2012 26th International Conference on Advanced Information Networking and Applications Workshops

An Ontological Approach for Dynamic Cross-Enterprise Collaboration

Vu Minh Hoang
Vietnam Posts and Telecommunications
Thua Thien Hue Branch
Hue City, Vietnam
e-mail: minhvuhue@gmail.com

Hanh Huu Hoang
Hue University
3 Le Loi Street
Hue City, Vietnam
e-mail: hhhanh@hueuni.edu.vn

***Abstract*— Cross-enterprise collaboration is one of 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 with 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 (O-HTN) based on HTN Planning and Web Service Modeling Ontology (WSMO) for forming collaborative business processes dynamically for the cross-enterprise collaboration.**

Keywords-BPM, Semantic BPM, Ontology, Semantic Web, virtual enterprise, Web Services.

I. Introduction

Cross-enterprise collaboration or so-called business-to-business integration (B2Bi) in some contexts is one of priority strategies of the e-business research to improve enterprise excellences [2]. It requires to exchange and share 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 forming and managing collaborative business processes to achieve business goals. Therefore, Business Process Management (BPM) is interested by scientists and the business managers.

Semantic business process management (SBPM) emerges as a promising solution to bridge 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 [5]. Managing businesses processes shall include methods, techniques and tools to support in designing and constructing rules, managing and analysing businesses operations. However, handling of 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 [3].

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 [3] is briefly described in the following section. Section 3 introduces background method of HTN planning supported by WSMO; and we identify phases for the business collaboration in Section 4. In Section 5, we apply WSMO-based HTN planning into forming collaborative business process with an automatic decomposition solution of tasks attached by web services. And the paper is concluded with a sketch of future work.

II. BizKB Framework

The ultimate goal of our BizKB approach is to build a platform for BP discovery and integration based-on Semantic Web technologies, which supports the process of cross-enterprise collaboration. Many initiatives restrict the range of standards they deal with for political, practical or technical reasons. For companies exposed to different national, industry or enterprise-specific standards – as is practically every business if all of its communications are addressed – this approach is clearly of low practical value. A universally usable methodology will avoid the predefinition of a range of manageable standards [6].

A. BizKB

As depicted in Figure 1, the overall conceptual architecture of the BizKB framework consists of two main parts: the BizKB and the Process Formulator. The output of BizKB framework is CBP with Semantic Web Services profiles attached to the CBP. BizKB is the heart of the BizKB Framework which contains the knowledge of the businesses in the form of Business Process Modeling Ontology (BPMO)-based collaborative business processes with different levels of the abstraction [3].

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 described in Figure 1, extracted artifacts of BPs are modelled using BPMO according to specific domains and kept in the BizKB. This repository is considered as the

978-0-7695-4652-0/12 $26.00 © 2012 IEEE
DOI 10.1109/WAINA.2012.128

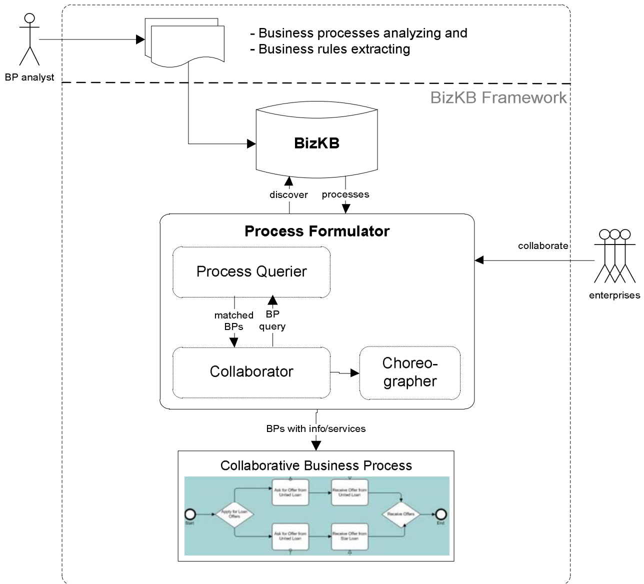

Figure 1. BizKB conceptual architecture.

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 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 [6].

B. *Collaborative Business Process Pattern*

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

Setup: Buyers and sellers source for potential suppliers and customers respectively. This phase is skipped when enterprises are collaborating with qualified (existing) buyers or suppliers.

Action: The buyer or seller contacts the potential supplier/customer after "short-listing" potential candidates, based on predetermined criteria. After mutually agreeable terms and conditions are established and two (or more) collaborators agree on the contract terms, declare constraints for non-compliance, and confirm the start of the collaboration. It is also at this stage that a new supplier/ buyer becomes and established supplier/buyer to the enterprise.

Wrap-up: Two collaborating companies seek to fulfil the terms of the contract. The creation and deliverance of the product or service and subsequent payment usually take place in this phase. After-sales services such as reverse logistics also take place here.

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.

C. *BizKB Ontology for CBP*

From above three B2B 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 B2B collaboration phases.

BO is a set of ordered compound or primitive task and methods. Compound tasks have one more "*hasMethod*" property since they can be decomposed into primitive tasks that can be performed directly using O-HTN. Each method has a prescription for how to decompose some task into a set of subtasks, with different restrictions that must be satisfied in order for method to be applicable and also various constraints of the subtask and relationship among them.

III. HTN FOR TASK DECOMPOSITION

A. *HTN in Brief*

The nature of dynamic business process formulation greatly resembles HTN planning from the field of artificial intelligence (AI) planning [8].

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.

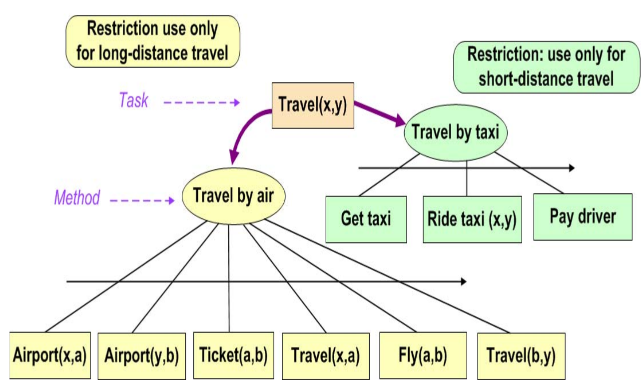

Figure 2. A travel problem represented as a HTN

For illustration, consider two methods of travel planning for the compound task *travel(x,y)* (Figure 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 short, 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.

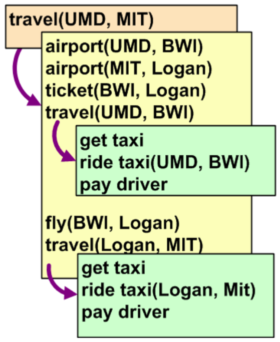

Figure 3. A plan generated by the HTN algorithm

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)" (Figure 3). Thus, it can be seen that HTN planning decomposes and sequences tasks (e.g. *travel (UMD, MIT)*).

B. *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 [1]. First, it is inefficient for autonomously finding 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 for 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 [4, 7]. Combination of architecture planning and CSP help solve problems above. HTN and CSP combination is better than an HTN alone when problems involve scheduling plus other parameters.

We illustrate an example as follows [2]: A user, who lives in Aizu City in Japan, wants to go to South Carolina in the U.S.A for a vacation. If the user wants to go by train to the Narita international airport near Tokyo, there are three stages: by local train from Aizu to Koriyama to Tokyo, and by JR Express from Tokyo to Narita, from where a series of flights completes the journey to South Carolina.

Therefore, the user calls an agent to construct an itinerary to South Carolina. For this, the user provides basic information such as the departure date and location, and the arrival date and location. Suppose that the user wants to depart at 2:00 PM from Aizu because of a special business meeting. Therefore, he adds this new constraint to the basic input information.

Now, when the travel planner solves this problem, the solution may produce other internal spontaneous constraints temporarily. For instance, the planner should reserve a one-night stay in a hotel near Narita and a flight the next day when there is no flight to South Carolina at Narita on that day. On another occasion, the user may specify the arrival time in South Caroline as a constraint, which the planner will also need to accommodate.

IV. CROSS-ENTERPRISE COLLABORATION WITH O-HTN

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

Main reasons for the creation of O-HTN: O-HTN is feasible for dynamically creating CBP task sequences ideal for direct Web service execution.

A. *Process Formulator*

The interactive part of the BizKB framework (Figure 2) is the *Process Formulator* component which consists of two main subparts – *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 to find the appropriate process patterns at a certain abstraction level. Due to the enterprise's discovery into the BizKB, the detailed level will be matched to the need. For example, in the Order Management process, one participant wants to identify the process of "Buy" products, however the participant cannot clearly identify parts of the process and related information, the Process Querier can help to identify the basic patterns, sample processes, and even the generalization levels of the needed process. After matched processes 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.

1) O-HTN Algorithm

Start with an initial high-level task and algorithm decomposes the task into subtasks, until primitive tasks are found that can be performed directly with web services. The O-HTN algorithm originates from [4, 8] and we have done improvements shown as follows.

Input: *Task to be decomposed*
Output: *Decomposed Tree, primitive actions*

```
Procedure HTNPlanning()
Create empty tree
Create three thread /*decompose for three
hierarchies of tasks for each collaboration
phase*/
Each thread
  Decompose (nameTask, listMethod, listTask,
criteria)/*save Task when decompose in BO*/
  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
/* subtasks will be chained in control flows */
            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
```

2) Process Formulator Workflow

The O-HTN based Architecture for the Process Formulator is described in Figure 4. User' request is presented in WSMO ontologies and a WSMO Goal.

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.

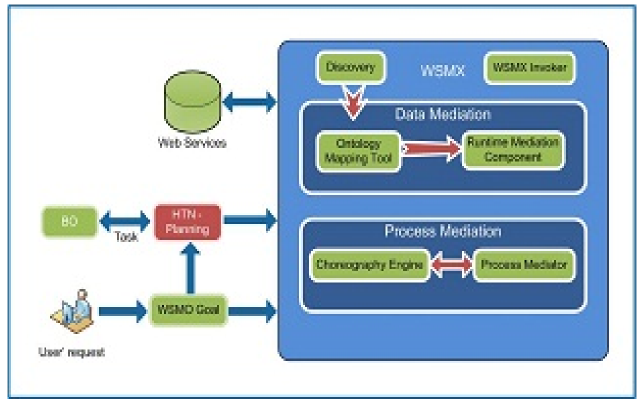

Figure 4. The O-HTN-based Process Formulator architecture

Every Semantic Web service has a specific choreography that describes the way in which the user should interact with it. This choreography describes semantically 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 WSMX is responsible for resolving mismatches between the choreographies of the user and web service.

If there is no single web service that satisfies 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. Thus 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 its execution. The stages for execution of Web services as a process model are like as single web services.

3) Service Caching

We optimize the Web service discovery at runtime. Therefore, we perform the Web services discovery through the way of manipulating the relations between ontologies and based on the functional, non-functional properties, and constraints specified by the user as a goal at process run-time. An example of this process can be seen in Figure 5.

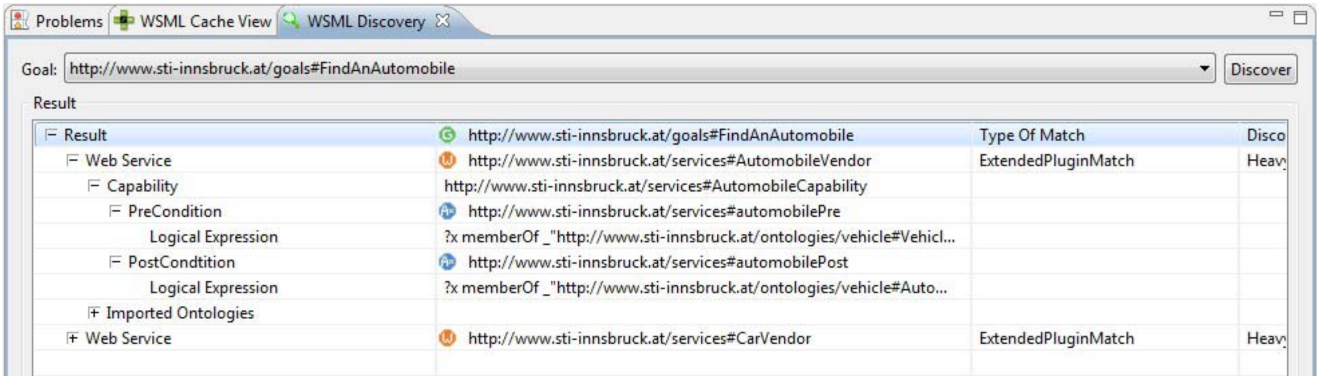

Figure 5. Discovery process using WSMT tool

Primitive tasks in BO are used for discovering appropriate Web services, and those services are matched to the goal. We do address that process using Web Service Modeling Toolkit (WSMT) and each primitive task can invoke an appropriate web service. This is saved in storage that captures relevant knowledge of design time. The discovery results will be effectively used for enhancing the computational performance of runtime discovery operations. This approach adopts the concept of caching to the context of Web service discovery.

B. O-HTN advantages

- *Flexible collaboration at anywhere and anytime:* Customers can access the system anywhere such as at office, at home, and at public Internet site, anytime.
- *Cost savings:* Customers can save much money, mainly for collaboration between businesses. Therefore they can find potential partners anywhere without costly travel.
- *Flexibility:* Customers can choose a partner that is most suitable to them with many diverse services.
- *Optimization:* This framework can quickly assess customer need and then provide the collaborative models to meet the needs of customers.
- *Diversity:* Many basic and specialized collaborative models can use the application O-HTN of collaboration between enterprises.

With the benefits listed above, the collaborative application O-HTN among businesses opens new opportunities in e-commerce environment. Customers may choose the appropriate partners. They also have many opportunities to contact with many new partners, save a lot of business resources, and access quality businesses.

C. BizKB GUI

The BizKB GUI is built on Java Server Pages. Based on the user inputs, the Servlet invokes the algorithm recursively comparing them with the relevant criteria of methods of tasks found in BO, and the correct control flow of all tasks required to fulfill the input goals and criteria (Figure 2) is generated for required business process tasks in a hierarchical tree diagram (Figure 2).

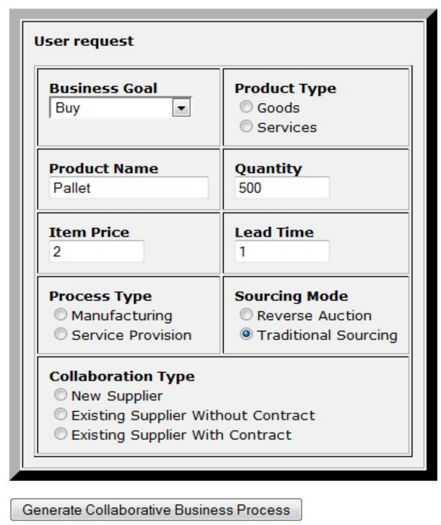

Figure 6. Input page

```
S-Setup
   Sequence
   D1-SearchForPotentialSuppliers
      Flow
      D1.1-ViaReferrals
         Sequence
         D1.1.1-ContactReferrals
         D1.1.2-ObtainPerspectivePartnersContactInfo
         SequenceEnd
      D1.2-SearchBizDirectory
      D1.3-SearchInternet
      D1.4-VisitingTradeShows
      D1.5-ProductCatalogInfo
         Sequence
         D1.5.2-ReceiveProductCatalogInfo
         SequenceEnd
      FlowEnd
   D4-PotentialPartnerListFound
   SequenceEnd
```

Figure 7. Task tree is generate of algorithm

V. Conclusion

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 web approach in efforts of bridging business perspective and IT world together, and provides an architecture that supports the dynamic semantics-based collaborative business process management in a new e-business environment.

We have successful implemented O-HTN Algorithm with some improvements in compared to [4, 8]. For the future work, we plan to improve the algorithm and the web services discovery with new ontology mapping approaches and do some experiments with mapping of attached web services into the execution level with practical examples.

Acknowledgment

This work was generously sponsored by Vietnam's National Foundation for Science and Technology Development (NAFOSTED) in the framework of the Grant 102.02-2010.14.

References

[1] S. Damodaran, "B2B integration over the Internet with XML: RosettaNet successes and challenges," *Proceedings of the 13th international World Wide Web conference on Alternate track papers & posters* 2004.

[2] P.-C. T. T. Hanh Huu Hoang, Thanh Manh Le, "State of the Art of Semantic Business Process Management: an Investigation on Appoaches for Business-to-Business Integration," *Springer Berlin / Heidelberg, City,* 2010.

[3] T. M. L. Hanh Huu Hoang, "Bizkb: a conceptual framework for dynamic cross-enterprise collaboration," *Springer Berlin / Heidelberg, City,* 2009.

[4] D. M. Incheon Paik, Michael N. Huhns, "A framework for intelligent web services: Combined htn and csp approach," *IEEE Computer Society Washington, DC, USA,* 2006.

[5] J. J. Jung, "Semantic Business Process Integration Based on Ontology Alignment," *Expert Systems with Applications: An International Journal,* 2009.

[6] C. Pedrinaci, Domingue, J, Brelage, C, van Lessen, T, Karastoyanova, D, Leymann, F, "Semantic Business Process Management: Scaling Up the Management of Business Processes," *icsc,* 2008.

[7] A. J. Ryan K. L. Ko, S. G. Lee Genesis, "Dynamic collaborative business process formulation based on business goals and criteria," *Congress on Services - I,* 2009.

[8] S. G. L. Ryan K.L.Ko, E.W.Lee, Andre Jusuf "Dynamic collaborative business process formulation via ontologised Hierarchical task network (htn) planning," *IEEE International Conference on Web Services,* 2009.