A New Heuristic Search with Local Optimization To Manage A Supply Chain

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***Abstract*—Supply chains are networks of independent companies in a dynamic environment. The goal of supply chain management is the coordination of these companies in dynamic environment. This research addresses the decentralized coordination of independent operations planning in order to achieve near-optimal solution. Using a heuristic search with local optimization we coordinate two partners of a supply chain. This approach requires only a minimum level of information sharing, by using incentive systems to influence their partner's planning. Our objective is to develop and to demonstrate that this approach can improve performance, compared to centralized planning and upstream planning.**

***Index Terms*—supply chain management, coordination, operations planning**

I. Introduction

The goal of supply chain management is the coordination of supply chain partners in dynamic environment. Coordination can be achieved in two major ways: centralized vs. decentralized coordination. Centralized coordination is not practical solution when different companies do not want share their critical information. In decentralized coordination, each member is modeled as a separate decision-making entity. This research addresses the decentralized coordination of independent operations planning in order to achieve near-optimal solution in dynamic environment. This approach requires only a minimum level of information sharing, because partners use financial incentives to influence their partner. Computational tests of our approach show that coordination can be achieved and the result of upstream planning can be improved.

The reminder of this paper is organized as follow. A literature review is presented in Section 2. Then, Sections 3 through 5 introduce the coordination strategy, the elements of our approach and the experiments carried out to demonstrate the performance of the proposed approach in a dynamic context. Finally, Section 6 concludes and presents directions for future research.

II. Literature Review

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Based on an analysis presented by Taghipour and Frayret (2013) [1], the techniques which represent the literature of supply chain operations planning coordination can be classified into five main techniques.

TABLE I. Coordination techniques

N	Techniques	Sub-techniques (Authors)
1	*Exact decomposition and constraint-based techniques*	***Lagrange decomposition*** (Barbarosoglu and Özgür 1999 [2], Chen and Chu 2003 [3], Ertogral and Wu 2000 [4]); ***Bender's decomposition*** (Poundarikapuram and Veeramani 2004 [5], Uster *et al*. 2007 [6]); ***Dantzig-Wolfe decomposition*** (Holmgren *et al*. 2009 [7]); ***Distributed search with constraint propagation*** (Gaudrealt *et al*. 2009 [8]).
2	*Hierarchical planning and information sharing techniques*	***Greedy coordination***, referred to as ***upstream planning*** (Bhatnagar *et al.* 1993 [9]); ***Partial aggregation*** (Pibernik and Sucky 2007 [10]); ***Information sharing and anticipation model*** (Váncza *et al.* 2008[11]).
3	*Heuristic search techniques*	***Distributed heuristic search with local optimization*** (Dudek and Stadtler 2005 [12], Jung and Jeong 2005[13], Taghipour and Frayret 2010 [14] & 2011b [15]); ***Meta-heuristic search*** (Silva *et al.* 2006 [16]); ***Interaction based coordination*** (Azevedo *et al.* 2005 [17]).
4	*Intelligent and adaptive techniques*	***Commitment-based approach*** (Cloutier *et al*. 2001 [18]); **Argument-based agent** (Jennings *et al.* 2001 [19]); ***Multi-behavior agents*** (Forget *et al.* 2008[20]); ***Learning-based agents*** (Fox *et al.* 2000 [21]).
5	*Bidding-based techniques*	***Contract-net*** (Davis and Smith 1983[22], Ahn and Lee 2004[23], Calosso et al. 2003 [24], Hu *et al.* 2001[25], D'Amours et al. 1997[26]) ; ***Auction*** (Lee and Kumara 2007[27]).

Exact decomposition and constraint-based techniques decompose a large supply chain planning coordination problem into several distributed sub-problems, which are

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solved, generally by using some form of mediator which coordinates partners using an exact search within the coordination space. The main issue concerning the application of these technics is the difficulty to interpret the information exchanged between the sub- and the master problems by operations managers.

In *hierarchical planning and information sharing techniques*, initiated by Hax and Meal (1975) [28], the decision problem is decomposed into a hierarchy problem and sub-problems linked by master/slave relationship. Coordination is carried out in a cascade process from long term to short term decisions, or from customer to supplier. The main issue with the class of coordination approach is the absence of a systematic search of the coordination space.

Heuristic search techniques use a heuristic search during the coordination process. Here, partners are capable of mutually adjusting their operations plans according to the constraints or capabilities of their partners. This form of coordination techniques requires the design of a convergence mechanism to guarantee the improvement and the feasibility of the collective plan, as well as termination conditions in order to stop the incremental process of mutual adjustment.

Intelligent and adaptive techniques exploit various advanced technics of goal-driven planning and learning in order to develop software agents capable of adapting to their environments in order to choose the most appropriate action to coordinate their planning decisions with other agents. The focus is put on the adaptive behavior of the agents. Because of this, such coordination approach can be referred to as adaptive heuristic coordination.

Bidding-based techniques involve several forms of coordination techniques based on negotiation. The general form of coordination of operations between an initiating company and others is made through the selection of partner(s).

Based on the analysis of the literature presented by Taghipour and Frayret (2013) [1], out of almost 105 selected contributions to the supply chain planning coordination problem, less than 23 % of these contributions consider the dynamic nature of supply chain coordination. This paper proposes to contribute to this gap by extending the approach introduced by Taghipour and Frayret (2011b) [15] and introduce a *distributed heuristic search with local optimization* coordination technic.

III. Coordination Strategy

In this mechanism, the supplier first identifies its optimal plan, in the neighborhood of the plan derived from the manufacturer's original plan. The positive difference between these two plans is referred to as the *Additional Supply Plan (ASP)* matrix, which represents the supplier's desire to increase the original order for specific products at specific time periods. Next, the supplier calculates the *Maximum Discount* (MD) that can be offered to the manufacturer if he accepts in totality to coordinate his OP in accordance with the *Additional Supply Plan (ASP)* of supplier. The *Maximum Discount* is defined as the gap between the profit generated from delivering its local optimal plan and the profit generated from delivering the manufacturer's original Order Plan OP. Finally, using the ASP and the MD, the supplier defines and offers a *Discount Plan* (DP) to the manufacturer, which consists in offering part of the *MD* for an adjustment of the original OP equal to part of the *ASP*. In other words, if the manufacturer accepts to increase its original order plan for specific products at specific time periods up to at least the specified portion of the ASP, than a fixed discount is offered to the manufacturer. The aim of this *Maximum Discount Plan* is to generate a base in order to propose different *Discount Plans* (DP) to encourage manufacturer deviate from its original order plan. At every round of the mutual adjustment, α percent of *Maximum Discount Plan*, referred as *Discount Plan (DP)* (DP= α * MD, $0 \leq \alpha \leq 1$) is proposed to the manufacturer, if he accepts to increase his original OP up to β percent of *Additional Supply Plan (ASP)* (β * ASP, $0 \leq \beta \leq 1$). First, if the manufacturer refuses a given discount plan, the supplier simply reduces the deviation asked to receive the discount (i.e., β) until the manufacturer accepts the discount plan. At this point, the supplier must validate any adjustments made to the order plan by the manufacturer upon the receipt of this discount plan. If the supplier does not improve its initial profit with this new order plan, it decreases the discount (i.e., α) offered to the manufacturer without adjusting the deviation asked (i.e., β).

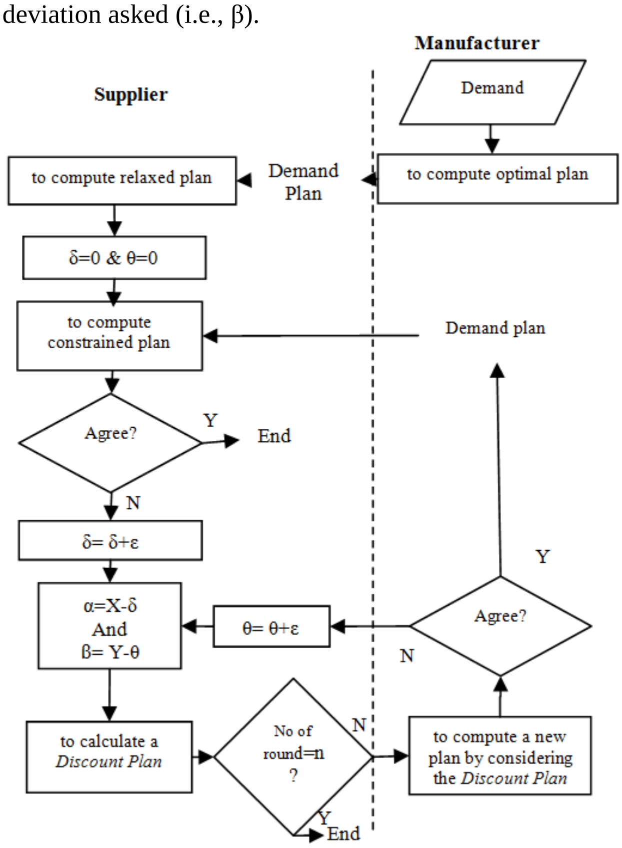

Figure 1. Search algorithm to explore the coordination space.

IV. Mathematical Models

Following is the presentation of the planning models which are multi-level capacitated lot-sizing models, inspired by Erengüc *et al.* (1999) [29] and presented in Taghipour and Frayret (2011b) [15].

Model 1 (Step 1): First Manufacturer Optimal Plan (Z_1)

The first models correspond to Step 1 when the manufacturer first optimizes his lot-sizes without considering any incentive.

Index sets

T Set of time periods

J Set of products produced by the manufacturer

J_j^s Set of products directly succeeding product j in the bill of material (BOM)

Indices

t Time period, $t \in T$

j Products produced by the manufacturer, $j \in J$

Parameters

ps_f Unit price of product f produced by supplier

$penalty_j$ Back order penalty for the manufacturer product *j* delivered to distributor

$D_{j,t}$ Demand for product j in period t (produced by manufacturer)

$u_{j,g}$ Unit requirement of product *j* by successor operation/product *g* ($g \in J$)

pm_j Unit price of final product *j* produced by manufacturer

cfm_j Fixed production setup cost of product *j produced* by manufacturer

cvm_j Unit variable production cost for product *j* produced by manufacturer

chm_j Unit holding cost for product *j* produced by manufacturer

com_r Unit cost of overtime (capacity expansion) of resource r for manufacturer

$cm_{r,j}$ Unit requirement of resource r to produce one unit of product *j* by manufacturer

$Cm_{r,t}$ Production capacity of resource *r* in period *t* for manufacturer

M A large number, which corresponds to the maximum quantity of product *j* that can be produced in a time period

Variables

$dm_{j,t}$ Tentative delivery quantity of product *j* in period *t* to the distributor

$om_{r,t}$ Overtime of resource r in period t for manufacturer

$xm_{j,t}$ Output of operation/product *j* produced (or demanded from supplier) by manufacturer in period *t* (order plan)

$ym_{j,t}$ Setup binary variable for production of product *j* produced by manufacturer in period *t*

$im_{j,t}$ Inventory level of product j in period *t*

$bom_{j,t}$ Back order of product j produced in time *t* by manufacturer and delivered to distributor

$Max\ Z_1$

$S.t.$:

1.1) $$Z_1 = \sum_{j\in J}\sum_{t\in T}\big(pm_j dm_{j,t} - cfm_j ym_{j,t} - cvm_j xm_{j,t} - chm_j im_{j,t} - ps_j xm_{j,t} - penalty_j bom_{j,t}\big) - \sum_{r\in R}\sum_{t\in T} Com_r om_{r,t}$$

1.2) $$im_{j,t-1} + xm_{j,t} = dm_{j,t} + \sum_{g\in J_j^S} u_{j,g} xm_{g,t} + im_{j,t} \qquad \forall j \in J, \forall t \in T$$

1.3) $$bom_{j,t} = bom_{j,t-1} - dm_{j,t} + D_{j,t} \qquad \forall j \in J, \forall t \in T$$

1.4) $$\sum_{j\in J} cm_{r,j}\, xm_{j,t} \le Cm_{r,t} + om_{r,t} \qquad \forall j \in J, \forall t \in T$$

1.5) $xm_{j,t} \le M\ ym_{j,t} \qquad \forall j \in J, \forall t \in T$

1.6) $xm_{j,t} \ge 0 \qquad \forall j \in J, \forall t \in T$

1.7) $dm_{j,t} \ge 0 \qquad \forall j \in J, \forall t \in T$

1.8) $om_{j,t} \ge 0 \qquad \forall j \in J, \forall t \in T$

1.9) $im_{j,t} \ge 0 \qquad \forall j \in J, \forall t \in T$

1.10) $bom_{j,t} \ge 0 \qquad \forall j \in J, \forall t \in T$

1.11) $ym_{j,t} \in \{0,1\} \qquad \forall j \in J, \forall t \in T$

The objective function 1.1 maximizes the total profit of the manufacturer, which represents the profit incurred from the revenue generated by products sold minus the cost of production, inventory, purchasing, penalty for back order and capacity expansion through overtime. Constraint 1.2 captures the flow balance between, inventory, production, delivery and internal consummation of products for production. Next constraint 1.3 captures the back orders. Constraints 1.4 represent capacity restrictions. Constraints 1.5 through 1.11 specify domains of variable values.

Model 2 and 3 (Steps 2 and 3): Supplier relaxed and constrained plan (Z_2 & $\overline{Z_2}$)

During Step 2, the supplier first computes its optimal relaxed lot-sizing plan, which consists in satisfying the total ordered quantity over the planning horizon.

Index sets

T Set of planning periods

F Set of products managed by supplier

F_f^s Set of products directly succeeding product *f* in the BOM

Fs Set of product sold by the supplier to the manufacturer

Indices

t Planning period, $t \in T$

f Products produced by supplier, $f \in F$

Parameters

ps_f Unit price of product *f* in period t produced by supplier

cfs_f Fixed production setup cost of product *f* produced by supplier

cvs_f Unit variable cost for product *f* produced by supplier

chs_f Unit holding cost for product *f* held by supplier

$De_{f,t}$ Demand for product *f* produced by supplier in period t from external customer

$v_{f,g}$ Unit requirement of product *f* by successor operation *g*

cos_r Unit cost of overtime (capacity expansion) of resource r for supplier

$cs_{r,f}$ Unit requirement of resource *r* to produce one unit of product f by supplier

$Cs_{r,t}$ Production capacity of resource *r* in period *t for supplier*

$Demandm_{f,t}$ Initial manufacturer order of product *f* in period *t*

M Large number

Variables

$xs_{f,t}$ Output of product *f* produced by supplier in period *t*

$ys_{f,t}$ Binary setup variable for production of product f by supplier in period *t*

$is_{f,t}$ Inventory level of supplier product *f* in period *t*

$ds_{f,t}$ Delivery quantity of product *f* in period *t* to manufacturer

$de_{f,t}$ Delivery quantity of product *f* in period t to external manufacturer

$os_{r,t}$ Overtime of resource *r* in period *t* for supplier

$Max\ Z_2$

$s.t.$:

2.1) $$Z_2 = \sum_{f\in F}\sum_{t\in T}\left(ps_f\left(de_{f,t}+ds_{f,t}\right) - cfs_f ys_{f,t} - cvs_f xs_{f,t} - chs_f is_{f,t}\right) - \sum_{r\in R}\sum_{t\in T} cos_r os_{r,t}$$

2.2) $$is_{f,t-1} + xs_{f,t} = de_{f,t} + ds_{f,t} + \sum_{g\in F_f^S} vs_{f,g} xs_{g,t} + is_{f,t} \qquad \forall f\in F, \forall t\in T$$

2.3) $de_{f,t} \le De_{f,t} \qquad \forall f \in Fs, \forall t\in T$

2.4) $$\sum_{t\in T} ds_{f,t} \le \sum_{t\in T} Demandm_{f,t} \qquad \forall f\in Fs$$

2.5) $$\sum_{f=1}^{F} cs_{r,f}\, xs_{f,t} \le Cs_{r,t} + os_{r,t} \qquad \forall f\in F, \forall t\in T$$

2.6) $xs_{f,t} \le Mys_{f,t} \qquad \forall f\in F, \forall t\in T$

2.7) $xs_{f,t} \ge 0 \qquad \forall f\in F, \forall t\in T$

2.8) $ds_{f,t} \ge 0 \qquad \forall f\in Fs, \forall t\in T$

2.9) $de_{f,t} \ge 0 \qquad \forall f\in Fs, \forall t\in T$

2.10) $os_{f,t} \ge 0 \qquad \forall f\in F, \forall t\in T$

2.11) $is_{f,t} \ge 0 \qquad \forall f\in F, \forall t\in T$

2.12) $ys_{f,t} \in \{0,1\} \qquad \forall f\in F, \forall t\in T$

The objective function 2.1 maximizes the supplier's profit, which represents the profit incurred from the revenue generated by sold products minus the cost of production, inventory, purchasing and capacity expansion through overtime. Constraint 2.2 captures the flow balance between inventory, production, delivery to the manufacturer, and internal consummation of products for production. Constraint 2.4 represents aggregated manufacturer demand satisfaction. Constraint 2.5 shows capacity restrictions. Constraints 2.6 through 2.12 specify domains of variable values.

Next in Step 3, the supplier computes its constrained lot-sizing plan. To do this, constraint 2.4 is replaced by constraint 2.4.1, while the same objective function is optimized (referred to as $\overline{Z_2}$ in this version of the model). Constraint 2.4.1 is used in order to satisfy exactly the manufacturer demand pattern.

2.4.1) $ds_{f,t} = Demandm_{f,t} \qquad \forall f\in Fs, \forall t\in T$

Once, both plans are computed, the supplier used equations 3.5 to 3.7 to compute the discount structure of $Discount_{\text{f,t}}$.

$ASP_{f,t}$ *Additional Supply Plan for product f at period t*

3.5) $ASP_{f,t} = \max(0;\ ds_{f,t} - Demandm_{f,t}) \qquad \forall f \in Fs, \forall t\in T$

3.6) Maximum Discount $= Z_2^* - \overline{Z_2^*}$

3.7) $$Discount_{\text{f,t}} = \left(ASP_{f,t} \,/\, \sum_{f\in F}\sum_{t\in T} ASP_{f,t}\right) * \text{Maximum Discount}$$

In brief, $Discount_{\text{f,t}}$ represents the maximum part of the discount that can be allocated to specific (product, periods) couples, in order to increase their "attractiveness" to the manufacturers. Once this discount structure is calculated, the supplier proposes a percentage of the discount ($\alpha * Discount_{\text{f,t}}$ with $\alpha \in [0,1]$) if the manufacturer accept to increase specific part of its order plan by a percentage of the Additional Supply Plan ($\beta * ASP_{f,t}$ with $\beta \in [0,1]$). This process can be repeated several times. At each round of negotiation the manufacturer receives a new discount plan in order to further improve the coordination. Once the manufacturer receives a discount plan, he optimizes again its lot-sizes taking into account the discount plan. In order to do that, the objective function and several constraints are adjusted and added.

Model 4 (Step 6): Manufacturer Optimal Plan with discount (Z_3)

Parameters

$Demandm_{j,t}$ Initial order of products *j* in period *t* by manufacturer

α Percentage of a complete discount plan offered to manufacturer

β Percentage of a complete ASP plan demanded by supplier

$ASP_{j,t}$ Additional supply plan proposed by supplier to manufacturer

$Discount_{\text{j,t}}$ Maximum Discount Plan proposed by the supplier to the manufacturer.

Variables

$q_{j,t}$ Volume of product *j* ordered (without discount) in period *t* below the initial order plan

$eq_{j,t}$ Volume of product *j* ordered (with discount) in period *t* above the initial order plan *z and* $w_{j,t}$ Binary variables used to enforce the discount structure

Modified objective function

$Max\ Z_3$

$S.t.$:

4.1) $$Z_3 = \sum_{j\in J}\sum_{t\in T}\Big(pm_j dm_{j,t} - cfm_j ym_{j,t} - cvm_j xm_{j,t} - chm_j im_{j,t} - penalty_j bom_{j,t} - ps_{j,t} q_{j,t} - (ps_{j,t}\, eq_{j,t} - \alpha * \ Discount_{j,t} * z)\Big) - \sum_{r\in R}\sum_{t\in T} com_r om_{r,t}$$

New constraints:

4.2) $xm_{j,t} = \ q_{j,t} + eq_{j,t} \quad \forall j \in Js, \forall t \in T$

4.3) $Demandm_{j,t} - q_{j,t} \le Mw_{j,t} \quad \forall j \in Js, \forall t \in T$

4.4) $eq_{j,t} \le M_j(1 - w_{j,t}) \quad \forall j \in Js, \forall t \in T$

4.5) $\sum_{t\in T}\big(eq_{j,t} + q_{j,t}\big) = \sum_{t\in T} Demandm_{j,t} \quad \forall j \in Js, \forall t \in T$

4.6) $eq_{j,t} \ge \beta * ASP_{j,t}\, z \quad \forall j \in Js, \forall t \in T$

4.7) $eq_{j,t} \le ASP_{j,t} \quad \forall j \in Js, \forall t \in T$

The objective function is similar to 1.1 except that it includes the discount. Binary variable z, together with constraint 4.6, is used in order to make sure that the discount is offered if and only if the manufacturer makes all increases of order quantity demanded by the supplier. In other words, if for a couple (product, period) the manufacturer does not respect the order increase corresponding to $\beta * ASP_{j,t}$, then the discount is not given.

Constraints 4.2 to 4.4 are used to calculate the part of the new order plan that is above the original order plan. Constraint 4.5 is used to limit the overall quantity of products ordered by the manufacturer to the level previously ordered. Similarly, thanks to constraint 4.7, the manufacturer cannot increase these quantities more than the ASP calculated by the supplier, as the impact of such increases on the supplier's profit would be difficult to anticipate. If the new resulted order plan is different from the original order plan, then it is sent to the supplier to be evaluated. The supplier can then either accept this new order plan, or propose a new discount if the maximum number of round has not been reached. In this case, Step 4 does not have to be repeated.

V. Experimentations

To apply our approach in a dynamic environment a rolling planning horizon that consists of four time periods, four planning cycles, and a planning cycle time of one time period is considered.

At the beginning of each planning cycle, the manufacturer and the supplier mutually negotiate and adjust their operations plans for the four time periods (i.e., the entire planning horizon). However, although all planning periods are planned, only the planning decision of the first period is implemented at the next planning cycle. Here, we do not consider a frozen horizon, because it does not affect results and it does not add any particular difficulty in term of implementation.

A practical issue here is the fact that after the beginning of a planning cycle, demand information changes for all periods, including the three first time periods, which were already negotiated and planned in the previous planning cycle. Therefore, it is necessary that both partners update the non-implemented time periods (i.e., periods 2 to 4 of the previous planning cycle) by mutually readjusting their plans, subject to these changes. This implies that any given time period of the planning horizon is planned four times before it is implemented.

In order to analyse the dynamic implementation of our approach, a set of experiments were derived from a test class described in the following. These tests include two partners, each of which possesses two manufacturing resources. The product structure considered has a five-level bill-of-material, which includes 30 products and components, produced by these two partners

The four mixed integer models presented in the previous section were implemented. Next, we derived two instances of test using this structure by combing one capacity utilization profiles and two cost structures created based on average ratio between holding and setup costs at buyer and supplier (equal, high at manufacturer/low at supplier). In addition, 5 values for α and β were considered (α=0.1 ... 0.5 and β=0.1... 0.5) in order to evaluate further the performance of coordination approach across the entire planning horizon. Then, in each planning cycle a new set of demand parameters is used by considering demand forecast and customer order adjustments. These adjustments are drawn from normal distributions with zero mean and a standard deviation of 10% of average demand of each sold product. These combinations of scenarios result in [2 (two instances) * 5 (five values for α) * 5 (five values for β)] 50 computational experiments in each of the four planning cycles.

In order to evaluate the solutions of the coordination approach, we also computed two benchmark tests by calculating the profit of the first implemented period of each planning cycle for each partner according a lower bound solution (i.e., upstream planning) and an upper bound solution (i.e., centralized planning). ILOG OPL 6.3 and Cplex 10 mathematical programming solver were used to solve the optimization models. An overview of the test results is given in the next section.

In order to evaluate the performance of coordination strategy following analyse is considered. Each test includes the 25 coordination solutions, which represent the total supply chain profit computed over all planning periods. In addition, the values (1) and (n)* respectively represent the start and the end of the coordination strategy process in order to illustrate the improvement of quality of solution. In the first scenario, and considering only the first planning cycle, the coordination approach starts with the supplier's first proposal with a discount plan (i.e., numbered (1)) with α=0.5 and β=0.5. Because there is non-agreement at this stage of the negotiation, the supplier proposes a new discount plan (i.e., numbered (2)*) with α=0.5 and β=0.4. At this stage, an agreement is reached with a 9% improvement ($Supply\ chain\ improvement\ rate = \frac{MAS\ profit - Upstream\ profit}{MAS\ profit}$) over the upstream planning for the global supply chain

For the second planning cycle of the first scenario, the negotiation starts identically (1) and an agreement is also reached for the supplier's second proposal (2)* with α=0.5 and β=0.4. This agreement represents a 2% improvement in the results of upstream planning for the global supply chain. For the third and fourth planning cycles of the first scenario, difference between the results of centralized planning and upstream planning is less than 0.4%. The coordination approach did not improve the initial solution; therefore, the upstream planning solution is used. For the first planning cycle of the second scenario, after three rounds of negotiation (shown as (1), (2) and (3)*), an agreement is reached. The two first proposals of the supplier do not change the results of upstream planning, with respectively α=0.5 and β=0.5, and α=0.5 and β=0.4. However, with values of α=0.5 and β=0.3, the supply chain profit improves by more than 7% the results of upstream planning for the global supply chain. For the second planning cycle of the second scenario, the agreement is achieved with the first supplier's proposal with α=0.5 and β=0.5, for a more than 1% improvement in the results of upstream planning for the global supply chain. For the third planning cycle of the second scenario, the agreement is achieved after five rounds of negotiation (shown as (1), (2), (3), (4) and (5)), with α=0.5 and β=0.1, and a less than 0.3% improvement for the global supply chain. Finally, for the fourth planning cycle of the second scenario, the agreement is achieved after three rounds of negotiation, with α=0.5 and β=0.3, which represents less than 0.5% improvement. The deviations between the best results of our approach and other approaches (centralized and upstream planning) show that by using this our approach, partners can achieve a coordination pattern which improves profit of supply chain up near to the result of central planning.

VI. Conclusion

In order to coordinate supply chain partners in a dynamic environment, this paper proposed a dynamic coordination approach based on mathematical rolling horizon programming approach, to coordinate two partners of a supply chain in a dynamic environment. Our approach is a distributed decision making problems which gives the same decision authority to all partners without any exchange of strategic information. An incentive system is used to encourage partners to participate in the coordination process. Computational analysis shows that the proposed approach produces a win-win strategy for two partners of supply chain and improves the results of upstream planning in each cycle of planning.

The performance of the dynamic coordination approach for the first implemented periods of the entire planning horizon can be evaluated. On the other hand, revenue sharing protocols can be proposed for the implemented periods.

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