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From islands to flexible business process networks - enabling the interaction of distributed workflow management systems,

FROM ISLANDS TO FLEXIBLE BUSINESS PROCESS NETWORKS - ENABLING THE 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. Further the Wide Area GroupFlow System (WAGS) for Groupware-based workflow management between distributed organizations and heterogeneous WFMS is introduced.

1. INTRODUCTION

Communication and cooperation between different organizations is highly important in times of international business with short product lifecycles. Dynamic global markets call for organizational structures of distributed enterprises that are shaped like dynamic networks of persons and the information they want to exchange. One concept to react on these changing organizational needs are virtual enterprises as referred to in Davidow/Malone [1992], Clemons/Row [1992] or Moad [1994]. The integration of business processes in these and other dynamic interorganizational networks by connecting the underlying computer-based information systems is still challenging.

Workflow management systems (WFMS) support the structured but flexible handling of repeating business processes by modeling process patterns called
workflow types using role concepts for the flexible assignment of work to various actors. Actual processes called workflow instances follow the process patterns but mostly have the option of ad-hoc exceptions for flexible reaction on unexpected situations. The concept to extract, redesign and model repetitive processes into workflow types and the controlled execution of derived workflow instances offers enormous potential of enhancing the quality of office work while cutting down processing time and providing a process monitoring. Currently available WFMS yet mostly focus on workflows within single organizations at one location.

In the past and present, various systems and standards for an integration of information systems across the borders of distributed organizations have been designed. For example the EDIFACT standard allows for the transfer of operational data like orders or invoices. It is based on the ASCII character set and uses rigidly standardized document types. With this approach, certain parts of the interorganizational information exchange have been realized successfully, but for the exchange of semi-structured, contextual and individual information types (sometimes called „soft“ information) like marketing plans, sales forecasts or project descriptions, EDIFACT is not suitable. Yet exactly these „soft“ information types form an important part of office information and are mostly laid down on paper in today’s office world. Interorganizational workflow is thus still mainly realized with letters and faxes, designed and printed out with wordprocessing software using object technologies like OLE or OpenDoc to integrate various information types like text, charts, tables and pictures. This form of paper-based information transfer is characterized by structure- and media-breaks that inhibit efficient information flow within and between organizations.

The World Wide Web (WWW) is another example for an interorganizational information system, but in its momentarily state, it is rather a presentation media than an interaction or even workflow platform. A main problem are missing security standards that keep organizations from transferring workflow information, that are usually confidential, using the WWW.

Up to now, one of the most successful systems for interorganizational information exchange is electronic mail (E-Mail). Yet most E-Mail systems (e.g. SMTP, MHS, X.400) are only capable of transferring rather simple, mostly textual information between personal environments. This is not sufficient for the enabling of distributed workflow management where highly structured data together with „soft“ information types have to be handed over between shared workflow environments in different organizations.

For intraorganizational information exchange, various Groupware platforms (e.g. Lotus Notes, Microsoft Exchange, Novell GroupWise) have rapidly spread on the market place. In distinction from WFMS, Groupware platforms support the important class of group-oriented, spontaneous-like and unplanned workflows as they combine powerful E-Mail systems with
information sharing. Groupware platforms are based on distributed shared document databases protected by powerful security systems.

All of the above mentioned systems have certain characteristics that, in useful combination, can enable efficient, flexible and secure workflow management between distributed organizations. From EDIFACT we can learn that a certain degree of standardization is important for interorganizational information exchange. The WWW contributes semi-structured and hypertext-enabled HTML-Documents and global availability of the underlying Internet. E-Mail has proven the benefits of fast and flexible electronic messaging systems. Finally Groupware platforms incorporate most of the mentioned features and additionally have brought the enormous potential of distributed shared databases and modern security systems to our attention. Yet none of the discussed systems „as is” provides all necessary components to enable a powerful and flexible DWM.

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.

We now want to introduce conceptions to approach this challenge.

2. CONCEPTIONS FOR THE INTERACTION OF DISTRIBUTED WORKFLOW MANAGEMENT SYSTEMS

2.1. Three new dimensions

Workflow management within a single organization at one location has been subject of science, research and product development for a longer time. Thus various theoretical concepts [Hasenkamp/Syring 1993] and ready-to-use systems [Erdl/Schönecker 1995, Weber/Karl 1994] are available, but they are all based on the following 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 enlarge the scope of workflow management towards an interaction of distributed WFMS, the prerequisites described above 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 project partners 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.

### 2.1.1. Information routing

Generally speaking, information routing (Fig. 1) between persons or groups can be realized in two ways: information are transferred 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.

In the context of DWM, the Send Model is applicable for simple but uncontrolled workflow actions that are easy to set up. The internal workflow information of the cooperating organizations remains completely separate. The Share Model, as realized in shared document databases of Groupware platforms, provides individual forms for each actor, detailed monitoring of several processes,
fine graduations of access to information as well as splitting and joining of partial processes. The setup of a workflow system in a shared database environment though requires more efforts than the application of the Send Model. With the Share Model, the distribution of information across different locations can be realized by placing (partial) copies of the shared databases at the involved sites and regularly synchronizing them by means of selective replication. This implicates a certain level of trust between the partners of a distributed workflow because they work in a common „virtual“ workflow sphere. Send and Share Model are to be regarded as complementary possibilities for information routing that can be combined efficiently for DWM.

As stated in chapter 1, the transfer of workflow information between distributed WFMS needs specialized containers. We want to call these containers *Message Objects* [Riempp/Nastansky 1996a], because they hold properties, routing information, methods and representation in an encapsulated structure and build a class of self-navigating mobile objects that connect distributed WFMS (Fig. 2). Message Objects can be transferred with different information routing technologies including messaging or replication.

The field-based data and the „soft“ information types stored within Message Objects can best be modeled with the help of semi-structured, hypertext-enabled document types (also called *Compound Documents*) as used in SGML, HTML, HyTime or Groupware platform documents (e.g. Lotus Notes).
2.1.2. Communication channel

The communication channels for DWM are wide area networks (WAN) and mobile systems like GSM. The transfer rates are comparably low and the possibility of hostile access to information is much higher than within local area networks (LAN).

As it is generally very important in workflow management systems to provide only and exactly the information needed by the performer of a certain task, this necessity for active filtering of information, called Content Management (Fig. 3), becomes even stronger when distributed workflow management has to be realized.

The main reasons for Content Management within DWM are:

• Providing, filtering and assigning the information needed to perform a certain task within a workflow, 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.

Fig. 3: Content management - from internal compound documents to external message objects

2.1.3. Organizational integration

Within DWM, we can divide two process categories: Internal processes in one organization are called intraorganizational, eventhough they may span
several locations, and processes that cross the legal boundaries of an organization at least once are called **external** or **interorganizational**.

A brief look at the different organizational forms shows a wide range of possibilities to integrate different enterprises. Thus we want to define a simplified *Continuum of Organizational Integration* (Fig. 4) that helps us to distinguish different forms of cooperation and thus different requirements for DWM.

![Continuum of Organizational Integration in Distributed Workflow Management](image)

**Fig. 4: Continuum of organizational integration - the degree of integration determines the form of cooperation**

To reflect the varying degrees of integration of enterprises (Fig. 4) and the subsequent intensity of cooperation, the following statements are useful combinations of the dimensions of organizational integration and information routing:

- **Intraorganizational** 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.

- **Interorganizational** 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.

### 2.2. Connection of distributed workflow parts

The strategies discussed up to now provide concepts and solutions for the selection of appropriate organizational and technical measures to realize DWM. During the planning and runtime phase of the interaction of distributed WFMS, we need concepts to ensure a useful connection and a timely synchronization of distributed workflow parts (Fig. 5).

<table>
<thead>
<tr>
<th>Connection type</th>
<th>Examples and synchronization strategies</th>
<th>Visualization</th>
</tr>
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</table>
| **1. Sequential workflow parts (SWP)** | Examples:  
- Enrollment of new software from headquarter to distributed subsidiaries  
- Release of new accounting regulations to different departments  
- Distribution of new product information and prices to customers  
Synchronization:  
- By sequence | ![Sequential Workflow Parts](image) |
| **2. Nested workflow parts (NWP)** | Examples:  
- Request for an offer from supplier during quotation process  
- Request to sales force for sales forecast within a company’s budget planning  
- Delegation of work to a partner company within a virtual corporation  
Synchronization:  
- By sequence | ![Nested Workflow Parts](image) |
| **3. Parallel workflow parts with synchronization (PWPS)** | Examples:  
- Distributed product development in a virtual organization  
- Preparation of a trade show with several departments involved  
- Evaluation of different financing strategies for a company merger by several teams  
Synchronization:  
- By common starting and synchronization nodes | ![Parallel Workflow Parts with Synchronization](image) |
4. Complete integration of workflow parts (CIWP)

Examples:
- Cooperation in a virtual organization
- Common project work between distributed subsidiaries
- Development of new sales methods between subsidiaries and members of mobile sales force

Synchronization:
- By common starting node and sequence

Fig. 5: Connection of distributed workflow parts and timely synchronization

The concepts for connection of distributed workflow parts (Fig. 5) are a specification of the interface 4 of the Reference Model for WFMS defined by the Workflow Management Coalition [Hollingworth 1994]. Whereas connection type 1 (SWP) and 2 (NWP) can both be realized using the Send Model as well as the Share Model, type 3 (PWPS) normally uses the Share Model and the capabilities of selective replication technology for synchronization purposes. The application of the Send Model for connection type 3 (PWPS) needs manual synchronization efforts at the synchronization points which is only applicable in rather simple cases. The complete integration of workflow parts (type 4) can include all other connection types and is realized using Send Model, Share Model or a combination of both.

In the case of connection type 3 a new type of workflow node called synchronization node is necessary. The joining of all parallel routing tracks before a synchronization node is an inevitable prerequisite for a complete synchronization process. The realization of connection type 4 poses the most problems in the planning phase and a tight cooperation of the planning teams in the involved organizations is necessary.

The Wide Area GroupFlow System offers all of the specified connection types for modeling and runtime operation.

3. WIDE AREA GROUPFLOW SYSTEM (WAGS)

We now want to introduce the architecture concept chosen to realize the Wide Area GroupFlow System (WAGS). First it is explained how the conceptional fundaments described in the preceding chapters have influenced the design of the system and secondary an introduction into its structure and usage is given.

3.1. From conception to design

In the case of intraorganizational DWM, all persons involved are known in advance and a comparably high level of trust can be assumed. As WAGS stores
all internal workflow information in shared databases, partial copies (called replicas) of these databases can be spread and synchronized between different locations of an organization and thus intraorganizational DWM can be enabled. The design of workflow types requires the inclusion of synchronization nodes. Content Management settings assure that only necessary information items are transferred to the respective locations.

The case of interorganizational DWM is more challenging: a comparably low level of trust makes it impossible to share the same workflow information between different organizations. Therefore WAGS provides the possibility to publish workflow connection points to external partners in a commonly shared directory service called External Directory. It is completely separate form the internal workflow management system. The External Directory also stores specifications about exchange formats for the Message Objects, available communication channels of an organization and the respective addresses to navigate the Message Objects.

To reflect the process-character of DWM, not persons or static hierarchies but externally available workflow tasks are published in the External Directory. During runtime operation, a flexible assignment of roles and persons to workflow tasks supports fast and adequate reactions also to unexpected situations.

To separate the actual processing of Message Objects from the internal WFMS, a Gateway application is part of WAGS. It performs all routing and conversion operations for DWM and thus allows for a monitoring and tracking of external processes. Before sending a Message Objects, Content Management and a subsequent RSA encryption is applied. As the Gateway application allows to convert Message Objects to different formats, it enables a DWM between heterogeneous WFMS.

As the development platform for WAGS, we have chosen the Groupware system Lotus Notes because it is available for all relevant GUI-based operating systems and supports all widespread network protocols. It offers a distributed shared database architecture for the handling of Compound Documents, offers reliable security mechanisms and has a unique integration of messaging and replication technology. We have added GUI-based tools written in C++ to make the modeling and control of distributed workflows as intuitive as possible. Lotus Notes has interfaces to all relevant E-Mail-Standards (e.g. SMTP, MHS, X.400, MS Exchange Mail, cc:Mail, SNA, PROFS) and is very well integrated with the WWW. The Gateway application of WAGS can use these interfaces for conversion purposes.

We base WAGS on the experiences we made during the development and application of GroupFlow [Nastansky/Hilpert 1994, Marshak 1995]. GroupFlow is a Groupware-based WFMS that combines the flexibility of team-oriented, self-organized workflows with the possibility to design and perform structured, pre-defined workflow types. It is focused on workflows within single organizations at one location, but already supports mobile workers. The application of GroupFlow, that is commercially available since 1995, in several organizations lead us to the conviction that the full potential of workflow
management can only be exploited if business processes can be integrated between multiple organizations along the value-add chain.

3.2. Structure and usage

The Wide Area GroupFlow System is designed following a layered structure necessary to distinguish the different parts of the framework and to show their interdependencies (Fig. 6).

Hardware, operating systems and LAN standards are covered by the enabling environment Lotus Notes (Fig. 6). 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, that is used to design the workflow process with its consecutive task-and-arrow structure as described in [Nastansky/Hilpert 1994]. 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.
The Gateway application is responsible for the handling of outgoing as well as incoming E-Mails or Message Objects. It performs Content Management, tracking, reminding, routing, conversion to foreign systems, communication channel selection as well as splitting and joining of all information objects that are transferred between distributed workflow parts. The External Directory contains global routing information (GRI) that are published to the respective partners. The GRI consists of an abstract address and a functional description of the tasks performed under this address. It is mapped with the internal routing information (IRI) that describes the task, role and organizational unit or person responsible to perform this tasks. The IRI is used by the Gateway application to transfer incoming Message Objects to the workflow application where the respective tasks are to be performed and is not public to external partners. The connection and synchronization between GRI and IRI is realized with the help of a special browser included in the Wide Area GroupFlow Modeler.

The distinction between external task address (GRI) and internal task address (IRI) was chosen for several reasons:

- Dynamic mapping of incoming Message Objects to workflows, tasks and thus persons.
- Publishing of distinguished sets of GRIs for each partner in order to adjust the amount and depth of workflow connection points visible from outside individually in a so-called external process hierarchy (Fig. 8)
- No possibility of gaining knowledge about internal structure or actual processes of an organization from outside because the GRI is completely abstract (e.g. PX130/55BD).

Once the addressing system between the involved organizations is set up in the External Directory, it allows an intuitive handling of external workflow connections during design and runtime phase: the planning of a workflow type in the Wide Area GroupFlow Modeler normally starts with one or several internal tasks, symbolized by icons connected with arrows (Fig. 7).
To include a task performed at an external organization, a special kind of node is drawn and a browser is opened to display the GRIs stored in the External Directory. The partner organizations are shown on the top level of a tree structure and below each partner organization, all available GRIs and their functional description are displayed in a hierarchical manner (external process hierarchy). A certain GRI is chosen by dragging it onto the respective node. In the following this node is displayed with the company logo of the organization that has published this task and the functional description below it. As a second step, a certain type of Message Object is selected and the settings for Content Management are specified. When storing the workflow type into the workflow repository, all information necessary to enable the external workflow connection during runtime phase are automatically set.

External Directory and Gateway application are set aside from the core workflow management system (Fig. 6) and normally exist only once per organization. All monitoring and tracking of DWM can be performed by evaluating the Gateway application with the WAGS Analyzer. A more detailed look at the function of the Gateway application and the External Directory during the runtime-phase connection of workflow parts with the WAGS is given in Fig. 8.

External workflow connections can be initiated in two ways: predefined during design phase in the Wide Area GroupFlow Modeler as described above.
with automatic execution at runtime. Additionally an actor can decide within a workflow instance to invoke an ad-hoc external workflow connection in form of an exception from the predefined workflow type. In this case the actor is presented a browser to select a GRI of a partner organization. In a second step the actor interactively filters the internal workflow information for the external partner (Content Management).

![Wide Area GroupFlow - connection of organizations](image)

**Fig. 8: Basic concept of the interaction of the WFMS in distributed organizations with Wide Area GroupFlow**

In both cases of predefined or ad-hoc external workflow connections, the sending workflow application in organization A addresses a Message Object with the GRI of the receiving task in organization B and posts it to its Gateway application (Fig. 8). Here the GRI is checked with the External Directory to set the address of the receiving Gateway application in B. Further tracking and the deletion of confidential fields are performed. Finally the Message Object is sent to the Gateway application in B using the communication channel(s) specified by B in the External Directory. The receiving Gateway application in B maps the GRI included in the Message Object with the IRI in the confidential part of the External Directory and sends it on to the workflow application where the task is actually performed. The response to A will be processed vice versa.

According to the level of trust between the partner organizations participating in the DWM, the depth of the process hierarchy published to the partners is adjusted. In the case of a very loose contact, an organization will most likely only publish the address (GRI) of its Gateway application and thus is a „black box“ for outside organizations. Message Objects arrive with a processing wish
like „please make an offer for your product XYZ“ and are manually assigned to an appropriate workflow. The more trust exists between the partners, the more of the process hierarchy is published and can be addressed. This process hierarchy starts from main processes like „quotations“ (grey box) going down to single workflow tasks („white box“). Each main process, sub-process or task is combined with a role. One or more persons, groups or departments are assigned to the role so that task - role - person(s) always build a unit. This structure allows for stable design and flexible job assignment during runtime phase.

The concept of a process hierarchy was chosen to reflect the process-orientation of workflow management. Tasks to be published with a GRI are aggregated into different levels in a bottom-up approach or can be planned top-down according to the organizations strategies and main competencies. Main processes, sub-processes and tasks can be stored in module libraries for re-use following an object-oriented paradigm.

4. CONCLUSIONS

The intention of this article was to discuss conceptions to structure the new requirements arising from Distributed Workflow Management (DWM) and to introduce the Wide Area GroupFlow System (WAGS) as a solution attempt. DWM is more complex than spreading known workflow management systems over several locations. Interorganizational workflow interaction needs concepts that allow cooperation without having to open once internal workflow information. The invention of a shared directory service like the External Directory, that is used to publish workflow connection points, exchange format and communication channels, supports distributed planning and execution of workflow management. Together with a dedicated „post office“ like the Gateway application for the routing and control of external communication processes and semi-structured containers integrating field-based data and „soft“ information types as Message Objects, we regard this to be a generic approach towards a connection of distributed workflow management „islands“ to form flexible business process networks.

5. REFERENCES


