A Ontological Collaborative Framework for Business Process Integration

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Abstract— **With the development of web services and its extension with Semantic Web augmented—Semantic Web Services (SWS), the modern approaches for business-to-business integration (B2Bi) focus on their business process integration between enterprises. Cross-enterprise collaboration is one of challenges on the 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 challenge. Semantic Web-based approaches for BPM have been foreseen as a promising solution with taking advantages of Semantic Web technologies such as ontologies, SWS. Taking into account the challenge of dynamically forming collaborative business processes with attached services into the execution, in this paper, based on our previous work, we propose a semantic framework for forming a dynamic collaboration of business processes within our BizKB systems for across-enterprise collaboration. We focus on a dynamic service discovery based on the consensus methodology.**

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

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 [1]. It requires exchanging and share business processes between business partners such as customers, suppliers, and 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 [2]. 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 artificial intelligence in managing the processes of the collaboration between enterprises discussed in [3].

In our previous work, we have proposed 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. The research results the CBP formed with help of O-HTN and attached services profiles. The next part is to discover the appropriate web services to match with service profiles kept in ontologies. In this paper, we introduce an approach using consensus methodology which is originated from solving conflict of data versions [4].

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 ARCHTECTURE

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 [5].

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

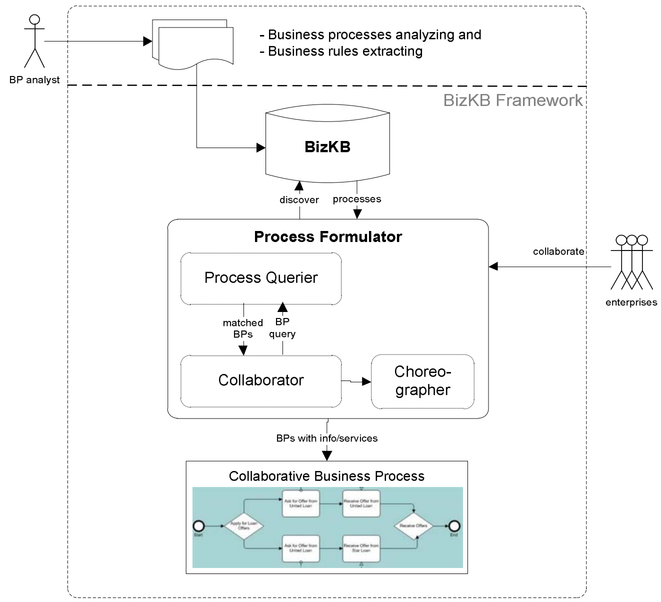

Figure 1. BizKB conceptual architecture.

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 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 [5].

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. O-HTN-AUGMENTED BIZKB FRAMEWORK

We have proposed O-HTN for dynamic collaborative B2B using Web Service Modeling Ontology (WSMO) as the modelling foundation [6], WSMO is a flexible ontology language with dynamic reasoning features, supports execution based-on Web services as well. BO describes 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.

A. Process Formulator

The interactive part of the BizKB framework ([3]) 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) Process Formulator Workflow

The O-HTN based Architecture for the Process Formulator is described in Figure 2. 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 is 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 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.

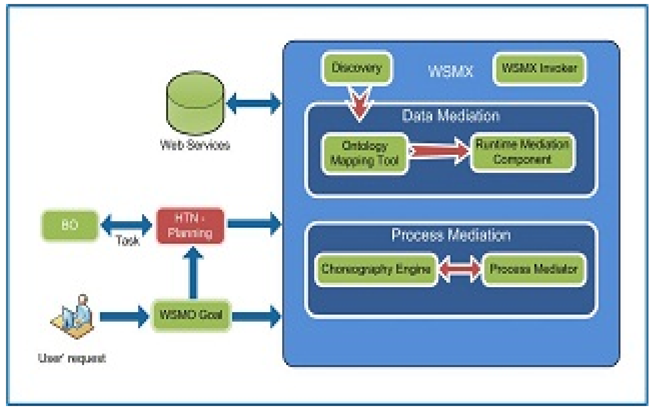

Figure 2. The O-HTN-based Process Formulator architecture

2) 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.

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.

IV. Collaborative Service Discovery for BizKB Framework

We have proposed an approach, O-HTN for dynamic collaborative B2B using Web Service Modeling Ontology (WSMO) as the modelling foundation [6]. The main reason for the creation of O-HTN-based BizKB is: O-HTN approach is feasible for dynamically creating CBP task sequences which is significant for a high level tasks composition for formed CBP. Furthermore, it is ideal for direct Web service execution. In order to complete the process in producing services attached CBP, there is another important task for BizKB. The task is about to find the appropriate web services to fill in the service profiles and this will be done by an ontology matching process.

In a collaborative environment, services are composed from different domains and contexts. Therefore, we can be challenged by the inconsistency of different knowledge-based domains. In our approach, we use the consensus methodology [4] to solve this problem.

A. Consensus methodology for inconsistent knowledege processing

Consensus methods were known in ancient Greece and were applied mainly in determining vote results. Along with the development of software methods we can see consensus methods can be applied into many applications fields, especially in solving conflicts and reconciling inconsistent data [4]. In this section, we would like to summarise the core part of the consensus methodology is the algorithms for processing inconsistency of knowledge. Consensus methods are used in a process of solving data inconsistency can be described as follows:

1. Defining the set of potential versions of data;
2. Defining the distance function between versions;
3. Selecting a consensus choice function;
4. Working out an algorithm for consensus choice.

The most important step and it makes the different is the second one, talking of the distance function between different versions of data. Applying this approach into a dynamic mapping method for semantic web services composition in different domains is the key of our approach.

B. The consensus-based semantic distance calculation

An ontology-matching algorithm is based mainly on the semantic measure.

Based on distance functions in consensus methodology [4] together with semantic distance calculation on hierarchical structure of ontologies, we propose a semantic distance algorithm as follows:

Input: Classes C_1, C_2, C_0
Output: Semantic distance between C_1 and C_2
Algorithm:
Semantic_Distance(C_1,C_2)
{
If C_1, C_2 are similar
Semantic_Distance(C_1,C_2) = 0 (1)
Else If exist the direct connection between C_1 and C_2
*Semantic_Distance(C_1,C_2) = w * d (C_1,C_2)* (2)
Else If exist the indirect connection between C_1 and C_2
Semantic_Distance(C_1,C_2) =

$$\frac{\sum_{C_0 \in SPath(C_1,C_2)} (w_{C_0} * d(C_1,C_2))^i}{k(k+1)} \quad (3)$$

Else
Semantic_Distance(C_1,C_2) =

$$\min\left(\frac{\sum_{C_0 \in SPath(C_1,C_2)} (w_{C_0} * d(C_1,C_2))^i}{k(k+1)}\right) \quad (4)$$

}

where:
- C_1, C_2: two classes (concepts) in ontology
- C_0: the indirect connection in the cases of (3) or (4).
- w: the weight between these two classes in case of existing direct connection.
- w_{C_0}: the weight between these two classes in case of existing indirect connection - (3) or (4).

The meaningful of the idea is that instead of considering the distance of weight value and conflict concept, we determine smallest distance between experts' opinion reflected in classes of ontologies about services profiles. In this case, we calculation the distance between service requests and services profiles to find out the appropriate services for our needs, and skip the process of consider all services.

In the case of the proposed solution for conflict of service requests is independent to solutions of each service requesters, and the consensus methodology is the right choice. However, the consensus solution must reflect the all solutions and a consensus accepted by all service requestors.

C. Consensus-based Collaborative Service Discovery

The ontology matching process is the results of alignments made by the semantic distance calculation. In order to discover the appropriate web services, we need to have an algorithm for evaluation the degree of semantic matching between classes. We call our approach is "collaborative service discovery" because of searching services from different partners with respect to their contexts and domain, and finding out a "consensus" solution for appropriate services.

1) Algorithm for semantic matching degree of outputs

Input: Outputs for requested and advertised services
Algorithm:
degreeOfmacth(req.out, adv.out)
{
If (req.out = adv.out) or
(subclassOf(req.out,adv.out)==true) then
Semantic_Distance(req.out,adv.out)=0
Else

If subsumesOf(adv.out,req.out)==true then
Semantic_Distance(adv.out,req.out)=
*w*d(adv.out,req.out)*
Else
If subsumesOf(req.out,adv.out)==true then
Semantic_Distance(adv.out,req.out)=

$$\frac{\sum_{C_0 \in SPath(C_1,C_2)} (w_{C_0} * d(req.out, adv.out))^i}{k(k+1)}$$

Else
Semantic_Distance(adv.out,req.out)=

$$\min\left(\frac{\sum_{C_0 \in SPath(C_1,C_2)} (w_{C_0} * d(req.out, adv.out))^i}{k(k+1)}\right)$$

}

2) Algorithm for semantic matching degree of input

Input: Inputs for requested and advertised services
Algorithm:
degreeOfmacth(req.inp, adv.inp)
{
If (req.inp = adv.inp) or
(subclassOf(req.inp,adv.inp)==true) then
Semantic_Distance(req.inp,adv.inp)=0
Else
If subsumesOf(adv.inp,req.inp)==true then
*w*d(adv.inp,req.inp)*
Else
If subsumesOf(req.out,adv.out)==true then
Semantic_Distance(adv.inp,req.inp)=

$$\frac{\sum_{C_0 \in SPath(C_1,C_2)} (w_{C_0} * d(req.inp, adv.inp))^i}{k(k+1)}$$

Else
Semantic_Distance(adv.inp,req.inp)=

$$\min\left(\frac{\sum_{C_0 \in SPath(C_1,C_2)} (w_{C_0} * d(req.inp, adv.inp))^i}{k(k+1)}\right)$$

}

where:
\+ *Semantic_Distance()* is the semantic distance calculated by the proposed algorithm.
\+ *d(adv.in, req.inp)* or *d(adv.out, req.out)* are the matching degree between services. The semantic matching degree is dependent to the ontology structure and RDFNode.

Similarly, these algorithms can be applied into requested services in service profiles and advertised services from different contexts. The solutions can be achieved with the basis of matching degree, multi-level matching and the combination in different levels of range of the function *degreeOfmacth()*.

D. Collaborative BizKB with O-HTN and Consensus Service discovery component

Applying these algorithms together with O-HTN in our approach, we structure the new process for CBP formulation and service discovery for BizKB framework as follows:

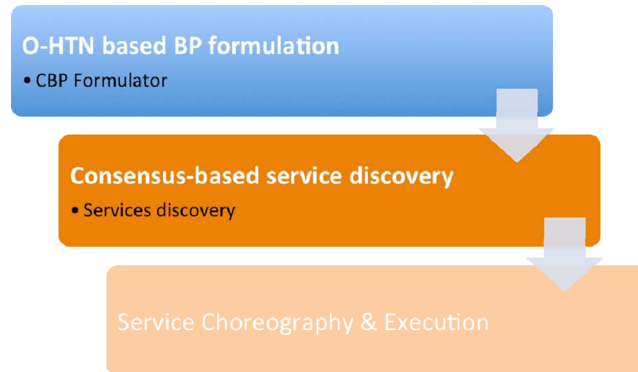

Figure 3: A collaborative Biz-KB process with support of O-HTN and Consensus service discovery mechanisms

Collaborative business processes are dynamically formed by using O-HTN algorithm in a flexible task decomposition process. Formed CBP with service profiles will then hand-in the services discovery phase for finding appropriate services.

The consensus service discovery based on newly invented ontology matching process helps to find out requested services in a better solution in collaborative service partner providers. The discovered services will be then transferred into the choreography mechanism for forming executable business processes.

V. CONCLUSION AND OUTLOOK

In this paper we have proposed a collaborative services discovery mechanism with the support of the consensus methodology. Together with ontology-based approach using Ontological-HTN and WSMO for forming collaborative business processes in the dynamic cross-enterprise collaboration [6]. 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 and the consensus-based ontology matching algorithms for web services discovery with some improvements in compared to [7, 8] which have not discussed the service discovery issue for CBP.

For the future work, we plan to improve the algorithms with case studies and do some experiments with mapping of attached web services into the execution level with practical examples.

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