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In this paper we present a 3-tier workflow model for cross-system and cross-organisational workflow interactions. It allows to model private partner workflows, public workflow views that act as their representatives, and public workflows that interconnect these views in a coalition. With this minimal approach, existing workflows can be re-used for B2B interactions whilst their privacy can be maintained.

1. INTRODUCTION

The Introduction of the notion of workflow gave an opportunity for a substantial re-use of applications. This is applicable within one organisation and across multiple cooperating organisational units, especially with emerging concepts of virtual organisations and emerging ideas of workflow deployment in the e-service area. In this paper we are facing the situation where companies want to set up a cross-organisational but integrated solution for their business needs and seek to evaluate possible ways to compose the new system. The problem is to model the environment and the new system to evaluate the feasibility of the initiative. This leads to the consideration of various incompatibilities in the new system due to pre-existing automated processes. We argue that the modelling of the interaction should be done as a workflow by itself that specifies the data that the individual workflows require to perform their tasks and the interactions, i.e. the protocols that lead from state to state in the overall system. Workflows can be composed fully or partially from the pre-existing component processes owned and being developed by independent organisations. Such a heterogeneous infrastructure requires modelling considerations beyond the currently accepted modelling concepts for individual, stand-alone workflow systems.

We introduce and investigate a cross-organisational workflow model and identify requirements and extensions to an existing intra-organisational workflow model to capture a higher-level representation of the integrated system. The extended model is intended to be used in an environment where a public workflow interconnects participants' private workflows. The main goal of this generalisation is to construct a model that will cover coalitions (integrated workflows) as well as individual workflows owned fully by one organisation. The model can also be seen as a base for definition of various views required for different purpose and external disclosure. The remainder of this paper is organised as follows: In section 2 we

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describe related work to our field or research. Section 3 describes general characteristics of cross-organisational workflows that we studied. In section 4 we introduce our 3-tier workflow model. We conclude with section 5, the summary.

2. RELATED WORK

Our overview of related work focuses on workflow models. We analyse them towards their capability to model both company-internal processes and processes that span multiple organisations. We argue that such an integrated approach must be pursued to allow for an understanding, verification, and exception handling of the dependencies between partners. In this section we briefly outline those approaches that we identified as most relevant to our work that we describe in this paper.

The Crossflow project (IBM, 1999) developed an approach to architect cross-organisational business process interactions. Crossflow introduces business contracts to describe the business operation between partners. Crossflow requires direct communication between partner organisations to execute a joint business process. There is no central instance that has a comprehensive view of the multi-organisational business processes.

The ebXML.org group (ebXML 2000, 2001) seeks to provide an open XML-based infrastructure enabling the global use of electronic business by all parties with the aim to provide support specifically for the B2B process issues - currently not addressed within the WfMC standards. ebXML provides the technical infrastructure and message formats for XML-based cross-organisational workflows. The ebXML business process developments are centred on support for peer-to-peer interactions.

Liu and Shen, 2001 describe a novel approach of modelling workflows with process views. They argue that business processes need to selectively expose activities without disclosing details about them. This concept is similar to views in database systems. The authors provide a thorough mathematical model of workflow and extend it to virtual process views. They then discuss order preservation in virtual processes and algorithms to generate minimum virtual activities.

XLANG (Thatte, 2001) is a relatively new business process specification for web services. It describes the constructs to model multi-party processes – it therefore goes beyond the static Partner Interface Processes of RosettaNet (RosettaNet, 2000). XLANG assumes loosely coupled workflows where the involved parties neither share applications and workflow implementations nor allow external control over their internal processes. There is a workflow that is known to all participants. Every participant provides a publicly visible behaviour description in the forms of messages exchanged and implements its behaviour using private means. XLANG specifies only the behaviour that the participants explicitly want to share with each other to understand and design their own workflows. However, XLANG assumes statically configured participants where all participants have prior agreements in place including agreements on communication endpoints.

The Business process Definition Language (BPML) (Arkin, 2001), seeks to complement ebXML by specifying the private elements of cross-system workflows. At this time, the BPML process model is a working draft, version 0.4. It is still open how BPML will further develop and how it proves itself in actual applications. BPML introduces the notion of an Abstract. It is the definition of a process that

cannot be executed. Abstracts are used to model processes supported by participants, or to define views of a process with regards to one or more participants. A process that interacts with a participant can be validated for completeness against that participant's abstract. A process can declare support for one or more abstracts.

A widely accepted and frequently quoted workflow model is the Workflow Management Coalition's (WfMC) Basic Process Definition Meta-model (WfMC 1995, 1999). The model is designed vendor-independently and will serve as our starting point and reference. For completeness of the paper we briefly summarize the main aspects of it below: The WfMC Process Definition Meta-Model (WfMC-PDMM) ER model comprises the Workflow Type Definition, Activity, Transition Condition, Workflow Relevant Data, Role, and Invoked Application. Each of the entity types has an extensive set of attributes that we shall not list here, but refer the reader to (WfMC, 1999) The WfMC-PDMM starts at its highest point of hierarchy with a Workflow Type Definition, which has Workflow Relevant Data. The Workflow Type Definition further consists of one or more Activities that use Workflow Relevant Data. An Activity may also use Invoked Applications. Both, Activities and Invoked Applications use Workflow Relevant Data. An Activity may refer to one or more roles that perform the Activity. However, the model lacks the constructs to model workflows that cross organisational boundaries.

If the above models support cross-organisational workflow modelling, then they always built on the assumption of a clear peer-to-peer relationship where workflows from one organisation are directly linked to workflows from another organisation. We argue that this violates privacy or, in the case of using services as connection means, contradicts the workflow paradigm, which always promised predictability and thus reliability of business processes. In our model we propose an approach where a publicly visible workflow interconnects the views that have been derived from the partner's workflows. In our perspective only a certain level of integrated modelling between the processes of the workflow participants allows for true verification, monitoring, and exception handling in the workflow interaction in a coalition.

3. CROSS-ORGANISATIONAL WORKFLOW CHARACTERISTICS

Our research started with an investigation into the complexity of cross-organisational workflow interactions. We found that the existing standards of the WfMC, but also many research projects on Virtual Enterprises assumed relatively simple interactions: Chained and nested. As we started an analysis on real-life processes we identified a number of compelling scenarios from different vertical industry domains, such as from automotive, oil and gas, pharmaceuticals, etc, and also a number of horizontal scenarios (procurement, quality certificate exchange). These real instances of this practical problem demonstrate the complexity of the interaction between distributed participants. We observed the general patterns in multi-party workflow interactions, which we categorized into model and protocol characteristics. The protocol-characteristics reached from simple "nested" to "parallel-deferred", up to rather complex "joint invocations", These protocol-characteristics are pervasive to our proposed workflow model, but will have to be published in another paper. For this paper we describe the model characteristics that

outline the non-protocol-related requirements of a cross-organisational workflow model. We call them Visibility/Confidentiality, Compose-ability, and Adaptability. We distinguish local workflows and activities that are only visible within the boundaries of an organisation and public workflows and activities that are visible to all members in a coalition (we refer the reader to (Schulz, Orlowska, 2001) for a description of the public/private workflow model).

Visibility/Confidentiality: There are individual activities or sets thereof that are only visible from within their own organisation OR for a set of partner organisations.

Compose-ability: An activity that is part of a cross-organisational workflow can be modelled as one or more local activities OR as one or more local workflows.

Adaptability: The same workflow may be involved in many different coalitions playing in each of them a different role and exposing specific data there. This indicates some properties of a workflow involved in a coalition are the properties of this involvement thus they may be different in another coalition. This propagates further to the level of individual activities.

4. CROSS-ORGANISATIONAL WORKFLOW MODEL

In this section we take our existing research on cross-organisational workflow architectures a step further by developing an integrated approach to model private and public workflows (Schulz, Orlowska, 2001). However we found that a workflow model needs to go beyond “private-public” and requires a modelling element that acts as “glue” or abstraction to link private workflows to public ones and in order to hide private workflows from other partners. In our notion, these are the workflow views that we introduce in this section. Our work is based on the Workflow Model of the WfMC, which we chose as our starting point because it is relatively mature and widely accepted.

We consider individual workflows that form one or more cross-organisational workflows that are cooperating towards a common goal within the context of a coalition. A coalition represents an organisational entity, such as a virtual enterprise or a group of organisations willing to collaborate towards a goal. Informally, this composition of pre-existing processes may be very tightly coupled where many details are known to the rest of the coalition thus forming a new well-defined process OR not tightly coupled where the sharing of internal information is rather limited but sufficient to the overall function of the coalition. The workflow model has to be sufficiently expressive to describe the task or activity that a workflow performs and the protocol, i.e. the publicly visible sequence of steps that require interaction to accomplish the task. Depending on the coalition in which a workflow is applied the protocol that a particular partner in the workflow “sees” may vary. We call this “workflow-views”. A workflow-view is generated from physical workflows or workflow-views and is considered as a virtual workflow. Its implementation is provided by its underlying physical workflow. We illustrate this in Figure 1 with private partner workflows in the centre. Organisations can principally participate in more than one coalition at the same time, they derive coalition-adapted views of their private processes and make them available to the coalition. On the level of the particular coalition, the views from the different partners are assembled to provide

the services that this coalition has to offer. To generate views from partner workflows, transformations are applied such as those introduced by Liu and Shen.

Figure 1- From Partner Workflows to Coalition Workflows via Workflow Views

A view of an existing workflow must be rich enough to capture the data about required interaction to allow the workflow to perform according to its business specification. Particularly interesting is the relationship of private workflow elements to the function of the public workflow. Figure 2 takes a sample workflow on the top and reduces all private tasks but task number 7. Because T7 loops back to T6, an entity that uses the workflow must be aware that it possibly needs to re-submit data to T6. A workflow-view needs to be able to express this.

Figure 2 - Partner Workflow – Workflow-View

We therefore argue, that a workflow needs to provide partner-specific views where private activities are largely hidden. This must allow for coalition-specific views and only the coalition-members shall access them. Views can be established from at least one workflow or a workflow-view. In the following we describe the entity types and the attributes of a “minimal” cross-organisation workflow meta-model. As most of the models, one can extend the one below. We argue however, that the model presented is sufficient for querying, monitoring and verifying global and local processes and serve as blueprint for their evolution and maintenance.

Coalition

Coalition is the most general entity in the proposed model. It may represent a virtual enterprise, extended enterprise, virtual organisation, etc. It is formed by a number of members that have agreed to cooperate for a particular period of time towards a common goal. A default method of interactions describes the technical interaction preferred in the coalition, whilst security rights describe the partners' rights to add, modify, view, and delete workflows.

Table 1: Coalition

Attribute	Description
List of Members	Members that form the coalition
Validity	The time of the coalition's existence, expressed as start and end date/time
Default Method of Interaction	Technical interaction preferred in the coalition. Can be overwritten by the workflow or activity.
Security Rights	Rights to add, modify, delete, and view workflows

Workflow

Workflow is the entity that represents private partner workflows, workflow-views and coalition workflows, thus providing the protocol to interact with activities.

Table 2: Workflow

Attribute	Description
Type	Partner/View/Coalition
Relationship to other workflow entities	Is view of partner workflow / Is element of coalition workflow
Process start and termination conditions	Conditions under which workflow starts and closes.
Security, audit, control data	Permissions to start/interact with a workflow
Specification language	Required to interpret the flows, decisions, etc. resolving the semantic integration issues.
Coalitions	Back-reference to the coalitions that this workflow belongs to
Owner	Owner of the workflow
Supporting WfMS	WfMSs that are able to execute this workflow. Dependencies: specification language, underlying organisational model, available resources
Location	Location of the Engine: geographical data.
Activities	List of activities
Default Method of interaction	Technical interaction preferred in the workflow. Usually determined by the capability of the executing workflow engine.
Transition Conditions	Transitions between the workflows activities and subworkflows

Activity

Activity entity type represents the tasks in a workflow. Besides activity input and output data, for an activity we declare their communication requirements, i.e. the messages to be interchanged with the environment during execution time. Even though an activity may be atomic, the underlying implementation may require executing several steps to perform the activity.

Table 3: Activity

Attribute	Description
Type	subflow, atomic flow, etc
Pre- and post- conditions	Conditions for activity to commence/finish
Other scheduling constraints	Such as temporal dependencies
Performing Wf-Engine	All engines that are involved in executing this workflow. Required for distributed workflows.
Activity share-ability	(exportable, private/internal only)
Activity input data	Data required by activity at the start of its lifecycle
Activity output data	Data produced by activity at the end of its lifecycle
Activity communication	Emitted and consumed messages with the outside world during the activity's lifecycle. Required to realize more complex protocol interactions.
Ownership	Owner of the activity
Default Method of interaction	Technical interaction preferred in the activity. Usually identical to the workflow's default method of interaction. Can be overwritten if activity is performed by external application, or a human
Role	The role that performs the activity

Transition Conditions

Transition conditions describe the paths amongst workflows and activities. The information about them is essential to form views. With the introduction of the entity "coalition", there are now "coalition-transitions" connecting publicly visible workflows and activities and internal-transitions within the private workflow of the organisations. If there is the need to expose an internal-transition to the coalition because it is part of a coalition-wide JOIN/SPLIT-condition, then this is made visible by setting the *Transition share-ability* attribute.

Table 4: Transition Condition

Attribute	Description
Flow condition	Edge been information source and information sink
Transition share-ability	Exportable/private/internal only

Implementation

This is the entity that describes implementation of an activity. A separation between activity entity type and implementation entity type is particularly sensible when coalition participants dynamically implement activities, such as in an eMarketplace: where the cross-organisational workflow should stay unchanged, but the binding to a particular implementation should be modified.

Table 5: Implementation

Attribute	Description
Execution parameters	Parameters required to execute the implementation
Location or access path	Execution semantics
Workflow	The workflow that implements this implementation
Activity	The activity that implements this implementation

Workflow Relevant Data and Role

For completeness of our model we mention these entities but refer the reader to (Schulz, Orlowska, 2001) for the cross-organisational rationale behind them. Workflow Relevant Data is used by the workflow itself and influences the transitions between the views. There is no clean separation between application data and workflow relevant data as the results of the application operation shall influence the workflow's transitions. Role is the entity in the model that describes the performer of an activity. It reflects an entity in an organisation and provides information how to possibly contact the role implementer.

5. SUMMARY AND OUTLOOK

In this paper we have presented a 3-tier cross-organisational workflow model that captures private partner workflows, workflow-views and coalition workflows. This is different to existing workflow models that often assume a 1-tier peer-to-peer model or a 2-tier private-public model. With this minimal approach, existing workflows can be re-used and their privacy be maintained. Workflows provide a minimal set of workflow-relevant data and protocol information so that a consumer of a complex workflows service is able to interact with them. We see further work in methods to transform private workflows into workflow-views, their verification and validation. Also the influence of workflow interoperability protocols on the model if of interest for us – we will address this in a separate publication.

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