SLA Specification and Negotiation Model for a Network of Federated Clouds: CloudLend

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Abstract:
The Cloud computing paradigm is remarkably evolving. Cloud customers have become more conscious about the QoS expectation from Cloud providers' services. Accordingly, Cloud providers are required to be responsive to customers' demands, be open to establishing federations with other providers in order to retain their shares in the competitive Cloud market. Cloud customers are always searching for optimized services, irrespective of which providers are taking part in a federation to deliver these services. They seek federated Cloud services to attain the maximum satisfaction level, which is measured by the degree of adherence to customers' quality of service (QoS). Such federations of Cloud services are typically governed by service level agreements (SLAs) that are negotiated between the Cloud customer, provider prior to service provisioning. This paper tackles the challenges related to SLA specification, negotiation in a federated network of Clouds, CloudLend. We first propose a weighted SLA specification model that captures customers' QoS, manages multi-level SLAs specification. We then introduce an autonomous SLA negotiation model that adopts an enhanced fair division game. The model enables federated Cloud services to examine SLAs, react to SLA offers, eventually sign an SLA contract. It autonomously detects changes in Clouds federations, revises SLA specifications accordingly. The proposed model is evaluated using a CloudLend simulator, which we developed for this purpose. Several test cases were executed,, the results we have achieved verified the fairness, efficiency of our proposed SLA specification, negotiation models in CloudLend.

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SECTION I.
Introduction

Cloud federation is a composition of different Cloud services implemented by different Cloud providers, so as to realize a particular customer's objective. The concept of Cloud federation is still not widely endorsed by Cloud providers, even though it has been adopted in some confined environments, such as governments and enterprises where services' collaboration and integration take place between distributed datacenters. Nonetheless, customers expect to obtain guarantees on service provisioning from providers at any Clouds federation, whether it is a public or private federation. SLA contracts are the means to provide such guarantees. They govern and control service provisioning within Cloud federation. However, Cloud federation adds a level of complexity to SLA management because fulfilling a single customer request requires a composition of Cloud services. As such, composition involves the management of multiple aggregated SLAs. Therefore, clear and specific definitions of SLA parameters and metrics that precisely capture customers' QoS requirements and accommodate the multi-level nature of SLA terms in federated Clouds are essential. Additionally, federated Clouds entail dynamic SLA negotiation, as services' federations can fluctuate through service provisioning based on customers' changing QoS. SLA negotiation is a mutual decision-making process for the purpose of resolving providers' and customers' conflicting objectives [1]. SLA negotiation takes place prior to federation establishment. Past SLA negotiation approaches used in SOA, web services and grid computing have been adopted in several recent works on SLA negotiation in Clouds. Some other research initiatives have adopted concepts in intelligent software agents and game theory in SLA negotiation. In this work, we use the principle of game theory [2] with the aim of achieving efficient SLA negotiation, which results in a fair, envy-free, equitable partitioning of SLA terms among players.

To feature our SLA specification and negotiation model we apply it to *CloudLend*, a network of federated Clouds, which we described in a previous work [3]. *CloudLend* is a network of federated Clouds that provides many features; for example, it enables Cloud services' discovery, interaction and collaboration. SLAs bound connections established between members of *CloudLend*. As members extend their connections and establish new relationships with other members in *CloudLend*, they require multi-level SLAs to govern and maintain the growing network. In a previous work [4], we introduced an SLA management model for federated Cloud environments. We examined the life cycle of SLA in our *CloudLend* network while focusing on SLA monitoring schemes. In this work, we refined the initial SLA specification scheme by incorporating weights into the definition of SLA terms. Moreover, we further studied the life cycle of SLA management to include the negotiation phase and proposed an automated SLA negotiation scheme that fairly enables federated Cloud services to review SLAs, respond to SLA offers and eventually sign SLA contracts.

This paper is organized as follows: the following section explains the problem, and its motivation. Section 3 summarizes related work in SLA specifications, as well as the implementation of game theory for SLA negotiation in service computing. Section 4 introduces the weighted SLA specification scheme, while Section 5 describes an autonomous SLA negotiation scheme based on a fair division game. Section 6 provides an overall description of the proposed SLA specification and negotiation models. Section 7 explains our model's evaluation approach and discusses the achieved results. Finally, section 8 concludes the paper and highlights planned future work.

SECTION II.
Problem and Motivation

Normally in Cloud computing, SLAs are defined by Cloud providers, and are published for customers to consider in a sort of “take-it-or-leave-it” approach. Customers do not get an adequate opportunity to review or negotiate SLAs in a way that grants them the privilege to impose their QoS requirements on Cloud providers. Enabling Cloud federation through portable APIs in order to provide value-added services is well considered as a dynamic and composite problem because choosing the most suitable Cloud service to participate in a federation, considering a set of customer-defined QoS requirements is a multi-criteria and multi-decision problem. A federation is required to match a customer's requirements, through an aggregated selection of Cloud services from different providers having different interests. Thus, SLA specification in a federated Cloud environment requires a comprehensive deliberation of the multilevel nature of connections among Cloud services. SLAs need to be defined in an aggregated manner so that the complexity of managing a chain of SLAs is hidden from the customer. Yet, constituent parameters need to be specifically defined and mapped each to the contributing services. Also, connections among Cloud services in such environments are dynamic. Cloud services can frequently initiate, abandon or fail relationships. When SLA definition distinctively captures the multi-level nature of federated Cloud environments, adaptation to changes becomes feasible, though this requires some autonomous mechanisms to detect relationship changes and revise SLA specifications accordingly.

SLA negotiation requires particular considerations because of specific characteristics exhibited by *CloudLend*. Cloud services' interconnections in the network are triggered by customers' requests. However, in most cases, connections can extend to reach further services in order to carry out minor subtasks that cannot be fulfilled by the contracted service. Furthermore, a Cloud service can establish connections with one or several other Cloud services simultaneously, which results in a chain of interconnected services that are managed by multilevel SLAs.

Therefore, there exists a need for a comprehensive and specific definition of SLA parameters and metrics, in addition to an autonomous SLA negotiation scheme that fairly enables federated Cloud services to review SLAs, respond to SLA offers and eventually sign an SLA contract. In *CloudLend* a negotiation scheme is required to manage the negotiation process, considering the complexity added by services' interconnections within the network. Therefore, the federated network will not be burdened by the multi-level SLA negotiation process. Additionally, SLA negotiation must not impede Cloud providers' resource utilization or overlook customers' QoS requirements. Hence, motivated by the lack of thorough and autonomous SLA specification and negotiation schemes in federated Clouds, we intend to achieve the following research objectives:

1. Propose a weighted SLA specification model to
    - clearly specify QoS requirements for customers and SLA parameters for Cloud providers,
    - identify and detect multi-level SLAs,
    - enable user-defined weights to prioritize SLA terms, and
    - allow adaption to changes in multi-SLA specifications.
2. Propose a game theory-based automated SLA negotiation model that is capable of
    - balancing the trade-offs among customers' various QoS requirements, as well as providers' resources utilization;
    - prioritizing the most important SLA terms to both Cloud customers and providers;
    - supporting both customers and providers in negotiation management; by automating the negotiation process, users can carry out multiple negotiation sessions simultaneously;
    - assisting customers in service selection by enabling evaluation of different service alternatives based on fair SLA terms' allocation; such allocation elects fair provisioning of a particular SLA term over the period of the SLA contract; and
    - evaluating the efficiency of the proposed SLA specification and negotiation model in a federated Cloud environment, *CloudLend*.

SECTION III.
Related Work

This section, surveys both research efforts on federated Cloud SLA specification and negotiation as well as research initiatives on game theory-based SLA negotiation.

A. Federated Cloud SLA Specification and Negotiation

A framework for SLA management is introduced in [5]. The framework is based on web service level agreement (WSLA) and is intended for inter-Clouds environments. The authors aim to address all phases of the SLA life cycle as defined by IBM [6]. They use an XML-based language to specify SLA parameters. Nevertheless, the framework does not specify how SLA negotiation is carried out. The framework also considers the effect federated Clouds have on SLA management in the specification phase only.

The authors in [7] introduce SLA@SOI, an SLA management framework for service-oriented environments. The proposed framework considers all phases of the SLA life cycle and is based on two modules: one manages SLA specification, while the other handles communication between other SLA management components. The SLA@SOI project addresses fundamental issues in SLA management, yet it is implemented in private, controlled, enterprise-like environments. Even though composed SLA management is considered within the framework, service discovery and binding are assumed to be arranged in advance between the business entity and Cloud provider.

B. Game Theory-Based SLA Negotiation

Game theory aims to optimize negotiation outcomes using several initiation conditions [8]. Studies in this area pay perfunctory attention to the characteristics of the negotiation process itself and are not concerned with the interaction between involved parties. On the other hand, the outcome of the negotiation process is what really matters. For any given negotiation game, the satisfaction level of different notions of an optimal solution is evaluated by the game's outcomes. We review research efforts on the implementation of game theory for SLA negotiation in service computing.

The authors in [9] implement a bargaining game approach to describe an automated one-to-one SLA negotiation for web services, while SLA negotiation in Cloud computing is implemented using another bargaining game in [10]. Both researches consider a two-player game with an assumption that players have complete information on the game's strategies, as well as on the corresponding outcomes of each other. In real time Cloud service provisioing, that assumption is not necessarily correct. A mathematical negotiation model is described in [11] for high-performance computing (HPC). The model implements a two-round signaling game; this type of game is either cooperative or competitive, which is unlike our proposed fair division negotiation game, which is strictly competitive. On the other hand, the problem of resource allocation in competitive grids is described in [12]. The authors present a negotiation strategy that leads to a fair resource allocation. However, SLA negotiation in grids and HPC is less complicated than SLA negotiation in Clouds. It is considered a straightforward process: customers directly contract with providers for some specific resources they are interested in utilizing. Nevertheless, the complexity of negotiation in Cloud environments is driven by market competition. In [13], a generic SLA negotiation platform is proposed for the SLA@SOI [14]. This research studies SLA negotiation protocols; nonetheless, our research focuses on SLA negotiation strategies.

To the extent of our knowledge, there is no SLA management model that captures the aggregated SLA specification properties of federated Clouds and guarantees efficient, simultaneous SLA negotiation processes. Our approach uses XML [15] to describe accurately multi-level SLAs, as well as to share them among different members of the *CloudLend* network unambiguously, without the need for any data conversion. Additionally, the proposed SLA negotiation model implements a fair division game [16] that is multi-player and sequential. This type of game assumes that players have perfect information on all former events that took place prior to their decisions, which makes the fair division game applicable for implementation within *CloudLend*.

SECTION IV.
SLA Specification Model

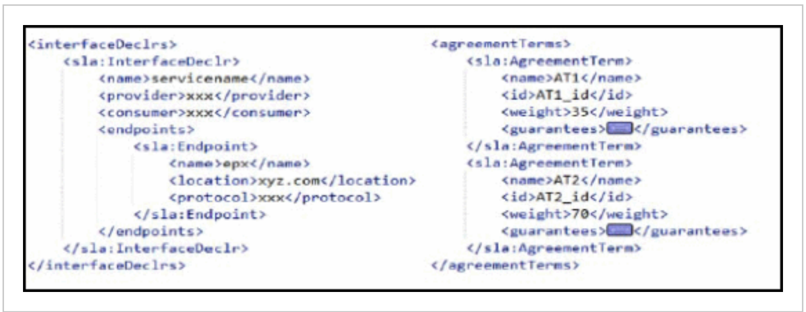
In this section, we describe the SLA specification model in *CloudLend*. SLAs in *CloudLend* are specified using XML [15]. XML provides a common syntax for interoperability among Cloud services within the network. XML is used to describe accurately a *CloudLend* member's profile, identifies member's QoS requirements and defines member's relationships. We propose an XML-based SLA specification model that contemplates the challenging characteristics of *CloudLend* and extends the SLA specification model in [4] in order to provide an SLA definition scheme, as described below:

1) For Every Cloud Service in CloudLend

An SLA profile is published for other Cloud services to review. This public profile is used by the *CloudLend* network to facilitate Cloud services selection and matchmaking. Once a customer selects a Cloud service to utilize, SLA negotiation and binding occurs. The public SLA profile in Fig. 1 includes the following specifications:

1. *Information related to the Cloud service*: e.g., service name, type, provider and reference to the service implementation interfaces.

2. *Information on QoS terms and their assigned weights*: terms' weights indicate the percentage of how much a *CloudLend* member values preserving his or her specified parameters for each SLA term.



```
<interfaceDeclrs>
    <sla:InterfaceDeclr>
        <name>servicename</name>
        <provider>xxx</provider>
        <consumer>xxx</consumer>
        <endpoints>
            <sla:Endpoint>
                <name>epx</name>
                <location>xyz.com</location>
                <protocol>xxx</protocol>
            </sla:Endpoint>
        </endpoints>
    </sla:InterfaceDeclr>
</interfaceDeclrs>

<agreementTerms>
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        <guarantees></guarantees>
    </sla:AgreementTerm>
    <sla:AgreementTerm>
        <name>AT2</name>
        <id>AT2_id</id>
        <weight>70</weight>
        <guarantees></guarantees>
    </sla:AgreementTerm>
</agreementTerms>
```

Fig. 1.
A sample of public cloud service SLA profile specification.

2) For Every Relationship Established Between Two Cloud Services

Within a Service Federation in CloudLend

An SLA document is generated to includes the following specifications:

1. *Information on both services engaged in the relationship*: service name, type, provider and reference to the service implementation interfaces, as described in Fig. 2.
2. *Information on the agreed upon relationship*: reference, type, initiator service, attendant service, time of creation and validity period; see Fig. 2.
3. *Information on QoS terms*: name, parameters and allocations, as described in Fig. 3.

```
<participants>
    <sla:Participant>
        <name> service_x </name>
        <id> x_id </id>
        <role>provider</role>
    </sla:Participant>
    <sla:Participant>
        <name> service_y </name>
        <id> y_id </id>
        <role>customer</role>
    </sla:Participant>
</participants>
```

```
<relationship>
    <sla:Relationship>
        <id> rcs_xxx </id>
        <agreedAt> 12/02/2016</agreedAt>
        <effectiveFrom> 01/03/2016 </effectiveFrom>
        <effectiveUnitl> 30/03/2016 </effectiveUnitl>
    </sla:Relationship>
</relationship>
```

Fig. 2.
A sample post-negotiation SLA: Relationship specification.

If an SLA term is realized by hiring another sub-service, the attendant service shall maintain a reference tn that sub-SLA document. References to both parent and child SLAs are maintained by an SLA management service implemented by the *CloudLend* network, which holds records on all established relationships on the network. In the case of unexpected relationship changes, the relevant SLA management service instance is notified so that required action measures are taken to revise affected SLA terms.

```
<agreementTerms>
    <sla:AgreementTerm>
        <name>AT1</name>
        <id>AT1_id</id>
        <allocations>
            <sla:allocation>
                <id>x_id</id>
                <allocationPortion>35%</allocationPortion>
                <guarantees></guarantees>
            </sla:allocation>
            <sla:allocation>
                <id>y_id</id>
                <allocationPortion>65%</allocationPortion>
                <guarantees></guarantees>
            </sla:allocation>
        </allocations>
    </sla:AgreementTerm>
</agreementTerms>
```

Fig. 3.
A sample post-negotiation SLA: Terms allocations.

SECTION V.
Enhanced SLA Negotiation Scheme Based on Game Theory

This section describes the SLA negotiation scheme in *CloudLend*. It introduces an enhancement to the previously adopted game in [17].

A. Model Description

As members in *CloudLend*, Cloud customers and services take part in the SLA negotiation game without an intention to win the game eventually. On the contrary, they intend to obtain the best allocation of SLA term that satisfies both players' requirements. The outcome of the SLA negotiation game is mainly an indication of the value a player would gain by establishing a connection with the other player. Such outcome is known as a player's *utility* in game theory. In *CloudLend*, SLAs are negotiated so that players get to evaluate the expected utility of a prospected connection, which they then use to assist in the decision of relationship establishment. Our proposed SLA negotiation scheme considers an SLA contract as a whole article that is composed of numerous, dividable SLA terms. Hence, through an SLA negotiation game, players bargain over the value of each individual SLA term, which sums up to realize the utility gain of the whole SLA contract. Every player values each individual SLA term differently. Ultimately, both players need to reach an agreement on the weight that every individual SLA term has on the total value of the SLA contract.

The SLA negotiation problem in *CloudLend* can be considered as a fair division game [16]. This type of game involves players in a sequential game over an item to be shared. Every player values that item differently, but they need to settle on the way to divide it among them. Fair cake-cutting [16] is an example of a fair division game, where a cake with different toppings is to be shared among multiple players, who prefer different parts of the cake. The division of the cake must be fair to all players. In this case, a fair share means that each player receives a slice of the cake with his or her preferred topping. Similarly, in *CloudLend*, the SLA contract is correspondent to the cake. Players will have different preferences for the SLA terms included in the contract. Ultimately, they need to reach an agreement on the impact of each individual SLA term on the overall value of the negotiated SLA contract. Generally, in situations where multiple players need to share a set of items but those items must be kept as a whole, a proportional and envy-free division procedure is used [16]. Such schemes include the adjusted winner (AW) procedure [18]. Once the AW game is played out, its outcome is proven to exhibit three important properties:

1. *Pareto optimal*: any alternative allocation of items that improves one player's outcome will worsen the other's;

2. *envy-free*: each player is allocated a share of items that is at least as large or at least as desirable as that received by any other player; and

3. *equitable*: every player believes that his or her allocation is valued the same as the other player's (based on their declared weights).

The AW procedure assures a fair division of a set of n items that are to be divided between two players. Every player has 100 points as a total weight to distribute among \boldsymbol{n} items. These points are a relative preference of the players for all weighted items in the set. In a previous work [17], we adopted the AW procedure as the most appropriate model of SLA negotiation in *CloudLend*. A list of essential elements of the SLA negotiation game is described as follows:

1. *Players* are the decision makers. Each has a goal to maximize his or her utility by choosing the appropriate actions. In *CloudLend* players are Cloud customers and Cloud providers.

2. *Actions* are choices available for players to make. In *CloudLend*, players' possible set of actions includes place an SLA offer, accept an SLA offer, reject an SLA offer, place an SLA counteroffer and end an SLA negotiation.

3. *Strategy* of a player is a rule that tells him or her which action to choose at each moment of the game, given his or her information set about the game and other players. In *CloudLend*, a player's strategy is represented by weights of SLA terms.

4. *Outcome* is the result of a player deciding to settle on a particular strategy, measured numerically. In *CloudLend*, the outcome of the negotiation game is allocation of SLA terms.

B. Tie-Breaking Rule for AW Procedure

In the case of both players sharing identical utilities for all negotiated items, AW yields an allocation that is characterized to be equitable but not Pareto optimal, nor envy-free due to the tie-breaking method used by AW, which starts by allocating all terms to one player and then starts transferring terms of lower weights to the other player until equality attained [19]. This is the case when both players equally strive to obtain the same SLA terms and submit identical weights for each SLA term. Consequently, as the number of negotiated SLA terms increases, chances are that one player is assigned the most highly weighted terms and the other is assigned the least highly weighted terms, which is an equal allocation, yet not fair. Therefore, we propose a tie-breaking rule, which in the case of both players sharing identical weights for all SLA terms, gives every player 50% of every SLA term in the negotiation contract. SLA terms allocation under this rule is Pareto optimal, envy-free and equitable because it splits all SLA terms between both players, giving half of every SLA term to each player [20].

SECTION VI.
Overview of the SLA Specification and Negotiation Model

The *CloudLend* network is a collection of interconnected Cloud services and customers that collaborate and form a network of Clouds. *CloudLend* aims to facilitate the provisioning of composite Cloud services by promoting collaboration among Cloud providers. Fig. 4 presents an overview of the *CloudLend* network. Members of *CloudLend* perform service lookup by browsing public SLA profiles published by other Cloud services in the network. A Cloud customer can initiate multiple negotiation sessions with a number of nominated Cloud services that potentially meets his or her requirements, as described in Fig. 5.

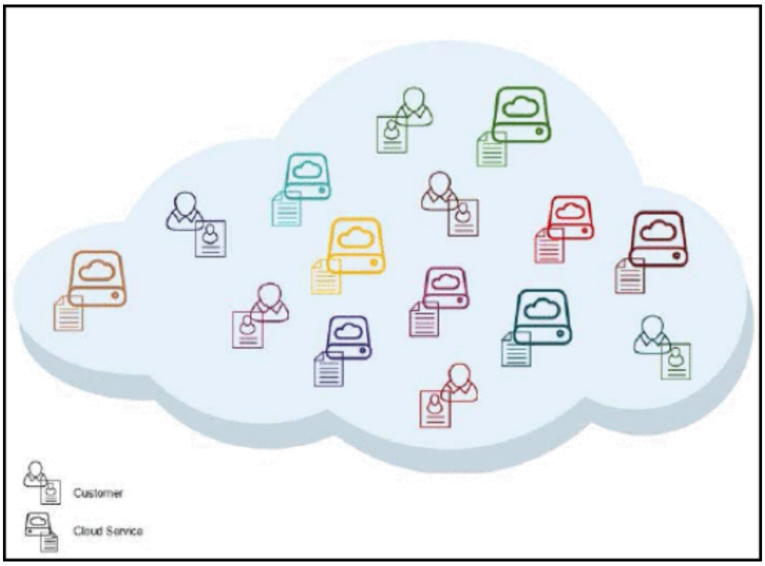

Fig. 4.
Relationship evaluation in *CloudLend* simulator.

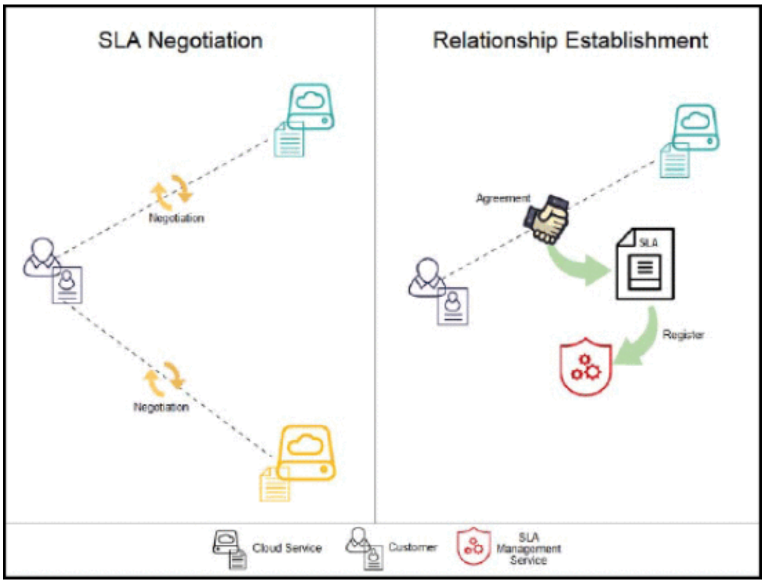

Fig. 5.
Overview of SLA negotiation in *CloudLend* network.

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Based on the SLA terms allocation result of the AW-based negotiation, the customer selects a Cloud service to hire. Consequently, a relationship is established and an SLA document is generated and registered by an SLA management service implemented by the *CloudLend* network.

SECTION VII.
SLA Negotiation Model Evaluation

This section introduces our *CloudLend* network simulator, explains test strategies that were carried out to evaluate the efficiency of our proposed model and presents our model's evaluation findings.

A. Cloudlend Network Simulator

To validate the efficiency of our proposed model, we ran several SLA negotiation test cases that compute the satisfaction level of both Cloud customers and providers. To achieve this, we implemented a *CloudLend* network simulator using the JUNG framework [21], which is a Java framework for graph visualization and network analysis. The simulator implements the following features:

1. *A graph generator* creates a random *CloudLend* graph of n members; each has m SLA terms with their weights published.
2. *The SLA negotiation manager* finds out the actual SLA terms allocations gained by executing the AW procedure.
3. *The federation evaluator* evaluates a potential relationship with any given *CloudLend* members. Relationship evaluation is carried out as illustrated in the Algorithm 1, Fig. 6. The algorithm begins with finding the expected SLA terms allocation for a negotiated SLA contract based on players' submitted weights. Next, the actual SLA terms allocation is found by running the AW procedure. Both allocations are finally compared to obtain the model's accuracy level.

Algorithm 1 Evaluate relationship in CloudLend simulator

Input: Array a_t includes all negotiated SLA terms weights

procedure EXPECTED-SLA-ALLOCATION(a_t)
    for each term t_i in a_t **do**
        Set array $a_x(t_i)$= ISEXPECTED($w^{t_i}_{p1,p2}$)
    end for
    Return a_x
end procedure
procedure ACTUAL-SLA-ALLOCATION(a_t)
    Set array a_c= AWPROCEDURE($w^{t}_{p1,p2}$)
    Return a_c
end procedure
procedure ACCURACY-LEVEL(a_x, a_c)
    for each term t_i in a_t **do**
        if $a_x(t_i) = a_c(t_i)$ **then**
            $z^{t_i}_{a_x,a_c} = 1$
        else if $a_x(t_i) a_c(t_i)$ **then**
            $z^{t_i}_{a_x,a_c} = 0$
        else if $w^{t_i}_{p1} = w^{t_i}_{p2}$ **then**
            $z^{t_i}_{a_x,a_c} = 0.5$
        end if
    end for
    $AccuracyLevel = \frac{\sum_{t=0}^{n} z^{t_n}_{a_x,a_c}}{n} * 100$
    Return $AccuracyLevel$
end procedure

Fig. 6.
Relationship evaluation ia *CloudLend* simulator.

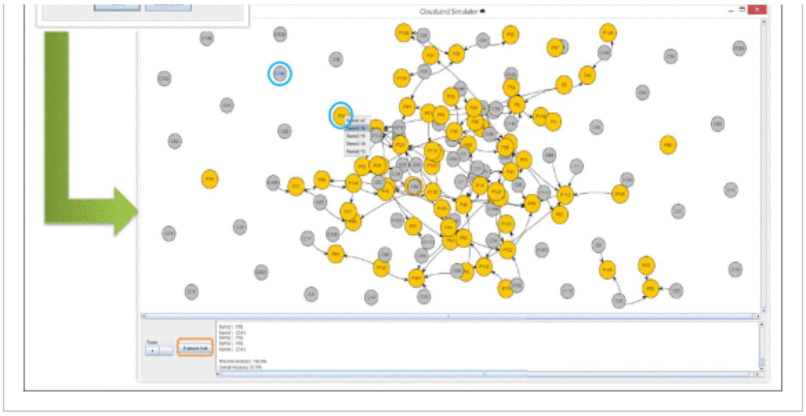

Fig. 7.
Snapshots of *CloudLend* simulator

B. Test Strategies

We ran the *CloudLend* simulator with several SLA terms and different SLA terms' weights. A sample test run in *CloudLend* simulator is illustrated in Fig. 7. For every test run, we calculated the model's accuracy level, which measures the difference between players' expected SLA terms allocation and actual SLA terms allocated by our proposed model. During any particular negotiation round initiated between a Cloud customer and a provider, the negotiated SLA contract shall include a number of SLA terms. In this test, we considered 5, 20 and 50 terms. The SLA terms' weights provided by the two players, customer and provider, shall be experimented upon as follow:

1. *Strategy 1*: Each player provides different and independent weights of all SLA terms.
2. *Strategy 2*: Both players provide identical weights for all SLA terms.
3. *Strategy 3*: Each player adopts a single-choice strategy, where a player allocates most of his or her weights to a single SLA term and neglects the others.

C. Results and Discussion

Fig. 8 illustrates the model's accuracy level in cases when the number of negotiated SLA terms is 5. When players provide different and independent weights, the negotiation model provides 93%–97% accuracy. However, it achieves 100% accuracy when both players submit identical weights for all SLA terms. Nevertheless, the model provides 94%–96% accuracy when players adopt the single-choice strategy.

Fig. 9 illustrates the model's accuracy level in cases when the number of negotiated SLA terms is 20. When players provide different and independent weights, the negotiation model provides 94%–97% accuracy. However, it achieves 100% accuracy when both players submit identical weights for all SLA terms. Nevertheless, the model provides 93%–96% accuracy when players adopt the single-choice strategy.

Fig. 10 illustrates the model's accuracy level in cases when the number of negotiated SLA terms is 50. When players provide different and independent weights, the negotiation model provides 83%–86% accuracy. However, it achieves 100% accuracy when both players submit identical weights for all SLA terms.

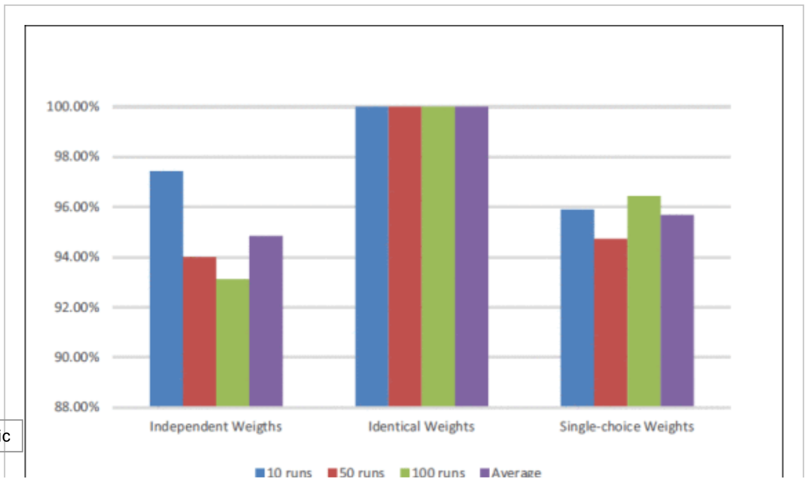

Fig. 8.
Accuracy level when no. of SLA terms: 5

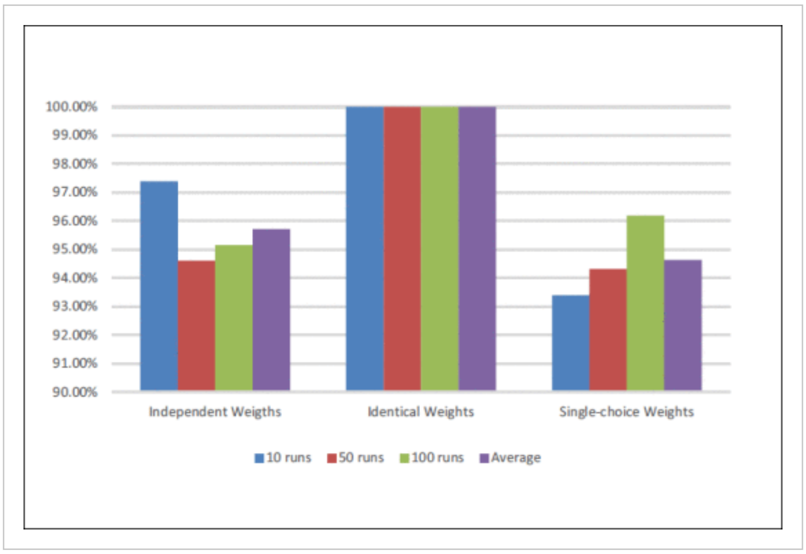

Fig. 9.
Accuracy level when no. of SLA terms: 20

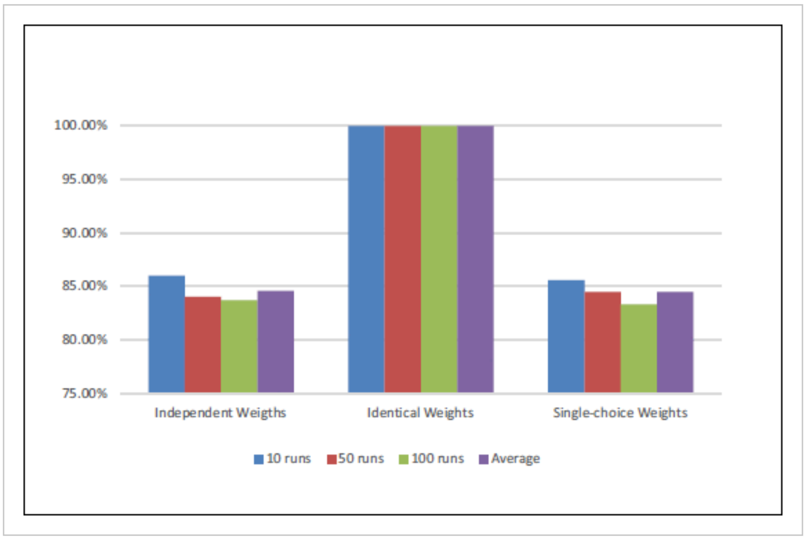

Fig. 10.
Accuracy level when no. of SLA terms: 50

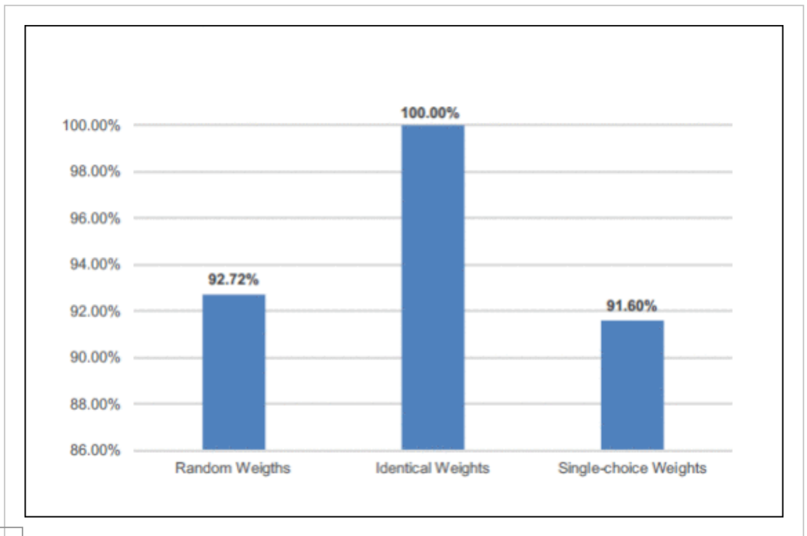

Fig. 11.
Overall average accuracy for all test cases

Overall average accuracy for all test cases

Nevertheless, the model provides 83%–85% accuracy when players adopt the single-choice strategy. Noticeably, the model's accuracy level marginally drops as the number of SLA terms increases. This is owing to the fact that the more terms to be included, the fewer points, out of the total 100 points, are available for weighting. This decreases the distance between submitted weights and increases the error ratio of misallocating terms when computing the expected terms allocation.

Fig. 11 summarizes the average accuracy level for the different numbers of negotiated SLA terms when adopting different negotiation strategies. As a result, we can see that the proposed model provides an acceptable accuracy level, regardless of the played out strategy or the number of SLA terms included in the negotiation game.

Conclusion

In this work, an SLA specification and negotiation model for federated Cloud services was proposed. The model proposed an SLA specification scheme that adapts to changes in multi-level SLAs. Additionally, it employed a fair division game called *Adjusted Winner* within the process of SLA negotiation in *CloudLend*. We illustrated an enhancement of the *Adjusted Winner* procedure and explained how it is implemented within the *CloudLend* network. Finally, several test cases were carried out in order to evaluate the efficiency of our proposed model using a *CloudLend* simulator we developed for this purpose. Results we have obtained demonstrate fair allocation of SLA terms among negotiating *CloudLend* members and prove the efficiency of our proposed SLA specification and negotiation model. As future work, we intend to study how our proposed model will affect the optimization of Cloud customers' satisfaction level, as well as the cost engaged by Cloud providers to satisfy customers' QoS preferences.

Keywords

IEEE Keywords
Cloud computing, Games, Quality of service, Game theory, Resource management, Computational modeling, Contracts

INSPEC: Controlled Indexing
quality of service, cloud computing, contracts, game theory

INSPEC: Non-Controlled Indexing
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