Towards Model Checking & Simulation of a Multi-Tier Negotiation Protocol for Service Chains

(Extended Abstract)

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ABSTRACT

The object of our research is resource allocation which considers contractual dependencies across service chain tiers to avoid overcommitment and overpurchasing. We propose a multi-tier negotiation protocol for solving this problem. The proposed artifact is developed from an interaction protocol engineering perspective and a protocol specification is given. Besides basic safety properties like the absence of deadlock, we formally verify that the protocol prevents overcommitments and overpurchasing by means of the model checker Spin.

Categories and Subject Descriptors

I.2.11 [**Distributed Artificial Intelligence**]: Multiagent systems; K.4.4 [**Electronic Commerce**]: Distributed commercial transactions

General Terms

Design, Economics, Experimentation, Verification

Keywords

multiagent systems, negotiation, resource allocation

1. INTRODUCTION

Service chains are characterized by multiple service providers contributing to the provision of a composite service to a customer. An explicit formal statement of the obligations and guarantees regarding services in a business relationship is referred to as a service level agreement (SLA) [9, p.1-5]. Thus, a SLA provides the operational definition of a service as part of a contract between a service provider and a service consumer in a service chain (SC). In real-world service chains, contractual agreements exist along the flows of services. For individual service requests, agreements have to be negotiated. These agreements depend either directly or indirectly on other agreements along the service chain (e.g., for procurement, outsourcing, etc.).

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The object of our research is service level agreement-based resource allocation in SCs. We address the problem of consideration of contractual dependencies across service chain tiers. If these dependencies are not considered, the fulfillment of contracts may be unaccomplishable or unnecessary due to (i) missing contracts to other agents which are required for the fulfillment (overcommitment) or (ii) missing contracts to customers (overpurchasing). We propose a multi-tier negotiation protocol for solving this problem. Therefore, we study SLA negotiation with regards to dependencies between SLAs on different service chain tiers and formally analyze these dependencies. The proposed artifact is developed from an interaction protocol engineering perspective [5]. Besides basic safety properties such as absence of deadlock, unreachable code, etc., it is formally verified that the protocol prevents overcommitment and overpurchasing by means of the model checker Spin [4].

2. PROBLEM STATEMENT

Service parameters and their values are subject to changes along the SC (SLA parameter aggregation), since the service provided to the customer is a composite service. For SLA parameter aggregation, Jaeger et al. [6] have identified seven relevant abstract composition patterns (CPs). For each combination of CP and SLA parameter type (quality of service dimension), one aggregation definition has to exist. For numerical SLA parameters, aggregation functions can be defined. Non-numerical SLA parameters can not be mathematically aggregated. Other aggregation definitions (e.g., rule-based) might be required [6].

The problem in the production of the requested service consists of both the non-determinateness of the individual customer requirements until the point in time of the demand, as well as the individuality of the requirements themselves. For the value creation it is possible to (i) utilize resources from the own inventory or (ii) buy services from a third party (subcontracting). The latter is done if the own capacity is not sufficient or if the utilization of the own capacity is economically not favorable because of the cost function (e.g., step costs). Here, the provider has to consider economically relevant values to determine the concrete service providers for the value creation. For individualized services, this implies that the individual requirements of the customer determine the requirements to SLAs that have to be established on upstream service chain tiers. Therefore, the protocol must allow for subcontracting activities by the service provider (SP) and for negotiating all (sub-)contracts for a concrete customer request in a coordinated manner; i.e., the protocol has to prevent overcommitment and overpurchasing. That is, is must prevent (i) contracts to customers without establishing necessary subcontracts and (ii) subcontracts without establishing contracts to customers.

3. COMBINATORIAL CONTRACT NET PROTOCOL

We propose a multi-tier negotiation protocol for composite service provision over multiple service chain tiers. The basis for the proposal is the FIPA Contract Net Interaction Protocol (CNP) [2], the FIPA interpretation of the original contract net protocol proposed by Smith [8]. The protocol allows subcontracting activities by the participants; i.e., a participant can evaluate if subcontracting is possible and feasible in advance to making binding proposals. We denote the proposed interaction protocol as Combinatorial Contract Net Protocol (CCNP), since the protocol enables the combination of tiers for coordinating interactions on different service chain tiers and consideration of service compositions. That means that the protocol allows consideration of dependencies over multiple tiers for subcontracting.

Adopting the existing CNP requires to extend its current communicative acts (performatives) [1] used. The cfp (call for proposals) message has to include explicit service parameter aggregation definitions; i.e., the execution of the task (i) explicitly requires multiple services or (ii) can be realized with a composite service, potentially composed at run time. Once an agent has completed one or more tasks, it sends a message to the initiator in which the agent has to aggregate the results of the single services which have been utilized to execute the task. This can be realized using the parameter aggregation definitions in the cfp message.

The model checker Spin [4] accepts protocol specifications in the verification language Promela (a Process Meta Language) [3]. Towards a Promela model of the CCNP we construct finite state machines (FSMs) for the participants. Thus, we assign states to the participants for every (alternative) interaction on the basis of UML sequence diagrams. For model checking the protocol with Spin, the behavior of the agents in the FSMs is translated to Promela. In contrast to FSMs, Promela allows concurrency and recursion. In addition, incoming and outgoing messages can be differentiated. The Promela model[1] of the CCNP has to be limited to a finite number of tiers as Spin is not capable of arbitrary recursion depth. The model checker Spin can verify basic safety properties such as absence of deadlock, unreachable code, unspecified receptions, and invalid endstates on the basis of basic Promela models [4, p.9-10]. In addition, Spin will check the validity of user defined assertions. In order to verify the avoidance of overcommitment and overpurchasing, as well as proper termination of the protocol for a customer request, these requirements have to be expressed in a Linear Temporal Logic (LTL) formula which has to be translated to Promela[1].

For the simulation experiment, a set of customer requests is generated. Prices are assumed to be fixed for each SP on a given tier to prevent the influence of the price function on the simulation results. The experiment is executed with and without nested negotiations.

4. CONCLUSIONS

The contribution of this research is a multi-tier negotiation protocol for composite service provision over multiple supply chain tiers. The specification of the protocol is provided in UML sequence diagrams and a Promela model. The model checker Spin is applied to formally verify safety as well as liveness properties of the protocol; i.e., it is formally verified that the protocol avoids overcommitment and overpurchasing. First simulation results [7] show the applicability and utility of the protocol and provide evidence that the CCNP avoids overcommitment and overpurchasing.

5. ACKNOWLEDGMENTS

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