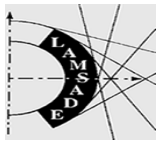

Coordination of Supply Chain Activities : A Coalition-Based Approach

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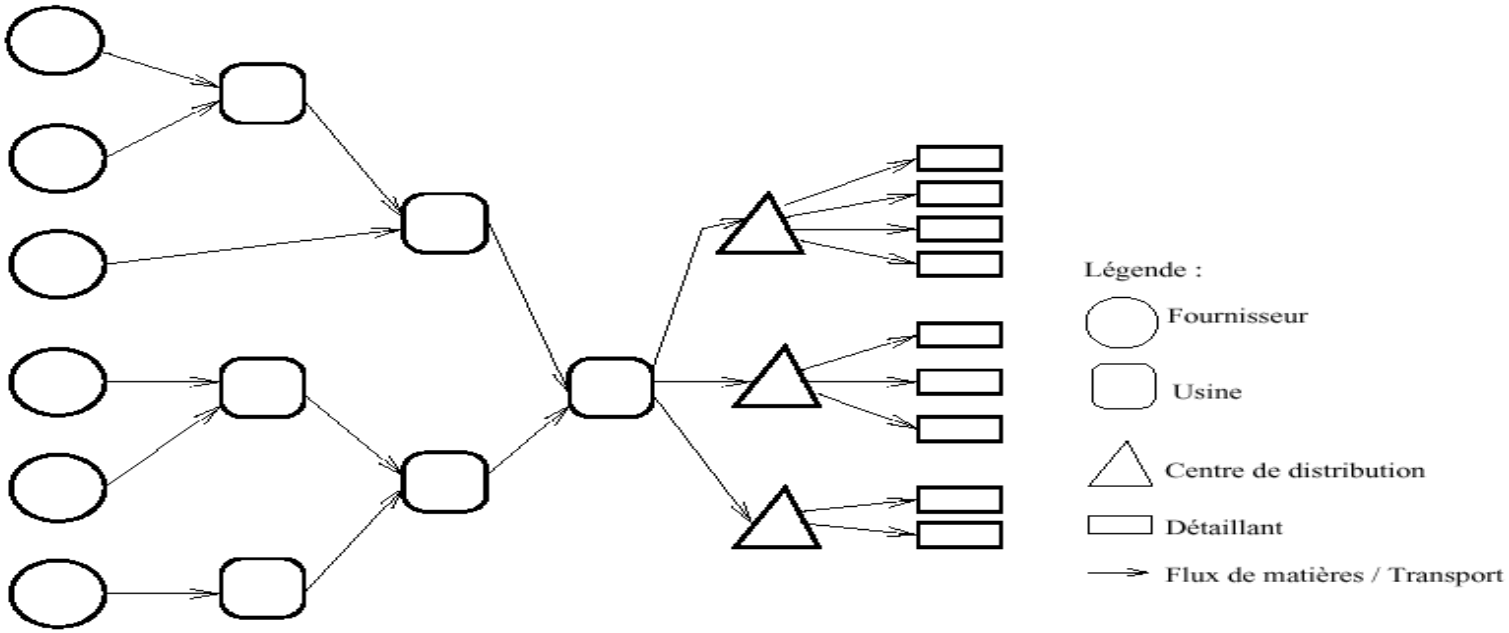
Plan

- The Supply chain coordination problematic
- Why Agent Approach?
- Related works
- Case study
- Coordination Mechanism
- Conclusion and perspectives

Coordination in Supply Chains



- Autonomous entities but with strong relationships operating in an increasingly dynamic environment
- Goal
  - A meticulous coordination and a perfect synchronization.
  - Supply Chains : group of several companies working in partnerships.

Why Agent Approach ?

- *An Agent is an entity characterized by :*
  - *Autonomy*
  - *Social Ability*
  - *Reactivity*
  - *Pro-activity*

- *Agent approach* : an interesting technology to model the complexity :

  Analytical side : intelligent agents and expert systems : autonomous entities able to decide in real time.

  Communicative side : Interaction protocols provided to agents in order to cooperate.

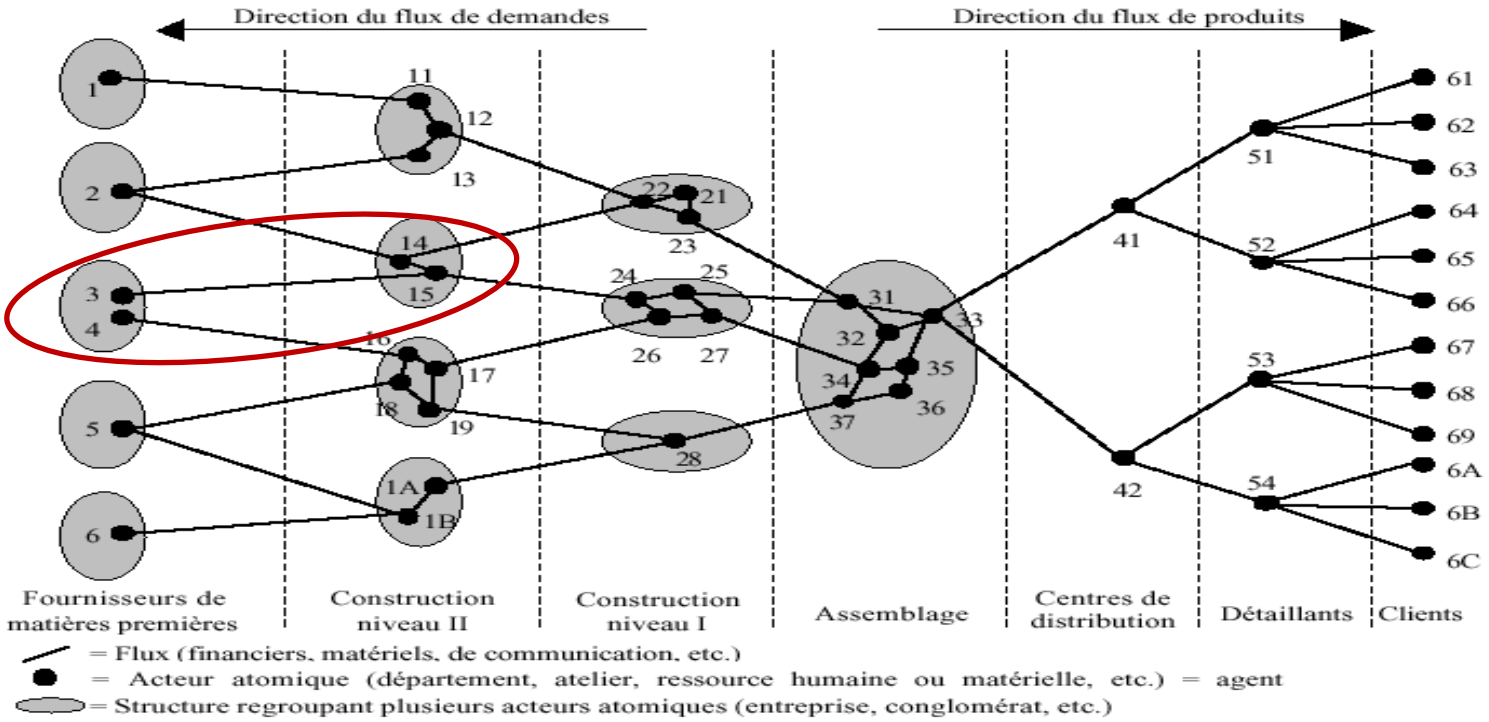
Related works

- Centralized analytic Methods (Beamon 1998), (Kok and al. 2003).
  - Factories' localization.
  - Production planning, Stock management.
  - Transport and distribution.
- Distributed dynamic methods.
  - Combination of both analytic and simulation methods, (Swaminathan and al., 1998).
  - Use of different coordination techniques resulting from MAS, (Parunak, 1996).
  - Use of interaction and negotiation protocols
    - Structured Conversations : Finite states automats (Fox and al., 1996, 2000).
    - Negotiation Protocols : AUML language (Nfaoui and al. 2006).
  - Use of coalitions' formation between buyers (Chaib-draa and al., 2002, 2003) (Hyodo and al., 2003)

Objective : Coordination using CF

A Coalition : group of agents which have decided to cooperate in order to reach a common goal (Shehory and Kraus, 1998).

- Why coalitions ?
  - Limited resources
  - Goals require or are achieved better by several agents
  - Groups of agents are not known *a priori*



Objective : Coordination using CF

⇨ **PURPOSE : To improve the performance of the company :**

- **Work in partnership (companies alliances)**
- **Ensure a perfect coordination**

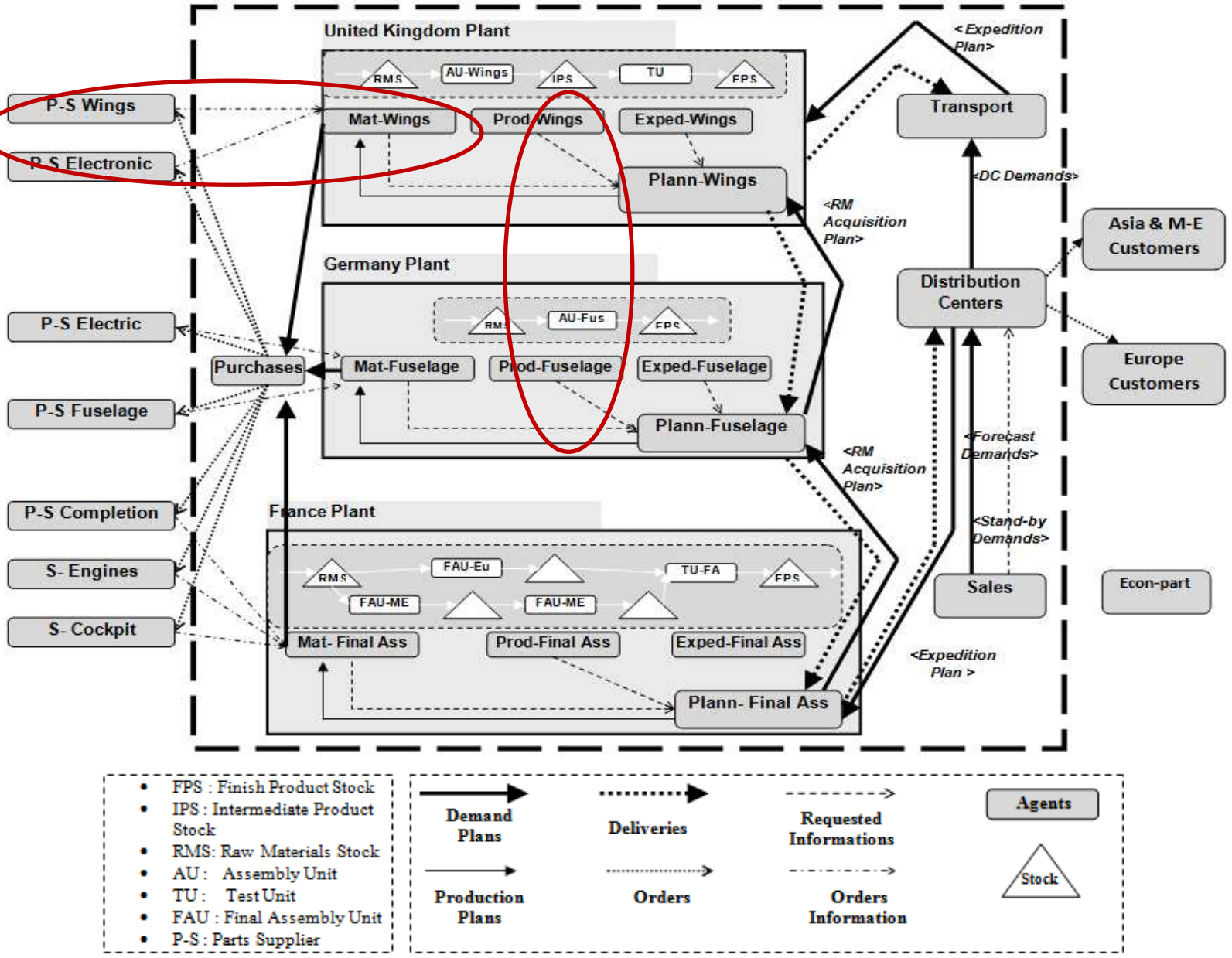
⇨ **Exploit the coalition formation mechanism allowing an automatic coordination.**

⇨ **2 abstraction levels for the coalition formation**

- ***Internal side*** **to the company (coalition formation involving the supply chain actors, i.e. Plants, DC, transportation entities …).**

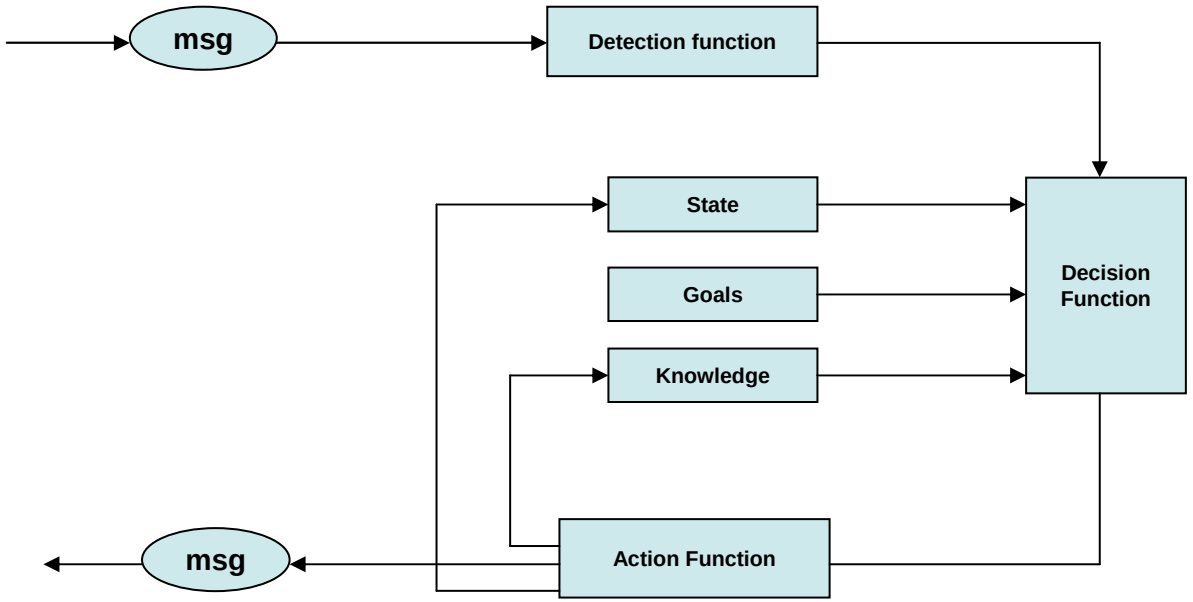
- ***External side*** **to the company (coalition formation involving both internal and external actors of the chain such as suppliers or any other economic partner …).**

Case Study


United Kingdom Plant
RMS
AU-Wings
IPS
TU
FPS
Mat-Wings
Prod-Wings
Exped-Wings
Plann-Wings
Germany Plant
RMS
AU-Fus
FPS
Mat-Fuselage
Prod-Fuselage
Exped-Fuselage
Plann-Fuselage
France Plant
RMS
FAU-Eu
TU-FA
FPS
FAU-ME
FAU-ME
Mat- Final Ass
Prod-Final Ass
Exped-Final Ass
Plann- Final Ass
P-S Wings
P-S Electronic
P-S Electric
P-S Fuselage
P-S Completion
S- Engines
S- Cockpit
Purchases
<Expedition Plan>
Transport
<DC Demands>
<RM Acquisition Plan>
Asia & M-E Customers
Distribution Centers
Europe Customers
<Forecast Demands>
<RM Acquisition Plan>
<Stand-by Demands>
Sales
Econ-part
<Expedition Plan >
FPS : Finish Product Stock
IPS : Intermediate Product Stock
RMS: Raw Materials Stock
AU : Assembly Unit
TU : Test Unit
FAU : Final Assembly Unit
P-S : Parts Supplier
Demand Plans
Deliveries
Requested Informations
Agents
Production Plans
Orders
Orders Information
Stock

Initiative/Proposal

1. **Model the autonomous entities by intelligent agents**



Agent structure

Initiative/Proposal

2. Propose a protocol of coalition formation for a complex activity

Definition of the strategy :

- Do we prefer a particular agent to another in order to solicit him to form the coalition,
- when accept a proposition from an agent,
- How to formulate its own proposals,
- When to reveal its own preferences …

Definition of the hypotheses :

- How agents send propositions to each other,
- If they are competitive,
- If they exchange information,
- If they have the same utility function and goals.

Definition of the protocol : Actions that could be done by the agent ("*initiator*"-"*solicited*") i.e. accept, refuse, cancel, disengage…, their status and their reiterations …

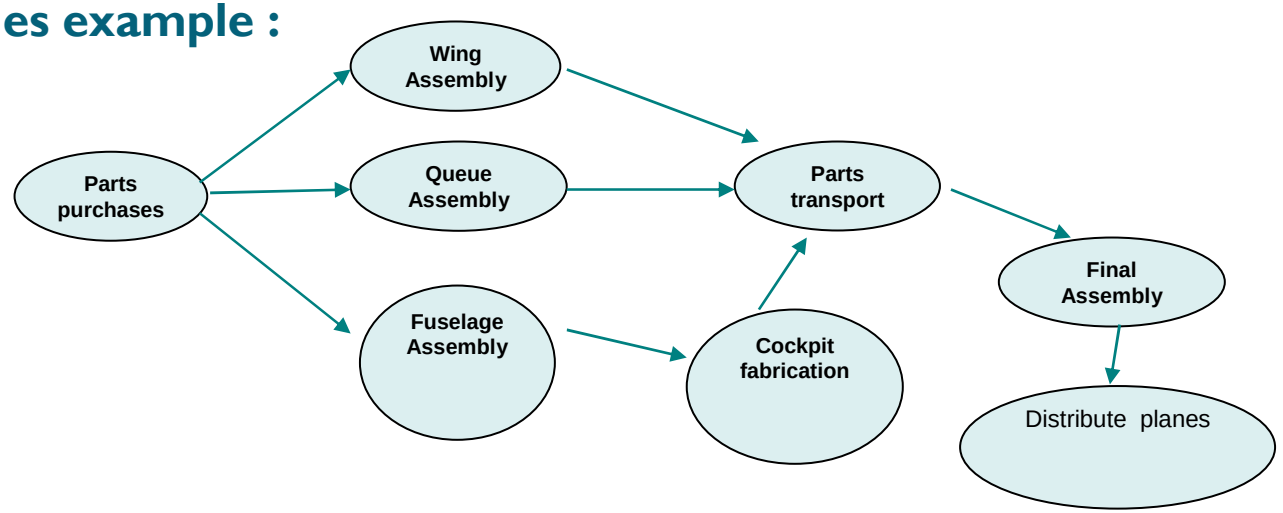
Coordination mechanism using CF

Concepts :

- $A=\{a_1 \cdots a_n\}$: set of the agents.
  $A = A^I \cup A^E$ with : $A^I = \{a_1 \cdots a_k\}$ the set of internal agents
  and $A^E = \{a_{k+1} \cdots a_n\}$ the set of external agents
- $T = \{T_1 \cdots T_c\}$: the set of the chain activities.
  $TC = \{t_1 \cdots t_m\}$: the set of complex activities subject to a coalition formation

We define an execution order of the activities that we model by an *acyclic oriented* graph <*TC, E*> avec $E = \{(t_i, t_j)\}$

Activities example :



Coordination mechanism using CF

- $Q^i = \langle q_1^i \cdots q_p^i \rangle$: capacities vector of the agent *i*.
- c_{t_s} : the execution cost of an activity t_s → **utility function** of the agent defined by a linear function.
- $cp_{a_i,a_j}^{t_s}$: cost of the output of an activity t_s from agent a_i to agent a_j
- given : $Z_{t_s}^{a_i} = \begin{cases} 1 & \text{if the agent } a_i \text{ is chosen to contribute to task } t_s \\ 0 & \text{else} \end{cases}$

Objective : Reduce the individual cost (activities) and consequently reduce the total cost of the chain :

$$\text{Min TC} = \sum_{a_i \in AP} \sum_{t_s \in TC} z_{t_s}^{a_i} c_{t_s}^{a_i} + \sum_{(t_s,t_l) \in E} \sum_{a_i,a_j \in AP} z_{t_s}^{a_i} z_{t_l}^{a_j} cp_{a_i a_j}^{t_s} + \sum_{a_i \in AR} \sum_{t_s \in T} c_{t_s}^{a_i}$$

S/to

Execution order of tasks : $\forall t_m, t_l \in TC, (t_m, t_l) \in E$

Agent capacity : $\sum_{t_s \in T} q_{t_s}^{a_i} z_{t_s}^{a_i} \le Q^i$

Cost of activities of the coalition

Cost of other activities of the chain

Coordination mechanism using CF

Assumption :

- Agents have a perfect knowledge on the environment.

Order

a_1
Final Assembly Unit

a_2
Assembly Unit Wings

a_3
Assembly Unit Fuselage

a_7
External Assembly Unit Wings

Coordination mechanism using CF

(1) Identification of agents to contact by calculation of the preferences model

(1.1) Identify, according to its knowledge, the potential agents (*AP*)

(1.2) Calculate the multi-criteria preference model and send it to other agents

(1.3) When received other models : Calculate unilateral attraction indices

(1.4) The agent having the highest indices initiate the CF proposition and blocks the process

(1.5) Calculate the bilateral attraction indices in order to identify which agent would be the best to join the coalition initially formed.

(2) Capabilities Verification, coalition formation and calculation of the total cost

(2.1) Each solicited agent will check the feasibility of the activity by examining all preceding tasks as its capacities and its utility function (execution cost)

(2.2) the agent send its answer to the initiator (temporary acceptance or refusal)

(2.3) according to received answers, the initiator decide to continue or to stop the process and calculate the TC of the chain express

Coordination mechanism using CF

Step 1 :

Having received (the order), a_1 starts a CF :

a_1 : Final Assembly Unit (Toulouse)

a_2 : Assembly Unit Wings (UK)

a_3 : Assembly Unit Fuselage (Germany)

a_7 : Assembly Unit China (external entity)

{PA: Potential Agents }

Delivery period criterion

Distance criterion

Individual and collective weights of solicited agents

$\mu(p_1) = 0.4$

$\mu(p_2) = 0.2$

$\mu(p_1, p_2) = 1$

Preferences criteria and their individual and collective weights

$$\prod_{a_1}^{2} = \begin{pmatrix} a_1 & a_2 & a_3 & a_7 \\ 0 & 0.12 & 0.14 & 0.18 \\ 0 & 0.18 & 0.16 & 0.10 \end{pmatrix}$$

Preferences Model of a_1 for PA according 2 criteria

$$\prod_{a_1} = (0, 0.132, 0.144, 0.132)$$

Aggregated Preferences Model

Calculation of the unilateral attraction indices :

U-att(a_1) = 0.162
U-att(a_2) = 0.142
U-att(a_3) = 0.148
U-att(a_7) = 0.123

→ **$C_1 = \{a_1\}$** →

Calculation of the Bilateral attraction indices :

B-att(a_2,C_1) = *0.019*
B-att(a_3,C_1) = *0.024*
B-att(a_7,C_1) = *0.021*

→ **a_3**

Passage to step 2

Coordination mechanism using CF

Step 2 :

a_3 : having the list of preceding tasks (here production of sections),

- Check the availability of raw materials, machine resources and the planning of the production process
- Calculate the cost : $c_{t_s} = \sum_{(t_l, t_s) \in E} c_{t_l}$
- Decide and send its answer to the initiator

a_1 : having answers from each agent, it checks if its goal has been reached then it stops otherwise it contacts other agents.

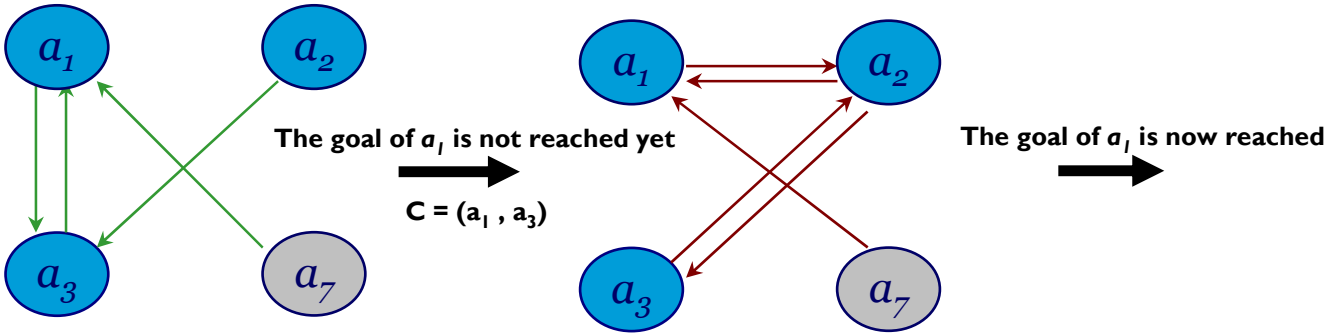
Once its goal is reached, it calculates the total cost of the chain.

Coordination mechanism using CF

Att(a_1) = (a_3 , a_2 , a_7)
Att(a_2) = (a_3 , a_1 , a_7)
Att(a_3) = (a_1 , a_2 , a_7)
Att(a_7) = (a_1 , a_3 , a_2)

1st iteration

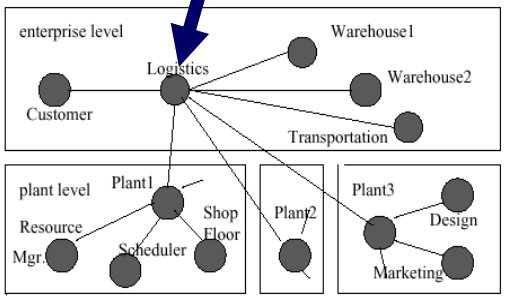
2nd iteration



The coalition is then formed of

(a_1, a_2 , a_3)

Centralized coordination



Coordination according to [Fox and al., 2000]

Conclusion and Perspectives

- A modeling way of the coordination in supply chain using a coalition formation mechanism in order to cover a distributed management of the chain activities.
- Propose a protocol taking into account all possible constraints related to supply chain (incomplete information about the environment « market rules », actors are not usually confident to each others).
- refine the model implementation and test it.

THANK YOU FOR YOUR ATTENTION