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A MODEL FOR DYNAMIC GENERATION OF COLLABORATIVE DECISION PROTOCOLS FOR MANAGING THE EVOLUTION OF VIRTUAL ENTERPRISES

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Many problems use to take place during the virtual enterprises (VE) execution and they must be properly handled in way VE goals can be achieved. However, the VE nature imposes tougher requirements as decisions shall be taken in a distributed and decentralized manner, regarding that members are autonomous and independent. Besides agility, quality is extremely important. This means that such decision-making should be somehow assisted in order to provide managers with means to evaluate the feasibility and impact of decisions at each member, for every VE enterprises they are involved in. This paper presents a model where decision protocols are generated on the fly to guide managers towards more effective solutions.

1. INTRODUCTION

The increasing competitiveness has persuaded companies to participate in strategic alliances to reduce expenses, increase capacity, broaden markets and to improve themselves with the knowledge acquired in businesses. Nowadays, the research field that has gathered studies about the variety of kinds of strategic bonds is Collaborative Networked Organizations (CNO). Its manifestations include supply chains, extended enterprises, virtual enterprises, virtual organizations, virtual organization breeding environments, professional virtual communities, and others (Camarinha-Matos and Afsarmanesh, 2004).

This work focuses on Virtual Enterprises (VE). A VE is a dynamic, temporary and logical aggregation of autonomous enterprises that cooperate with each other to attend a given business opportunity or to cope with a specific need, where partners share risks, costs and benefits, and whose operation is achieved by a coordinated sharing of skills, resources, information and knowledge, mostly enabled by computer networks (Rabelo et al., 2004), offering a group of services abroad as they were an only organization (Camarinha-Matos et al., 2005).

There are four major phases in the VE life cycle: *i)* the creation phase, when all the objectives are settled and partners are selected to make the required tasks; *ii)* the operation phase, which manages the execution of such tasks; *iii)* the evolution phase, where *any* kind of changes necessary to be done in the VE plan and schedule are handled; and *iv)* the VE dissolution phase, which manages all actions when the VE goals are achieved. This work focuses on the VE evolution phase.

In the evolution phase, different *operational* problems should be managed. For example: the anticipation or delay on parts/products delivery, partners performance below to the established metrics, collaborative tasks not accomplished or not as expected or out of the specifications, alteration on the initial product's specification, partners replacement, among many others.

Many decisions have to be taken to (try to) solve such problems. However, in a VE scenario, and especially considering the autonomy, geography dispersion and heterogeneity of working methods, is not possible to handle the problems traditionally, as an enterprise does internally, typically applying classical hierarchical mechanisms. Actually, a CNO scenario imposes different requirements to management methods (Table 1).

Table 1. Comparison of traditional management and VE management models

	Traditional Model	**CNO/VE**
Decision scope	*Intra-organizational*	*Inter-organizational*
Decision	*Typically centralized*	*Preferably decentralized*
Information sharing among partners	*No or eventual*	*Yes*
Decision transparency	*No or Low*	*Yes*
Quality decision evaluation	*No or Low*	*Yes*
Decision process rigidity	*Inflexible / Workflow*	*Flexible / Ad-hoc*
Information integration between partners	*Low / Medium*	*High / Very High*
Trust among partners	*Implicit*	*Explicit*
Decision objective	*Best local result*	*Feasible global result*
Mutual help level between partners	*Cooperation*	*Collaboration*

Decision-making in a CNO scenario comprises the execution of a number of activities, which starts with the identification of the problem and its severity, passing by the reasoning about the involved partners and the affected product's components, and ends with the application of the right procedure and the final problem resolution. One of the main problems in this scenario is not only to be able to react and to trigger actions towards the problem solving, but also to be agile in this.

Another fundamental aspect that should be noted is that a VE is something unique. This means that the way a problem was solved in a given/past VE is not necessarily valid for another VE. A business opportunity (BO) that generates a VE comes from different customers and countries, which have different cultures, different regulations, different idioms and jargons, different standards, and that apply different metrics in terms of e.g. quality, manufacturing processes and environmental cares. Considering that enterprises are often involved in several VEs simultaneously and that some of them are inter-related, it is not difficult to realize how ample and complex a decision-making in CNO is.

Handling these issues properly is likely impossible to be made by a human. If it was considered that most of CNO companies are composed of SMEs, this difficult is even harder. Despite the technological complexity it represents, current approaches to deal with this fail in not offering the comprehensive, flexible and holistic environment where all these CNO-related requirements and elements – from the VE *evolution* phase perspective – can be embraced and handled. Such approaches usually provides some good supporting elements but only to the "VE manager" (or equivalent), who is considered the only one allowed to have the global map and information about the situation, and who takes the decision, centralized, just informing the other companies about it. On the other hand, a decentralized scenario imposes the need of having several discussions through the

network, which, in practice, is not efficient as they use to be conducted without much organization and it is very easy to lose the focus of the discussion. As a consequence, the decision-making is slower and potentially has lower quality.

In this context, the presented paper focuses on how discussions among the VE partners – and further decision-making – can be carried out more effectively. In general, the idea is to provide a supporting methodology, which can systematize and guide the discussions about a given problem within a VE towards its resolution. This methodology is represented as decision protocols, which are generated on the fly in order to cope with the various specificities of each VE and problems' states.

This paper is organized as follows. Chapter 1 presented a general analysis of the requirements for VE management and the complexity to deal with this in the evolution phase. Chapter 2 gives an overview on the management theories and methodologies that have being used in distributed management activities. Chapter 3 introduces the proposed model and framework. Chapter 4 gives an example of the envisaged dynamic generation of protocols. Chapter 5 presents some conclusions and next steps.

2. VIRTUAL ENTERPRISE MANAGEMENT

Managing the planning, execution and control of the organizations gathered to attend to a new market demand is not new and solid works have been developed around this. This chapter presents a general view of relevant issues that are directly related decision-making problem in a distributed scenario.

2.1. Virtual Enterprise as a Project

One of the most relevant foundations to support this is the *Project Management Body of Knowledge*, or just *PMBOK* (PMBOK, 2004). PMBOK states that "a project is a temporary effort to create a unique product or service", whereas a VE is a "dynamic and temporary alliance of organizations that share abilities, competencies and resources to attend a business and to offer valuable products and services …" (Camarinha-Matos et al., 2005). As it can be noted, managing a VE seems equivalent than managing a project from the PMBOK point of view. Jansson et al. (2005) advocate that VE management is more than managing a project, as the creation of a VE requires a long and previous preparation. However, focusing on VE evolution, it seems quite acceptable to state that a VE have equivalent features than a project, as both are temporary and unique in view of the creation of a product or service.

From the project management perspective, VE evolution management comprises verification, measurement, planning and discussion. More concretely, it requires three important aspects: *i)* performance monitoring (via e.g. *BSC*, *SCOR* and *OLAP*); *ii)* performance evaluation (e.g. via modeling *simulation*, *queue theory* or *analytical modeling*); and *iii)* collaborative discussion (e.g. via mechanisms like *HERMES*, *Delphi*, and *groupware*).

The mentioned methods are just examples. The existing project management reference models are generic to be instantiated with any managerial models (Karvonen et al., 2005).

2.2. Virtual Enterprise Management and Decision Protocols

VE management "designates arrangement, allocation and coordination of the resources and their tasks, as well as their inter-organizational premises, to reach the VE goals, respecting time, cost and quality" (Jansson et al., 2005). VE evolution management is defined in this paper as "the decision process expressed as management knowledge that tries to offer the right direction to human decision-makers in applying adequate problem-solving techniques and computational support to handle unexpected events that happen in a VE and that modifies its initial plan, in such way VEs' goals are kept".

In terms of generation of decision protocols, three previous works can be mentioned as they are the only ones found out in the literature that cover this. ILMSS (Rabelo et al., 1998), DBPMS (Rabelo et al., 2000) and SC^2 (Rabelo and Pereira-Klen, 2002) are systems that deal with the VE evolution phase and that assist managers on decision making. However, they use a pre-defined, fixed and general decision-protocol.

Another system, the VOM Toolkit (Pěchouček and Hodík, 2007), is an integrated environment that has been developed to help the so-called VO manager in doing several activities, such as VO performance monitoring, alert about possible changes in the expected performance, and rescheduling and reconfiguration simulation to optimize the VO performance. However, as in those other three systems, it leaves to the VO manager to implement the necessary corrections to better solve the conflict. No guidelines or supporting methodology is offered to help him in these activities. As it was stressed in the previous chapter, managing the VE evolution requires several other features.

2.3. Project Management Reference Models

PMBOK model consists on the application of knowledge abilities, tools and techniques in favor of reaching the decided goals in the beginning and planning (PMBOK, 2004). It is a comprehensive model but too general in the part that deals with how changes in a project should be managed. The *Capability Maturity Model Integration* (CMMI, 2006) has been mostly used in software development. It assists organizations in the improvement of their processes and their capacity to manage the development, acquisition and maintenance of products and services. The *Agile Project Management (APM)* model faces the changing need as an adaptation in the exploration of alternatives that can fit to new scenes (Leite, 2004). There are other management models, such as the *ECM - Engineering Change Management* (Tavčar and Duhovnik, 2005), *CC - Configuration Control* (Military Handbook, 2001) and *CM – Change Management* (Weerd, 2006), which are used to analyze a project, covering phases of problem identification; demanding the necessary change; verification; analysis and change approval; implementation; and maintenance of the results of changes. Elements of these models shall be used as the basis for the envisaged VE evolution management framework.

2.4. Collaborative Discussion

In terms of computing support for discussions over the network, groupware tools only cope with a partial part of the problem. The matter is not only to make partners talking to each other, but rather to globally coordinate their discussions, integrating information for further auditing, giving transparency to the whole process, and regulating partners' involvement and information access as long as decisions are

taken. Four works have been considered useful to give some support to the desired discussion environment.

HERMES is a support system to collaborative decision making by means of argumentation. It helps in the solution of non-structured problems, coordinating a joint discussion among decision makers (Karacapilidis, 2001). It offers an online discussion about one or more specific subjects, where each participant can suggest alternatives to the problem or simply point out their pros and cons in relation to current alternatives.

Delphi is a much known method (Dalkey and Helmer, 1963) created with the purpose to find the most reliable opinions without argumentations. This method collects all the participants' opinions individually, elaborates a summary and sends them back without any identity exposure. Participants provide their vision along diverse rounds about their initial judging until a consensual agreement among all the participants is reached.

Sowa and Sniezynski (2007) developed a security framework that controls information access dynamically according to partners' roles in a VE. Ratti and Rabelo (2007) present an integrated communication infrastructure including a set of groupware services (e-mail, forum, chat, etc.) tailored to VEs.

The combination and some adaptations in these works is seen a feasible starting point to support the envisaged conversation scenario.

3. PROPOSED MODEL

To delineate the scope of the model it is essential to also delineate the basic actions involved in each phase of the VE life cycle. Figure 1 illustrates the authors' vision about that. In general, this means that VE operation comprehends the monitoring of a VE after its creation, whereas the VE evolution is responsible for the analysis, management and implementation of eventual changes in the VE along its execution. These actions in turn request an interaction with the VE creation phase when the solution of a given conflict involves the replacement of partners.

In order to attend the previously mentioned requirements, the proposed model is based on four pillars. The *Organizational* pillar comprises the issues related to both intra and inter-enterprises processes that should be involved in a decision-making. The *Human* pillar endows managers with user-friendly and comprehensive decision environment where they can check and intervene (using supporting techniques and experience) along the process. The *Knowledge* pillar is related to "all" information, knowledge and management tools (methods, techniques, etc.) that can be used to support the decision-making. The *Technological* pillar refers to information and communication technologies (ICT) that support an easy and secure communication among VE members.

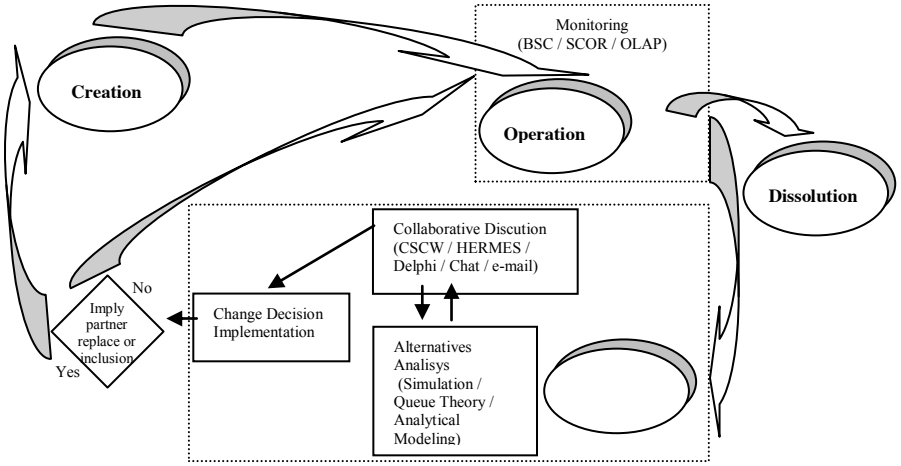

Figure 1. Interaction of VE Evolution phase within the VE life cycle

In the proposed model, project management reference models have provided the basis for the definition only of the macro phases that should be pursuit to solve a problem in a VE. This is because these models are (naturally) too generic to be ready used in a given concrete VE scenario when a problem takes place.

In general, the proposed model takes and partially automates such macro steps. The idea is to make VE members to follow some solid "guideline", which drives the discussions' evolution as long as partial solutions are achieved. During the discussions (via Internet), members can consult a group of available supporting methods that may help them in the solution as well as can check some effects of potential decisions on their companies. This creates a collaborative decision-making environment where all the involved partners can check such effects at the same time, validating or aborting a decision much faster and with more reliability.

The proposed model doesn't intend to automate the resolution of every different problem of every different VE. Instead, it intends to create a distributed/decentralized and integrated "cockpit" environment, where decision-making can be driven by a flexible and "open" protocol that offers *knowledge* to *human* managers to go through *organizational* processes using *technological* means (see the four pillars mentioned before).

A protocol is a sequence of steps that describes the activities that should be executed. Each activity should be expressed in terms of *what, why, where, when, who* and *how* it should be done towards the problem resolution. In other words, the so-called dynamic generation of decision protocols refers to taking those *reference* macro phases and to *instantiate* them according to the problem / VE. However, there is not an "engine" for automating the protocols' steps execution. This is a crucial difference to other approaches. Managers are the ones who should trigger the steps while discussing about the problem and possible alternatives, allowing them to use their experience and managerial feeling. Figure 2 shows the proposed reference protocol.

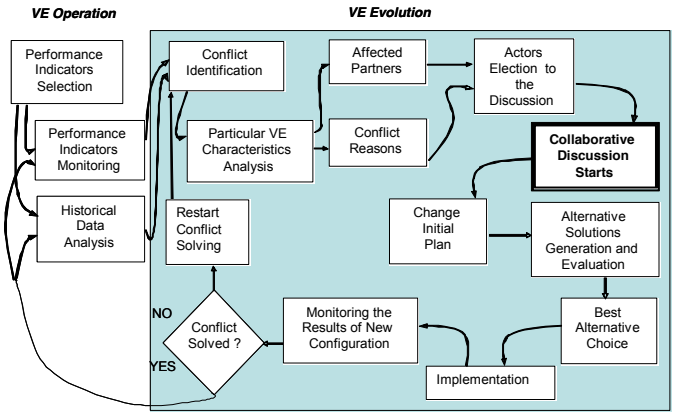

Figure 2. Reference decision protocol model for VE evolution management

The protocol instantiation varies from VE to VE and from problem to problem. This means that although the steps may be the same, the methods, number of required interactions among partners, sub-steps, etc., can be different, and the resulting solution can be different as this also depends on partners' opinions and agreements. Yet, depending on the case, steps can be even suppressed or tackled in a very simple or more complex way. Another aspect is that only part of the protocol involves activities related to conversation among partners. Other steps refer to analysis, visualizations, etc.

Performance evaluation through simulation gives an outline of which strangulation points are in the process, delays, etc. Performance evaluation techniques through performance measurement systems can be used to identify hidden or imminent problems. Therefore, decisions tend to be taken based on some foundation. This facilitates argumentations between partners and hence turns decisions faster and potentially more reliable to help a VE in reaching its goals.

A problem is not necessarily solved at once and a problem may be constituted of many sub-problems. Each sub-problem can demand diverse rounds of exchange of information, computer-aided analysis and managers' opinions. The process ends when a considered good/feasible alternative is found. In the case no solutions are found, the situation is passed to the tactile and strategic levels (which are out of scope of the proposed model) in such way decisions like negotiation with customers, cancellations, etc., can be evaluated and taken.

The protocol and underlying approach cope with the main requirements for decision-making in VEs, supporting agile collaborative decisions, respecting partners' autonomy, process transparency, offering theoretical supporting managerial framework, and providing means for some guided conversation.

4. THE DECISION PROTOCOL: AN EXAMPLE

In order to generally illustrate the protocol generation, it is possible to imagine a VE that has been created to transform five regular cars into personalized vehicles to an automotive fair. In this case, there would be different partners responsible for each of the following tasks: bodywork and painting, audio and video equipment, tires supply, engine adaptation and calibration. As partners are in different cities, not more than 100 km away from each other, which would be the best way to solve

a one-week delay in one of the necessary engines? Which tasks have to be delayed? Which partners were affected? Is it possible to simulate tasks rescheduling in order to minimize the delay? Wouldn't it be better to get this engine from another supplier? Answers for these and other related questions can be expressed in a sequence of general steps to follow helped by a collaborative discussion support.

If the problem was caused by a fail in the product's specification, what sequence of tasks shall be executed to solve the problem? In the VE *operation* phase the manager would have used *OLAP cube* to measure the VE indicators performance and to identify the problem. After this - so now within the VE *evolution* phase - a particular protocol to guide the problem resolution is generated using the reference protocol, as roughly exemplified below.

1. *When a problem emerges, the first evaluation is how deeply this would affect the VE operation. If its necessary, ask for solution;*
2. *Depends on the VE particularity, different steps and tools should be used;*
3. *The VE manager and the partner responsible for the product out of specification identify the others partners affected by this problem, specially in view of tasks delayed;*
4. *In parallel, they intensively try to find the reasons of the problem;*
5. *At this point the affected members have to be invited to discuss together about the problem and on how it can be solved;*
6. *Starting the discussion that would be conducted through / assisted by a system (something like a merged HERMES system and Delphi method);*
7. *Two different solution might emerge: suggest the partner to redo the component following the correct specification (if there is trust and time to do it), or to keep discussing if this is not possible;*
8. *In the second case, it is necessary to inform that the changes should consider the VE initial goals and plan;*
9. *The VE manager and partners would use a simulation tool to see which different scenarios could be acceptable and evaluate which is the best one to solve the problem. The affected partners should exchange results.*
10. *Once agreed, this solution is settled in the VE plan and partners can monitor the VE execution again. This means that evolution is over and now the VE management goes back to the* operation *phase.*

Figure 3 shows the multi-level model, illustrating the sequence of a protocol instantiation with the reference initial protocol related to the problem (regarding the specificities VE), passing by the generation of a particular protocol, the sequence used in the discussion phase, and the different tools that would be used to help in each protocol's step.

5. CONCLUSIONS

This paper has presented an approach to assist VE members in the problem solving when conflicts take place in the VE evolution phase. A decision protocol, which is automatically and dynamic generated taking a reference protocol into account, essentially represents this approach. If on one hand the protocol is relatively generic, on the other hand it is a concrete mean to enable partners to be guided and assisted during the problem-solving, giving the potential for a faster and more reliable, feasible and collaborative decision-making. Actually, this protocol intends to face the new requirements in terms of management brought up with the VE concept, in particular the fact that decisions shall be

taken collaboratively and distributed, with transparency, preserving the autonomy and independence of each VE member.

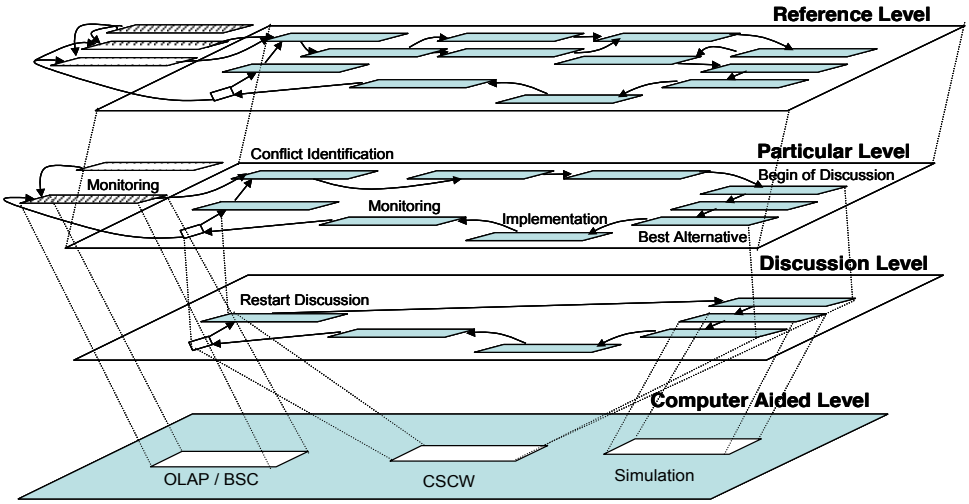

Figure 3. Example of the Reference Protocol instantiation

It is argued that a protocol shall be somehow generic to accommodate the different ways of solving a problem from different groups of managers, depending on the VE's specification, its goals, and its partners.

The protocol is focused on the VE evolution phase and it only embraces problems at operational level. Its steps were fundamentally devised based on the most relevant project management reference models.

In terms of partners' communication and information exchange, this work assumes that a VE is created from a *VBE* (Virtual Organization Breeding Environment) so partners have already some trust built. Besides that, it is assumed that the sort of supporting information and methods for problems solving are available in the VBE as this is a usual asset VBEs have.

This work is at its initial phase. The focus of the research has been put on the model and the protocol. There is not any implemented prototype so far, although a sort of services and methods are expected to be got from the ECOLEAD partners and the open-source community. Other modules should probably be implemented to attend the features of the envisaged scenario. Yet, the current version of the protocol cope with only part of the requirements identified in Chapter 1.

One important consideration about this work is the fact the decision-making can be not as fast as expected depending on the chosen techniques (e.g. simulation). However, it may be a price to pay to comply with the VE requirements.

Next steps of this work will mainly cover: the extension the protocol and computer assistance to support the other VE requirements; a prototype implementation (especially the part related to the mixing of Delphi method, HERMES system and CSCW integrated services); and the election of which performance evaluation techniques and tools should compose the "knowledge box" to support a more robust decision-making environment.

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