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Managing business processes in virtual enterprises - interaction of distributed workflow management systems


Workgroup Computing Competence Center Paderborn

- Project group Wide Area Workflow Management -

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Managing business processes in virtual enterprises - interaction of distributed workflow management systems

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Abstract: Workflow management systems (WFMS) have proven to be powerful computer-based platforms for the handling of business processes by enhancing quality and flexibility of office work while cutting down overall processing time. Yet current WFMS mostly focus on processes performed within a single organization at one location. Therefore conceptions and solutions for the interaction of distributed WFMS are needed to form global workflow management networks as integrating platforms for business processes.

In the following we line out new organizational and technical challenges of Distributed Workflow Management (DWM). Further the Wide Area GroupFlow System (WAGS) for Groupware-based workflow management between distributed organizations and heterogeneous WFMS is introduced. In the last part we present a life cycle and implementation model for the different steps leading from local workflow management to distributed interaction of WFMS.

1. Introduction

Communication and cooperation between organizations is increasingly important in times of dynamic global markets with short product lifecycles. One concept to react on these changing organizational needs are virtual enterprises as referred to in [DaMa92], [ClRo92], [HaCh93] or [Moad94].

Virtual enterprises are formed by synergetic combination of the core competencies of several partner companies mostly distributed over multiple locations. For a seamless integration of business processes in such virtual enterprises, IT-structures of the partner companies have to be connected in a sound manner. From a conceptional and technological point of view, this is still challenging.

Workflow management systems (WFMS) have proven to be powerful platforms for the handling of business processes in computer-based networks by enhancing quality and flexibility of work while cutting down overall processing time. Yet current WFMS mostly focus on tasks performed within a single organization at one location. Therefore conceptions and solutions for the interaction of distributed WFMS are needed to form global workflow management networks as integrating platforms for business processes in virtual enterprises.
The challenge of distributed workflow management (DWM) is to hand over selected information items from one shared workflow environment to another with secured containers that hold highly structured, field-based data as well semi-structured, „soft“ information types and can be seamlessly integrated into the receiving workflow environment without conversion. The participating organizations of a DWM have to agree on certain format standards to allow that seamless integration. In most cases, partners of an *interorganizational* workflow management are not willing to give access to their internal workflow information. To enable a distributed planning of DWM, there have to be possibilities to publish workflow connection points to partner organizations in a safe manner. These connection points are the "gates" through which the containers are exchanged.

2. Conceptions for distributed workflow management in virtual enterprises

Workflow management within a single organization at one location (as described in [ErSc95], [WeKa94]) is based on the following fundamental prerequisites:

- All actors, routing paths and storage locations in the workflow are known.
- Legal, organizational and security aspects are under control of a single management.
- Hardware, operating systems and workflow management applications are mostly homogenous.

As we connect processes between distributed organizations, these prerequisites are no longer given. We face a variety of new challenges that can be summarized within three orthogonal *Dimensions of Distributed Workflow Management*.

![Three dimensions of Distributed Workflow Management](image)

*Fig. 1: Three dimensions of Distributed Workflow Management*
The three dimensions (Fig. 1) line out challenges and possible solutions for distributed workflow management in a cube with 18 segments. Each segment describes a certain constellation with special technical and organizational measures. For example the case of an engineer requesting quotations provided in shared databases of partner organizations in a virtual enterprise via notebook, modem and cellular phone would be located in the upper right segment in the front row. Solutions provided for this case are applicable to similar situations and thus form a distinguished class. The arrows at the axes indicate the direction of increasing complexity for the respective dimension.

The dimension of information routing (Figure 3) can be realized in two ways: information are routed from one person to another by sending messages (Send Model) or by giving access to common information bases (Share Model). We know the Send Model from letters, faxes or E-Mail and the Share Model from black boards, libraries or shared databases.

The Continuum of Organizational Integration (Figure 2) specifies more detailed the dimension of organizational integration in Figure 1.

| Continuum of Organizational Integration in Distributed Workflow Management |
|---|---|---|---|---|---|---|---|
| Intra-organizational | Inter-organizational |
| One organization with distributed subsidiaries | Trust (standard form) | Profit center system in an organization or trust | Virtual organizations | Strategic partnerships | Market interaction, e.g. Customer & supplier | No connection |
| one legal domain | separate legal domains |

Fig. 2: Continuum of Organizational Integration

To reflect the varying degrees of integration of enterprises (Figure 2) and the subsequent intensity of cooperation, the following statements are useful combinations of the dimensions of organizational integration and information routing:

- *Intra*organizational Distributed Workflow Management (DWM) is appropriately supported with the Share Model by implementing distributed shared databases that allow the distribution and synchronization of workflow information across multiple locations.

- *Inter*organizational DWM with loose cooperation is best realized by sending Message Objects (Send Model) because of a simple setup and a remaining complete separation of internal workflow information.
• Interorganizational DWM with closer cooperation can be realized by maintaining a shared environment for publishing of workflow connection points, declaration of exchange formats and technical details like network addresses and transferring the actual workflow information by sending Message Objects. By selectively publishing certain structural information in shared environment, the internal workflow information can be kept separate.

The Wide Area GroupFlow System (WAGS), that is introduced in chapter 3, supports all of the above mentioned approaches.

3. Wide Area GroupFlow System (WAGS)

The Wide Area GroupFlow System (WAGS) was developed on the basis of the groupware platform Lotus Notes with its architecture of distributed shared databases synchronized by replication and its powerful messaging capabilities.

A fundamental design criteria for WAGS was the observation that legally separate organizations are not willing open their internal workflow repositories to external partners because of the highly confidential information stored here. Therefore WAGS allows to publish certain workflow steps (called workflow connection nodes or external tasks) to external partners in the External Directory (Figure 3) without giving access to the internal workflow management system.

![Wide Area GroupFlow - Architecture Concept](image)

**Fig. 3: Architecture Concept of the Wide Area GroupFlow System**

Hardware, operating systems and LAN standards are covered by the enabling environment Lotus Notes (Figure 3). The workflow repository layer stores process structures, organizational layout (infrastructure) and processed information. The workflow application layer builds
the runtime system of Wide Area GroupFlow as it performs and controls internal and initiates external workflow parts.

The interactive graphical tools of the tool layer are used to configure the corresponding applications in the workflow repository. The central tool is the process modeling software, called *Wide Area GroupFlow Modeler* (Figure 4), that is used to design the workflow process with its consecutive task-and-arrow structure as described in [NaHi94]. To enable distributed workflow management, features like special nodes for outgoing and incoming tasks, synchronization nodes, Content Management sets, hierarchical clustering for process parts and a browser for the External Directory are included in the Wide Area GroupFlow Modeler. The Process Simulator performs ex ante testing of designed workflow types whereas the ex post control of internal and external workflow parts is conducted with the Process Analyzer.

For routing of outgoing as well as incoming Message Objects (Send Model) and for replication purposes (Share Model), the *Gateway Application* was invented. It performs transfer, content filtering, tracking, reminding, converting to different formats (e.g. X.400, SMTP, HTML, EDIFACT), splitting and joining of all information objects exchanged between distributed workflow parts.

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**Fig. 4: Assignment of a task performed in a partner organization during design phase within the Wide Area GroupFlow Modeler**

The design of a workflow type in the Wide Area GroupFlow Modeler starts with one or several internal tasks or sub-workflows (Fig. 4). To include an external task, a special kind of node is drawn and the External Directory browser is opened showing the external partner organizations with their available tasks. A certain task is chosen by dragging it onto the respective node that then shows the external company’s logo. Further settings about provided information, expected results and due date can be specified in a dialog box. After design the
workflow type is stored in the workflow repository layer (Fig. 3) and is immediately ready to run.

This design approach of WAGS allows for fast creation and flexible runtime performance of distributed workflows in virtual enterprises. It helps to integrate distributed business process with enormous potential for enhancing quality of work while reducing costs without forcing the partner organizations to open their internal workflow repositories.

4. From local to distributed workflow management - the challenge of implementation and maintenance

4.1. Lifecycle concept

The implementation of a workflow management system is, as with most information systems, a complex process. It requires fundamental organizational, technological and social changes within an organization. Long-used process patterns are examined, revised and changed, competencies of workers are shifted, social structures are altered and privileges and status symbols are in danger of being removed.

Therefore detailed planning and intensive communication as well as training during the start-up phase are necessary to prevent deciders, planers, technicians and users from being disappointed by the practical performance of the system invented. A main focus hereby is the acceptance by the users in the initial phase of implementation and their conviction that the workflow management system will definitely help them to enhance flexibility and quality of work while reducing processing time and costs. This conviction can only be achieved by presenting the workflow management system to the involved users at an early point in time, showing realistic scenarios to illustrate the benefits of the new system and finally an intensive training phase to make users familiar with their new working environment.

Further a constant maintenance and actualization of workflow management systems is of enormous importance in order to really benefit from the investments made. The capability of workflow management systems to react in a flexible manner on changes occurring during runtime phase is directly linked to the efforts in keeping the underlying process and personnel information actual. As real world scenarios are constantly changing, workflow management systems have to be actualized and adjusted in a never ending process of optimization. This process is described in various lifecycle concepts as discussed in [Hilp95], [Jabl95] and others.

Given the fact that workflow management technology in local applications has already matured to a business tool that is used by many organizations since several years, we want to proceed and introduce a model for the implementation and maintenance of systems for distributed workflow management. As this further step poses new challenges, we suggest a systematic approach for an opening of local workflow management systems towards the capability of supporting the interaction between distributed, legally autonomous organizations.

The following Figure 5 shows the Wide Area GroupFlow Lifecycle describing necessary steps towards a systematic interaction of WFMS. Starting from existing local workflow management systems within the participating organizations in a cooperation scenario like virtual enterprises, the first step will most certainly be initial negotiations about the aims of an interaction. The topics that should be discussed within such negotiations are explained in the Implementation Model described in following chapter 4.2.
After the partner organizations have agreed on the terms of the cooperation, they start to implement the technological and organizational infrastructure as discussed in the Implementation Model. The next step of the Wide Area GroupFlow Lifecycle (Figure 5) after the implementation is the publishing of workflow connection nodes from each organization to the respective partners. These connection nodes contain information about services offered by an organization, the possible exchange formats, communication addresses and the structure of the information expected. The initially published connection nodes have been agreed on in the preceding negotiations. Services offered by an organization via connection nodes could for example be "request quotation", "provide product information", "calculate machine equipment", "provide sales forecast" or many others (as shown on the right side of figure 4). The Wide Area GroupFlow System uses the External Directory to publish the connection nodes in a shared environment of the partner organization.

Once the connection nodes have been published and distributed, each of the partner organizations can start to model their own process parts within the network of the planned cooperation. By linking workflow tasks of local processes to external connection nodes, as shown in Figure 4, the exchange of information containers between the distributed process parts during runtime operation is prepared. A simulation process allows for the detection of faults and inefficiencies before workflow instances are actually started.

During runtime operation, users create instances of the workflow types modeled before. At the respective external nodes, the external workflow connection is initiated. The users are informed about their next tasks via worklists. These worklists show which tasks have arrived from internal colleagues and which have arrived from external organizations. When users have finished their work on a task, they can route it to the next agent. If this agent is located in an external organization, the user is prompted to filter internal information that are not intended
to leave the own organization. If this occurs in a repetitive manner, filtering can be planned in advance during the modeling phase and is then executed automatically during runtime operation. The filtering process is called *Content Management* and is described in more detail in [RiNa96a] and [RiNa97].

All runtime operations are tracked in order to be able to compare the planned workflow types with the actually performed workflow instances. All messages transferred to external organizations are tracked in the *Gateway Application* of WAGS (*Figure 3*), so the can be centrally analyzed. As distributed workflow management can create fairly complex process structures, a graphical software tool like the WAGS Process Analyzer (*Figure 3*) can support administrators to gain an overview over internal and external workflow instances.

In most cases, the analysis of actually performed workflow instances shows inefficient or inadequate parts in workflow types. They are mostly indicated by repeating exceptions performed by users during the work on their respective task. The causes for these exceptions have to analyzed in communication with the users. Then a new cycle begins with the adaptation of published connection nodes and a reengineering of workflow types in a design tool like the Wide Area GroupFlow Modeler.

### 4.2. Implementation Model

While the Wide Area GroupFlow Lifecycle is intended to support the whole process of planning, implementation and continuous improvement of a distributed workflow management systems (DWMS), the *Implementation Model* serves as a conceptual framework for the structuring of requirements of DWMS and the realization of practical solutions for the technological aspects of such systems.

The following *Figure 6* shows the structure of the *Implementation Model*. It is designed using discrete modules that help to reduce complexity and support a useful timely arrangement of consecutive steps during the implementation phase. Through the definition of interfaces between the modules, mainly in the computing level of the model, the development and adjustment of the modules can be partly realized in parallel. Through the usage of defined interfaces the replacement of certain modules is simplified and the re-usage in similar cases becomes possible. With the increasing experience in realizing systems for distributed workflow management, reliable modules can be stored in module libraries.

Because the requirements of distributed workflow management will constantly change and therefore systems have to be continuously adapted, the *Implementation Model* also has a circular approach that allows for the entering into a new cycle of reengineering when the need for adjustment arises.

**Organizational level**

The organizational level of the *Implementation Model* (*Figure 6*) is aimed at a clarification of the determinants for a distributed workflow management within and between the cooperating organizations. The topics indicated by the five questions are to be discussed in the initial negotiations between the organizations.

In form of a commonly shared information structure (e.g. shared database), the cooperation partners, their relationships and especially the level of trust among each other have to be described (*Who?*). Depending on the level of trust, the degree of opening of internal information to partners will vary. While the description of such a network of organizations and their interdependencies is rather trivial for a small number of participants, it can become fairly
complicated with an increasing number of partners, especially when each partner organization consists of multiple subsidiaries at different locations.

The next step is the clarification of the contents that are to be exchanged within the distributed workflow management scenario (*What?*). They are derived from the common goals and projects that in the case of a virtual enterprise can be the development, production and marketing of one or several products. The description of the exchanged contents has to be done on different levels of granularity ranging from a qualitative textual lists to a detailed definition of data models with records and fields.

In the following, the type of cooperation is derived from the common goals and projects (*How?*). It can range from loose communication, realized with the Send Model (e.g. e-mail) to an intensive cooperation using a shared database environment with common access (Share Model). As described above, also mixed forms of these approaches can be realized to allow for closer cooperation while keeping information systems separate. The Wide Area GroupFlow System can use the External Directory as a shared environment for the publishing of connection nodes and the Gateway Application for the sending of Message Objects [RiNa96a, RiNa96b, RiNa97].

The description of the duration and frequency of the exchange (*When?*) determines which investments are reasonable for the implementation of a distributed workflow management system. While short sporadic workflow connection may well be realized with existing e-mail channels, extensive project cooperation over a long time may justify the implementation of common servers, satellite communication or other more costly measures.

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**Wide Area GroupFlow Implementation Model**

Fig. 6: Planning of organizational determinants and technological modules during the implementation phase of distributed workflow management systems with the Wide Area GroupFlow Implementation Model
Finally the geographical distribution of the cooperation partners are to be described in a common structure, for example to allow for a correct addressing of appropriate subsidiaries in worldwide operating trusts.

The information gained within the organizational level of the model are shared between the cooperation partners and build the basis for the practical implementation in the computing level.

**Computing level**

The *Information Model* serves for the structuring of the information exchanged between the distributed partners. While internal workflow information is mostly stored in highly structured environments like databases, external communication media like letters, faxes or E-Mails are of low structure. Therefore the usage of these communication media requires are costly dissolving of structures in the sending and a not less costly restructuring in the receiving organization. Thus the exchange of field-level-structured information containers is important and the specification of the structure of such containers is laid down in the information model. The specification of the format and structure of the exchanged containers has to be agreed on between the cooperation partners. This can happen in advance during the initial negotiations or during runtime operation by publishing new formats or structures in a common environment. The Wide Area GroupFlow System (WAGS) uses Message Objects, a class of self-navigating agents containing field-level-structured information, methods and representation, for the purpose of transferring structured information containers. The module *Information Model* is mainly influenced by the modules *Exchanged Contents* and *Type of Cooperation* of the organizational level of the *Implementation Model*.

The module *Content Management* serves for the filtering of internal information before they are send to a partner organization. It maps the internal and the external information model of the cooperation scenario. Content Management has three main purposes:

- Providing, filtering and assigning the information needed to perform a certain task in an external organization, including the access to related and the denial of access to restricted information.
- Retaining confidential internal information and additionally protecting transferred information against hostile access.
- Adjusting the work load according to the availability, transfer rates and costs of possible communication channels at different times as well as the communication frequency.

The module *Addressing System* serves for the identification of cooperation partners and the navigation of the exchanged information containers. It additionally holds information about multiple communication channels (e.g. Internet, ISDN, modem, satellite etc.) to allow for a least cost routing. Furthermore exchange formats (e.g. HTML, SMTP, EDIFACT, ODMA etc.) and security options like encryption (e.g. RSA, DES) that an organization is able to use are published here. In WAGS this module is realized in the External Directory that is synchronized with the partner organizations via selective replication or broadcasting mechanisms known from the ISO X.500 standard.

The *Type of Communication* module has to realize the different approaches mentioned above like Send Model, Share Model or combinations of both. It is responsible the handling of group addresses, multiple recipient messages (1:n) and multiple sender collection (1:m). WAGS uses the Gateway application to realize this tasks and thereby centralizes all external workflow communication in one module for easier tracking and monitoring.
The technical realization of the connection of organizations via different Communication Channels (e.g. modem, ISDN, Internet, satellite etc.) needs special measures. They are centralized in this module and are then offered to the users in order to allow for least cost routing of exchanged information containers. In the Wide Area GroupFlow System, the underlying groupware platform offers interfaces to all relevant communication channels and can therefore be easily used to realize this module.

For a reliable Security Management there have to be possibilities of access limitations, encryption and digital signatures. They are realized in the respective module and are crucial for the function of a system for distributed workflow management. Information processed in workflow management systems are usually highly confidential and therefore have to be protected with the best security mechanisms available. The discussion about security measures in the Internet/World Wide Web like firewalls or encryption standards (e.g. SSL, PGP) have shown the enormous sensitivity of organizations concerning the transfer of confidential information via public networks.

The module for the Identification of Workflows is necessary because of the fact that information containers leave the domain of an organization and all requests and answers referring to a certain container stemming from the own organization have to be identified correctly. Facing the fact that larger organizations have thousands of external contacts a day (today mainly realized with letters, faxes etc.) makes it necessary to have commonly accepted standards for the identification of information containers and the underlying workflow instance. Today's standards for this problem in the paper-based office world are invoice numbers, customer numbers etc., which have to be enriched for distributed workflow management.

On the basis of a correct identification of workflows, the last module for Monitoring & Analyzing of distributed workflow management can illustrate the structure, usage, costs etc. of the external communication efforts. A detailed tracking of each workflow step provides the necessary information for monitoring at a certain point in time or analyzing of already completed workflows. Because in distributed workflow management scenarios, information containers leave organizations and enter into others, there have to be certain measures to allow single organizations to gain an overview over the whole workflow network. In the initial negotiations the cooperation partners can agree on certain tracking measures that allow information containers exchanged between them to be tracked. There are two main strategies:

- **Self-Tracking**: The information containers maintain a protocol of all steps they go through and the respective tasks performed during the distributed workflow.
- **Send-Tracking**: After each workflow step and thus performed task, the information container initiates the sending of a message directly reporting the event to the organizations involved in the workflow outside the organization that momentarily hosts the information container.

Both methods can be applied in combination, for example by using self-tracking for several steps and then sending an aggregated protocol at certain steps of the workflow.

The modules of the computing level of the Implementation Model have different users within an organization and therefore have to fulfill different requirements. We want to divide three views on these modules:

- **Developer View**: The developer has the function of realizing the functionality of a module based on the requirements stated in the organizational level of the Implementation Model.
- **Administrator View**: To allow for a sound runtime operation, the administrator configures the modules and adjusts settings when changes occur.
• User View: In order to make distributed workflow management as easy to use as possible, the modules need intuitive graphical interfaces. Thus users are able to handle the complexity inherent to complex cooperation scenarios.

Using these three views, the structuring and handling of the modules can be simplified.

5. Conclusions

The aim of this article was to introduce in a first step some fundamental conceptions to describe the new challenges of distributed workflow management. In the following the Wide Area GroupFlow System (WAGS) was presented. It is a prototypic framework to illustrate possibilities for a practical solution of the conceptions discussed before. A main focus of this article was then to discuss strategies for implementation and maintenance of systems for distributed workflow management. In a two level approach, first a general lifecycle concept for distributed workflow management systems was explained and in a second step a more detailed circular concept for the practical implementation of such systems was presented in form of the Wide Area GroupFlow Implementation Model.

This two level approach is based on the experiences of the authors made with the invention of local workflow management systems since several years. The new approach has been applied in several test environments of partners in industry, but still has to be evaluated and refined based on practical experiences in large scale applications.

References


Proceedings of the CSCW and CAT. Ed.: Krcmar, H., University of Stuttgart-Hohenheim, Stuttgart 1995


