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ABSTRACT

A key planning activity within a Virtual Enterprise (VE) is to establish agreed inter-organizational processes. This activity, or meta-process, has to allow for gradual evolution of the VE processes and for a multi layer development from informal business agreements to precise workflows. To support this meta-process, a collaborative electronic whiteboard supported by a tuplespace is proposed. The whiteboard supports a mixed graphical and text interface, with support for keeping track of the changes made. The participating organizations upload workflow definitions from their own IT systems into the tuplespace. Workflows are then discussed, modified and evolved before being downloaded again and mapped to the partners' individual systems.

Keywords: Virtual Enterprises, B2B Collaboration, Inter-enterprise workflows, Electronic Whiteboards, Tuplespaces

1. INTRODUCTION

In an earlier paper [1], two of the current authors addressed the issue of IT support for developing shared workflows in Virtual Enterprises (VEs). VEs are characterized as formalized, but not permanent, alliances negotiated between autonomous organizations, where the goal is to present seamless business services to customers. Members are encouraged to agree upon and then enact processes that follow overarching guidelines evolved by the VE. These processes may evolve during negotiations to establish the VE or during the lifetime of the VE as conditions of the alliance are changed. Processes may eventually be discontinued when the alliance is dissolved. Negotiating efficient cross organizational processes can be of critical importance to the business value of the VE.

In this paper we define a *shared workflow* as a business process that two or more organizational entities agree to follow. A shared workflow is related to the private workflows of the individual organizations, but may only contain a partial view of them; each participating organization may not want elements of its internal processes to be externally observable. The term *evolutionary* means that shared workflows have not all been settled in advance, but need to be negotiated incrementally in step with the evolving business agreements between the organizations. A *meta-process* is a procedure – or process - whose purpose is to establish a business process that will be enacted for operational business cases. The term *multi-layer* derives from the earlier paper, in which several layers in the meta-process were identified, the first three being a) informal discussion b) agreeing a business process model and c) agreeing an executable workflow system.

The VE, or the subset of members involved in each particular business collaboration, needs to reach a final agreement on one or more inter-organizational processes that represent the way they agree to inter-operate. However each individual organization will usually also need to adjust its private processes to fit in with the new collaboration. For example, it may need to provide additional facilities for notifying partner organizations of progress, for responding to requests for status reports, or for dealing with exceptions such as non-response from the partner.

The question is - how best can IT be used to help the meta-process? Our intuition is that even if the VE has developed guidelines, the meta-process can never be as strictly predefined as with typical production workflows. But it is equally unrealistic to assume that the meta-process is totally informal. One possible intermediate paradigm is a negotiation model, but typical negotiation models focus on a limited number of measured utility parameters such as price, delivery time etc. Our task is to find something equivalent to a negotiation model that will allow the parties to make proposals, counter-proposals and agreements on a whole range of issues such as the nature of tasks, the order they should occur in, the data that should be provided, the persons that are authorized to commit to a decision, the rules governing exceptional situations - and so on.

This paper proposes a way to support the collaborative meta-process of evolving a set of workflows that will coordinate the activities of a VE. The collaborative activity is assumed to take place over the internet in the online equivalent of a meeting room [2], and that communication can be abstracted to the exchange of a series of events related to the collaboration. It includes the use of graphics exchange protocols for real time.

However our approach aims to avoid explicit dependence on any particular process model diagram or language standard, other than that the model can be represented in XML.

In this paper, section 2 summarizes the related work in business process modelling in B2B, business contract architectures, inter-enterprise workflows, evolutionary workflows, whiteboard/blackboard models, and coordination models using tuplespaces - with related software developments. Section 3 describes the architecture and basic model of our proposed approach. Section 4 discusses a possible way of implementing our approach with available software. Section 5 presents our conclusions and directions for further work.

2. RELATED WORK

ebXML [3] has been proposed as a standard approach to B2B e-commerce. It envisages that, at the level of the structure and sequence of messages to be passed, each organization proposes a Coordination Protocol Profile (CPP); the organizations then negotiate an agreed protocol (CPA). However ebXML has not yet recommended a meta-process for agreeing a CPA – use of an ebXML-familiar broker (consultant) is assumed.

Automatic and formal approaches for aligning business processes from different organizations have been proposed by Mahleko [4] and Grossmann et al [5]. However the orientation here is to find an *integrated* process, rather than the shared sub-process that represents only what happens *between* the organizations.

Negotiation of a shared process and negotiation of a contract are very closely linked. The contract will specify the duties of each party in both physical and informational terms. A description of our work in conjunction with the Business Contracts Architecture of Milosevic et al is given in [6] and [7].

The CrossFlow project [8], which is based on services-based cross-organizational workflow (SCW), looks at contracts as the key element in defining inter-enterprise workflows. Other important issues in CrossFlow include reliability, trust and service management (see also [9]).

Collaboration involving workflows in virtual enterprises has been addressed by Ludwig and Whittingham [10] and Wynen et al [11].

Analyses of alternative architectures for inter-organizational workflow have been made by van der Aalst [12]. Schulz and Milosevic [13] have carried out a good analysis of cross-organizational process architectures, primarily oriented to B2B E-commerce. Wing, Liu and Colomb [14] introduced the notion of incremental trading, implying a loosely-coupled VE in which the members gradually get to know more about each other. Action Workflow [15] is also relevant as a well-established workflow approach (and software product) that is based on a pattern of exchanges of information along the lines of offer and acceptance. This closely mirrors the situation in many shared inter-organizational workflows.

In terms of the process of evolving workflows through collaboration and negotiation, the most notable work was done on the ORCHESTRA Esprit project [16].

In the pre-electronic age, the people negotiating the shared process would most likely meet in a room with a white (or black!) board and interactively agree the processes and data standards. The web based equivalent of this environment is a virtual meeting room [2] with support for a shared digital whiteboard. Shared whiteboards are used by many desktop conferencing systems, including Microsoft's NetMeeting. A state of the whiteboard is determined by its initial state and a sequence of events that are incrementally applied to it. Some of the issues involved in transmission of data streams used by common shared whiteboard tools are described in [17].

The idea of a tuplespace has its origins in coordination languages such as Linda [18]. A tuple is a vector of fields. Users of a tuplespace can post and retrieve tuples using coordination primitives [19]. A number of extensions of the Linda primitives have been introduced; some of these offer *reactive programming* [20] functionality. This can support, for example, triggering of user notifications or program calls on an event such as the insertion of tuples into a tuplespace.

An XML document can be stored in a tuple field value (or values). The ability to match on nodes in the XML document using some form of query language such as XQL is supported by tuplespace implementations such as TSpaces [21] and XMLSpaces [22]. TSpaces also includes reactive programming primitives, including the ability to register with the server for notifications based on whether a tuple that matches a specific template is written to the server by any client.

The most relevant work to date in combining Linda-based workspaces with workflows is described by Tolksdorf [23].

3. ARCHITECTURE AND BASIC MODEL

3.1 Multi-layer model

The previous paper [1] saw the evolution of business processes for a VE as a multiple set of layers, each of which would need to be agreed as part of the meta-process. Since the system level implementation of the processes will generally involve application layer protocols, it is useful to regard the layers as an extension of the standard seven layer ISO/OSI (Open Systems Interconnection) reference model. The extra layers introduced were as follows:

Table 1: Layers of a meta-process as an extension above the ISO/OSI communications profile, from [1]

Layer	Nature of interaction
11	Informal discussions of terms of agreement, procedures and rules
10	Tailoring of proposed or potential process patterns by cooperative and interactive use of whiteboard technology.
9	Agreeing formal and/or executable models incorporating process and data, using shared data and workflow models
8	Agreeing domain-specific models for terminology, and for task and data transfer
7a	Agreeing standard message structures (XML schemas etc) for carrying transferred processes, tasks and data
7b	Coordinating requests between computer software systems across data communication facilities

At layer 11 the negotiation is between senior business managers. They may introduce a mediator, or may resort to a tried and tested set of choreographed exchanges to perform the negotiation, similar to an auction with set rules. The emphasis is on the broad principles of the collaboration. This includes determining which parts of the process are to be under joint control and which are a purely local responsibility. The data being passed at this layer is mainly informal. If it is recorded at all, it is likely to be free text based, e.g. emails with optional attachments. These text messages can be supported in our system as message based tuples.

At layer 10, more detailed negotiation takes place (involving business process analysts, lawyers, accountants etc) to work out potential process patterns. The subject matter includes not only the basic control flow in the process model, but also such things as required data, authorized roles, time limits, action to be taken on exceptions – in fact anything that could appear in a legal clause. At this level, the parties may not be using compatible – or indeed any – formal diagramming notations. However whiteboard-style negotiation will be easier if some simple diagramming is used.

At layer 9 the meta-process would work with formal diagrams representing data structures and process patterns. The process diagram needs to show the process dependencies in the shared workflow. Since the organizations may use different modelling conventions, a standard format is used on the whiteboard, which is mapped to the individual organizations' models using WfXML. However it should be noted that many workflow systems include more than just control flow, and may employ more than one type of diagram for capturing the total design of a workflow pattern.

At layer 8 the meta-process is limited to agreement on whether or not to use a certain domain-specific standard , e.g. RosettaNet [24] for the IT electronics industry. We are not concerned with what happens below layer 8. Agreement on standard message structures and basic request-response communications is made between the IT managers of the organizations. In many cases, the decision will be made when each organization chooses its B2B software.

3.2 Motivating example

We consider a simple case where two organizations currently both offer a set of business services that allow customers to place single and multiple orders, enquire about prices and availability etc. Because they operate in related markets, the organizations wish to introduce a number of shared processes to streamline the service they can offer the customers. The idea is that each organization will offer the other organization's products as well as its own, but would need to check availability and prices across the organizational boundary. As a result, a) each partner's service interface would need to be adjusted and b) a shared process would need to be started up.

A tuplespace is also useful for supporting dynamic groups of users where participants can join and leave at any time. A participant who joins an ongoing session can retrieve, by matching against a set of tuples, existing data exchanged by other participants since the start of the session. This is useful in the support of the changing membership of alliances that is often common in VEs.

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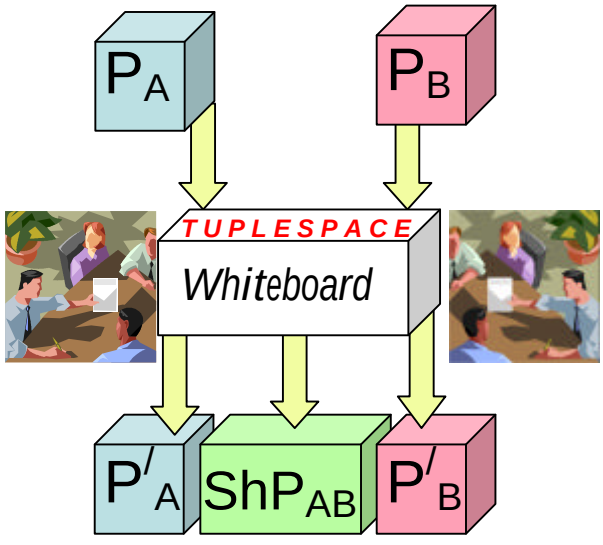

Figure 1: Overview of the whiteboard-assisted meta-process

The meta-process changes the situation from two separate processes P_A and P_B to a shared process ShP_{AB} flanked by two private processes P'_A and P'_B, as shown in Figure 1 above,. ShP_{AB} may be more than a simple choreography if brokers or other intermediaries are

involved. Figure 2 explains what is contained within the processes P_A etc. The interface (at the front) can be with either a human user or a program (e.g. part of an end customer's purchase order system). The control flow determines the hierarchy, sequence, branching, parallelism and iteration of a set of activities (human or computer). Secondary perspectives cover all other information necessary to fully define the process.

3.2 Representation of the model as a tuplespace

A tuplespace approach has advantages for the type of collaboration scenario we wish to support because it offers functionality similar to both active database and pattern-based messaging. It can also support situations where the relationship between data items is dynamic and transitory rather than following rigid data models.

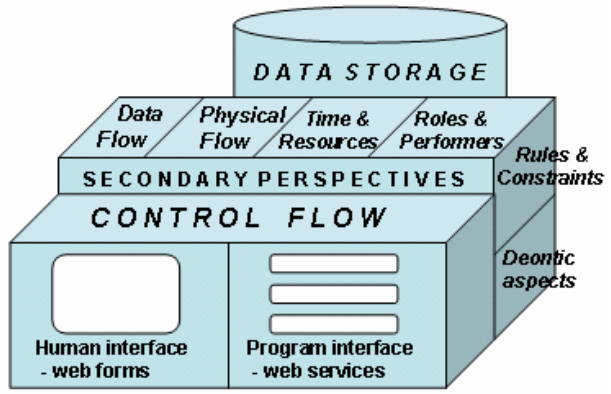

Figure 2: Contents of a customer process

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The workflow definitions being evolved could be in many different forms, such as a) a business process modelling tool; b) a workflow management system or c) workflow facilities within an enterprise resource planning (ERP) system such as SAP [25]. The key to being able to correlate processes is the existence of reliable mappings between the workflow definitions and the XML data represented in the tuples in the tuplespace. We use Wf-XML [26] as a unifying format, although this will not in general be sufficient to cover all the process semantics. We propose to supplement Wf-XML with the use of a *constraint document* encoded in OCL (Object Constraint Language) [27]. Beyond this there may still be a need to hold other tuple-based data structures as required.

In our approach we first translate the definitions of the existing workflows into Wf-XML, which provides the initial state of the tuplespace. The combined workflows are then presented for discussion in a neutral graphical format, using swim lanes to distinguish the different partners and intermediaries. Input and output messages are also shown on the graph, and can be expanded by clicking. In the discussion the order of actions may be changed; actions may be inserted or removed; or the constraint document modified to change triggers for certain actions, or to change the conditions for transitions between actions to occur. When a participant in the meta-process makes a change, we capture these changes as generic whiteboard events, by adding tuples to the tuplespace. In order to preserve the order of incremental state changes, we keep track of event sequence numbers.

4. IMPLEMENTATION APPROACH

A tuplespace implementation which matches our requirements for shared virtual data spaces on the internet is TSpaces [21] developed by IBM. A TSpaces server can support multiple tuplespaces instances and a client can locate a TSpaces server on the web and then attach to a named tuplespace instance hosted on the server. Once a client connection to a tuplespace is established the various supported TSpaces operations can be used to interact with tuples (read, write, take, update, delete etc). Access control is implemented at the tuplespace level so that each operation requested by a client to be performed on a particular tuplespace instance has a related list of AccessAttributes that need to be satisfied for the operation to be allowed. As part of the supported operations there are blocking commands where a client can use a WaitToRead or WaitToTake command. The TSpaces server implements a callback functionality which can be used to inform clients of the arrival of tuples matching an outstanding query. Clients can therefore setup notifications which can be used to keep track of a set of required tuples (e.g. client can wait for tuples required to perform an action).

In terms of XML support, the TSpaces server supports the use of an XML field in a tuple and creates a *tuple tree* for XML documents which mirrors the DOM (Document Object Model) tree which corresponds to the XML structure. A subset of the XQL query language is supported to allow path expression based matching on data within an XML document. IBM has also developed the TSpaces services suite, which helps to automate the development and management of web services using tuplespaces. It is interesting to note that XMLSpaces [22], which is a direct extension of TSpaces, has added new functionality to provide a more detailed incorporation of XML into tuple fields and XML support for the original Linda definition of the matching relation for tuples. XMLSpaces also extends TSpaces by offering distributed tuplespace support across multiple servers.

We are experimenting with Version 2.1.2 of the TSpaces server software running on a web server with an additional software layer that is used for transformations and connectivity with SAP Netweaver [28]. Netweaver is a Wf-XML compatible tool for

orchestrating both SAP and non-SAP services that is based on SAP Business Workflow. Examples of transformations needed by the system are the mapping of whiteboard protocols to coordination primitives and the use of XSL [29] for transformation between various XML document structures. A limited set of basic TSpaces tuple data structures have been defined to represent evolutionary workflows to be exchanged in the system:

```
WorkflowTuple = (PartnerRole, Id,
TimeStamp, XMLDoc, [ActionTuple]+)
ActionTuple = (PartnerRole, Id, XMLDoc)
MessageTuple = (PartnerRoleTo,
PartnerRoleFrom, Id, Subject, Text,
XMLDoc)
```

where + represents a field which can be repeated multiple times, PartnerName identifies a particular business partner, Id is a unique number which can be used as a way to track sequences and set membership, and XMLDoc represents an XML document structure. TSpaces-supported coordination primitives can be used to interact with these tuples and to generate other temporary data tuples as needed, using reactive programming techniques.

5. CONCLUSION AND FUTURE WORK

Our proposed system supports collaborative activities for evolving workflows for a virtual enterprise, based upon (a) interactive use of a shared whiteboard (for tailoring potential process patterns based on graphical interaction) and (b) cooperative discussions of the terms of agreement, procedures and rules using a blackboard architecture (interaction based on message exchange). We have described how this can be achieved using tuplespaces, and are working on a prototype implementation using IBM's TSpaces.

Future work plans include 1) improved handling of the secondary perspectives, possibly incorporating a general ontology for process negotiation; 2) specialization of the whiteboard interface for the different layers (i.e. top management (layer 11), business analysts and lawyers (layer 10), and line managers and process specialists (layer 9); and 3) catering for volatile N-way negotiations including intermediaries as well as partners who join and leave VE agreements.

We also intend to continue working towards the presentation of a full prototype implementation.

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