Decision support system for virtual organization management

J. Hodík[a], J. Vokřínek[a], R. Hofman[b]

[a] *Department of Cybernetics, Faculty of Electrical Engineering, Czech Technical University, Technická 2, 166 27, Prague, Czech Republic*
[b] *CERTICON Corp., Applied Research, Václavská 13/316, 120 00 Prague, Czech Republic*

Abstract

The Decision Support System (DSS) for Virtual Organization Management is a component of the Virtual Organization (VO) management toolkit, which is being developed in the ECOLEAD project. The DSS mainly supports VO operational and strategic management by simulated rescheduling and reconfiguration of a VO. Such simulations allow "what-if-analysis", verifying and comparing various configurations and their robustness, discovering possible bottlenecks, and pre-preparing potential adaptations of VO configuration and schedule. The outputs are presented in a "human-friendly" way to support the VO manager in decision about and negotiation for VO adaptation.

Keywords: Virtual Organization, Simulation, Multi-agent systems

1. Introduction

The Decision Support System (DSS) for Virtual Organization Management is a research prototype of a tool supporting a Virtual Organization (VO) manager. This tool is dedicated to provide with simulation of individual VO members and their performance in the VO. The simulation is one of the core functionalities of the workflow management systems [1].

In the ideal case, there is no need for any changes in VO configuration or schedule during the VO lifecycle. In the case of any deviations, i.e. if now or possibly in the future either VO configuration or schedule are not in line with the expectations (e.g. deadlines cannot be kept), they might have to be adapted. The task of DSS is to support finding a new more appropriate VO configuration. The outputs help VO manager decide about the negotiation for VO adaptation.

For the design and the development of DSS, experience and components from other projects related to VO have been used. The information about contracted and potential partners will be obtained from VBE Management System, e.g. partners' profiles and competency management tool e-Cat [2]. The DSS also contains a simulation unit, which is based on intra-enterprise planning tool ExPlanTech [3].

The DSS mainly supports VO operational and strategic management by simulated rescheduling and reconfiguration of a VO (created in a VBE) plan and schedule (represented by WBS and contracted allocation of partners' resources to VO tasks). Besides rescheduling and reconfiguration, there is also another task of VO management supported by the DSS. It is the "what-if-analysis" – simulation of various possible scenarios of alternative futures. Such simulation allows verifying and comparing various configurations and their robustness, discovering possible bottlenecks and pre-preparing potential adaptations of VO configuration and schedule.

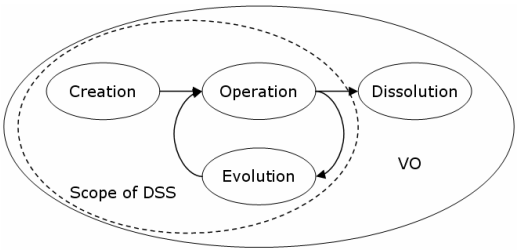

Fig. 1. Scope of DSS in Virtual Organization lifecycle

The DSS suggests adaptation of VO structure and thus the specific features of the VO structure must be taken into account. They are mainly:

- **VO members.** They are autonomous, self-oriented and distributed
- **Limited access to information.** VO manager has no access to the partners' internal information. She/he is limited only to information provided by members and performance indicators.
- **Already concluded contracts.** Withdrawing from a contract or changing the concluded details is limited by the contract and the affected member's willingness.

1.1. Added value

Added values of the DSS are the following features:

- **Using latest VO operational data.** Integration with other tools for VO operational management allows the DSS to provide manager with VO simulation based on the latest VO data.
- **Impending deviations alerting.** After starting the system VO manager is informed whether any milestone has been elapsed without and there is no sufficient information about fulfilling it, or if any such milestone is expected in close future.
- **Suggestions of local adaptation and alternative VO configurations analyzer.** In case of deviation or possible improvement of VO the simulation part of DSS provides alternative schedule/configuration of VO. The DSS compares current VO schedule/configuration and an alternative one and provides a list of details that have to be negotiated and re-contracted with VO members in order to transform the VO according to the new schedule/configuration.
- **Murphy generator.** Generator of random deviations (negative as well as positive) of keeping deadlines and abilities to meet an engagement allows proving the VO configuration robustness. Outputs are presented in VO configurations analyzer.
- **Thin client.** Using web interface as system GUI, the DSS may be maintained by any supporting institution. In such case DSS users (VO managers) are provided with tools that they could not afford or maintain individually. This support saves VO managers' resources that would be used for maintaining local decision support systems. If required, the DSS may be deployed on the VO manager's server as well.

1.2. Relation to VO lifecycle

The VO lifecycle has been presented many times. We refer to the one presented by Camarinha-Matos and Afsarmanesh [4], who concentrate the whole VO lifecycle management. The DSS supports VO manager during most phases of their VO lifecycle phases except dissolution: creation, operation and evolution (see Fig. 1). The DSS is a tool for rescheduling (operation phase) and VO reconfiguration (evolution phase). Moreover, the DSS may be also applied during the creation phase for VO configuration and scheduling. During the whole VO life-cycle the DSS provides VO manager with the possibility of what-if analysis.

1.3 Relation to other components of VOM toolkit

The Virtual Organization Management (VOM) toolkit, which is being developed in the ECOLEAD project, is a distributed system consisting of several components developed by partners across the project. The components are partially independent with defined functionalities and interfaces. To provide full functionalities the VOM toolkit should consist of all the components. On the other hand, the modular architecture ensures utility of the system even if some components are not present in the system and usage of any component in any other VOM toolkit. The global architecture of the VOM toolkit is described in the [5]. The VOM toolkit consists of:

- **VOMod** (VO-Model), which describes the actual state of contracted VO. It contains VO topology, Work Breakdown Structure, management and

communication details and measurements of defined performance indicators. VOMod allows VO manager to model the VO structure and provide the overview of the contracted VO.

- **SID** (Supporting Indicator Definition), which is a component for maintaining indicators' information.
- **DI3** (Distributed Indicator Information Integrator), which is responsible for information retrieval from VO member locations according to VO management demands.
- **MAF** (Monitor and Finance), which provides visualisation and access to information present in the VOPM.
- **DSS** (Decision Support System), to which this paper is dedicated.

The DSS is configured according to actual state of the VO. The configuration data are gathered from the VOMod, which contains another model of the same VO. Contrary to the DSS, which provides possible states of VO; the VOMod reflects the VO actual configuration details and the latest information of the actual VO state.

For the DSS, the VOMod is a source of information such as VO specification, concluded contracts details, and the latest information (reported by DI3) about the VO performance.

2. (Re)scheduling and (re)configuration

When the VO team is pre-negotiated and its task is known, negotiations about resource allocation and schedule is started. The term scheduling means *allocation of resources to activities*. In the VO domain the activities are components of the VO task that have to be executed; resources are defined as combination of VO member and its competencies (another competency of the same member is another resource from the VO point of view even if using one competency may limit using the others). To allocate activities to resources a plan must exist. The plan creation is *a finding the way how to reach the goal using available resources*. Theoretically, for a particular VO more than one plan may exist. In such case the plan to be implemented is selected during the scheduling. It is important to use the plan with the feasible schedule, which is at least good as schedules for the other possible plans.

Rescheduling process generates a modified version of an already existing schedule. It is applied when optimality or applicability of the schedule is corrupted. As proved by dynamic programming [6], any component (sub-schedule) of the optimal schedule is also optimal. On the contrary, the local optimality of individual schedule components does not ensure optimality of the whole schedule. Thus, to keep the entire schedule optimal, it is not sufficient to simply compose the entire solution of locally optimal sub-schedules. Each local change may corrupt global optimum although the change is locally optimal. To get the schedule optimal, new global schedule has to be generated. The new schedule may but not need to correlate with the old schedule in any component except e.g. the one that caused the rescheduling.

If the schedule is required to be optimal, the rescheduling implies the whole plan scheduling. On the other hand the scheduling (without impact to the schedule optimality) may be handled as an extreme case of rescheduling – a local requirement to reschedule covers the global schedule.

During the adaptation of a VO schedule an assignment of activities to resources may be changed. If the team of VO members is not affected this task is operated within rescheduling. If any member is removed from VO and/or any new member joins the VO this task is identified as VO reconfiguration. In such case it comes under the evolution phase of VO lifecycle.

The scheduling, rescheduling and reconfiguration are not in general easy; very often they are NP problems. For such cases heuristics are developed that provide acceptable results although they do not guarantee optimality. In case of too hard problems (not only NP hard) the rescheduling algorithm may vary from the scheduling algorithm due to possibility of utilization of partially existing schedule and related constrains. The adaptation of VO during the VO lifecycle is such problem.

3. Architecture

The DSS consists of 3 functional modules supported by the *Portal* (user interface), and *Local repository* of VO configurations. Functional modules are: *VO configuration editor*, *Alternative configuration analyzer*, and *VO simulation* module. The Fig. 2 presents the architecture of the DSS. Description of all modules follows:

- **Portal**
  The portal is web-based GUI to DSS for the VO manager. The GUI is connected to the other DSS components and allows their configuration, usage and control. It is inherited from the Cockpit Agent of the ExPlanTech project [3].
- **Local Repository**
  When any VO configuration or schedule is generated, the manager may upload it to the repository. The stored results are used for the negotiation about VO reconfiguration or rescheduling.
- **VO data editor**
  The editor allows editing configurations already present in the Local Repository and creating new configurations. A new one can be uploaded to DSS from the VO manager's local computer, created by VO manager through the Portal, or based on the actual state of the VO.
- **Configuration analyzer**
  This module is capable to compare original (contracted) VO configuration and results of the simulation. The differences are presented to the VO manager as a set of details that should be discussed with the VO members to adapt the VO. The results of simulations can be used for identification of potential risks or bottlenecks of the running VO. Capability of alternative configuration evaluation is one of the most important features of the DSS.
- **VO simulation module**
  DSS uses multi-agent technology for simulation of individual VO members to allow setting up their specific features. Properly configured agents can be applied in simulated negotiation of VO adaptation to estimate behaviour of the real VO members. It saves resources needed for recurrent negotiation about even small adaptations of VO schedule and configuration.

The simulation is the core of the DSS. Therefore it has dedicated the following subsection.

3.1. Simulation of VO

Inside the simulation module, existing and potential VO members are represented by agents. The agent is created at the moment when VO manager

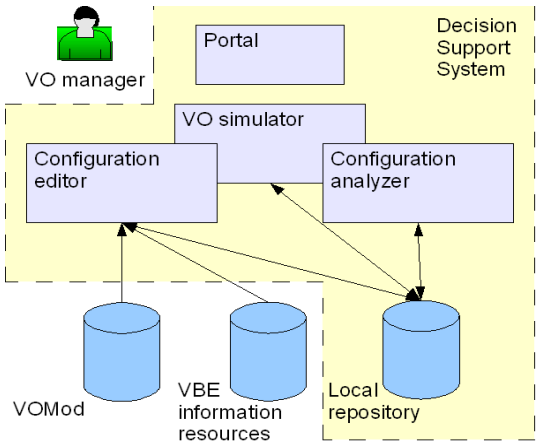

Fig. 2. Architecture of the DSS

decides to include the partner to the VO (existing VO member) or when he decides to include the partner to the re-scheduling process or what-if analysis (potential VO member). Each agent is configured to be as good model of a partner as possible in the simulation of VO (re)configuration and (re)scheduling. The information about partners' profiles, competencies, assigned tasks, fulfilments, supposed behaviour and others comes mainly from the VO configuration.

If it is required (during the VO reconfiguration) new VO members may be included to the simulation online. In such case the basic profile of the partner is defined by the VO manager who may utilize any information resource usually e.g. during the VO creation phase.

The simulation module uses agent based model inherited from the ExPlanTech and ExtraPlanT projects [3]. Each VO member is represented by one independent agent. The agents from ExPlanTech/ ExtraPlanT were developed to schedule mainly in intra-enterprise environment; for the DSS these agents are adapted and extended by abilities to negotiate in extra-enterprise environment.

During the simulation, both the configuration of the simulation and the agents may be adjusted by VO manager. The VO manager changes configuration details according to his/her expert knowledge and accessible information about VO members. When the request for reconfiguration or rescheduling appears, the agents negotiate as the modelled partners are supposed to do. Any generated configuration may be released as a potentially alternative configuration of the VO.

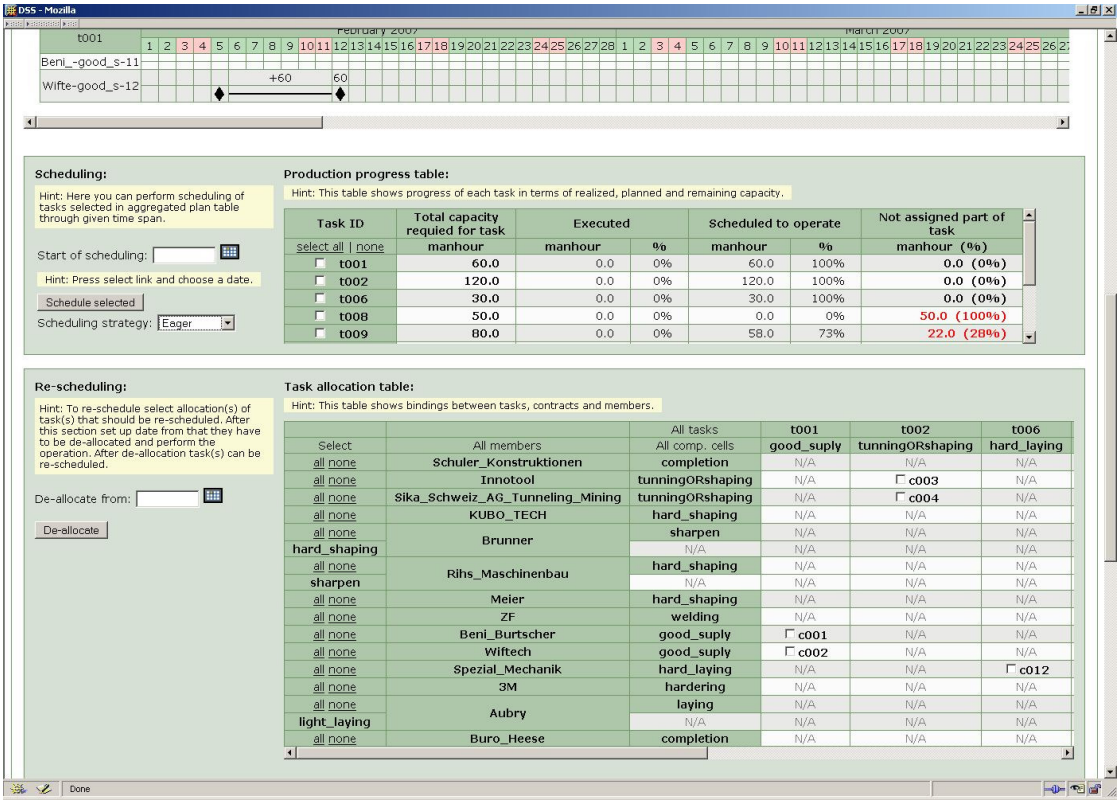

Fig. 3. Scheduling and re-scheduling interface of DSS

The negotiation of agents is based on communication (information exchanging) and information evaluation. The process of communication is defined by negotiation protocols. The communication makes such information accessible that the provider aims to be accessed by those who want to access them. The actions of decision making what information should be provided and decision making utilizing the information, although they directly influence the communication, are not elements of communication.

During simulation, random and pseudo-random events (violating a schedule) are handled by the sub-module called Murphy. This module is responsible for changing the service related configuration details of VO members' (e.g. delivery date and actual availability and capacity) by defined values, by defined probability and in defined time – all of them defined by the VO manager. The Murphy is not crucial for the DSS but if present it allows testing robustness of generated VO configurations and their schedules.

4. Use Cases

The DSS concentrates on operation and evolution phases of the VO lifecycle (It can be applied during the creation phase as well.). Firstly, a VO manager configures DSS according to the current state of the VO. Relevant data such as VO specification, concluded contracts details, and description of already executed tasks are gathered from VOMod (another component of VOM toolkit).

When the DSS is configured, a manager is allowed to change tasks and their assignment details, to select tasks to start negotiations about their un-assignment and to invite new members into the VO. The un-assignment is negotiated with model of related VO member. In similar way, the manager is allowed to adapt schedules and contracts. The Fig. 3 presents screenshot of the sscheduling and re-scheduling interface of DSS. To assign a free task, the manager is required to define a current VO member, which is able to provide appropriate competency and work on the

task, or another VBE partners have to be identified as potential VO members. Their models are consequently used for negotiations about cooperation within the VO. The output of the DSS is information whether the VO can continue its mission, set of details that have to be negotiated with real VO members to adapt the VO if it is necessary to reschedule or reconfigure VO, and information about robustness of the VO configuration and schedule.

5. Related work

Multi-agent technology was successfully studied in lot of other workflow oriented projects such as [1] (summary of capabilities of workflow and agent technology), [7] (workflow management system based on agent technology), ExPlanTech [3] (intra-enterprise scheduling agent based tool), PRODNET II [8] (agent based distributed information management system of Virtual Enterprise), JBees [9] (agent based distributed workflow system), WARP [10] (agent based architecture for controlling the workflow operation of distributed services).

6. Conclusion

In this paper we presented the DSS that is a component of a Virtual Organization Management toolkit. The DSS provides its user (VO manager) with simulation of a VO; the simulation is based on up-to-date information. The simulation module of the DSS utilizes multi-agent technology, where each VO member is represented by an agent.When the simulations in the DSS are executed, potential new configurations and schedules (including constrains) are generated for the VO. The results of simulations can be used for identification of potential risks or bottlenecks of the running VO.

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