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AN ONTOLOGICAL APPROACH TO CROSS-ENTERPRISE COLLABORATION

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Abstract. Cross-enterprise collaboration is one of the challenges on the business-to-business integration (B2Bi) research nowadays. With the support of Semantic Web technologies, the gap between business and IT communities has been reduced in order to tackle the mentioned challenge. Semantic Web-based approaches for BPM have been a promising solution taking advantages of Semantic Web technologies such as ontologies, semantic web services. In this paper, we propose a new approach called Ontological Hierarchical Task Network based on HTN Planning and Web Service Modelling Ontology for forming collaborative business processes for the cross-enterprise collaboration.

Keywords: Business Process Management, Semantic BPM, B2B integration, Cross-enterprise collaboration, Ontology, Semantic Web, Web services.

1 Introduction

Cross-enterprise collaboration or so-called business-to-business integration (B2Bi) in some contexts is one of the priority strategies of the e-business research to improve enterprise excellences [2]. It requires exchange and share in business processes between business partners such as customers, suppliers, distributors. One of the most important challenges in integrating or collaborating between companies in the e-business environment is how to collaborate business processes automatically, accurately, flexibly and effectively. The success of the integration between businesses requires the forming and managing of collaborative business processes to achieve business goals. Therefore, scientists and the business managers are especially interested in Business Process Management (BPM).

Semantic business process management (SBPM) emerges as a promising solution to the gap between businesses and information technology field with the approach to perform business actions which are supported by the information technology with perspective of business process rather than technical perspective. Managing business processes shall include methods, techniques and tools to support in designing and constructing rules as well as managing and analysing businesses operations. However, handling the BPM automatically in integrating business processes among enterprises is still low due to the interaction between the business process collaboration's semantics. To solve this problem, many researchers have recently proposed solutions in apply article intelligences in managing the processes of the collaboration between enterprises discussed in [2].

This paper proposes an approach called Ontological HTN (O-HTN) based on HTN Planning and Web Service Modeling Ontology (WSMO) for forming collaborative business processes dynamically for the cross-enterprise collaboration.

With these motivations, the paper is structured as follows: BizKB Framework [1] is briefly described in the following section. Section 3 introduces a background method of HTN planning supported by WSMO; the business collaboration phases are identified in Section 4. In Section 5, we apply WSMO-based HTN planning into the forming of a collaborative business process with an automatic decomposition solution of tasks attached by web services. The conclusion is made with a sketch of future work.

2 BizKB Framework Overview

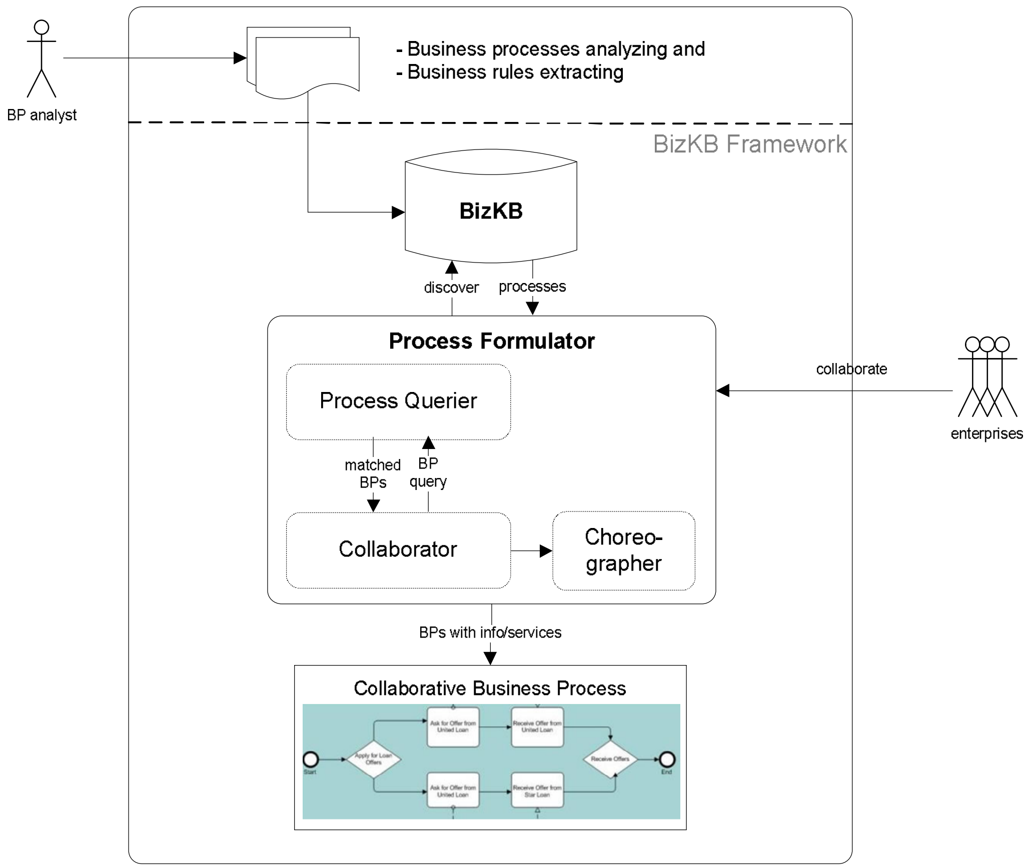

Fig.1. *BizKB conceptual architecture: The framework architecture contains three main parts, the BizKB - BP knowledge base; the Process Formulator component and the Pre-processing stage for business processes analysing.*

BizKBis the heart of the framework depicted in Fig.1 which contains the knowledge of the businesses in form of BPMO-based collaborative business processes with different levels of the abstraction [1].

In order to formulate these BPMO-based processes to store in the BizKB, the BP analysts are required as an important human factor of the system. Based on the analysis on the BPs, the found CBP patterns, level of the abstraction and associate business rules are also extracted and realised.

As depicted in Fig.1, extracted BP artifacts are modelled using BPMO according to specific domains and kept in the persistence of BizKB. This repository is considered the process feeder for the later stage of the CBP pattern discovery and CBPs formulation.

Establishing a complete reference collection as a knowledge base beforehand is very unlikely due to the fact that the number of standards, their evolution speed and the cost a complete analysis would create if it were at all possible. Thus the knowledge base has to be flexible, in the sense that its evolutionary growth is not only possible but also a substantial building criterion. Clearly, an approach that does not start with a fully developed knowledge base shows weaknesses in the starting phase. Due to its initially small knowledge base, references supplied by the system might be erroneous and incomplete. But with the growth of the knowledge base, quality improvement occurs quickly [5].

3 HTN Background

The nature of dynamic business process formulation greatly resembles HTN planning from the field of artificial intelligence (AI) planning [13].

In HTN planning, a goal to a problem is realised via a plan of simple steps generated by the dynamic decomposition of a hierarchical network of compound tasks into sub-tasks in a domain. The lowest level task is a primitive task. To decompose and chain task, the HTN planning algorithm matches the constraints with the criteria of the appropriate method.

For illustration, consider two methods of travel planning for the compound task *travel(x,y)* (Fig.2). The choice whether to travel by taxi or by air depends on the distance between *x* and *y*. If the distance (i.e. the constraint) is large, *travel(x,y)* will be decomposed into sub-tasks via the method “travel by air”; if the distance is small, the *travel(x,y)* task will be decomposed into sub-tasks “travel by taxi”. All tasks are represented in a network of parent-child relationships.

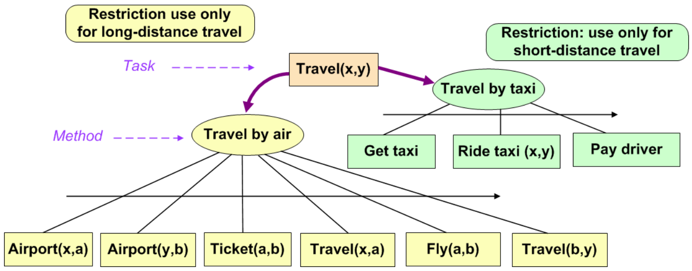

Fig.2. *A travel problem represented as a HTN.*

After the HTN planning algorithm traverses through the HTN recursively decomposing tasks according to the matching methods, a result (or plan) is generated for "travelling from University of Maryland (UMD) to Massachusetts Institute of Technology (MIT)" (Fig.3). Thus, it can be seen that HTN planning decomposes and sequences tasks (e.g. *travel (UMD,MIT)*).

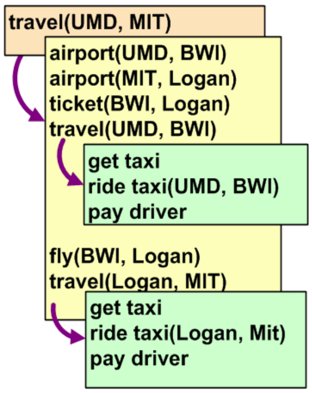

Fig.3. *A plan generated by the HTN algorithm decomposing travel(x,y)*

3.1 HTN and CSP Combination

Users require various types of information and constraints, and automatic service composition requires several rounds of planning because of trial and error, or for flexibly coping with dynamic exceptions. Web service composition by a planner alone has limitations that apply to a more general and intelligent composition of services [7]. First, it is inefficient for autonomously to find a solution in planning because it does not provide a suitable basis for dealing with the evaluation of planning results with constraints. Second, although it works well for task ordering in planning, it is not good in dealing with a user's various requests for information. As real-life problems involve planning, scheduling, and executing, web service composition in real life requires not only planning information, but also additional information requests with constraints, which can be met by scheduling tasks jointly. A constraint satisfaction problem (CSP) formulation provides a strong basis for scheduling in a variety of real-life problems on the web. Third, it is weak regarding maintenance because of the frequent invocation of services on the web. Although an Hierarchical Task Network (HTN) planner can invoke outside web services during planning; this causes severe restrictions and inefficiency because service invocations in the planner are merged with the planning strategy [7, 13].

Combining of HTN planning and CSP for a basic problem-solving engine provides a solution for automating the Web Services composition that tackles the mentioned problems. HTN and CSP combination is better than an HTN alone when problems involve scheduling plus other parameters.

3.2 Web Service Modeling Ontology (WSMO)

WSMO defines a model to describe semantic web services based on the conceptual design set up in the Web Service Modelling Framework WSMF. WSMO identifies four top-level elements as the main concepts:

- **Ontologies**: provide the (domain specific) terminologies used and are the key element for the success of Semantic Web Services. Furthermore, they use formal semantics to connect machine and human terminologies.
- **Web services**: are computational entities that provide some value in a certain domain. The WSMO Web service element comprises two components namely capability and interface which are described.
- **Goals**: describe aspects related to user desires with respect to the requested functionality, i.e. they specify the objectives of a client when consulting a web service. Thus they are an individual top-level entity in WSMO.
- **Mediators**: describe elements that handle interoperability problems between different elements, for example two different ontologies or services. Mediators can be used for resolving incompatibilities emerging between different terminologies (data level), communicating between services (protocol level), and combining Web services and goals (process level).

Besides these main elements, non-functional properties such as accuracy, performance, scalability, and reliability are used in the definition of WSMO elements that can be used by all its modelling elements. Furthermore, there is a formal language to describe ontologies and Semantic Web services called WSML (Web Service Modelling Language) which contain all aspects of Web service descriptions identified by WSMO. In addition, WSMX (Web Service Modelling Execution environment) is the reference implementation of WSMO, which is an execution environment for business application integration.

Used as the modelling foundation, WSMO is a flexible ontology language and the execution based-on Web service as well.

4 Cross-enterprise Collaboration Phases

The Cross-enterprise collaborations generically sequentially consist of some or all of the following three phases:

- **Setup**: Based on the preconditions, the list of potential partners will be gathered. This phase is skipped when enterprises are collaborating with qualified (existing) buyers or suppliers.
- **Action**: Enterprise will choose partners to participate in the collaboration. However, before confirming the starting point for collaboration, two collaborators must have the agreeable contract terms and the penalty for every business that does not comply with the terms offered. The results of this phase are formalizing and establishing new partners involved in the collaboration between enterprises.
- **Wrap-up**: The collaborators have to finish the terms of the contract. The creation, deliverance and payment of the product are the main activities in this stage including logistics.

BizKB Ontology for Collaborative Business Processes

From the three collaboration phases, a comprehensive list of CBP tasks can be modelled in BizKB Ontology (BO). First, the sequences and hierarchies of granular tasks were synthesised into the three collaboration phases.

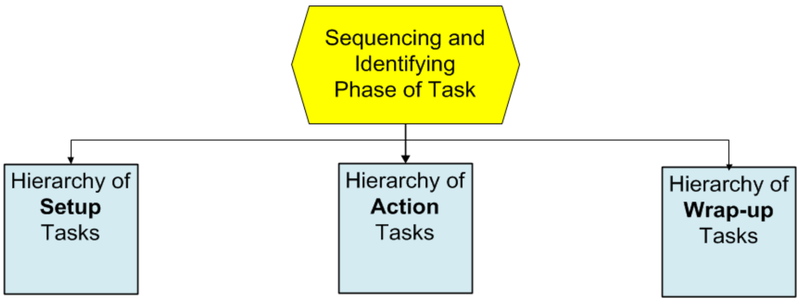

Fig.4. *Synthesising B2B collaboration task lists from B2B standards into three hierarchies of tasks for each collaboration phase*

4.1 CBP Tasks and Methods

Tasks. Business processes are a set of ordered compound or primitive tasks. In BO, both compound tasks and primitive tasks are modelled as tasks. The two tasks may be differentiated by their "*hasMethod*" property. Compound tasks have one or more "*hasMethod*" properties since they can be decomposed; not primitive tasks. Fig.5 shows the "Buy" compound task and its properties (i.e. *hasMethod, hasActor, hasParent*) [26, 27].

```
relationInstance hasMethod(_"http://www.owl-
ontologies.com/Ontology1231158528.owl#B-Buy", _"http://www.owl-
ontologies.com/Ontology1231158528.owl#MethodBuy.A")
relationInstance hasActor(_"http://www.owl-
ontologies.com/Ontology1231158528.owl#B-Buy", BuyerActor)

relationInstance hasParent(_"http://www.owl-
ontologies.com/Ontology1231158528.owl#B-Buy", B2BCollaboration)
```

Fig.5. Simple task description in BO

Methods. A single compound task may have more than one method to decompose into primitive tasks. Each method has a prescription for how to decompose some tasks into a set of subtasks with different restrictions. This must be satisfied enabling a method to be applicable with various constraints of the subtask and relationship among them [26, 27].

```
relationInstance hasSubtasks(_"http://www.owl-
ontologies.com/Ontology1231158528.owl#MethodBuy.A", _"http://www.owl-
ontologies.com/Ontology1231158528.owl#S-Setup")

relationInstance hasSubtasks(_"http://www.owl-
ontologies.com/Ontology1231158528.owl#MethodBuy.A", _"http://www.owl-
ontologies.com/Ontology1231158528.owl#A-Action")
```

Fig. 6. *A local method definition with embedded criteria and control flows of subtasks*

5 Cross-enterprise Collaboration with O-HTN

5.1 Motivation

We propose an approach, called O-HTN, for the dynamic collaborative B2B using Web service modelling ontology (WSMO) as the modelling foundation. WSMO is a flexible ontology language with dynamic reasoning features; it supports execution based-on Web services as well. BO describes the hierarchical relationships between compound and primitive B2B collaboration tasks, methods for task decompositions and relevant planning criteria (e.g. cost, quantity ordered, type of collaboration, etc) embedded in the methods. Different criteria input by the user result in different permutations of sub-tasks.

There are three main reasons for the creation of O-HTN [9, 10]:

- **Dynamic CBP task decomposition**

In decomposing tasks to lower levels, the sequence of tasks must be kept. This presumes the existence of an ontology to describe the relationships among business process tasks between two enterprises.

- **Facilitate dynamic task ordering during decomposition**

In dynamically sequencing business process tasks, the sequence of the tasks must be correct.

- **The functional perspective over-shadowing the process perspective**

Current B2B business process standards such as RosettaNet, ebXML and OAGIS classify the common tasks into scenarios and departments.

5.2 Process Formulator

The interactive part of the BizKB framework (Fig.1.) is the *Process Formulator* component which consists of two main sub-parts – *Process Querier* and the

Collaborator. These parts are interacted by the demanding enterprise to find out the appropriate CBP patterns to form a collaborative business process with the help of the third subpart - *Choreographer*.

The Process Querier helps find the appropriate process patterns at a certain level of the abstraction. Due to the enterprise's discovery into the BizKB, the detailed level will be matched with the need. For example, in the OM process presented in **Error! Reference source not found.**, one participant wants to identify the process of "Buy" products, but the participant cannot clearly identify parts of the process and related information, the Process Querier can help identify the basic patterns, sample processes, and even the generalization levels of the needed process. After matched processes have returned, the Choreographer will coordinate to finalize the output collaborative business process to fulfil the B2B integration demand. Here, we use O-HTN Algorithm as described in following sub-section for this phase.

The new formed CBP is attached with WSMO services profiles for specific Semantic Web Services. This process is serialized using WSMO standard which conforms the unification of the framework's BPMO standard (which is based on WSMO) and benefits from Semantic Web Services advantages.

5.3 The O-HTN Algorithm

Start with initial the high-level task (not goals) and algorithm which are decomposed into subtasks, until primitive tasks are found and can be performed directly.

```
Input: Task to be decomposed
Output: Decompose Tree, primitive actions
Procedure HTNPlanning()
      Create empty tree
      Create three thread
      Each thread
            Decompose(nameTask, listMethod, listTask, criteria)
  Return tree
End HTNPlanning
Procedure Decompose (nameTask, listMethod, listTask, criteria)
      Count number of methods in nameTask
      If there are no methods
         Mark task nameTask as primitive task for service execution
         Extract actor of task nameTask
         Write nameTask in tree
      Else
         While there are methods for namTask not processed
            Select the next method nameMethod of nameTask
```

```
            Check supervised criteria of nameMethod with user criteria
            If supervised criteria matches user criteria
               Check number of control flows in nameMethod
               While there are still control flows in nameMethod
                        Read the outermost control flow cf
                        Write the start of the cf in tree
                        For each subtask st in cf
                              Decompose(st,"","",criteria)
                        Write the end of cf in tree
                  End While
            End If
         End While
      End If
End Decompose
```

5.4 Process Formulator Components

The O-HTN based Architecture for the Process Formulator is described in Fig.7. Users' request is presented in WSMO ontologies and a WSMO Goal.

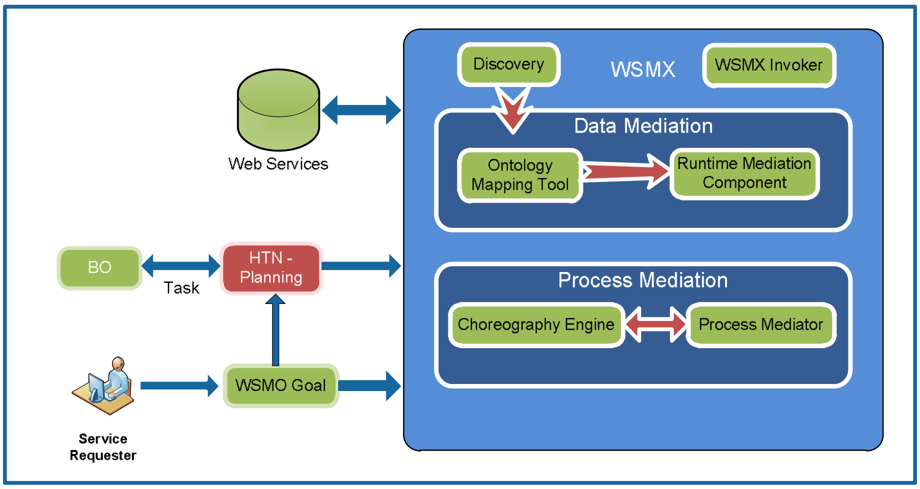

Fig.7. *The O-HTN-based Process Formulator architecture*

In the next step, WSMX uses the discovery component to find web services profiles which have semantic descriptions registered through their capabilities and interfaces. A set of properties strictly belonging to a goal are defined as non-functional properties of a WSMO goal. A goal may be defined by reusing one or several already-existing goals by means of goal mediators.

During the discovery process the users' Goal and the web services description may use different ontologies. If this occurs *Data Mediation* is needed to resolve heterogeneity issues. Once these mappings are registered with WSMX, the runtime data

Mediation component can perform automatic mediation between the two ontologies. Once this mediation occurred and a given service that can fulfil the user's goal is chosen, WSMX can begin the process of invoking the service.

Every Semantic Web service has a specific choreography that describes the way in which the user should interact with it. This choreography semantically describes the control and data flow of messages the Web Service can exchange. In cases where the choreography of the user and the choreography of the Web Service do not match, process mediation is required. The process Mediation component is built on WSMX. This component is responsible for resolving mismatches between the choreographies of the user and web service.

If there are no single web services that satisfy the request then the request will be offered to the planner. The planner then tries to combine existing Semantic Web services and generate the process model. In the proposed framework, the process generator is based on HTN-planning. The process generator to tackle the problems of heterogeneous ontologies and choreography uses discovery component of WSMX. Therefore, via this component, the process generator will be able to discover the appropriate Semantic Web services for dynamic cross-enterprise collaboration. Finally the process model will be offered to the WSMX for execution. The stages for execution of Web services as a process model are like single web services.

6 Conclusion and Future work

In this paper we have proposed an ontology-based approach using Ontological-HTN and WSMO for forming collaborative business processes in the dynamic cross-enterprise collaboration. The approach is motivated by the semantic approach in efforts of bridging business perspective and IT world, and provides an architecture that supports the dynamic semantics-based collaborative B2B in the new e-business environment.

We have successfully implemented O-HTN Algorithm with some improvements in comparison to [9]. For the next steps, we plan to do some experiments with mapping attached web services into the execution level with practical examples.

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