

An agent-based Web service workflow model for inter-enterprise collaboration

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Abstract

The service-orientated computing paradigm is transforming traditional workflow management from a close and centralized control system into a worldwide dynamic business process. A complete workflow serving inter-enterprise collaboration should include both internal processes and ad hoc external processes. This paper presents an agent-based workflow model to address this challenge. In the proposed model, agent-based technology provides the workflow coordination at both inter- and intra-enterprise levels while Web service-based technology provides infrastructures for messaging, service description and workflow enactment. A proof-of-concept prototype system simulating the order entry, partner search and selection, and contracting in a virtual enterprise creation scenario is implemented to demonstrate the dynamic workflow definition and execution for inter-enterprise collaboration.

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1. Introduction

Workflow management systems provide the automation of business processes where a collection of tasks is organized between participants according to a set of defined rules to accomplish some business goals (WfMC). The traditional inter-enterprise workflow is related to EDI (Electronic Data Interchange) and recently ebXML (electronic business XML) (ebXML), which coordinates business partners with pre-defined terms and thus constructs a close and secure business community. However, due to the lack of flexible mechanisms to deal with real-life situations, such as fast changing customer requirements and enterprise goal shifts, a static workflow definition designed at build time is inflexible to meet the complex, dynamic situations that happen at run time such as partner search and selection, bid negotiation, and workflow re-configuration.

In a dynamic, loosely coupled collaborative environment such as B2B or B2C, a flexible and adaptive inter-enterprise workflow is more suitable for those small and medium Internet-based business enterprises (Yan, Maamar, & Shen, 2001). For a flexible workflow, only a rough, role-based workflow pattern is defined at the beginning. The initial workflow needs to be specified or pre-processed until such a workflow pattern can be described by a clear and executable workflow definition.

Web services (W3C) provide an industrial standard for deploying, publishing, discovering and invoking enterprise's services. From its emergence, many specialists have predicted that Web services will revolutionize the distributed computing paradigm and it will make various kinds of e-business (e.g., inter-enterprise collaboration and ASP paradigms) a reality. BPEL4WS is such a workflow process language for providing a formal specification of business processes and business interaction protocols. It uses executable business process and abstract process to ensure that different business processes can understand one another in a Web services environment, and that they can realize a dynamic composition. However, to achieve the required

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dynamic composition of a workflow, BPEL4WS still falls in short of building a direct logical relationship between an abstract process definition and an executable process definition, except developers manually define such a relationship. Ontology and reasoning mechanisms must be added on top of BPEL4WS to describe the relationships between workflow components, such as tasks, services and resources, for automatic reasoning and interpretation of a dynamic workflow process. Thanks to the emergence of Semantic Web research and standardizing efforts, OWL (Web Ontology Language) (W3C) becomes a promising ontology representation language that combines the description logic, formal logic and Web service standards.

On the other hand, as significant research work has proved that software agents can provide a flexible, reconfigurable and coordinated approach to enhance workflow management (Xu, Qiu, & Xu, 2003; Yan et al., 2001), the merging of agents with workflow brings a promising result. An agent-based workflow can be considered as a workflow process that is planned, performed, communicated, and coordinated in a multi-agent environment, in which the workflow is decomposed into multi-level collaborative tasks and each task represents a logical piece of work that contributes to the process.

This paper presents an agent-based workflow model by integrating software agents, Web services, and workflow ontology to support dynamic workflow definition and execution for inter-enterprise collaboration. The proposed workflow model should include both internal and external workflow processes for their strong coherence relations.

The paper is organized as follows: Section 2 introduces Web services, workflow ontology, and agent technologies in workflow coordination; Section 3 proposes an agent-based workflow model; Section 4 presents the basic definition of workflow ontology and its reasoning; Section 5 describes a virtual enterprise creation case study; Section 6 depicts the implemented proof-of-concept prototype; finally, Section 7 provides a conclusion and discusses our future work.

2. Web services, workflow ontology and agents in workflow coordination

Web services provide a standard means of interoperating between different software applications, running on a variety of platforms and/or frameworks. Web services are characterized by their great interoperability and extensibility thanks to the use of XML, and they can then be combined in a loosely coupled way in order to achieve complex operations (W3C). The basic components of Web services, such as SOAP (Simple Object Access Protocol), WSDL (Web Services Description Language) and UDDI (Universal Description Discovery and Integration protocol), solve the interoperability problems of heterogeneous applications, but they are still not sufficient for large-scale industrial applications because of the lack of

abilities to construct inter-enterprise workflow management systems. Facing this challenge, many workflow-oriented Web services components, such as ebXML, BPEL4WS, OWL (W3C) and OWL-S (W3C), have been proposed on top of those basic components for automating business process management. Among these components, BPEL4WS is particularly notable for providing a formal specification of business processes and business interaction protocols. BPEL4WS uses executable business process and abstract process to ensure that different business processes can understand one another in a Web services environment. However, the challenge is that Web services are hooked up on the fly and it may be beyond human capabilities to analyze the required services and compose them manually using BPEL4WS. On the other hand, manually created WSDL files for a process workflow could not meet the requirements of dynamic virtual enterprise collaborations.

Workflow ontology is being widely used to describe the relationships between workflow components, such as tasks, services and resources, for automatic reasoning and interpretation of a dynamic workflow process. OWL (W3C) is a standard ontology representation language that combines the description logic, formal logic and Web standards. OWL-S (W3C) is an OWL ontology evolved from DAML-OIL for Web services (DAML). It describes a set of classes, properties and relations that are specific to the description of Web services. The OWL-S consists of three service models: the service profile model for describing service advertisements, the process model for the actual program that realizes the service, and the service grounding model for message transportation.

Since OWL-S provides semantic-based service description, service discovery and logic reasoning and BPEL4WS offers the automation of a business process, some researchers have tried to combine the OWL-S with BPEL4WS to use both of their merits (Mandell & McIlraith, 2003). For example, Liu, Khalaf, and Curbera (2004) built a direct mapping from DAML-S to BPEL4WS for composite processes and atomic processes.

Considering the dynamic instantiation of a flexible workflow, the runtime flexibility required by a business workflow can naturally be achieved when we consider merging the agent concept into workflow automation scenario. Software agents can provide a flexible, reconfigurable and coordinated approach to enhance workflow management at both inter- and intra-enterprise levels (Shen & Norrie, 2001; Shen, Norrie, & Barthes, 2001). A software agent system satisfies the requirement of inter-enterprise workflow management in that:

- agent-based workflow can be considered as a workflow process that is planned, performed, communicated, and coordinated in a multi-agent environment;
- the workflow is decomposed into multi-level collaborative tasks and each task represents a logical piece of work that contributes to a process;

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