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A Commitment-Oriented Framework for Networked Manufacturing Co-ordination

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Abstract :

In the rapidly changing world of market place evolution and pressures, many authors have studied new organisational forms. Within these new trends, this paper deals particularly with network organisations. An approach is thus proposed to integrate the overall business organisation and to coordinate the business processes involved in achieving the overall organisation goals. In this study, integration is concerned with the implementation of collaborative information structures, enabling efficient operation management and control among heterogeneous business entities. Thus, based on the contract theory from economic science, philosophical work done on conventions and the multiagent systems paradigm, a commitment-oriented co-ordination framework for business integration is proposed. These concepts present a new comprehensive formalisation of business collaboration within networked manufacturing, insofar as they concern the modelling of all kinds of business interactions, including collaborative contingencies management and collaboration performance measurement. In order to illustrate this approach, a multiagent prototype using the commitment-oriented approach is finally presented.

Keywords :

Co-ordination framework, network organisation, collaborative manufacturing, multiagent systems, business integration.

1 Introduction

Due to market place evolution and pressures (Browne, *et al.* 1995), organisations have been forced within the last century to adapt their business processes and structures in order to meet the changing market requirements. With the entry into the 21st century, organisation structures are shifting from rigid and mechanistic towards agile and organic structures (Halal 1994). Many organisational forms and concepts have been proposed to cope with market volatility. Virtual organisations (Ettighoffer 1992, Goldman *et al.* 1995, Gunasekaram 1998) propose a distributed and reconfigurable enterprise structure whose life duration can be limited and predefined. The paradigm of extended enterprise proposes to consider all the enterprise components intervening in the life cycle of a product as part of the global enterprise (Browne *et al.* 1995, Jagdev and Browne 1998). The internal market paradigm deals with the internal decentralisation of buyer/supplier forms of governance (Ackoff 1993, Halal 1994, Hauser *et al.* 1996). Holonic forms of organisations have been studied for a long time (Mathews 1996). They propose many manufacturing applications such as cellular manufacturing systems as well as holonic robotic and manufacturing systems. Finally, Miles *et al.* (1997) propose an organisational form called the cellular organisation, which is particularly adapted to cope with creativity and innovation requirements, as well as continuous learning.

This paper deals with network forms of organisations (Thorelli 1986, Miles and Snow 1986 and 1995, Powell 1990, Snow *et al.* 1992, Poulin *et al.* 1994; Achrol, 1997), and proposes a framework for the formalisation of the co-ordination of interdependent business processes, and thus, to explicitly describe the collaborative planning and control processes in networked manufacturing.

The concepts proposed in this article are part of the NetMan project which aims at developing an operation system for networked manufacturing. NetMan includes ideas and concepts that present and formalise a new and comprehensive approach to operate network organisations (Montreuil *et al.* 2000, Frayret *et al.* forthcoming). This paper specifically introduces a conceptual approach to coordinate business processes in network organisations as well as a multiagent framework to formalise information exchanges co-ordination allowing explicit collaboration among agents. To do so, this paper is outlined as follows : the NetMan organisational approach and the need for co-ordination in networked manufacturing is firstly presented; then, the commitment-based approach's foundations and the framework used to co-ordinate information exchange in distributed organisations are introduced; finally, the NetMan Operation System and the developed prototypes are briefly presented.

2 The NetMan organisational approach and the co-ordination need

NetMan aims at providing a formalised vision of networked manufacturing organisations and operations. It proposes an heterarchical structure, based on the distribution of business responsibilities inside and outside the enterprises, onto autonomous business centres. This distributed approach is a fundamental premise in NetMan. Thus, in order for these autonomous business centres to work collaboratively, they must be geared up to cope with the co-ordination of all interdependent business processes. This section firstly introduces the NetMan organisational approach. Then, the coordination problem is presented in order to finally define the commitment-oriented framework foundations.

2.1 The NetMan organisational approach

In 1965 Jay Forrester introduced "A New Corporate Design" in which hierarchical relationships within organisations are replaced with more «constitutional» and «democratic» forms of control. In this

approach, performing profit centres are constituted, interacting through electronic data processing systems. Later, along the same line, some authors recognise that management styles based on authority are becoming ineffective (MacMillan and Farmer 1979).

The NetMan approach inherits these principles, and formalises a strategic framework to design and operate manufacturing networks. The NetMan paradigm formalises manufacturing businesses as responsibility-based networks (Montreuil and Lefrançois 1996) of business units called NetMan centres. These heterarchical networks (Duffie 1990) constitute comprehensive sets of nodes connected by links translating their business relationships. These nodes may be internal as well as external (plants, departments, workstations, machines, suppliers, subcontractors service providers, etc.). For example, a manufacturing firm can be modelled as a network of autonomous and interdependent decision and operation centres, developing and maintaining their own business links, inside and/or outside the firm boundaries. Centres are then responsible for satisfying other centres specific needs within a collaborative framework. This implies that manufacturing, logistics and servicing processes are planned and controlled on the basis of massive, real-time, quality information sharing regarding centres' actual and forecasted needs, capabilities, resources, etc. To do so, they are capable of making their own decisions and taking their own initiatives. Within such distributed manufacturing contexts, in order to satisfy end-consumers' demand, efficient networks of centres need to rely on a well designed and planned co-ordination structure. These centres, through their distributed decision making processes, now take better advantage of manufacturing and logistics information, since they deal in a more intensive way with fewer business partners. The dynamic interactions among the centres of the network are supported by electronic forms of data interchange, therefore, by an extensive use of new information technologies. These massive and complex exchanges of data highlight the need for information passing to be co-ordinated.

In this context, centres define their business relationships through the establishment of rules-of-thegame that translate their explicit collaborative strategies. These relationships can support different kinds of flows (information, material, service and resource), as they are mainly expressed in terms of needs and needs satisfaction. The exchange relations between contractual partners in the network enterprise can be defined on two different levels (Paché and Paraponaris 1993): (1) through the physical space of goods exchange and (2) through the transmission, the computing and the storage of information that allow partners to manage their operations. In other words, the flow of material and services in network organisations is supported, at another level, by the exchange of information.

In the NetMan modelling framework, centres share a set of features concerning their identity, their relationship and finally their operational perspectives (Montreuil *et al.* 2000). Finally, in order to situate the NetMan concepts within a CIM (Computer Integrated Manufacturing) perspective, the generic model proposed in Vernadat (1996) is used here. This model contains three definitions of integration levels, such as the physical system integration, the application integration, and finally the business integration. NetMan corresponds to the business integration level insofar as it concerns the organisational level and the business processes co-ordination.

2.2 The co-ordination problem

The co-ordination problem in organisations arises from their need to realise efficiently interdependent business processes, parts of the Order Fulfilment Process (Lin and Shaw 1998), in order to satisfy their clients' needs. To better understand the nature of the co-ordination problem, a definition of a co-ordination structure has been proposed (Malone 1987). It is presented as a pattern of decision making and communication among actors, performing tasks in order to achieve goals. Traditionally, two co-

ordination structures had been studied and described as two opposed philosophical approaches: markets and hierarchies (Williamsom 1975). Since the early 80's, the network forms of inter-organisation co-ordination structure have been given more importance. MacMillan and Farmer (1979) explain that "*it is simplistic to believe that the problems of interorganisational co-ordination can be resolved through integration where the appeal to higher authority inherent in a hierarchical managerial system is the only effective instrument that can be applied*". In the network relationships approach, it is assumed that one party may be dependent on another's resources. This implies specific inter-firm dependencies that are different from the general dependencies in the traditional market model (Johanson and Mattsson 1987). Hence, the need for coordinating these inter-dependencies is brought to the fore. Grandori (1997) proposes a classification of these inter-dependencies as two generic classes: the collective action and transaction interdependencies. In the first class, the author presents the *pooled inter-dependence*, where two firms are linked by the use of the same pooled resources, and the *intensive inter-dependence*, involving embedded complex activities. In the second class, the *sequential inter-dependence*, where the output of one activity in firm A is the input of an other activity in firm B, is first introduced. Finally, the *reciprocal inter-dependence* is presented in which an output from firm A requires, in order to be completed, the explicit expression of its specification form firm B.

In the NetMan context, these inter-dependencies' classification may be adapted to relationships involving both internal and external centres. Thus, if the organisation is designed as a network of autonomous and inter-dependent business units, such as in the NetMan approach, the co-ordination of all the business processes involved need to be satisfied, insofar as it conditions the performance of the overall cluster.

3 The commitment-oriented approach foundations

As explained in a previous part, in order to improve the global performance of the network in satisfying end-consumers' needs, NetMan centres not only need to perform locally, they also need to contribute efficiently to the overall performance of the network. This global concern is translated through the concept of business rules-of-the-game. These rules-of-the-game are co-operatively defined by the centres, and/or guided by their owners centres. They form centres' collaboration structures. They stipulate the way centres want to do business together. Their implementations are inspired, among other ways, by some research in economy where the study of co-ordination mechanisms between economic agents is apprehended through the notion of contract. More precisely, in contract theory, a contract is an agreement by which economic agents commit themselves to do or not to do certain things (Brousseau 1993). In the market structures, the notion of contract is considered as a universal frame used in inter-firms co-ordination. Regardless of the degree of collaboration between two firms, contracts are usually the base of established agreements. However, business relationship practices using no contract have been known and studied (Macaulay 1963). Along the same line, many authors study the trust-based forms of governance in organisations, which falls outside the notion of contract (Powell 1996, Creed and Miles 1996). Moreover, the conventionalist approach of the contract theory (theory of conventions) defines the convention as a generalisation of the contract notion. According to this approach, no explicit contract is signed among economic agents, but they act and make decisions according to conventional behaviours shared among them.

The commitment-oriented approach proposed here does not deal with the legal aspect of contracts. It is rather used to formalise the foreseen rules-of-the-game between centres in a manner inspired by the contract theory. These formalised rules-of-the-game are then used by the centres to do business together, whatever their nature : explicit contract or trust-based relationship.

3.1 Multiagent systems: a natural metaphor for network organisations

Multiagent systems (MAS) is a sub-field of Distributed Artificial Intelligence (DAI) concerned with the study of autonomous and communicating components called agents. A MAS is composed of multiple interacting software agents, interacting in order to solve a common problem, compete for the use of shared resources, or simply co-ordinate themselves to avoid conflicts.

The agent paradigm is a natural metaphor for network organisations since the distributed manufacturing units own the same characteristics as the agents: autonomy, pro-activity, social ability and reactivity (Wooldridge and Jennings 1995). Some authors have already applied the agent concept in Computer Integrated Manufacturing. Vernadat compares the functional entities in CIMOSA to agents (Vernadat 1996). Furthermore, CIMOSA views the whole enterprise as a federation of communicating agents.

In the NetMan approach, one of the strategies proposed for solving the complex problem of coordinating the various business processes in a network organisation, is to develop normative structures and frameworks to support communication between system entities, and to involve small organisational business centres in responsible decision making. Thus, the agent abstraction has been used as a tool for modelling the network organisation, on the one hand, and to study its inherent coordination problems on the other hand.

The proposed co-ordination framework is based on three concepts: convention, agreement and transactions. Briefly, *conventions* and *agreements* are explicit structures that describe interaction protocols and rules that are then instantiated into *transactions*. These transactions lead the agents to *commit* themselves to the operations they will perform. In other words, business partners adhere to contract-like agreements that stipulates the way they will interact in the future. These are more than simple question/answer or purchase / order / acknowledgement interactions among centres. The centres are becoming involved into complex flexible conversations that may lead them to a consensus on task commitments (deliver products, perform processes, provide resources, payments, etc.). In other words, manufacturing organisational centres perform electronic transactions to get other centres committed on some tasks. The next sub-section details these aspects.

The commitment notion is widely studied in DAI. In MAS, agents commit themselves to perform specific actions at specific times. The commitment, as Jennings stated (Jennings 1996), is considered in DAI as a fundamental mental attitude in co-ordination mechanisms. With commitments and their underlying agent's behaviour, agents have an efficient tool to explicitly co-ordinate their activities. The next sub-section presents the foundations of the commitment-oriented approach mainly based on the co-ordination framework used by the NetMan centres to obtain commitments from each other, to exchange information, to negotiate to solve problems, etc.

3.2 The four-tiers foundation of the commitment-oriented approach

In order to describe the commitment-oriented approach used to co-ordinate networked manufacturing operations, a four-tiers foundation is first introduced. Before any manufacturing action is performed, business partners design and agree upon specific co-operation strategies. In order to guide the design of such strategies, NetMan proposes some standards that are captured into *generic* co-operation strategies. Actually, generic (or common) co-operation strategies are known and applied by all the centres while specific co-operation strategies are specifically designed for sub-groups of manufacturing partner

centres. The resulting co-operation strategies, both specific and generic, are formalised into a set of explicit co-ordinations structures that represent the designed rules.

In this co-ordination approach, the commitment is the fundamental element that allows the agents to co-ordinate themselves on punctual activities, such as delivering a product A at place P and at date D. However, even though the co-ordination of activities is done through commitments, some mechanisms must be proposed to let the agents get these commitments. These mechanisms are stipulated in the explicit co-ordination structures, using the CAT co-ordination framework.

CAT (Convention, Agreement and Transaction) provides a set of tools for the business centres to declare explicit generic and specific co-ordination structures. The objective of these co-ordination structures is to enable the business partners to share high-level information, engage themselves in complex interactions such as negotiations, and obtain commitments from each other on punctual manufacturing or informational actions to perform in the future. The problem of structuring highlevel information exchange is first discussed before the framework itself is presented.

As seen in the previous sub-section, the co-ordination problems have been widely studied in DAI. Group co-ordination can be achieved through information exchange, regulated using rules or structures. Formal structured protocols have been used to accomplish specific tasks. The contract net protocol (Smith 1988) and the partial global planning approach (Durfee and Lesser 1991), among others, are good examples of these protocols. Some researchers have proposed generic frameworks for formalising conversation protocols (Burmeister *et al*. 1993; Barbuceanu and Fox 1995). Providing the agents with some structured conversation representations contributes to the global system cohesion and co-ordination.

Three levels for the co-ordination of information exchange in high level systems such as multiagent systems have been identified: (1) information exchange protocols, (2) conversation protocols and behavioural rules, and (3) co-ordination frameworks. The first level concerns information passing protocols such as KMQL (Finin *et al,* 1994) and FIPA/ACL (FIPA 1998). At this level, the agents are exchanging finite messages that can be understood by each other. At the second level, these messages may be organised into *conversations* that are finite and coherent sequences of messages exchanged between two or more agents. Languages for describing such conversation protocols have been proposed (e.g. COOL (Barbuceanu and Fox 1995)). They can be used for describing complex protocol such as negotiation protocols. Moreover, at that second level, some *behavioural rules* may stipulate actions to perform when some messages are exchanged. In fact, a behavioural rule activation may lead to sending a message, committing on future actions, performing an action right now, etc. This approach is used in *Agent-Oriented Programming* (Shoham 1991; de Greef 1996). Even if *behavioural rules* are not as powerful as *conversation protocols* for representing complex conversation structures, they are appropriate for describing simple actions or commitments resulting from some situations or some punctual interactions.

At the third level, the *co-ordination framework* concept has been introduced (Cloutier *et al*. 1999). Co-ordination frameworks allow agents to organise several conversation protocols and behavioural rules into *utilisation contexts*. Utilisation contexts may describe, for example, *when* and *for what purpose* a conversation protocol may be used and with *whom*. Moreover, utilisation contexts describe the commitments resulting from conversation protocols instantiation. For example, a structured conversation may be related to a goal the agent may achieve when using it. Furthermore, coordination frameworks provide flexible elements, such as behavioural rules, to add flexibility to the rigid conversation protocols which have the disadvantage to be inflexible.

The CAT co-ordination framework that is introduced here is based on the three concepts of *Convention*, *Agreement* and *Transaction*. Furthermore, CAT is inspired by three sources: work on *co-ordination* in distributed artificial intelligence, the *contract theory* studied in economic sciences and philosophical studies done by Lewis on *conventions* (Lewis 1969). The basic concepts involved in CAT are briefly introduced in Table 1. These three elements refer to interaction structures that are introduced in Table 2. The transaction concept is fundamental since it is the instantiation of the conventional and/or agreed co-ordination structures. In the NetMan vision, the distinction between the notion of business transaction, which translates a complete business relationship between two centres including all kinds of flow for a given period of time, and the notion of transaction between centres, which may or may not lead to a commitment between them, is crucial. Basically, the latter notion of transaction corresponds to a set of informational interactions among centres based on the instantiation of the coordination structures declared in agreements and conventions. Figure 4 presents the transaction life cycle from a NetMan centre point-of-view. In a dyadic business relationship, any transaction is initiated by one of the two business partners. In fact, from one of the partner's point-of-view, the transaction is initiated either internally (by itself) or externally (by its partner). Internal motivations may be either internal events that lead to situations detection or internal goals that lead to goal planning. Both situations detection and goal planning may lead to the initiation of conversations (based on conversation protocols). Situation detection may lead to the triggering of contingency rules or commitment rules. This means that an agent may use its agreed upon or conventional co-ordination structures to solve an internal problem (react upon a situation, or try to achieve a goal).

Getting commitments

It has already been stated that the commitment is a central element in the NetMan approach. It is used to co-ordinate activities among centres. Figure 1 presents the four-tiers foundation of the commitment-oriented approach and illustrates how co-ordination structures contained in agreements and conventions may be used to instantiate transactions that may lead to commitments. Figure 2 shows more details on the relation between the different co-ordination structures presented above. These details concern contingency management as well as performance measurements.

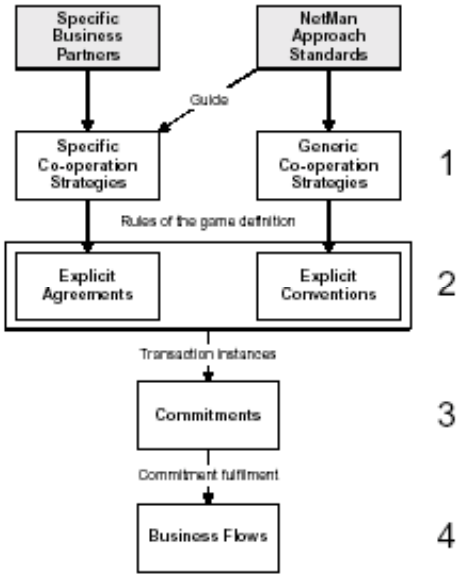

Figure 1 : The four-tiers foundation of the commitment-oriented approach

According to the co-ordination framework, transactions and their resulting commitments can be used to co-ordinate different business flows. Some transactions between centres can lead to a commitment concerning the sharing of a production model, a capacity loading forecast, a need forecast, etc. In these cases, the centres commit together to perform information sharing. These kinds of commitments translate the tight co-operation between the centres that share information on specified manufacturing aspects. Others transactions can lead to commitments concerning : the delivery of a product at a given time for a given cost and given penalties for eventual delays, the providing of a service or the realisation of a process for a given client, in given conditions, the providing of a given processor, etc.

Beyond the agreement, convention, transaction and commitment concepts, the NetMan paradigm requires from the centre a responsible behaviour: (1) they must respect the conventions and their particular agreements and (2) they must fulfil their commitments. For example, a NetMan centre that cannot satisfy a commitment for any particular reason should inform affected centres instantaneously (this is stipulated in a conventional contingency rule). In fact, each centre will establish its own way of planning, controlling and monitoring its operations in conformity with its own co-ordination strategy.

Contingency management

When NetMan centres rely on explicit co-ordination structures to interact, they must be geared up to cope with events that fall out of normal situations. Hence, the notion of contingency management is an important feature of this approach.

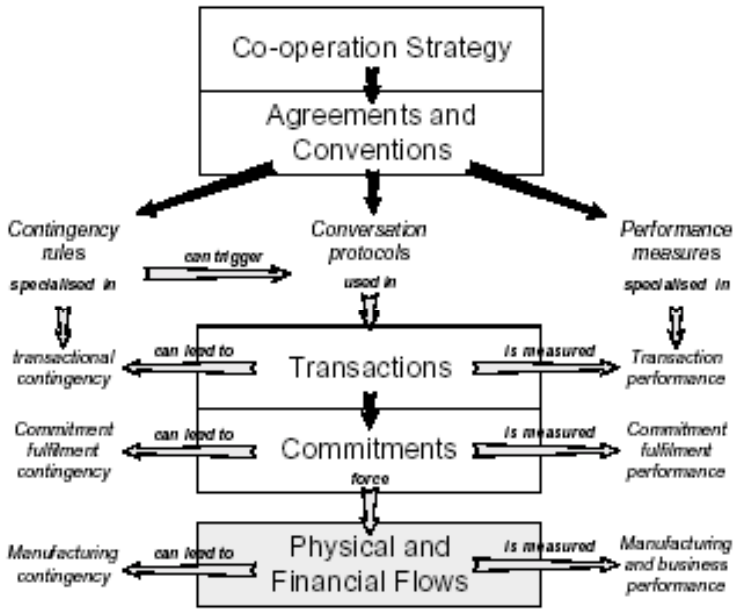

Figure 2 : Agreement role in the four-tiers foundation

In NetMan, three levels of contingency management are proposed: (1) local contingency management; (2) local contingency management with need expression to partners; and (3) collaborative contingency management with eventual need expression to partners. Figure 3 presents these three levels.

The first level of contingency management only concerns problems for which local solutions can be found without any kind of propagation in the network. Whatever the nature of the contingencies, their solution may sometime involve solely the centre where they occur. In this situation, the local

perturbation is not considered as a contingency by the network partners. Thus, this level does not directly concern the commitment-oriented approach in the sense that it does not involve many centres, but only the local efficiency of one centre, to solve the perturbation.

The second level is still not directly involved as a part of the contingency rule concept. At this level, the involved centre cannot solve the problem locally. The perturbation, rather, forces it to involve another (or many) centre(s), by expressing it (them) some needs that may help it to solve the problem. These needs, such as extra resources or spare products, are thus considered by the partners as normal interactions, even though the needs' priority may be high.

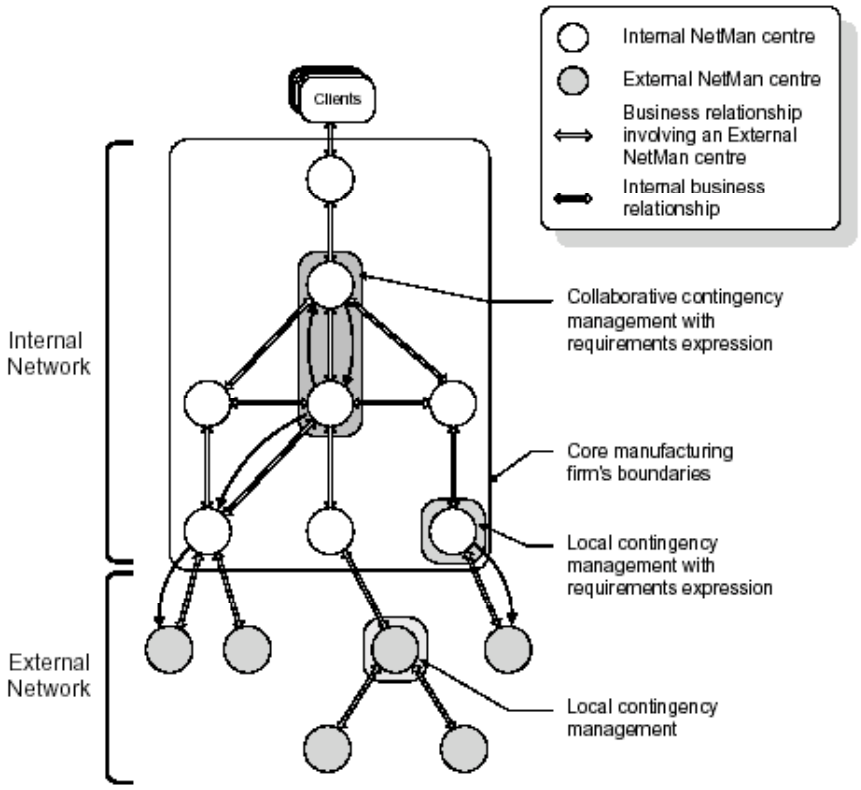

Figure 3 : Three levels of contingency management

The last level directly involves the contingency rule concept. In this context, the centres have previously identified specific situations for which they have to act promptly. An action can be simply the communication of the problem to the partner. In other cases, the centres can execute a collaborative contingency plan, in other words, trigger a conversation protocol that may lead to a solution. The partner centres have agreed (in an agreement) upon the identification of these situations, called contingencies, as well as plans, or set of actions to take, in order to solve the problem or perturbation. Some contingency management could also be specified in conventions. Contingency rules usually identify situations where some external events, from one partner's point of view, may have important impact on its own operations and committed actions.

As an example, Figure 5 shows how an internal perturbation may induce a centre to act according to agreements and conventions. NetMan centre *A* detects at time t_0 that a process p_1 (for which it is committed to be completed at time t_1) is taking more time than anticipated. The centre may have internal solutions to solve this problem (adding resources, accelerating some processes, etc.). In this

case, the perturbation remains internal (level 1). However, if no internal solution is found, the centre may adopt a goal that would lead to goal planning and, eventually, to the initiation of a new conversation that could allow the agent to achieve this goal (level 2 contingency). In this example, the centre may adopt the goal to obtain an additional human resource to finish p_1 on time. NetMan centre *A* has an agreement with NetMan centre *B* on human resource sharing (A and B are business partners in this context). This agreement stipulates that a conversation protocol CP_i may be used to obtain additional human resource (that is, getting the partner committed to sharing one of its human resources). In order to attenuate its internal perturbation, *A* will engage a conversation with *B* to get it committed on sharing a human resource at time t_0. In this example, CP_i could have been part of a convention. However, the ability of an agent, that is the actions on which it may commit, are described in agreements (abilities cannot be conventional). If no solution is found, the situation may be considered as a collaborative contingency situation. In this case, a contingency rule may then lead *A* to inform *C* of the problem. Thus, NetMan centre *C* gets involved in the problem solving and could eventually contribute to find a solution to the problem. In that instance, the contingency have raised to level 3.

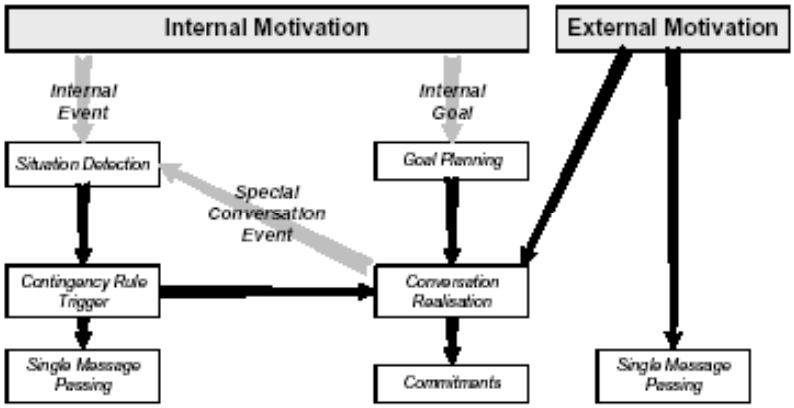

Figure 4 : Transaction life cycle

It is important to note that this example is a specific case where there is a progression of the problem from level 1 to level 3, and that is it not always the case. Actually, in many situations, a problem directly corresponds to a situation that triggers a contingency rule (level 3). Also, some problems may directly correspond to level 2 contingencies.

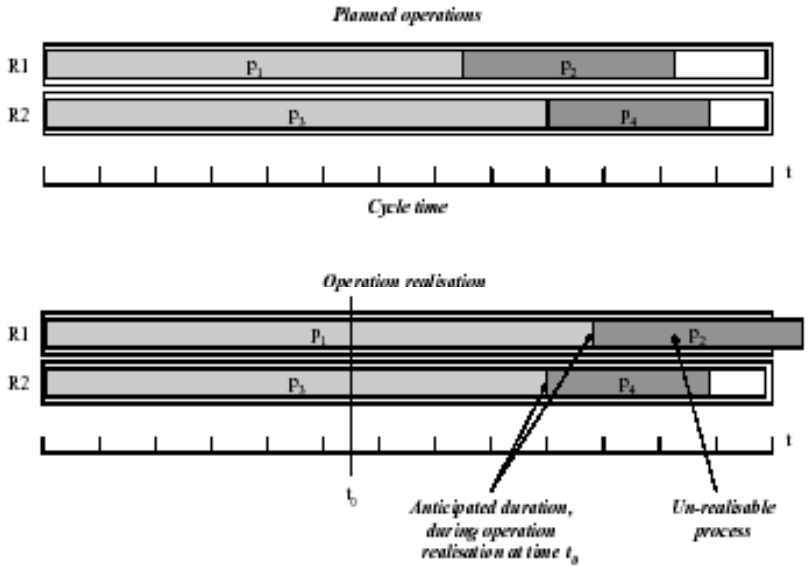

Figure 5 : Plan on workstation A

Performance analysis

As described in Figure 2, each of these three aspects (transaction, commitment and business flows) may be concerned by specific contingency rules and performance measures. For example, on the one hand, centres may need to track the efficiency of the collaboration with a partner centre involved in a given agreement. Thus, an agreement may stipulate some performance measures that evaluates : (1) how efficiently transactions lead to commitment; (2) how one's partners respect their commitments; and (3) what the need satisfaction quality is. One the other hand, centres may need to manage different kind of contingencies eventually occurring during the transactions, during the commitment fulfilment, or during the manufacturing or logistic operations.

This aspect of the agreement concept opens the door to the improvement of the collaboration between the involved business partners. Since each partner is geared up to evaluate its own contribution performance in its collaborative relationships, as well as the overall performance of the collaboration, performance measurements and analysis may lead to the improvement of the agreements in order to gain efficiency and performance, and to remain adapted to changes in the environment. The same rule may be applied to conventions.

4 The NetMan prototyping approach

The NetMan approach described in the previous section leads to a great volume of information sharing, processing and storing. Given this factor, NetMan business practices need to be supported by a collaborative information system to transmit, compute, analyze and store the required data.

In the NetMan approach, the extensive use of information technologies is one of the features of the project. However, co-ordination of electronic transactions is known to be a complex problem, especially when applied in highly dynamic environments such as in the manufacturing domain.

Prototypes have been developed according to the concepts introduced above. These prototypes, based on the multiagent system paradigm, involve many features, such as external transaction coordination, planning, scheduling, monitoring, and the simulation of the physical systems.

The developed prototypes are based on a real case inspired by the world class bus manufacturer Prévost Car, from the Volvo group, partner of the NetMan project. Frayret *et al*. (forthcoming) delve further into the description of the manufacturing case. Figure 6 presents the latest manufacturing network designed in the implementation of the NetMan prototypes. The Bus Sale Department (SD), which does not produce anything itself, directly interacts with clients that order buses. According to clients' demands, the Bus Sale Department interacts with the Bus Assembly Line Co-ordinator (HALC) that is responsible for co-ordinating the assembly line. This centre communicates with subcontractors NetMan centres, called Workcentres (from WS6210 to WS6320), responsible for assembling the buses according to HALC's specifications. These Workcentres form together the assembly line. They are also responsible for managing their own supply processes, interacting directly with their suppliers, i.e. Prelco, BC and a supply centre (SCD) responsible for aggregating workcentres' needs and for dealing with two external suppliers FabriMetal and MultiFoam. A Human Resource Centre (MWD) has been designed to provide specialized workers to the Workcentres when needed. Finally, HSLC and SAC are responsible for providing bus structures to the assembly line. The real system is composed of two assembly lines, each involving 15 workstations. Moreover, The real system involves more than 500 suppliers.

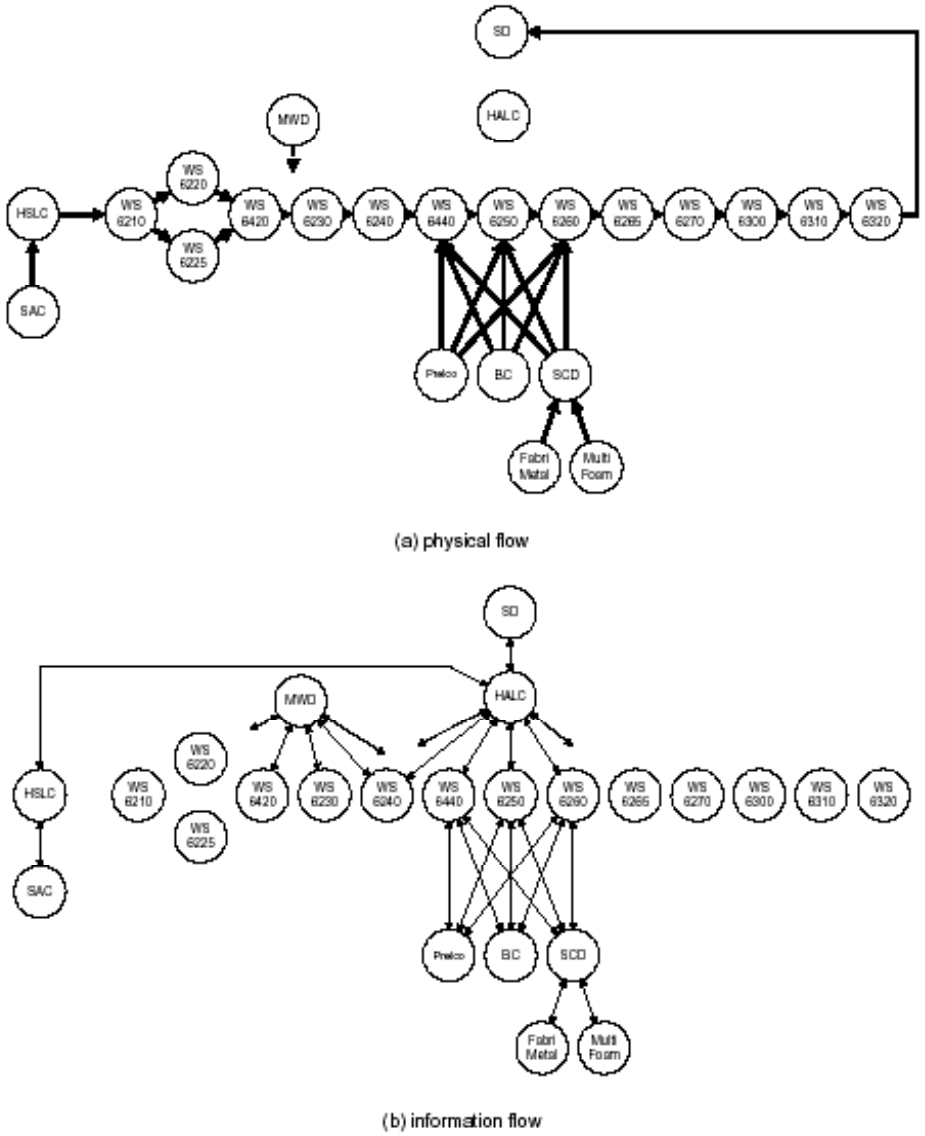

Figure 6 : NetMan centres involved in the prototype

In order to test the commitment-oriented approach, conventions and agreements among the interacting centres have been designed. These co-ordination structures stipulate the way centres will exchange information and pass messages to accomplish transactions. These transactions lead the centres to commit on manufacturing or supplying actions to perform.

As a first example, the agreement defined between the Bus Assembly Line Co-ordinator (HALC) and the Workcentres is briefly discussed. This agreement specifies the action for which the Workcentres may commit themselves according to their specialities, and their material and human resources. The agreement also stipulates the way transactions should be conducted. That is, a conversation protocol is specified, defining sequences of messages that have to be exchanged to get one workstation committed to the Bus Assembly Line Co-ordinator on specific processes. A contingency rule stipulates that Workcentres should inform the Bus Assembly Line Co-ordinator each time a commitment cannot be fulfilled.

As a second example the agreement stipulated among the Workcentres is briefly presented. This agreement formalises the way Workcentres are geared up to solve some disturbances like human

resource absenteeism or delayed processes (see the example presented in the section about contingency management above). In these cases, Workcentres can negotiate, in other words initiate conversations, in order to try to switch processes or human resources to solve the problem. This negotiation will lead them to commit each other to the processes they have exchanged or on the human resource they will share at a certain time.

The current prototype includes both planning activities, that lead NetMan centres to commitments on actions, and production activities, that may lead them to apprehend disturbances and contingencies through electronic transactions.

Agreements	They are composed of *conversation protocols, contingency rules, commitment rules* and *performance measures*. An agreement is "signed" among a sub-group, usually two, agents. The agents involved in an agreement must then to act upon it.
Conventions	They stipulate generic *conversation protocols* and *contingency rules.* Conventions are shared among all the agents in the system. Agents act according to conventions, knowing that all the agents will act according to them. In NetMan, conventions stipulate general behaviours to manage desynchronisation of conversations instances, lost messages, incorrect messages, unknown protocols, but also conversation protocols for expressing needs, accepting offers, modifying needs, etc.
Transactions	They are the collection of all the conversation instances and fired rules (both commitments and contingency rules) resulting from an initial conversation initiated by an agent or an event that trigger a contingency rule. In other words, a transaction can be composed of a well accomplished conversation instance with the resulting commitments and actions, but also, it can be made of the set of triggered elements, both conversation instances and rules, when some *situations* arise during or before the conversation instances. Performance measures refer to transactions. Transactions are useful for monitoring, performance measurement, and eventually, learning.

Table 1 – The CAT components

5 Conclusion and perspectives

Within the trend of heterarchical organisational structures and responsibility decentralization concepts, a new approach to business processes co-ordination has been proposed. In hierarchical organization, activities coordination is usually defined by the governance structure of the organisations. According to the proposed approach, heterarchical organisations must define explicit co-ordination structures instead of leaving the co-ordination emerging from a set of very simple collaborative and conventional rules.

In the NetMan approach, centres are associated with software agents that communicate manufacturing information in order to plan and operate the network organisation activities in a dynamic and volatile environment. According to this principle, actions related to physical flows are previously committed among centres. In other words, business partners commit to each other on actions to perform such as delivering a product, providing a human resource, realizing a process, etc. The concept of commitment and its application on collaborative networked manufacturing have been defined.

Before any business partner centres commit on actions or get commitments from other, some interaction standards must be described. Using this perspective, an open co-ordination framework that gives horizontal organizations a tool to formally define and control their coordination mechanisms has

been proposed. This framework allows the business centres to define rules that regulate their future interaction, such as ordering process, information sharing, etc. It also allows the specification of complex conversation protocols such as : (1) negotiation protocols to apply for conflict resolution and/or problem solving; (2) actions to perform when delivery delays occurs; (3) safety plans to execute when contingencies occur in the manufacturing system, etc. This open coordination framework, named CAT (Convention, Agreement, Transaction) can be seen as a set of constructs used to formally specify the collaboration strategies and coordination mechanisms among business partners in the network organisation. The four main constructs are conversation protocols, contingency rules, commitment rules and performance measures.

The four-tiers foundation of the commitment-oriented approach has been presented. Once collaboration strategies have been developed among business partners, explicit conventions and agreements are specified. These NetMan partners then behave according to these formalized conventions and agreements to co-ordinate their interdependent activities. To do so, they use the coordination structures described in agreements and conventions in order to perform transactions that may lead them to commit of specific actions to take. These commitments stipulate punctual actions to perform in the future by the involved partners.

This paper has also presented the NetMan prototyping approach. An example has been presented. It is strongly inspired by the world class bus manufacturer Prévost Car, an industrial partner of the NetMan project. Further developments include scaling up experiments and improvement of the cooperation strategies among business partners to enhance co-ordination.

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