

# Towards Collaborative Service Level Agreement Negotiation

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**Abstract.** A critical issue in the Service Level Agreement management for service composition is to control the relationship between the composite service and the component services in the negotiation. However, existing approaches are inefficient. This paper presents a novel agent-based collaborative approach to address this problem. We introduce a negotiation protocol, under which the agents on the service providers' side collaborate by exchanging information with each other to gain global knowledge of the negotiation. The collaboration can facilitate the progress of the negotiation. We also discuss the corresponding impact on the decision making strategies.

**Keywords:** Agent, Negotiation, Service Composition, Service Level Agreement

## 1 Introduction

Service-Oriented Computing (SOC), empowered by the Web services technology, has become a main trend in business process research. In this area, an active topic is the management of Service Level Agreement (SLA), which defines and governs the obligations of the participants in service provision. The adoption of SLA is able to establish a healthy competitive environment, thus benefiting both service consumers and service providers. On one hand, by introducing SLA management system, matured service providers could consolidate their important clients. At the same time, newly-rising service providers could attract potential clients. On the other hand, service consumers' rights could be ensured by evaluating the quality of service provision according to the items defined in the SLA. Penalty for SLA violation prevents service providers from lowering the quality of services sneakily after grabbing consumers by establishing attractive SLA.

In service composition scenarios, the utilisation of SLA has more to expect. In such applications, service providers from different organisations cooperate with each

other to meet the end user's needs. Research on service composition has been carried out for some time [2] [6]. The responsibilities of the service providers are more critical here, as any failure to meet local requirements of the component service would result in exceptions of a global application. In a sophisticated Web services environment, the agent technology is complementary to the Web services technology, and enables the operations between service providers and consumers. Particularly, utilising the agent technology is a convincing approach to automate the management of SLA, where minimum intervention of human beings is desirable. In service composition scenarios, it is strictly required that relationships between the composite service and the component services be under control, especially in the process of SLA negotiation.

To ensure that the composite service can satisfy the end user's needs, the quality of each component service needs to be guaranteed by unambiguously defined SLA. This is completed in the process of the SLA negotiation. But current SLA negotiation approaches are inefficient. To address this problem, this paper reports our innovative research on efficient SLA negotiation. A novel SLA negotiation protocol and discuss of the corresponding impact on decision making strategies are presented. The distinction of the approach is to enable the service providers to exchange information with each other and adjust their offers according to the global knowledge of the negotiation, aiming at fulfilling the global requirements of the composite service. Here, the "global knowledge of the negotiation" includes information about the discrepancy between the intending offers and the current global requirements of the composite service.

The remainder of this paper is organised as follows. In Section 2, a procurement example is described as the motivating scenario, followed by a general description of our extended agent-based framework in Section 3. In Sections 4 and 5, we introduce the negotiation protocol and discuss its impact on the decision making strategies. Section 6 presents a case study. Section 7 briefly reviews major related work. Finally, Section 8 concludes this paper and outlines our future work.

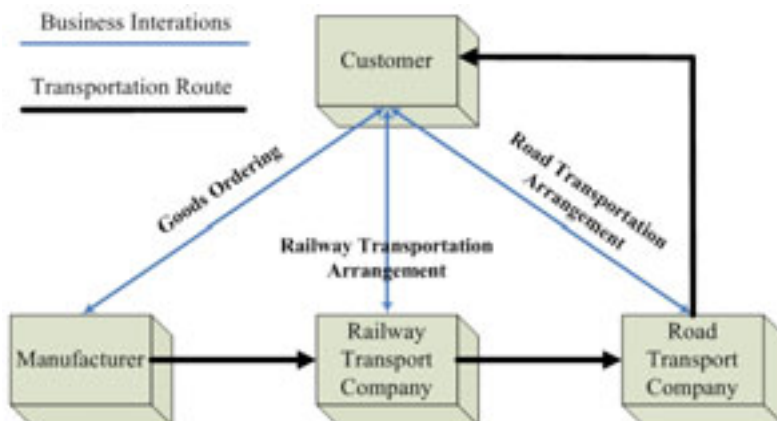
## 2 Motivating Scenario

In the service composition scenario, a composite service is comprised of a set of component services, which may be provided by a group of service providers. SLA management in such a scenario is a very complex task and needs to be well addressed. To illustrate the motivations of this research, a simplified scenario, procurement, is presented in this section.

This business process in the scenario involves a customer, a manufacturer, a railway transport company and a road transport company. The process is composed of four phases:

1. The customer places an order for the goods;
2. The manufacturer produces the goods;
3. The railway transport company transports the goods to the destination area;
4. The road transport company transports the goods to the customer.

The business interactions and the route of the goods are presented in Figure 1.



**Fig. 1.** The Business Process of Procurement

Generally speaking, one of the customer's major concerns is the time consumption of the whole procedure. In this scenario, the time is consumed in three phases: manufacturing, railway transportation and road transportation.

The customer expects to receive the goods in an acceptable time frame. Thus, the customer needs to adjust the time consumption for each phase of the procurement in order to obtain appropriate global time consumption. The SLAs can define the time consumption for the manufacture, railway transportation and road transportation. All of these issues will be negotiated over between the service consumer and the service providers.

Service providers may publish their SLA templates as advertisements [14]. One of the most important information in an SLA template is the advertised values describing the quality of the service. Based on these advertisements information, the service consumer can select appropriate service providers. These advertisements are also the basis of the SLA negotiation. In the procurement example, the service providers publish their SLA advertisements, in terms of time consumption, as presented in Table 1.

**Table 1.** Time Consumptions of Service Providers

Service Providers	Parameters	Reserved Time / Advertised Time (Days)
Manufacturer		6 / 10
Railway Transport Company		5 / 6
Road Transport Company		6 / 7
<b>Total</b>		<b>17 / 23</b>

Apart from the advertised values, each service provider can have reserved values. For example, in Table 1, the reserved time is the least acceptable time to the service provider. The reserved value is internal to the service provider and is not included in

the SLA template. Depending on the capability of the service provider, the reserved values of a service are usually fixed at a time.

The service consumer can access the SLA templates and evaluate whether these service providers can fulfil its requirements. In this example, we assume that the service consumer requires the goods within up to 18 days. Clearly, the advertised values of the service providers' values cannot satisfy the requirements. Therefore, timely negotiation is required.

The result of the negotiation depends on the negotiation protocol and the strategies of the involved parties. In conventional approaches, the service consumer negotiates with various service providers independently. This is time consuming, i.e. inefficient, because the service providers are equipped with local information only. Thus they make negotiation movements simply based on their own decision making strategies without the consideration of collaborating with other service providers. The lack of interactions among the service providers prevents them from gaining global knowledge of the negotiation and making better decisions. We believe the collaboration among the service providers could largely accelerate the negotiation process.

### **3 Extended Agent-based Framework for SLA Management**

In the SOC environment, Web services are designed to provide transparent automated utilisation of heterogeneous resources and applications. But there are inherent flaws of Web services [16]: 1) A Web service does not know about its users; 2) Web services cannot use and reconcile ontologies; 3) Web services are always passive until invoked; and 4) A Web service is not autonomous. Agents are capable of extending Web services in all of the above aspects, since agents are self-aware, communicative and autonomous. Besides, agents can provide mutually-comprehensible ontologies between service providers and service consumers. Hence, we designed an initial agent-based framework to implement comprehensive management of SLA [10], based on which we carry out our research work.

In our framework, different components in the agent are responsible for various tasks in the SLA management. In the service consumer agent, the Agreement Initiator component accesses the service registry to retrieve the SLA templates and select the service providers. And then the Agreement Negotiator component interacts with the service provider agent to perform the negotiation task. In the service provider agent, there is also an Agreement Negotiator component that takes the responsibility for the negotiation task. The Agreement Factory component in the service provider agent composes the agreement with related details achieved through negotiation.

In a service composition scenario, in order to enable the interaction between SLA responders, an additional component, namely Collaborative Negotiator, is added in the service provider agent, as presented in Figure 2. The Collaborative Negotiator component takes the responsibility for sending, receiving and aggregating information, and delivering the aggregated information to the Agreement Negotiator component. Based on the information, the Agreement Negotiator components can adjust their offerings.

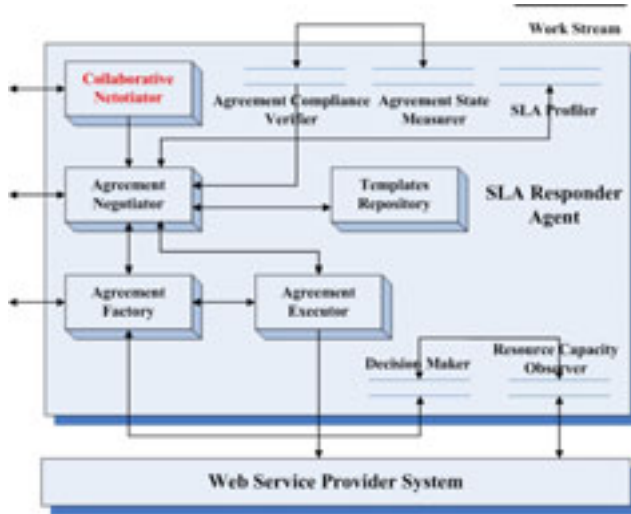


Fig. 2. Collaborative Negotiator in Service Provider Agent

## 4 Negotiation Protocol

Based on the framework presented in Figure 2, the negotiation is carried out autonomously by the agents of service providers and service consumer, following a particular negotiation protocol. Different protocols and decision making strategies have different goals, such as guaranteed success, maximising social welfare, maximising individual welfare and Pareto efficiency [23]. Our work aims at improving the efficiency of the SLA negotiation by providing the service providers with the ability to gain global knowledge of the negotiation by exchanging information and then further adjust their offers during negotiation.

In a service composition scenario, a composite service consists of several component services provided by a group of service providers. The service consumer needs to negotiate with each service provider and contract SLA on each of these component services. The SLAs must fulfil the local requirements of every component service. The aggregation of all the SLAs also must fulfil the global requirements of the composite service. Usually, as long as the global requirements of the composite service are met, the service consumer concerns little about how they are met. Take the procurement for example, the customer hardly concerns about the time each individual phase takes.

The initial mapping from the global requirements of the composite service to the local requirements of the component services is done by the service consumer before the SLA negotiation. The aim of the negotiation is to gradually diminish and finally eliminate the discrepancy between the service consumer's and the service provider's requirements by offering and counter-offering. Our negotiation protocol provides the

service providers with the ability to obtain the global knowledge of the global negotiation and adjust their offers in order to improve the efficiency of the negotiation.

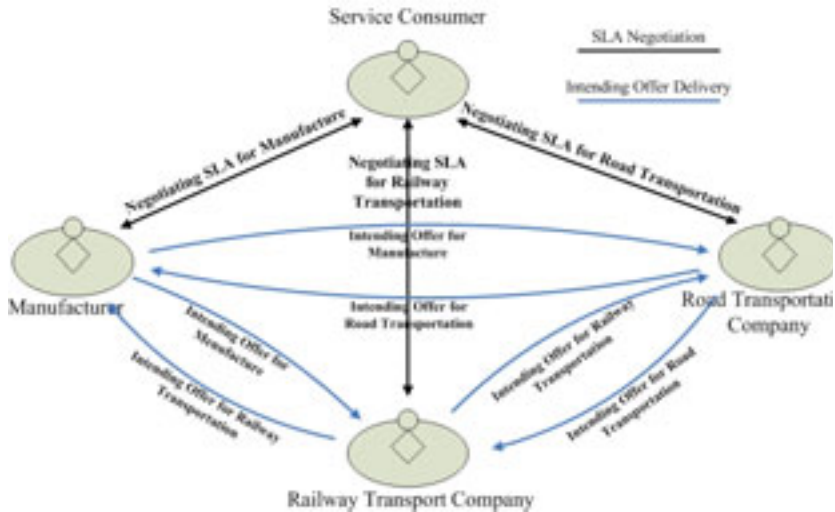
The negotiation protocol involves two types of interactions:

1. Consumer-provider negotiation.  
The service consumer negotiates with every single service provider over specific component services respectively. This part comprises of service providers proposing offers and service consumer sending back counter-offers, based on their own decision making strategies.
2. Provider-provider information exchanging.  
Service providers send their intending offers to other service providers. The intending offers contain the attributes being negotiated over and the values the service providers intend to offer to the service consumer. The exchanged information could help them gain the global knowledge of the negotiation. Based on the knowledge, they can further adjust their offers in order to get closer to the global requirements of the composite service.

Along with the counter-offers, the service consumer's current global requirements of the composite service are also sent to the service providers by the service consumer. For example, the manufacturer receives not only how many days are required for the goods to be produced, but also how many days are required for the whole procurement. Meanwhile, information about involved service providers, say the contact information, are also sent by the service consumer to the service providers.

Based on Figure 2, at the beginning of the service composition, the Agreement Initiator component in the service consumer accesses the service registry to retrieve the SLA templates and selects the appropriate service providers. In the SLA templates there are fixed parameters and negotiable parameters. Only the negotiable ones could be negotiated over. By checking the advertised values, the service consumer can figure out whether the initial values in the templates are satisfying. If yes, further negotiation will not be necessary. Otherwise, the service consumer will need to propose counter-offers according to its decision making strategy. The offering and counter-offering between the service consumer and the service providers can go through several rounds until they reach an agreement, or time out. Substantial research has been done in this area (e.g. [18]). We will not introduce specific strategies due to the space limitations.

Upon the receipt of the counter-offer from the service consumer, a service provider will not immediately send back a new offer. Instead, it sends its intending offer to other service providers. Research in this paper is under the assumption that the service providers will honestly send out their intending offers and meanwhile believe that the intending offers sent by others are credible. With the intending offers sent by other service providers, every service provider is able to gain the global knowledge of the negotiation, based on which they can adjust their offers. The worse situation would be that a service provider may insist on its intending offer in the case of either selfish decision making strategy or running out of concession. However, we believe that based on appropriate and reasonable decision making strategies and the global knowledge of the negotiation, the negotiation will be much more efficient. As depicted in Figure 2 and Figure 3, the procedure of the SLA negotiation between the service consumer and each service provider for service composition is as follows:



**Fig. 3.** Interactions among Involved Parties

1. The Agreement Initiator component in the service consumer accesses the service registry and selects appropriate service providers according to their SLA templates;
2. The service consumer checks that whether the advertised levels of the component services can fulfil the global requirements of the composite service;
3. If the service consumer is satisfied with the offer provided by the service provider, negotiation succeeds and it contracts an SLA with the service provider on the specific service. Otherwise, the Agreement Negotiator component in the service consumer sends a counter-offer to the service provider according to its own decision making strategy;
4. Upon the receipt of the counter-offer, the service provider determines its intending offer;
5. The Collaborative Negotiator component in the service provider sends the intending offer to other service providers;
6. By aggregating the received information and its own information, the service providers gain the global knowledge of the negotiation;
7. The service provider adjust its intending offer accordingly and sends it to the service consumer as the new offer;
8. Back to step 3.

## 5 Impact on Decision Making Strategies

Decision making strategies are diverse and sophisticated [23]. There are three main methods based on which decision making strategies are implemented, namely game theoretic [20], heuristic [9] and argument-based approaches [19]. The problem of finding optimal strategies through game theory is in general computationally intractable, and construction and evaluation of the arguments add considerable overheads to the negotiation process. Therefore, heuristic approaches are considered appropriate for agent-based SLA negotiation and discussed in this paper.

Apparently, rational service providers are willing to make reasonable concessions aiming at achieving negotiation success. In SLA negotiation for service composition scenarios, concessions made by various service providers contribute collectively to achieving negotiation success. As discussed in Section 4, sharing of negotiation information among service providers enable them to obtain global negotiation knowledge which may further shape their movements and help accelerate negotiation.

We assume that all service providers involved in SLA negotiation have genuine incentives to achieve negotiation success. This incentive implies that many service providers have a degree of collaboration which forms part of their decision making strategies. Upon the receipt of other service providers' intending offers, each service provider can calculate the discrepancy between the current global requirements of the composite service and the aggregated values of the intending offers for the component services. Here, the aggregation of the intending offers depends on the structure of the composite service and the characteristics of the negotiation objectives. For example, the end-to-end time consumption in the procurement example discussed in Section 2 is calculated by the sum of time consumptions caused by all service providers. This information is provided by the service consumer at the beginning of the negotiation. With awareness of the discrepancy, the service providers may adjust the values in their intending offers and form new offers by making further concessions. The size of the further concession depends on a service provider's degree of collaboration. The larger the degree of the collaboration is, the bigger the further concession could be. Therefore, the aggregation of the new offers will be more acceptable to the service consumer and the negotiation will be accelerated.

In the worst case, a service provider shows no intention of collaboration. In order words, a service provider is "totally selfish" and its decision on movements will not be influenced by obtaining the global negotiation knowledge. Although a totally selfish service provider will not modify its intending offer, it places no negative impact on other service providers' decisions.

For multi-attribute negotiation, the protocol is also applicable, as long as the attributes and the relationship between them can be precisely defined in the SLA. This requirement can be fulfilled by adopting unambiguous SLA specification [11]. In our approach, the cost of additional exchange of the intending offers is the only extra expense. However, considering most service providers are collaborative, this cost is easily overwhelmed by the benefits it can bring.



## 6 Case Study

In service composition scenarios, basic services provided by a group of service providers are used as fundamental components to form a composite service. As described in Section 2, a representative procurement process involves manufacture, railway transportation and road transportation. The service consumer needs to negotiate with the manufacturer, the railway transport company and the road transport company over the time consumption in each phase of the procurement. For the purpose of consistency, we assume that the preferences of the service consumer and the service providers are the same as presented in Section 2. The maximum global time consumption allowed by the service consumer is 18 days. The reserved and advertised values of the time consumption of the manufacturer, railway transport company and road transport company are 6/10, 5/6 and 6/7 days respectively.

At the beginning, the service consumer selects appropriate service providers for specific services based on the SLA templates published as advertisements in the service registry. By calculating the sum of the advertised values of time consumption, the service consumer will find out that its requirement cannot be met, since  $10+6+7=23>18$ . To counter-offer, the service consumer may propose 8, 4 and 5 days to the manufacturer, the railway transport company and the road transport company, as  $8+4+5=17$  days can perfectly fulfil its requirement. Along with the counter-offers, consumer's current requirement of global time consumption, 17 days, is also sent to each service provider. Receiving the counter-offers, the service providers will make their concessions to make their offers more acceptable to the service consumer. The intending offers may be 8, 5 and 6 days respectively. Then they will send their intending offers to each other. By comparing the service consumer's global requirement, 17 days, and the total time consumption of their intending offers, 19 ( $8+5+6$ ) days, the manufacturer may make a further concession by 1 day. But the railway transport company and the road transport company cannot afford to concede any more since their reserved values of time consumption are 5 and 6 days respectively. After the adjustments, the service providers will send their new offers, 7, 5 and 6 days to the service consumer. Upon the receipt of the offers, the service consumer will accept the offers, since the total time consumption of the values of the offers, 18 ( $7+5+6$ ) days, can meet its requirement. Thus, the negotiation succeeds.

Furthermore, if the manufacturer adopts totally selfish decision making strategy, it will not make the concession by 1 day when there is still discrepancy between the service consumer's global requirement and the service providers' intending offers. Then the negotiation may need to continue for one or more rounds.

The benefit of our negotiation protocol may be reflected with this case study. Exchanging information with each other help the service providers gain the global knowledge of the negotiation. Based on the knowledge, they could make a further concession to make their offers more acceptable for the service consumer. Thus, the negotiation is more efficient. Besides, we will develop a prototype for evaluation.

## 7 Related Work

The SLA management has been an important part of service oriented computing system. Related research covers a lot of aspects, such as SLA specification, SLA formation, monitoring, adaptation and so on. [11] analyses SLA specification in terms of precision and flexibility. WS-Agreement [1] aims at standardising the terminology, concepts, and the overall agreement structure. [13] describes CREMONA, a WS-Agreement based middleware that defines mechanisms to implement interactions among organisational domains. Similarly, SNAP [5] defines a general framework within which various resources can be reserved and acquired in a uniform fashion through the process of negotiation. [12][21][22] present how to specify and monitor SLA in Web services and grid services environments. [4] evaluates six architectures that perform SLA auditing both quantitatively and qualitatively, focusing on the performance penalty that auditing introduces and comparing the architectures based on non-functional aspects. [3] presents an approach for QoS adaptation to enable the dynamic adjustment of behaviour of an application based on changes in the pre-defined SLA. [17] proposes an SLA negotiation protocol based on the Iterated Contract Net Protocol for job scheduling on the Grid, which divides the SLA negotiation into two levels, meta-SLA negotiation and sub-SLA negotiation.

Particularly, research on automated contract negotiation for service composition has been an active area. [7] proposes an agent-based coordinated-negotiation architecture to ensure collective functionality, end-to-end QoS and the stateful coordination of complex services. [15] describes a logic-based method for service composition and marketplace-based system architecture supporting agent communication, negotiation and semantic reasoning in the composition process. [8] provides a multi-agent negotiation based service composition approach to deal with end user on-demand service requirements. A significant problem of SLA management for service composition is to satisfy the global constraints of the service during negotiation. Unfortunately, current approaches are not efficient. In this paper, we introduce a novel SLA negotiation protocol for service composition, under which the service providers can exchanging information and adjust their offers, aiming at improving the efficiency of the SLA negotiation.

## 8 Conclusion and Future Work

In order to improve the efficiency of SLA negotiation for service composition, we propose a novel collaborative multi-agent negotiation protocol. Under this protocol, service providers can exchange information with each other and adjust their offers during the negotiation. We also discuss how the decision making strategies are impacted under the negotiation protocol.

In the future, we will further investigate into multi-attribute collaborative SLA negotiation. For this new attempt, we will model different decision making strategies for multi-attribute SLA negotiation and consider the parties' behaviours in a collaboration-oriented environment. Besides, we will develop a prototype and apply it to some real applications.

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