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Autonomous service level agreement negotiation for service composition provision

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Abstract

Efficient management of service level agreements which specify mutually-agreed understandings and expectations of service provision has been a subject of research for a few years. A critical issue in this area is for service consumers and service providers to effectively achieve agreements on non-functional aspects of service provision, such as quality of service. However, this issue has not been well addressed, especially in the context of service composition provision which implies the establishment of a set of interrelated agreements on quality of service between the service consumer and multiple service providers offering various services in the composition. There is a lack of supporting frameworks and techniques to automatically and dynamically achieve agreements on quality of service constraints for individual services in a service composition, aiming at fulfilling composition's end-to-end quality of service requirements.

This paper reports the authors' recent research in addressing this issue, using the agent technology. In this research, the service level agreements for a service composition are established through autonomous agent negotiation. To enable this, an innovative framework is proposed in which the service consumer is represented by a set of agents who negotiate quality of service constraints with the service providers for various services in the composition. This negotiation is well coordinated in order to achieve end-to-end quality of service requirements. Based on this framework, a new negotiation protocol is presented to support coordinated negotiation. A utility-function-based decision-making model is proposed based on which agents can proactively decide on the course of further actions. Moreover, this paper also contributes the novel design of the negotiation Web service on the service providers' side for the purpose of interoperability. Finally, the prototype implementation for the purpose of proof-of-concept is discussed.

Keywords: Agent technology; Coordination; Negotiation; Service composition; Service level agreement

1. Introduction

Service-Orientated Computing (SOC) is an emerging paradigm that utilizes services as fundamental elements for developing distributed applications such as e-business processing [14,27]. The uniqueness of SOC is that it promises an approach to development in which the externally observable behaviours of the business applications are semantically described and advertised as services. These distributed business applications can be composed in a seamless manner with little effort into a network of services. Therefore, organizations are able to create dynamic business processes and agile applications within and across organizational boundaries. The most well-known integration platform for SOC is the Web services framework which is based on a family of related XML-based standards, including the Web Services Description Language (WSDL), the Universal Description, Discovery and Integration (UDDI), and the Simple Object Access Protocol (SOAP).

In SOC, the provision of a service always implies a service consumer's consumption of a service that is purchased

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from a service provider. This buy and offer relationship is commonly governed by an agreement, known as *Service Level Agreement* (SLA) [1,3,19]. A SLA is a contractual obligation between the service provider and the service consumer by specifying mutually-agreed understandings and expectations of the provision of a service. The core of a SLA is specification of the service guarantees, which define both functional and non-functional guarantees of a service provision. On one hand, the interactions that need to be carried out are defined in order to specify the functionality (service) to be offered. On the other hand, a set of Quality of Service (QoS) constraints, for example, price and response time constraints, are agreed in order to specify how well the service should be offered. In addition, a SLA often contains general information such as the parties involved in service provision and their respective roles, and the validity period of the SLA. Business rules in terms of the service provision restrictions, payment, and penalties can also be specified in a SLA.

Obviously, one critical issue in SLA management is to determine the QoS constraints in a SLA in order for the fulfilment of the user QoS request. However, this issue has not been addressed satisfactorily so far in the context of business processes. In SOC, a business process which can also be exposed as a service, i.e., a composite service or a service composition, consists of a set of logically connected services. The buy and offer relationship in this scenario may involve one service consumer, i.e. the service composition provider, and many service providers offering various services in the composition. Thus, given user QoS requests, i.e. end-to-end QoS requirements, SLA management for a service composition requires the establishment of a set of interrelated QoS constraints in either one or many SLAs. These QoS constraints, governing the provision of various services in the composition, should collectively fulfil the end-to-end QoS requirements. Unfortunately, today's SLA management largely relies on static customer QoS requests on individual services in a composition or manual configuration to determine various QoS constraints. There are lacks in supporting frameworks and techniques to autonomously and dynamically determine QoS constraints for various services in the service composition, which can collectively fulfil the end-to-end QoS requirements.

To address this problem, this paper reports innovative research on SLA management for service composition provision with a focus on autonomous establishment of QoS constraints. A novel framework and corresponding techniques are presented which enable autonomous, dynamic and user-transparent establishment of QoS constraints. The distinction of this approach is to use agents to negotiate the QoS constraints and dynamically select providers for various services in the composition, aiming at fulfilling end-to-end QoS requirements. since this research focuses on QoS constraints in a SLA, in the remainder of this paper, SLA negotiation refers to negotiation of QoS constraints in a SLA.

The rest of this paper is organized as follows. The next section briefly introduces major related work in the area of SLA management and agent negotiation, and the background work of this research. Section 3 presents a framework for agent-based, coordinated SLA negotiation. Based on this framework, Section 4 discusses the techniques for SLA negotiation, including the novel design of the negotiation protocol, the decision-making model, and the design of the negotiation Web service. After that, the prototype implementation is discussed in Section 5. Finally, Section 6 concludes this paper and outlines authors' future work.

2. Related work and background

SLA management has been a topic of research for a few years and some research results have been published. Section 2.1 discusses some major related work in this area. Background work of this research is introduced in Section 2.2.

2.1. SLA management and agent negotiation

Active research on SLA management, mainly carried out in the context of single service offering, has covered various areas such as SLA specification and languages, SLA creation, operation, monitoring, termination, and so on. Just to name a few, [23] studied the importance of SLA management in SOC comprehensively. The Global Grid Forum (GGF) published the Web Service Agreement Specification (WS-Agreement) which is an XML language for specifying an agreement between a service provider and a consumer, and a protocol for creation of an agreement using agreement templates [1]. Similarly, WS-Negotiation is an XML-based language which contains the Negotiation Message, Negotiation protocol and the Negotiation Decision Making process [15]. [28] has identified the base components in typical SLA specification aiming at specifying SLAs in precise and unambiguous manner as well as keeping the specification flexible. A Web Service Level Agreement (WSLA) framework for defining and monitoring SLAs in inter-domain environments is presented in [19]. [9] presented an approach for SLA-driven management of distributed systems using common information model (CIM). An exploratory study to identify requirements on negotiation support for the processes associated with SLA development is discussed in [10]. SNAP [8] defines a general framework within which a client can reserve and acquire any resources from resource providers in a uniform fashion. [2] evaluates six architectures that perform SLA auditing both quantitatively and qualitatively.

The use of negotiation as a means of establishing service contracts has been a topic of considerable interest for quite some time now within the agent community [13,17,26]. Software agents offers abilities of autonomous operations, interaction and cooperation that can be used in automating negotiation [17,18,22,24], partner selection [5], complex e-service contracting [21], and coordinated service and resource sharing [6,11]. Given the similar environments in which web services and software agents operate, Web services can benefit from the features of multi-agent technology. However, within the community, agent-based negotiation has principally been in the context of one-to-one negotiation or one-to-many negotiations but for the provision of a single service. There has not been much work on the negotiation of end-to-end QoS constraints.