes into consideration the benefits of the distributor and wholesaler. Hence, Mediator 2 indirectly acts in favor for the retailer agent because the order that was placed earlier to the distributor has already taken the retailer's benefit. As a result, ordering strategies will indirectly influence each other for the benefits of all entities, which reduces information distortion. This behavior propagates from left to right of the entire supply chain.

2.1 Local Information and Adaptive Rules

Based on the received inputs ($I_L(t)$, $B_L(t)$, $I_R(t)$, $B_R(t)$) by the trusted mediator agent, it computes the inventory and the backlog cost as high or low. The cost of an inventory i is high, if $h \times I_i(t) \geq h \times E[O]$. Otherwise its cost is low and the same applies for the backlog. $E[O]$ is the expectation. If the order distribution is uniform $u(a, b)$, then $E[O] = \frac{(a+b)}{2}$. If it is Poisson with arrival rate λ, then $E[O] = \lambda$.

The rules are based on the policy $O(t) = x(t) + y(t)$, where $y(t)$ is the predicted value at day t. The order received from the downstream is $x(t)$ and the order placed to the upstream is $O(t)$. α and β are increased or decreased using $update^{+-}(\alpha)$ and $update^{+-}(\beta)$ in steps of 10%. α is a negative small number ($-1 \leq \alpha \leq 0$) and β is a positive small number ($0 \leq \beta \leq 1$). If $I_L(t)$ is high, the mediator applies Rule 1, otherwise it applies Rule 2. In Rule 1, if $B_R(t)$ is low, α gets decreased, otherwise it gets increased. In Rule 2, if $B_L(t)$ and $B_R(t)$ are both high, β is decreased, otherwise it is increased.

Rule 1: If $I_L(t)$ is high and $I_R(t)$ is low, then the supplier must be guided gradually to increase its inventory without incurring higher backlog costs. However, if $I_R(t)$ is high, the order becomes close to zero by decreasing α. Formally:

$$\alpha(t) = update^{+-}(\alpha(t-1)),\ y(t) = \alpha(t) \times x(t)$$

Rule 2: If $I_L(t)$ is low and not able to satisfy its downstream order, then β is increased gradually as new orders arrive to increase the inventory. However, if $B_L(t)$ and $B_R(t)$ are high, then the placed order must satisfy the downstream order. Formally:

$$\beta(t) = update^{+-}(\beta(t-1)),\ y(t) = \beta(t) \times x(t)$$

3. SIMULATION RESULTS

The framework was implemented in AnyLogic. The adaptive rules were compared against the one-to-one policy and $(x+1)$ policy. In all of the experiments, our framework performed much better in terms of the total accumulated cost, the total backlog, and the total inventory. The mediator agents were able to manage the inventories efficiently. In calculating the costs, a \$1/item/day is used for the inventory ($h = 1$) and \$2/item/day is used for the backlog cost ($b = 2$) [1, 2]. Initial values of inventory were set to zero. Figure 2 (a), (b), and (c), show that the saving in the total accumulated cost is of an order of magnitude. Figure 2 (d) shows the rules that were applied by seven mediator agents (larger SC). At 95, $O_{M1}(95) = x(95)+1, O_{M2}(95) = x(95)+2, O_{M3}(95) = x(95) + 2, O_{M4}(95) = x(95) + 2, O_{M5}(95) = x(95) + 3, O_{M6}(95) = x(95) + 3, O_{M7}(95) = x(95) + 4$. In summary, based on the experimental results, it is confirmed that the mediator agents were able to find effective ordering policies to maintain balanced inventory levels.

4. CONCLUSION AND FUTURE WORK

We proposed a framework based on trusted mediator agents to find efficient ordering policies while keeping local information confidential and private. The mediators employ adaptive heuristic rules that take into consideration the costs of inventory and backlog in the SC. Our experiments show better performance in all demand distributions that were considered in the literature. This work will be extended to consider other factors that occur in real supply chains.

5. ACKNOWLEDGMENTS

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