CoopFlow-R: a registry for collaborative workflows

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***Abstract*—The work we present here is in line with a novel approach, called CoopFlow, for workflow cooperation that consists of the four steps (1) workflow abstraction, (2) workflow advertisement, (3) workflow matching and interconnection, and (4) workflow cooperation. In this paper, we continue our contributions within the CoopFlow approach. The main objective is to develop new tools for workflow advertisement to realise the second step of CoopFlow. Therefore, we present a new ontology for semantic description of cooperative workflows. This ontology will be used as a semantic model for cooperative workflow advertisement. In addition, we define an architecture and design a knowledge base for cooperative worklfow advertisement and discovery inspired of the steps of the life cycle of Web services.**

I. Introduction

The last few years have witnessed a large-scale adoption of workflows in big number of enterprises thanks to their increasing benefits. A workflow is seen as an "automation of a business process, in whole or part, during which documents, information or tasks are passed from one participant to another, for action, according to a set of procedural rules" [1]. The automation of a part or the totality of enterprises' operations, requiring a considerable physical and mental effort in the past, allowed not only the reduction of the operational costs and the improvement of the productivity [2], but also the saving of time and the increase in the work quality of the enterprises [3]. However, few enterprises transform raw materials into end products or execute the complete life cycle of products or services. To improve their productivity, these enterprises have expressed a need for openness and cooperation with other enterprises. They need to interact with other enterprises of complementary competencies in order to cooperate on projects which are not within the range of only one enterprise (for example, merger of groups, extension of the enterprise structure, etc). With this intent, the enterprises offer more and more their services via the Web and tend to automate their interactions as well as their cooperation. Automatic cooperation of enterprises creates a new form of network of enterprises known as virtual enterprises [4].

Cooperation within virtual enterprises can be defined as short or long term. A short-term cooperation allows dynamic interconnection of a set of partners with complementary skills according to their needs. In this paper we focus on inter-enterprise workflow short-term cooperation. Setting up such a cooperation one must fulfill requirements like the preservation of *privacy*, *established workflow* and *established Workflow Management Systems* (WfMS).

To deal with these requirements, we have developed the CoopFlow approach that consists of the following steps: (1) workflow abstraction, (2) workflow advertisement, (3) workflow matching and interconnection, and (4) workflow cooperation. In the first step of the CoopFlow approach, each partner has to advertise, using a common registry, its offered activities within its workflows. In order to preserve the autonomy, one must reduce workflow inter-visibility to be as minimal as the cooperation needs. Therefore, we proposed an abstraction of a workflow's behavior. In the third step, one has to match advertised abstractions. Matching takes into account the description of the control flow, the data flow, and the business semantics of cooperative activities. Given two workflow abstractions, the matching result can be positive (i.e., abstractions match as long as some conditions hold) or negative (i.e., abstractions do not match). If the matching result is positive, the workflows are then interconnected. The fourth and last step consists of the inter-enterprise workflow cooperation (deployment, execution, management, etc.). We have already presented the basic ideas of the CoopFlow approach and compared it with the existing approaches for workflows cooperation [5]. We have used Petri nets and symbolic observation graphs as theoretical foundations for workflow abstraction (second and third steps) [6]. To realize the fouth step of the CoopFlow approach, we have developed a workflow cooperation platform which allows different WfMSs to interconnect their workflows for cooperation [7]. This platform enforces cooperation policies (representing matching conditions) identified during the workflow interconnection step.

In this paper, we continue our contributions within the CoopFlow approach. The main objective is to develop new tools for workflow advertisement to realise the second step of CoopFlow. Therefore, we present in this paper a new ontology for semantic description of workflows. This ontology will be used as a basis for workflow advertisement. All the published workflows are instances of that ontology. In addition, we define an architecture and present an implantation of a knowledge base for worklow advertisement and discovery.

The paper is organized as follows, In Section II we define an ontology for workflow collaborative workflows. Thereafter, sections III we introduce the process of publishing workflows described with semantic annotated XPDL and an example that illustrates this process. Section IV introduces the proposed knowledge base for the advertisement and the discovery of workflows. Section V concludes the paper with an outlook to future work.

II. Ontology for collaborative workflows

A. *Workflow description languages*

In order to describe inter-organizational workflows, huge efforts have been made and several languages have been proposed. In what follows we present a survey of the most important among proposals. Business Process Execution Language for Web Services (BPEL) [8], [9] is a language useful for specifying business processes behavior based on Web services and business interaction protocols. BPEL processes allow for the definition of abstract and executable processes. However, it does not support many concepts that are important for inter-organizational collaborative activities. In fact, it does not profit from the rich concepts of exiting workflow management systems as the notion of manual activities, applications and it does not address the integration, since it uses Web services exclusively which represent a limit to call other types of services (i.e. activities). The XML Process Definition Language (XPDL) [10] was proposed and standardized by the Workflow Management Coalition. Its most important entities are Workflow Process, Activity, Transition, Application, and Participant.

B. *XPDL meta-Model*

The XPDL Meta-Model [11] describes the top-level entities contained within a Process Definition, their relationships and attributes. It also defines various conventions for grouping process definitions into related process models and the use of common definition data across a number of different process definitions or models.

It is composed of six main entities which are Process, Activity, Transition, Participant, Application and Data Reporting. A workflow (process) has several attributes (date, author...), and contains several activities, transitions, which will allow participants to specify all the steps of the workflow and all participants, whether human actors or applications.

Activity performs a particular task in the workflow and is performed by a human actor or an application.It is linked to other activities through the transitions; the activities can access the data workflow.

This meta-model does not meet our needs for the discovery workflows for two reasons. First, it contains information that we deem unnecessary for collaborative partners such as the resources utilized and applications performing activities.On the other hand, some information necessary for cooperation are not described in this meta-model, such as the distinction between internal activities and cooperative activity, because each activity has a particular feature. However, only cooperative activities are directly involved in the cooperation. Thus, it is necessary to distinguish between cooperative activities (activities of workflows that communicate with other workflows) and internal operations.

Our objective is to extend this meta-model in order to define a new ontology for workflows necessary for collaborative work definition and used as a schema for work publication that will be used within coopflow approach. In the next action we present this ontology.

C. *Ontology for collaborative workflows*

Ontologies are used in various domains of computer science, such as knowledge engineering, information systems, multiagent systems or semantic Web. Ontologies have taken an important role because they allow for the sharing of knowledge and resolve semantic heterogeneity problems, which exist in distributed applications, useful in various domains. For instance, ontologies are used in information retrieval in order to support the indexing mechanism [12], in Semantic Web for the composition of web services [13], in the discovery and matching between web services [14] or in multi-agent systems to support automatic negotiation between agents [15].

In this paper, we show that ontologies also play an important role in inter-organizational collaborative workflows. We design a register containing ontology for workflows and a set of workflow instances advertized by the various partners, this register will represent a knowledge base for the storing and searching inter-organizational workflows. We propose an ontology based on the meta model of XPDL [10]. We modified this model to be consistent with an inter-organizational context.

The workflow class is composed of a set of alternative sequences scenarios and / or a set of activities. A sequence is composed of a set of activities (Figure 1) This property is transitive; the activities composing a sequence in a workflow are themselves activities of the workflow. the classes ”inter” and ”cooperative” allow to distinguish the cooperative activities of internal activities, in this way only the cooperative activity will be published in the directory, and this in order to preserve the private aspect of the organization is protected even under the cooperation.

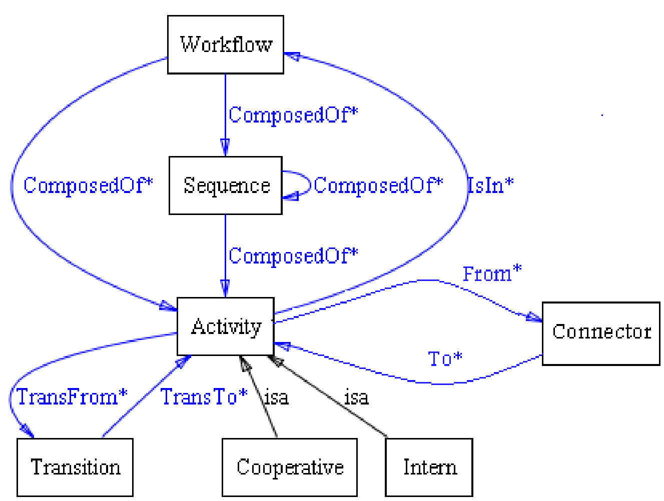

Fig. 1. Ontology for worflow (part 1)

We add the connector class as a way of linking activities together (Figure 2). Between tow activities there is a connector that can be of the following types [5]: AND-Split, AND-Join, XOR-Split or XOR-Join.

We also add a new type of activity (Figure 3) this type represent the events that can be the sending of messages (Evmessage class), the class message that present the message.

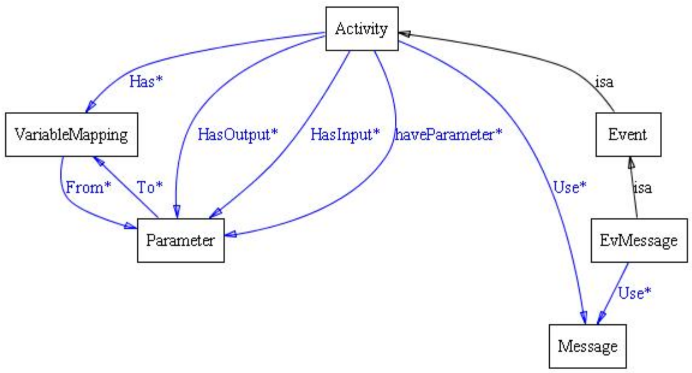

Fig. 3. Ontology for workflow (part3)

An activity can use a task (Figure 4). Hence we add a class EvTache. A task may be of two types: manual task or automatic task

III. Publication of annotated XPDL workflows

A. Semantic annotated XPDL

SAXPDL (Semantic Annotation for XPDL) is an approach for semantic annotation of XPDL descriptions. SAXPDL is based on XPDL and aims at providing a semantic description of collaborative workflows. SAXPDL also allows semantic annotation of XPDL using different types of ontologies. It is completely independent of the language of representation of the ontology. The annotation is done by adding two attributes in SAXPDL descriptions namely:

- The $modelReference$ attribute specifies the association between XPDL or an XML schema and a concept in a domain ontology that describe the business semantics of a specific domain. It is used to annotate an activity, or a given type defines as an XML schema.
- $schemaMapping$ attribute that allows to establish correspondence between a concept structure definition in an ontology and an XMLschema structure.

One advantage is that SAXPDL allows multiple annotations. This means that the same XPDL element XML schema type can be associated with multiple concepts. Thus $modelReference$ offers the possibility of referring several concepts.

B. Transformation from SAXPDL to RDF

XPDL annotation is done at the component activity by adding the attribute $modelreference$. This attribute will reference the ontology of collaborative workflows, we have presented in Section II-C, in order to distinguish the intern activities of cooperative activities. Further the components of XPDL involved in the cooperation of workflows exist in the ontology of collaborative worklfows.

To illustrate the SAXPDL to RDF transformation, let's consider an example used which is an adaptation of an example given in [16] which is inspired by electronic bookstores. There are four processes, modeling a customer, a bookstore, a publisher and a shipper. In our case we are interested to the process of publisher Figure 5. In this process we find cooperative activity (activities in white) and internal activities (activities in gray) Figure 5 presents the publishers workflow. When receiving an order from a bookstore, the publisher evaluates the order and either accepts (b_accept) or rejects (b_reject). After that, when the publisher is informed (p_inform) that a shipper was found, he sends the book to the shipper (send_book). Finally, after shipment or a request reject, the publisher can return to its initial state (p_init).

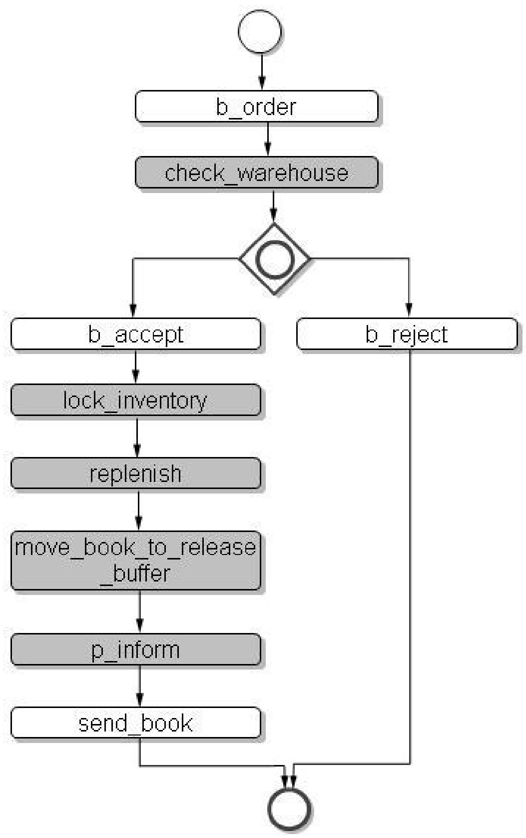

Fig. 5. Publisher Workflow in BPMN

Figure 6 shows the SAXPDL description of the activity check_warehouse. $modelreference$ attribute specifies the type of this activity as internal activity while referencing the concept cooperative of the ontology of collaborative workflow.

The transformation to RDF triples will extract from SAXPDL the information needed for cooperation between workflow (Figure 7), such as type of visibility of activities, connectors used (AND, OR), activities to choose from these connectors, various transitions possible starting from this activity, etc..

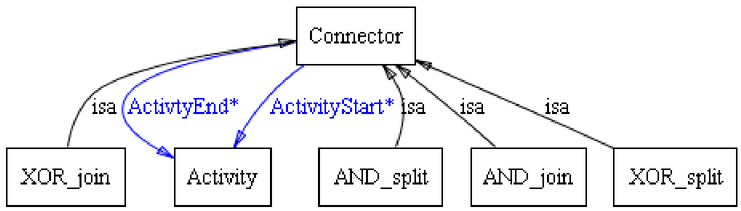

Fig. 2. Ontology for workflow (part2)

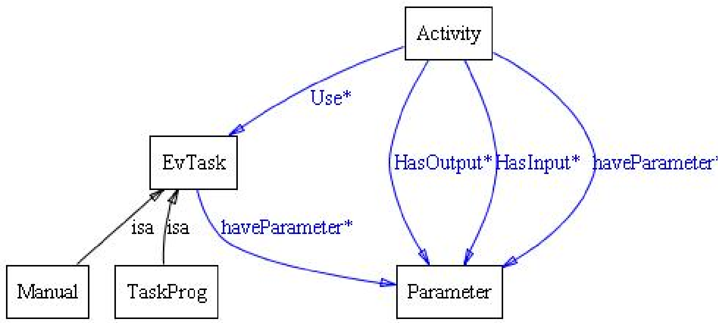

Fig. 4. Ontology for workflow (part4)

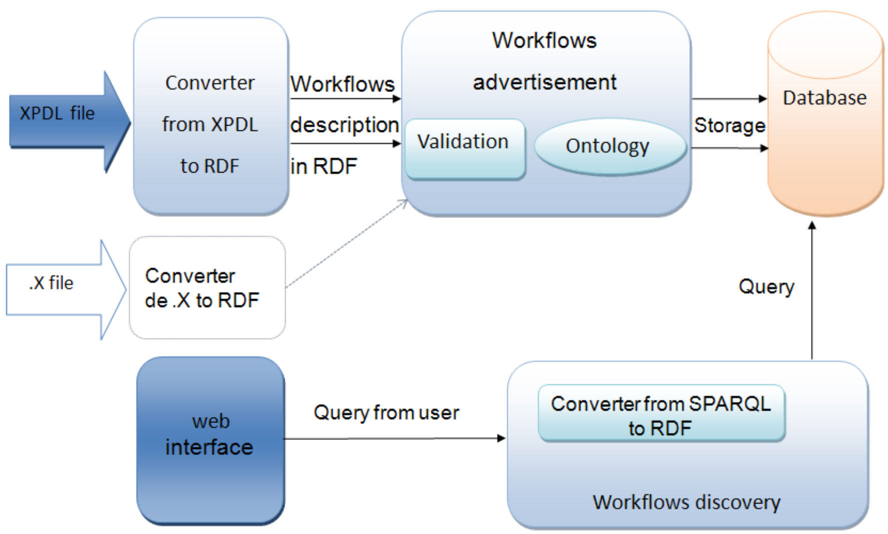

Fig. 8. Architecture of the knowledge base

IV. A Knowledge base for advertising and discovering collaborative workflows

Within a context of inter-organizational cooperation, respective entities, looking for collaboration, need to advertise their workflows; they also require the use of effective tools enabling them to discover the workflows of their potential partners. This requires that the workflows must be stored, at the same time the necessary mechanisms must be provided for searching within such directories and retrieving appropriate workflows. The architecture diagram for the essential components of such a system is given in Figure 8.

By instantiating the ontology defined, we have a set of workflows described and semantically consistent with that ontology. The storage of these instances with the ontology in a database, leads to a knowledge base for the advertisement and the discovery of workflows.

the Figure 8 shows the architecture of the knowledge base we have defined. This architecture is based on de the steps of the life cycle of web services (description, advertisement, discovery) which are applied with cooperative workflows. In the following we present the components of this architecture.

The knowledge base stores semantically described workflows in RDF. We aim at storing workflows described syntactically in the knowledge base. This requires the addition of transformation module from syntactic description languages to RDF. We propose a converter XPDL to RDF.

```
<xpdl:Activity Id="2" Name="check_warehouse"
saxpdl:modelReference="http://www.int-evry.fr/OntoWorkflow#intern>
   <xpdl:TransitionRestrictions>
       <xpdl:TransitionRestriction>
           <xpdl:Split Type="OR">
               <xpdl:TransitionRefs>
                   <xpdl:TransitionRef Id="tr_7"/>
                   <xpdl:TransitionRef Id="tr_8"/>
               </xpdl:TransitionRefs>
           </xpdl:Split>
       </xpdl:TransitionRestriction>
   </xpdl:TransitionRestrictions>
</xpdl:Activity>
```

Fig. 6. The SAXPDL description of the activity check_warehouse

```
 <rdf:Description rdf:about="check_warehouse">
    <rdf:type rdf:resource="OntoWorkflow:intern"/>
 </rdf:Description>
 <rdf:Description rdf:about="tr_8">
    <ontoWorkflow:TransTo >
        b_reject
    </ontoWorkflow:TransTo>
    <ontoWorkflow:TransFrom >
        check_warehouse
    </ontoWorkflow:TransFrom>
    <rdf:type rdf:resource="OntoWorkflow:Transition"/>
<rdf:Description rdf:about="tr_7">
    <ontoWorkflow:TransTo >
        b_accept
    </ontoWorkflow:TransTo>
    <ontoWorkflow:TransFrom >
        check_warehouse
    </ontoWorkflow:TransFrom>
    <rdf:type rdf:resource="OntoWorkflow:Transition"/>
 <rdf:Description rdf:about="check_warehouse_connector">
    <ontoWorkflow:endActivty >
        b_reject
    </ontoWorkflow:endActivty>
    <ontoWorkflow:endActivty >
        b_accept
    </ontoWorkflow:endActivty>
    <ontoWorkflow:startActivity >
        check_warehouse
    <ontoWorkflow:startActivity>
    <rdf:type rdf:resource="OntoWorkflow:OR_split"/>
  </rdf:Description>
```

Fig. 7. The activity check_warehouse in RDF

The trannsformation phase through a phase of analysis of XPDL files to extract the data using a parser automatically generated by the EMF framework. These data are then written in the format of an RDF description, respecting the ontology already proposed.

The workflow advertisement module receives as input workflows described in RDF. RDF (reference) is the W3C standard for encoding knowledge. It is a directed, labeled graph data format for representing information in the Web. Workflows must be audited in terms of syntax and view compliance with the ontology of workflow before being stored in the database. If this condition is checked the data will be extracted and stored in the form of RDF triples.

Search in the knowledge base is through a web interface. We are looking in a database that store RDF. And to do that we use to use the query language SPARQL. SPARQL is a query language for RDF. It sends queries to the RDF description to extract data. In our case we have a database that contains descriptions of a very large number of workflows. Otherwise, loading the whole database in memory will be very expensive. So use a converter from SPARQL queries to SQL.

V. Conclusion and future work

We have presented in this paper new mechanisms for advertisement and discovery of collaborative workflows. The developed registry is based on a new ontology for the description of collaborative workflows. We have in addition defined a new way for semantically describe workflows to be published.

Using an ontology will allow to enhance the search and analysis of published workflows. This will be based on new inferences rules that should be defined.

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