Managing Supply Chains of Software as a Service through Agent Negotiations

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Abstract

This paper introduces a new mediation mechanism into agent negotiations. The negotiation mechanism takes a supply-chain perspective to the construction of software services, attempting to co-optimise individual negotiations between service providers and service consumers along the chain. Parties negotiate acceptable ranges of values for either independent or multi-linked issues. This enables mediator agents to collect negotiation information throughout a supply chain and formulate it as sets of optimisation objectives and constraints. Two examples are presented to demonstrate how the model operates.

1. Introduction

Web service can be componentised, reused, and rearranged in various sequences to meet various business needs. The potential of web services is furthered by the Software as a Service (SaaS) vision [1, 2], in which software is developed to meet necessary and sufficient requirements, in a highly personalised, fine-grained, and transparent manner. In this context, software services will be recursively composed of a number of sub-services varying in granularity. Thus, constructing a software service is equivalent to constructing a supply chain (SC) of sub-services. SC members are expected to exchange information in order to satisfy end-user’s requirements while maintaining their own interests. We argue that constructing such a SC can be supported by autonomous, intelligent agents negotiating with their counterparts on behalf of service providers and consumers in the SC. The aim is to optimize agreements on multiple issues, including service functionalities, delivery time, price, and the like.

The competitive nature of negotiations among self-interested, utility-maximising agents leads to two problems. The first is that individual non-coordinated negotiations are unlikely to produce optimal results at supply-chain level. This is because the agents lack visibility beyond the counterpart agents they directly negotiate with. The other problem is agents’ dissatisfaction toward the results of competitive negotiations. Agents’ negotiation strategies reflect their own positions in respective service markets so a negotiation result could be satisfactory to an agent in the dominant position while unsatisfactory to the other weaker agent.

2. Negotiation Process

A typical agent negotiation model [3] usually involves three roles of agents: buyer, seller, and broker. A broker agent handles buyer/seller’s enquiries about service availability and service registry. Once sources of suitable services are located, buyers will negotiate with respective sellers directly. Here, in order to tackle the problems described in Section 1, we add two new elements into the conventional model.

A third-party, trustworthy mediator agent is introduced to provide mediation services when enlisted by brokers or a registry directory. Once a final service buyer demands a mediation service, the mediator will be passively involved in all the negotiations along the supply chain. The mediator will collect information about on-going negotiations and buyer/seller’s preferences toward negotiation outcomes. The mediator’s neutral stance means that buyers/sellers can reveal their preferences without the risk that counterpart agents may exploit this sensitive information. The mediator thus can have sufficient visibility on all participants and their negotiation details across the whole SC allowing it later to fine-tune the agreed ranges of negotiation issues in order to optimize the overall SC performance and buyer/seller’s satisfaction.

Negotiations in this model are range-based in contrast to conventional agent negotiations where
issues are mostly presented as single values (e.g. time = 20 sec). There are two reasons for using this mechanism. Firstly, the risk of revealing agents’ true preferences over negotiation issues and the chance of negotiation failures can be both reduced [4]. Secondly, when negotiation issues are settled and represented as agreed ranges, a mediator can fine-tune negotiation results within all agreed ranges. Thus this gives the mediator the flexibility to explore possible values within the ranges to discover optimal solutions for the whole SC.

2.1 The negotiation process

The proposed negotiation process consists of three stages. In **Stage 1 (preliminary negotiation stage)**, the Buyer and Seller have to firstly agree to use a Mediator and then settle the ‘scope of range’ (SoR) and ‘range length’ (RL). After a Buyer engages a Mediator for mediation service, it sends a Call for Proposal (CFP) to the Seller for a quotation of the seller’s offered service. The Seller replies the CFP with both a quotation and consent on the Mediator’s involvement. Such consent is necessary as Mediator needs information from the SC for final optimisation. The incentive for both parties to do so is that Mediator will fine-tune values within agreed ranges according to their preferential values.

In Figure 1, the Buyer offers a SoR of price while the Seller may have a different price range. After several rounds of bargaining, the Buyer and the Seller agree on a SoR, and then they negotiate RL. RL is a proportion to SoR in any given issue, and the length of a RL should not be larger than that of the SoR.

As the negotiation continues, the number of unresolved issues may decrease and, if successful, both sides reach an agreement upon all issues. The maximum number of negotiation rounds in this stage can be predefined to avoid excessive rounds. Once both parties agree the SoRs and RLs on all issues, they submit the negotiation results to Mediator as proofs. Mediator then simply replies both parties with acknowledgement messages.

In **Stage 2 (formal negotiation stage)**, both the Buyer and Seller initiate a formal negotiation based on the agreed SoRs and RLs. For each negotiation issue, the Seller/Buyer picks up an interval equivalent to RL in the respective SoR and formulates it as an offer range (OR). All ORs are summarised in an offer message and send to the counterpart agent. The counterpart reviews all the ORs and makes a counteroffer message. After the negotiation is settled, both Seller and Buyer send the results to the Mediator. Three types of information are provided: the agreed ranges of all negotiation issues, the set of Buyer/Seller’s private preferences per issue, and the Buyer’s and Seller’s weighting distributions among negotiation issues. Any given preferential value should fall well within the corresponding agreed range. The Mediator receives and acknowledges the results.

In **Stage 3 (optimisation stage)**, the Mediator collects final negotiation results and analyses the results and preferences to formulate them as constraints (agreed ranges required for mediation) and objectives (least total deviation from preferential values, performance criteria of the SC). It uses internal algorithms to find optimal solutions.

2.2 Optimization with independent issues

Figure 2 is an example of the information collected by the Mediator on the SC from the first two stages. This SC has four service providers (SP): SP_A, SP_B, SP_C1, and SP_C2.

The end-user directly contracts with SP_A (acting as the Final Service Provider, FSP). For simplicity, we consider only price (P) and time (T). The end-user’s non-technical requirements of the service X are that the price and delivery time must not exceed £1 and 30 minutes respectively after all negotiations are concluded. Note that both issues are independent and their utility functions are unrelated. Taking the negotiation between SP_B and SP_C1 (termed Neg_B-C1), in Stage 2 both agents reach agreed ranges over price (10–20 pence) and time (10–15 min) issues. For the Mediator, to optimise Neg_B-C1 or any other negotiation on the SC is impossible, as both issues are independent and the Seller (SP_B) and Buyer (SP_C1) prefer upper and lower bounds respectively. One solution to this
problem is to use a weighting distribution on issues. In NegB-C1, we assume that SPB has a total weighing equals to 1 of which a weight 0.8 is allocated to price and 0.2 is allocated to time. Similarly, SP C1’s weighing distribution is 0.5 to price and 0.5 to time (Table 1). Agent’s weighing distributions have been sent to and are only known by the Mediator. The Mediator has to pick a price value and a time value within both ranges.

Table 1: List of weightings and agreed ranges

<table>
<thead>
<tr>
<th></th>
<th>Price (pence)</th>
<th>Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agreed range in NegA-B</td>
<td>60–70</td>
<td>20–25</td>
</tr>
<tr>
<td>SPA weighing in NegA-B</td>
<td>0.6</td>
<td>0.4</td>
</tr>
<tr>
<td>SPB weighing in NegA-B</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Agreed range in NegB-C1</td>
<td>10–20</td>
<td>10–15</td>
</tr>
<tr>
<td>SPB weighing in NegB-C1</td>
<td>0.8</td>
<td>0.2</td>
</tr>
<tr>
<td>SP C1 weighing in NegB-C1</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Agreed range in NegB-C2</td>
<td>20–30</td>
<td>12–18</td>
</tr>
<tr>
<td>SPB weighing in NegB-C2</td>
<td>0.6</td>
<td>0.4</td>
</tr>
<tr>
<td>SP C2 weighing in NegB-C2</td>
<td>0.3</td>
<td>0.7</td>
</tr>
</tbody>
</table>

The goal is to optimise the below objectives below while trying to satisfy the constraints mentioned above:

\[
\text{Min. } \text{Diss}_{A-B}, \text{Diss}_{B-C1}, \text{and Diss}_{B-C2} \quad (7)
\]

\[
\text{Min. } P_{\text{Final}} = (P_{A-B} + 15), T_{\text{Final}} = (T_{A-B} + 3) \quad (8)
\]

In Eq. (7), the Mediator’s goal is to minimise members’ dissatisfaction for each agent. A SP’s dissatisfaction is defined as the total squares of the differences between the provider’s preferred values and Mediator’s chosen values on all issues of all the negotiations involving the SP. In Eq. (8), the Mediator aims to minimise the total cost (P_{\text{Final}}) and total building time (T_{\text{Final}}). Note that same inferences can be made on SP FSP profit margin (15 pence) and time for composition (3 min). Putting Eq. (7) and (8) in the SC context, we contend that our model enables Mediator to meet two objectives we set out in Section 2: to enhance participants’ satisfaction with mediated outcomes and to improve performance criteria such as total cost and time on supply chain level.

2.3 Optimization with multi-linked issues

In real-life negotiations, issues are often multi-linked. When a Buyer and a Seller negotiate over price and time issues, they should come up with the agreed ranges on both issues. However, they must also agree on a global utility function while having their own utility functions. We propose a structural voting method for the Mediator to involve both sides to negotiate over a global utility function. Continuing with the example in Section 2.2, since now price is related to time, SPB and SP C1 have to agree a utility function on a 2D plane which covers the price (10–20 pence) and the time (10–15 min) (see Figure 4). SP B’s and SP C1’s internal utility functions are divergent.

To agree on a global utility function, the Mediator gives an initial utility function for both agents to vote. The initial utility function can be viewed as a function comprised by a number of discrete lines on the tops of the columns, which are like stacks of discs.

In the Buyer’s internal evaluation (Figure 4A), the decision to add or remove a disc depends on whether the current discrete utility function falls within or
outside of the Buyer’s ‘zone of acceptance’ (ZOA).
The two dotted lines represent the upper and lower bounds of the Buyer’s ZOA, while the dashed line represents the Buyer’s internal utility function. So if a section of the focal utility function is above the zone, the Buyer will use a vote to remove a disc from the column; if below the zone then a disc is added on the column. Figure 4B illustrates Seller’s internal evaluation on the focal utility function and possible options to reshape it. After all votes are used, the focal utility function is expected to conform as closely as possible both Seller and Buyer’s ZOAs.

![Figure 4: Buyer/Seller internal evaluation](image)

In the previous example, after all service providers’ voting is finished in their respective negotiations, the Mediator will have three shared utility functions of in negotiation NegA-B, NegB-C1, and NegB-C2 (Figure 5). The three agreed utility functions can be represented as a set of discrete linear functions. In Figure 4 all assumptive discrete utility functions can be translated to three sets of constraints (Eq. 9, 10, and 11) which show the price-time relationship. Apart from optimization at SC level, the Mediator’s aims to enhance all service providers’ satisfaction toward mediated outcomes. Finally, Mediator can derive a set of constraints and optimization objectives (Eq. 7 and 8).

3. Related research

Our model differs in several aspects compared to other works in agent negotiations. Firstly, the mediator in our model only passively collects information from the SC. The passive role is different from the mediator of Fatima et al. [5], where the mediator generates agenda for negotiators to make negotiations more likely to complete. Secondly, the way that ranges of issues are processed in our model is different from that of Bartal et al. [4]. Bartal’s method aims to reduce the uncertainty of negotiations and to secure Seller/Buyer’s sensitive information. Stage 1 of our model reduces this uncertainty by aborting if insufficient commitment is present. Thirdly, Zhang and Lesser [6] showed how to exploit the nature of multi-linked negotiations to improve flexibility in scheduling and compress delivery time on a SC. Our model achieves similar ends despite being range-based. To facilitate agents to analyze the utility space of voting on multi-linked issues, we employ a similar notion mentioned by Lin and Chou [7].

4. Conclusion and future work

We have presented a new agent negotiation model which uses a mediator and range-based negotiation model to optimize both the SC performance of service composition and the satisfaction of SC participants with the mediated results. We also provide numerical examples to demonstrate how the model works for both independent and multi-linked issues. Future work involves extending our current Jadex implementation of the model and creating optimization algorithms for the mediator.

5. References