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THE P2P APPROACH TO INTERORGANIZATIONAL WORKFLOWS

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Abstract **- This paper describes in an informal way the Public-To-Private (P2P) approach to interorganizational workflows, which is based on a notion of inheri- tance. The approach consists of three steps: (1) create a common understanding of the interorganizational workflow by specifying a shared public workflow, (2) partition the public workflow over the organizations involved, and (3) for each or- ganization, create a private workflow which is a subclass of the respective part of the public workflow. Using an example, we explain that the P2P approach yields an interorganizational workflow which is guaranteed to realize the behavior spec- ified in the public workflow.**

Index Terms – P2P Approach.

I. Introduction

In today's corporations, products and services are typically created by business pro- cesses, and workflow technology can be used for enhancing the flexibility and efficiency of these processes [14, 19]. Corporations often operate across organizational bound- aries, for example in E-commerce and extended enterprises [11, 20, 27]. Consequently, workflows between organizations — interorganizational workflows — are becoming increasingly important [21, 12]. Interorganizational workflows are typically subject to conflicting constraints of the organizations involved. On the one hand, there is a strong need for coordination to optimize the flow of work in and between organizations. On the other hand, the organizations involved are essentially autonomous and have the freedom to create or modify workflows at any point in time. Some of the issues resulting from these conflicting goals will be tackled in this paper: We introduce the Public-To-Private (P2P) approach to interorganizational workflows which provides the means to specify a common public workflow, to partition it according to the organizations involved and to allow for private refinement of the parts by the organizations, based on a notion of inheritance. The P2P approach guarantees that the private workflows of the participat- ing organizations (or, as we prefer to say, the domains) satisfy the public workflow as agreed upon; it consists of the following steps:

– Step 1: The organizations involved agree on a common public workflow, which serves as a contract between these organizations.
– Step 2: Each task of the public workflow is mapped onto one of the domains. Each domain is responsible for a part of the public workflow, referred to as its public part.

Step 3: Each domain can now make use of its autonomy to create a private work- flow. To satisfy the correctness of the overall interorganizational workflow, how- ever, each domain may only choose a private workflow which is a subclass of its public part.

This paper introduces the P2P approach in an informal way, guided by an example of an electronic bookstore. The paper is structured according to the steps mentioned, and for each step concepts and notations are introduced when required; the complete definitions and the technical details of the proofs can be found in [4]. Sections 2 through 4 present the phases of the P2P approach, and Section 5 summarizes the main results. A discussion of related work and concluding remarks complete this paper.

II. Designing the Public Workflow

A. *Figures and Tables*

The example used throughout this paper is inspired by electronic bookstores such as Amazon [8] and Barnes and Noble [9]. In this section, we design the public workflow for ordering books. The scope of the workflow process includes the ordering, billing and shipping of books, involving the customer, the bookstore, the publisher, and the shipper.

The P2P approach uses workflow nets (WF-nets) [2] for modeling workflows, which are a specific form of Petri nets. In WF-nets, tasks are modeled by transitions, and causal dependencies are modeled by places and arcs. In fact, a place corresponds to a condition which can be used as pre- and/or post-condition for tasks. An AND-split cor- responds to a transition with two or more output places, and an AND-join corresponds to a transition with two or more input places. OR-splits/OR-joins correspond to places with multiple outgoing/ingoing arcs. A WF-net has one source place and one sink place because any case (i.e., workflow instance) represented by the WF-net is created when it enters the workflow management system and is deleted once it is completely handled. An additional requirement is that there should be no dangling tasks or conditions, i.e., tasks and conditions which do not contribute to the processing of cases. Therefore, all the nodes of the workflow should be on some path from source to sink. WF-nets with these properties are called sound [1, 2].

Figure 1 shows the public workflow N publ of the electronic bookstore. This work- flow can be regarded as a contract between the domains, i.e., the customer, the book- store, the publisher, and the shipper. We stress that the public workflow does not nec- essarily show the way the tasks are actually executed; the real process may be much more detailed, and it may involve much more tasks. The public workflow only contains the tasks which are of interest to all parties. The public workflow shown in Figure 1 is defined as a WF-net. While the mapping of the tasks to domains is only done in the next step, one can think of the tasks in the left column as performed by the customer, for instance the place c order task. The next columns to the right belong to the bookstore (containing, e.g., the handle c order task to handle the customer order), the publisher (e.g., eval b order), and the shipper (e.g., eval s req), respectively.

The workflow process is initiated by a customer placing an order (represented by the task place c order). This customer order is sent to and is handled by the bookstore (handle c order). The electronic bookstore is a virtual company which has no books in. Therefore, the bookstore transfers the order of the desired book to a publisher (place b order). The bookstore order is evaluated by the publisher (eval b order) and either accepted (b accept) or rejected (b reject). In both cases an appropriate signal is sent to the bookstore. If the bookstore receives a negative answer, it decides (decide) to either search for an alternative publisher (alt publ) or to reject the customer order (c reject). If the bookstore searches for an alternative publisher, a new bookstore order is sent to another publisher, etc. If the customer receives a negative answer (rec decl), then the workflow terminates. If the bookstore receives a positive answer (c accept), the customer is informed (rec acc), and the bookstore continues processing the customer order.

Once the order is confirmed, the bookstore sends a request to a shipper (req ship- ment), the shipper evaluates the request (eval s req) and either accepts (s accept) or rejects (b reject) the shipping request. If the bookstore receives a negative answer, it searches for another shipper. This process is repeated until a shipper accepts. Note that, unlike the unavailability of the book, the unavailability of a shipper can not lead to a can- cellation of the order. After a shipper is found, the publisher is informed (inform publ), the publisher prepares the book for shipment (prepare b), and the book is sent from the publisher to the shipper (send book). The shipper prepares the shipment to the customer (prepare s) and actually ships the book to the customer (ship). The customer receives the book (rec book) and the shipper notifies the bookstore (notify). The bookstore sends the bill to the customer (send bill). After receiving both the book and the bill (rec bill), the customer makes a payment (pay). Then the bookstore processes the payment (han- dle payment) and the interorganizational workflow terminates.

The public workflow shown in Figure 1 is indeed a sound WF-net, since it has exactly one input place and one output place, at the moment when the workflow reaches the output place, all tasks have completed, and there are no dead transitions, i.e., all tasks of the WF-net are in fact reachable during workflow executions.

III. Partitioning the Public Workflow

In the second step of the P2P approach, the public workflow is partitioned according to the domains, and the public parts are related to each other, making up an interorganiza- tional workflow. An interorganizational workflows is defined by an interorganizational workflow net (IOWF-net). An IOWF-net consists of a set of WF-nets, a set of channels, a set of methods, and a channel flow relation.

In our example, the public workflow is partitioned over four domains: the customer domain, the bookstore domain, the publisher domain, and the shipper domain, as shown in Figure 2. Methods of the domains are represented by shaded boxes, and they are linked to channels by the channel flow relation, which is represented by arrows. In Figure 2, the public parts of the customer, the bookstore, the publisher and the ship-
per are represented by boxes N part, N part, N part, and N part, respectively. Channels
C B P S
are represented by icons, and the channel flow relation represented by arrows specifies the linkage of the domains. For example, the c order channel and the attached arrows represent the fact that customer order information flows from the customer domain to

the bookstore domain, while the confirmation of the order flows in opposite direction, making use of channel c confirm.

Based on this description it is clear how the public workflow needs to be partitioned. The public part of the customer domain is quite simple (cf. Fig. 3): The customer first places an order, using the method place c order. Then either the order is accepted, the book and the bill are received and the bill is paid, or the order is declined. Notice that for each transition in the WF-net, there is a method linked to it by a dotted line, representing the actual function which is invoked when the task is executed.

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The public part of the bookstore workflow is slightly more complex (cf. Fig. 4): After the order arrives, the bookstore checks for a publisher ready for providing the ordered book. If no publisher can be found, the order is rejected. Otherwise, shipment is requested from a shipper, and payment is handled. The public parts of the publisher and shipper workflow are shown in Figure 5.

The IOWF-net is a high-level representation of the domains and their dependencies; its semantics are given in terms of a labeled P/T net. A IOWF-net is transformed into a labeled P/T net by taking the union of all WF-nets, adding a place for each channel, con- necting transitions to these newly added places, and removing superfluous source and sink places. We call this the flattening of the interorganizational workflow. As shown in [4], we can easily make sure that the partitioning is valid, i.e., all public parts are sound WF-nets and there is no multiple activation. We mention that the flattened IOWF-net equals the public workflow.

IV. SUMMARY & RESULTS

The To summarize the P2P approach, in the first step the public workflow is specified in terms of a sound WF-net; it serves as a contract between the business partners involved. In the second step, the public workflow is partitioned over the set of domains. Note

that each domain corresponds to an organizational entity. As a result of the partitioning, each fragment of the partitioned workflow corresponds to one of the domains and is represented by a sound WF-net, called public part. In the final step, the public parts are replaced by private workflows. Each private workflow corresponds to an actual work- flow as it is executed in one of the domains. The P2P approach guarantees that each private workflow is a subclass of the corresponding public part under projection in- heritance. It is important to note that the P2P approach is constructive: By applying the three transformation rules introduced above, the design is guaranteed to be correct without the need to check whether each private workflow is actually a subclass of the corresponding public part.

Following the general tone of this paper, we explain the main results informally and introduce concepts if and when required. Please refer to [4] for a detailed theoretical discussion. The first result concerns the overall workflow, which consists of all private workflows of the participating domains.

Result 1: The overall workflow is a sound WF-net.

This property is based on the observation that a part of a WF-net (called sub- flow) can be replaced by a specialization (i.e., a subclass subflow) without endangering soundness of the overall workflow. This result is proven in [4], based on a theorem which shows the compositionality of projection inheritance. From an application point of view, Result 1 makes sure that the P2P approach guarantees that the overall workflow is free of deadlocks and other anomalies.

Result 2: The overall workflow is a subclass of the public workflow.

This result shows that the dynamic behavior of the interorganizational workflow which the business partners agreed upon in the public workflow is in fact guaranteed to be satisfied by the execution of the interorganizational workflow, i.e., the overall workflow. From an application point of view, this is an important result, since it provides the business partners with the ability to perform any private modifications to their public workflow part, as long as the subclass relationship holds. Transformation rules are used for this purpose. Hence, an organization can be sure that its private workflow indeed satisfies the requirements specified in the contract, i.e., the public workflow.

The next result is based on the notion of local views of the domains. To introduce local views, we mention that each domain is aware of its private workflow and of the public parts of the other domains. The information which each domain has with respect to the overall workflow is called the local view of that domain. With respect to local views, the following interesting result can be obtained, which stresses the soundness of the P2P approach.

Result 3: The overall workflow is a subclass of the local views of all domains, which in turn are subclasses of the public workflow.

For the final two properties we have to introduce some notation. Since projection inher- itance is a partial ordering on the set of WF-nets, the Greatest Common Denominator (GCD) and the Least Common Multiple (LCM) can be defined. GCD and LCM are general concepts that apply to any ordering, and there are different applications of these

concepts in the context of WF-nets, as described in more detail in [6]. In essence, the GCD of a set of WF-nets is a WF-net that captures the part these nets have in common, i.e., the part where they agree on. The LCM captures all possible behaviors. Note that projection inheritance is a partial order but not a lattice. Therefore, suitable definitions of GCD and LCM are far from trivial but can be defined as is shown in [6].

V. Conclusion

Petri nets have been proposed for modeling workflow process definitions long before the term "workflow management" was coined and workflow management systems became readily available. Consider for example the work on Information Control Nets, a variant of the classical Petri nets, in the late seventies [13].

Only a few papers in the literature focus on the verification of workflow process definitions. In [16] some verification issues have been examined and the complexity of selected correctness issues has been identified, but no concrete verification proce- dures have been suggested. In [1] and [7] concrete verification procedures based on Petri nets have been proposed. This paper builds upon the work presented in [1] where the concept of a sound WF-net was introduced. The technique presented in [7] has been developed for checking the consistency of transactional workflows including temporal constraints. However, the technique is restricted to acyclic workflows and only gives necessary conditions (i.e., not sufficient conditions) for consistency. In [23] a reduc- tion technique has been proposed. This reduction technique uses a correctness criterion which corresponds to soundness and the class of workflow processes considered are in essence acyclic free-choice Petri nets.

This paper differs from the above approaches because the focus is on interorgani- zational workflows. Only a few papers explicitly focus on the problem of verifying the correctness of interorganizational workflows [3, 17]. In [3] the interaction between do- mains is specified in terms of message sequence charts and the actual overall workflow is checked with respect to these message sequence charts. A similar, but more formal and complete, approach is presented by Kindler, Martens, and Reisig in [17]. The au- thors give local criteria, using the concept of scenarios (similar to runs or basic message sequence charts), to guarantee the absence of certain anomalies at the global level. Both approaches [3, 17] are not constructive, i.e., they only specify criteria for various no- tions of correctness but do not provide concrete design rules such as the transformation rules.

In the last decade several researchers explored notions of behavioral inheritance (also named subtyping or substitutability), see [10] for an overview. Researchers in the domain of formal process models (e.g., Petri-nets and process algebras) have tackled

similar questions based on the explicit representation of a process by using various notions of (bi)simulation . The inheritance notion used in this paper is characterized by the fact that it is equipped with both inheritance-preserving transformation rules to construct subclasses [10] and transfer rules to migrate instances from a superclass to a subclass and vice versa [6]. These features are very relevant for a both constructive and robust approach towards interorganizational workflows.

We have developed a tool named Woflan (WOrkFLow ANalyzer [2, 28]). Woflan is an analysis tool which can be used to verify the correctness of a workflow process def- inition. The analysis tool uses state-of-the-art techniques to find potential errors in the definition of a workflow process. Woflan is designed as a workflow management system independent analysis tool. In principle it can interface with many workflow manage- ment systems. At the moment, Woflan can interface with the workflow management systems COSA (Software Ley [25]), METEOR (LSDIS [24]), Staffware (Staffware [26]), and with the business process re-engineering tool Protos (Pallas Athena [22]). Woflan has not been designed to analyze interorganizational workflows. However, it can be used to verify the soundness property used throughout this paper, and it can also check whether a given workflow is a subclass of another workflow.

In the future we hope to extend the P2P approach in several directions. First of all, we want to address local dynamic changes. The transfer rules presented in [6] can be used to migrate workflow instances from a superclass to a subclass and vice versa. Therefore, it is possible to change the workflows in each of the domains on the fly, i.e., it is possible to automatically transfer each case to the latest version of the process. Other aspects of future work include the reconfiguration of interorganizational work- flows (tasks move from one domain to another), the usage of alternative inheritance notions and the implementation of the concepts in prototypical workflow management systems, e.g., by using METEOR [5, 24] or InterProcs [18].

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