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Using Reputation Information on Internet-of-Services Markets

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ABSTRACT

The paper identifies trusting problems between autonomous services in the Internet-of-Services (IoS). This scenario vision describes a general computational paradigm, which allows companies to procure computational resources externally. The arising conflicting interests between providers and consumers lead to strategic behaviour of single services. Usually trust and reputation models are proposed to set incentives for acting honestly. But when using Double Auctions to match buyers and sellers, these trust and reputation models fail to close this "trusting gap". This paper proposes a modified Double Auction protocol fulfilling the deducted requirements. Simulation experiments show that the usage of this modified protocol leads to increased trustworthiness for the participants.

1. INTRODUCTION

The increasing dynamic of markets leads for companies to the need of adapting their processes to continuously changing environment. For every-day business, the use of computationally intensive information technology (IT) seems essential to implement new flexible business models within a short time.

The *Internet-of-Services (IoS)* describes a general computational paradigm, which allows companies to procure computational resources externally and thus to save both internal capital expenditures and operational costs. The notion of Internet-of-Services follows the idea of consuming different services externally, provided by distinct Service Providers (SP), but from a blurred cloud of resources within a single business unit or even between different businesses [10]. As the interaction frequency is assumed to be very high and the volume of a single interaction is assumed to be very small, the whole process has to be fulfilled without human interaction. The process includes finding a suitable SP, negotiating with it, invoking the service and fulfilling some post-processing steps if necessary.

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To match providers and consumers, an efficient allocation mechanism between service demand and supply is needed: a market [28]. But introducing a market will lead to other problems, for example asymmetrically distributed information between SPs and consumers. SPs usually have more information about quality or availability of the services they provide, than Service Consumers (SC). Further, the effectively provided functionality might differ from the promised functionality. This case of asymmetrically distributed information usually leads to suboptimal results due to the uncertainty on the consumer side, and thus to an inferior usage of the service environment in total. Contrarily, consumers have more information about their liquidity. In addition, both interaction participants deal with uncertainty caused by environmental factors (for example network failures).

One common way to overcome this asymmetrical information distribution is the usage of trust and reputation models [13]. The own experiences, experiences from other participants or just gossiping received from other participants about a target service can influence one's behaviour. The usage of trust and reputation models is quite common in decentralized environments, because no central entity has to be implemented that has central knowledge or even central control.

From Electronic Commerce research different payment models are "known": the *pay-before* model determines the payment before a service invocation takes place, the *pay-later* model works vice versa. The choice of the payment model directly impairs the direction of the aforementioned asymmetrical information distribution. These models are also assumed for IoS.

This paper will especially focus on the usage of Double Auctions to coordinate a future IoS. Coordinating sellers and buyers by a Double Auction means, that there is a central Auctioneer that receives the bids of sellers and buyers. The Auctioneer matches these bids following a known algorithm, which determines the price [22]. Following Streitberger et al. [28], a Double Auction represents an efficent mechanism to coordinate resource allocation in service systems.

With this paper we are going to investigate the question if it is possible to use reputation information in order to achieve trustworthy interactions in a Double Auction-coordinated IoS environment. Therefore, the paper is structured as follows: whereas section 2 presents foundations and related work for this paper, section 3 explains the proposed design of the Double Auction protocol. Section 4 demonstrates and evaluates the proposed protocol in combination with the $AVALANCHE_{dec}$ reputation model. Finally, section 5 concludes the paper and presents future work.

2. FOUNDATIONS AND RELATED WORK

This section presents foundations of the work and related work. Foundations can be split into the *AVALANCHE* reputation model, requirements and hypotheses on Double Auctions that are deducted from literature. Related work comprises papers regarding trusting relationships between the actors Seller, Buyer and Auctioneer.

2.1 AVALANCHE Reputation System

Trust and reputation models have been discussed in research extensively in the past (see for example [25]). Due to the simple requirements a reputation model has to fulfil as soon as it is assumed that no cognitive acting humans are directly involved, we chose a simple mathematical model to discuss the usage in Double Auctions: "*AVALANCHE*". Discussing the generalizability of the findings for other models will be not part of this paper.

Padovan et al. [19, 20], the authors of the *AVALANCHE* system, denote their reputation coefficient as R_Y^X, whereas X denotes the identity of the rating software agent (Evaluator), and Y denotes the identity of the rated agent (Target). The reputation coefficient obtains values in between $0 \leq R_Y^X \leq 1$. $R_Y^X = 1$ denotes the best reputation (target agent seems to be a reliable agent), $R_Y^X = 0$ denotes a bad reputation (target seems to be non-cooperative). Per se the reputation coefficient represents a private value for each agent, such that two different agents might differ in their coefficient about target agent three: $R_3^1 \neq R_3^2$. "In general, the reputation coefficient is used to adapt the software agent's negotiation strategy according to its partner's expected cooperative behaviour." [19, p. 6]

To structure the trust and reputation mechanism, Padovan et al. distinguish four stages: obtaining the reputation coefficient, adapting this coefficient to the own negotiation strategy, rating the partner's behaviour after the transaction and last but not least the distribution of the reputation information.

2.1.1 Obtaining Reputation Information

Within the obtaining stage, Padovan et al. [20] identify three different cases: The target agent is unknown for all agents. In this case the agent has to estimate the risk of an interaction with the target. To do that, the authors propose as an alternative to a default value between 0 and 1 the average value of all known reputation values. If no reputation value is available (first interaction), a default value has to be chosen.

If the agent has already made personal experiences with the target, the agent can use its personal own information about the target's cooperative behaviour and eventually take further information from others, for example if this information is not reliable.

Table 1: Assessment of price and reputation [19]

I	Y_i	p_i	$R_{Y_i}^X$	$2 - R_{Y_i}^X$	p_i^*	rank
1	12	47	$R_{12}^X = 0.63$	1.37	64.39	2
2	3	52	$R_3^X = 0.65$	1.35	70.20	3
3	16	54	$R_{16}^X = 0.85$	1.15	62.10	1
4	5	56	$R_5^X = 0.44$	1.56	87.36	4

2.1.2 Adapting Reputation Information to Negotiation Strategies

At the beginning of the negotiation phase (after the information phase) the agent has received a list of potential interaction partners. These offers and the corresponding agents are ranked in by an assessed offer price $p_{Y_i}^*$ that is calculated based on the initial offered price p_{Y_i} and its reputation coefficient $R_{Y_i}^X$: $p_{Y_i}^* = p_{Y_i} + (R_{Y_i}^X * 0 + (1 - R_{Y_i}^X) * p_{Y_i}) = p_{Y_i} * (2 - R_{Y_i}^X)$

Table 1 illustrates one example with four offers. The agent X starts to negotiate with partner number 16. If this negotiation fails, X will negotiate with number 12 [19].

2.1.3 Rating Cooperative Behaviour

After each settlement phase of a transaction, the agents are able to rate each other. This value is denoted by the authors with r_j, whereas j represents the index of the transaction. Successful transactions are rated with $r_j = 1$ (best value), unsuccessful transaction are rated with $r_j = 0$ (worst value) [19].

2.1.4 Distribution and Updating

This obtained rating value r_j updates the reputation coefficients of the involved transaction partners X and Y. To emphasis latest ratings compared to older ones, the authors use an average weighting calculation with a weighting factor α. This weighting factor can be instantiated by the agent owner. Following, the new reputation value is calculated as follows: $R_{Y_i}^X = R_{Y_{i-1}}^X * (1 - \alpha) + r_j * \alpha$. If a global reputation agency is used (centralized model), a global value for α has to be defined. Based on the assumptions on future IoS environments we avoid using a central unit that coordinates the reputation values.

The main difference of a decentralized to a centralized reputation mechanism is not the concept itself. Instead the process of exchanging reputation information increases in its complexity. While in a centralized model, as *AVALANCHE* represents one, the reputation unit manages all published reputation information, in a decentralized model neighboured agents have to be requested for information on other participants. Each participant has to manage reputation information for its own. In order to extend the initial *AVALANCHE* model to the decentralized version $AVALANCHE_{dec}$, we just have to modify the reputation communication process.

For the remaining paper, we are assuming the decentralized version of the reputation model. That model has been validated against the original model within the SimIS [15] environment before conducting the simulation experiments. The used replication methodology follows the replication replication process model of Sansores and Pavon [27] and bases on experiments and corresponding simulation data of [19]. The result of this replication has been positive.

2.2 Hypotheses on Double Auctions and Reputation Usage

In order to define the requirements for the research artifact [12], we will present the hypotheses that have been deducted from literature review in König et al. [16] (see table 2). The table combines the negotiation roles Service Provider (SP), Service Consumer (SC) and Auctioneer (Auct.) with the two possible payment models *pay-before* and *pay-later*. Using one of the two payment models determines whether the SC or the SP role acts as trustee (has cheating possibility).

Agents acting strategically regarding the reputation model usage might have different interests regarding the process of generating and distributing ratings. This includes the rating of target agents and the memetic acting, that means participating in gossiping. This subsection considers the overlapping of the reputation roles describing the agents' participation in the overall reputation process.

In their work, Conte and Paolucci [11] define the four different agent roles as follows:

- The set M is a group of agents that sends information to other agents.
- Set E are all agents which evaluate a certain target T.
- Set T, on the other side, are the agents which are evaluated by E.
- Finally, set B is defined as a group of beneficiaries that benefit from the evaluations performed by the evaluators (set E) about the targets (set T) that can be spread through the memetic agents (set M). The beneficiaries benefit from it as they receive information about the degree to which the target conforms with the social norm. [11, p. 74 et seqq.]

As soon as two or more roles overlap, certain effects regarding the reputation model can occur [11]. For us, especially two hypotheses are of interest:

H1: $B \simeq E, B \cap T = E \cap T = \emptyset$: The overlapping of the sets B and E and the non-overlapping of T lead to working reputation system, because participants are motivated to provide their own experiences, the reputation system works well.

H2: $B \cap T, B \cap E = E \cap T = \emptyset$: As soon as all sets are disjunctive from each other, the participants have no incentives to participate at the reputation system.

Even if we implement a model like $AVALANCHE_{dec}$, it is not possible to gain an adequate system when using Double Auctions. The problem in this case is that neither the SC nor the SP are fulfilling the Beneficiary role. Instead, only the Auctioneer in terms of a Double Auction might benefit from correct ratings due to a higher fulfilment of its users' expectations.

Table 2: Reputational Configurations in Double Auctions (following [16])

Negot.	**Trustee**	**SP**	**SC**	**Auct.**	**H1**	**H2**
DA	SP	T	E	B	No	**Yes**
	SC	E	T	B	No	**Yes**
DA_{Rep}	SP	T	E,B		**Yes**	No
	SC	E,B	T		**Yes**	No

2.3 Requirements on Trustworthy Double Auctions in the IoS

The mechanism this work is going to design and develop should focus on the trust relation between the set of buyers and the set of sellers. In addition, the coordination mechanism should be denoted by a Double Auction.

R 0 The mechanism to design must focus on the trusting relationship between the set of sellers and the set of buyers. Further, a Double Auction mechanism has to be used in order to fill the identified research gap.

In order to reach *H1* instead of *H2*, we have do find a configuration of the Double Auction protocol that shifts the B role (Beneficiary) from the Auctioneer to the SC in the pay-before case and respectively to the SP in the pay-later case (see table 2). If it is possible to design such a mechanism, the trustor can use reputation information in order to choose negotiation partners. For the trustee on the other hand, this information is not important as it can not be cheated during the interaction. We will hold this requirement as following:

R 1 The trustor must be able to use its information on the reliability of the matched partner or the partner to match in order to benefit from this information.

In order to design the mechanism as flexible as possible, it should be resistant against a change in the payment model. This means that a change of the payment model from pay-later to pay-before should have no effect on the system and vice versa. If the mechanism would be able to fulfil this requirement, a change of the payment model would not determine major changes in mechanism design. Further, the required flexibility regarding the trustor-trustee relationship will enable a pay-later or a pay-before or even an arbitrary combination of both models.

R 2 The protocol to be designed should work in a symmetric way in order to stay flexible to changes in the trustee-trustor relationship. This change can be determined by the change of the payment model.

The Auctioneer has to follow clear rules in order not to adulterate the economic outcome of the matching process. That is, the decision for matching a SC and a SP should be made by each side based on the reliability, which is indicated by the available trust and reputation information.

The decision should not be possible based on price information. More concrete, as soon as SP and SC are matched, each side should be able to refuse the partner based on its information on the former behaviour and not on the price.

R 3 SP and SC must be able to decide on the acceptance of an offer based on the former behaviour of the opponent and not based on the price of the matching (see for example [34])

2.4 Trusting Relationships between Auctioneer, Seller and Buyer

Within this subsection, we are going to consider approaches that regard the trusting relations between the Auctioneer, the set of sellers and the set of buyers. Figure 1 illustrates the three different emerging trusting relationships [30].

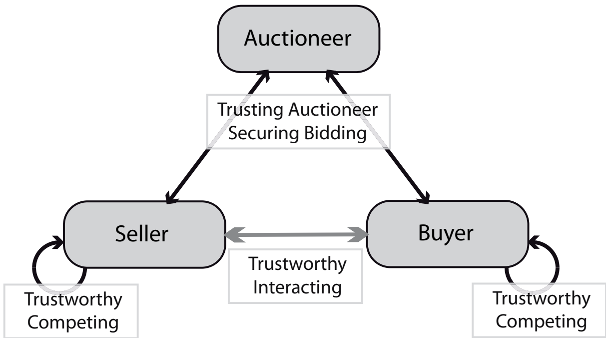


Figure 1: Classification of Competing Approaches, in analogy to [30, p. 145]

The first category regards the trusting relationship between the role of an Auctioneer and the role of bidders. Bidders can be divided into the set of sellers and the set of buyers. These groups are integrated to the group of bidders due to the fact that the trust relation does not differ between the set of sellers and the set of buyers.

Franklin and Reiter [14] mention in their work some of the most important challenges when designing electronic auctions with an Auctioneer instance: the Auctioneer can inform a collaborator regarding submitted bids, the closing time could be manipulated, such that interested bidders are not able to submit their intended bids, the Auctioneer could accept bids after the closing time, the Auctioneer could award the auction to another bidder than the winning bidder, the Auctioneer could collect money from the non-winning bidders and finally the winner could refuse to pay to the Auctioneer [14].

The same authors propose a mechanism for sealed bid auctions that ensures that bids are not revealed until the bidding period has been ended, the Auctioneer collects the money for the service from the winner. All other bidders are ensured that they do not have to pay and only the winner is able to consume the negotiated service [14]. Franklin and Reiter ensure this by the usage of cryptographic techniques.

Brandt [4] specifies this approach for Vickrey Auctions. In second price auctions the Auctioneer has an additional cheating opportunity. It could increase the second-highest bid in order to increase the effective price the winner has to pay. The mechanism of Brandt [4] considers especially the highest and the second price in Vickrey Auctions. Later, the same author proposes a mechanism in which the Auctioneer becomes obsolete as the bids are shared on all bidders [5]. This might solve the trusting problem between Auctioneer and bidders. Brandt [6] also proposes a mechanism for the (M+1)st price mechanism that is also used here in this paper. The author proposes a technique based on the El Gammal encryption. Following this mechanism, a trusted third party can substitute the trusting relationship between bidders and Auctioneer. A similar approach has been proposed by Baudron et al. [2]. An overview of cryptographic approaches without a trusted third party is given by Bogetoft et al. [3]. Wang [31] considers the problem of anonymity in Continuous Double Auctions and the traceability of false offers in this kind of Double Auctions.

The next category of trust relationships goes beyond the analysis of Turel and Yuan [30] (see figure 1). It is the trust relationship between participants within the groups of seller or buyers. Brandt and Weiss [7] name participants, which behave in a fashion that they reduce the profit of competitors, "antisocial" agents. These agents follow this goal beside the goal of maximizing the own profit. Following Brandt and Weiss, these agents "need to deviate from the dominant truth-telling strategy" [7, p. 335]. Among other researchers, Sandholm [26] adresses the problem of truth-bidding by the usage of the Clarke-Groves pricing mechanism, a generalized Vickrey auction. Zhou and Zheng generalize the truth-bidding for Double Auctions in their framework, called TRUST [34].

Finally, we are going to consider the category that represents the focus of this work: the trust relationship between the both bidder groups: seller (SP) and buyer (SC). This problem has been identified and examined by Braynov and Sandholm [8]. In a subsequent work the same authors address, beyond others, this problem [9], but use a single-sided Vickrey auction (in our terms: Auction) to solve this problem. Ramchurn [23] proposes a mechanism to ensure a trusted relation between sellers and buyers, but he also makes use of single-sided auctions. Tafreschi et al. [29] assume the same problem. But within their proposal to solve this problem they make use of a Fixed Price Auction protocol.

Summarizing, we can state that none of the existing approaches focuses the trusting relation between sellers and buyers within a Double Auction. They fail to meet requirement *R0*. We will now propose a design that allows to address the trusting problem within Double Auctions. Therefore, the Negotiation Protocol module has to be modified and the interface for agents to make decisions has to be designed.

3. DESIGN AND DEVELOPMENT

Following the Design Science process of Peffers et al. [21], the protocol is now designed. But before describing the results of this process in this paper, we will consider the underlying assumptions.

3.1 Assumptions and Simulation Environment

The approach assumes that participants might defect the system through not answering the service or payment requests not as expected. The Matcher, instead, is assumed to always act honestly. Keeping related work in mind, this assumption could be dropped in future. Further, no trusted third party for example to fulfil the payment process is available. Finally, the decision, if a trustee is playing honest or fraudulent, is modeled as a binary decision, that is the services can be clearly divided into honest and cheating services.

3.2 Protocol

In order to meet the requirements, the Double Auction protocol has to be re-designed. In this approach, the Matcher makes use of the (M+1)st price rule. The (M+1)st price rule sets the clearing price (the price buyers have to pay and suppliers earn) at the (M+1)st highest price of all bids [33]. For reasons of simplicity, the focus of the protocol will lie on the matched participants only: in case of the unmatched bidder, the Matcher sends a "Lost" message to the set of unmatched SPs and the set of unmatched SCs. For these participants the current Double Auction round is finished without success. In this case no trusting relationship occurs due to the failed attempt to find a suitable partner (to consume or to provide a service).

The protocol proposal is illustrated in figure 2 in terms of an UML sequence diagram. The process starts with an announcement of a new Auction round by the Matcher. Sending this broadcast message simplifies the service discovery process that is also a necessary part of the service life cycle. The process of how to find a service that promises the desired functionality is assumed to work. That means that the functionality can be exactly described with underlying service descriptions and the Matcher will only match with SPs and SCs that have equal service or demand descriptions. Within the following simulation the service is denoted by a textual string that represents the unique service and demand description.

The negotiation process starts with the aforementioned *Call-for-Bids* message that is sent by a broadcast message delivery to all participants. As soon as the SP has resources available to offer, it will answer this Call-for-Bids message with a *Sell* message. Symmetrically, the SC answers in case of an open demand the Call-for-Bids message with a *Buy* message. Both answer messages have to include the price for the proposal. For the SP the price denotes the lowest bid on which it will provide the service. For the SC on the other side, the price denotes the maximum price it is willing to pay for the service.

The Matcher follows the (M+1)st price matching algorithm [33] and stores the proposals in the corresponding proposal sets. In periodic matching proceedings, the proposals are matched regarding the (M+1)st price matching and price determination rule.

The matched services and demands instead, are notified by a *Ask-if-Opp-Is-Ok* message. This message includes the name of the matched opponent. The message does not include the (M+1)st price, such that no economic side effects can occur,

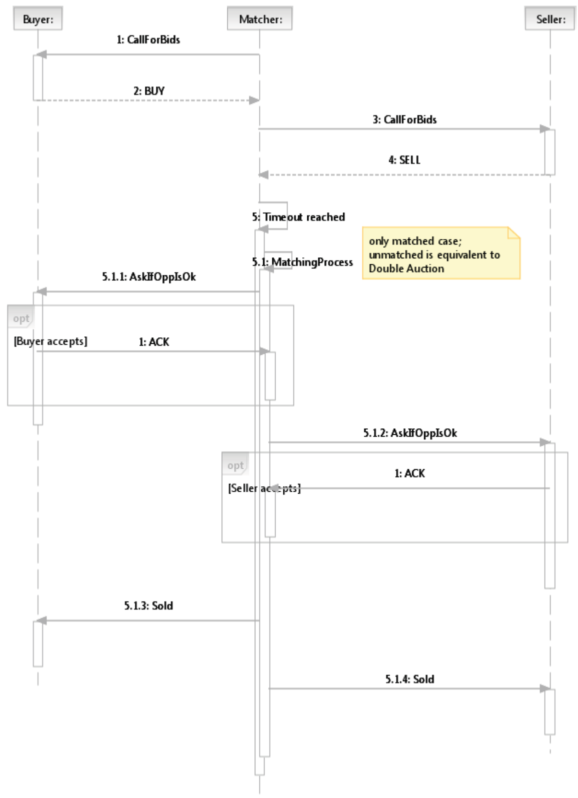


Figure 2: Modified Double Auction Protocol

i.e. refusing the matching due to the high or low price.

The Matcher stores the matched pairs in a new data structure. This data structure is able to store additional flags for each participant that denotes the fact if the corresponding agent has already confirmed the matching. The decision whether to confirm the matching or not, can be made by each agent on individual preferences: if the matched agent is sufficienty trustworthy, the matching is accepted, otherwise it is rejected. This decision point represents the interface to a potential usage of a trust and/or reputation mechanism to confirm the decision with more information, here on historic behaviour of the service or participant. The individual preference is modelled by an individual threshold that determines this decision.

As soon as the matched SP and the corresponding SC accepted the matching and announced this with an *ACK* message to the Matcher, the Matcher sends the final *Sold* message to both sides. This message includes the price on which offer and demand have been matched. At this point the agent can influence its future personal strategy regarding the negotiation itself and can increase or decrease its estimated market price.

4. DEMONSTRATION AND EVALUATION

4.1 Simulation Environment

In order to evaluate the mechanism later, we have to introduce a simulation environment, called SimIS [15], that follows the IoS vision. This system is able to model Internet-like networks where the nodes are hosting active services.

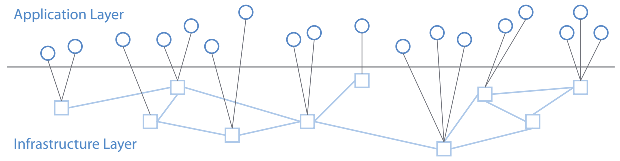


Figure 3: SimIS Architecture [15]

The messages follow the SOAP messages structure and the service interfaces follow real-world Web Services technology, like discussed in Lee and Winslett [17]. These interfaces conform to the widle-used interaction protocols in service economies.

4.1.1 Technological Base: Repast Toolkit

The SimIS[1] toolkit was implemented as an extension to the Recursive Porous Agent Simulation Toolkit [24], developed at the Argonne National Lab, Chicago. Repast is a free and open source agent-based modelling toolkit [18]. This foundation was chosen due to its comprehensive API, the very generic and easy to use set of data gathering and analysis functions as well as the support for network modelling (including respective programming libraries). Technically, the current version of SimIS is based on Repast Symphony and is completely implemented in the Java programming language.

4.1.2 SimIS Architecture

In order to map the abstract IoS architecture to our simulation model a two-tiered architecture for SimIS seems suitable. The overall system is thus divided into an Application Layer and an Infrastructure Layer. An overview of the overall architecture is illustrated in Figure 3.

The *Infrastructure Layer* models topological settings of the IoS. The basic idea is that all Application Layer Agents or Services are linked to a single Infrastructure Agent each, which is representing their server platform. This platform is therefore responsible for sending messages to other Application Layer Agents (including routing and communication patterns, such as broad- or multicast), and receiving messages from other Infrastructure Agents and passing them on to either other Infrastructure Agents (in case the agent represents only the next step on the message's route) or to one or more Application Layer Agents associated with it (in case these are the recipients) [15].

Within the *Application Layer* the actual services of the IoS vision are modelled. Basically the underlying Infrastructure Layer provides us with a high-enough flexibility for implementing any service logic in terms of Application Layer Agents communicating via the offered message objects and routing functionality. Each service (Application Layer Agent) is implemented as a plain Java class and can therefore exploit the full potential this programming language offers in addition to the libraries present within the SimIS toolkit.

4.2 Simulation Experiments

4.2.1 Simulation Scenario

As just mentioned, the topology will again be divided into an Infrastructure Layer consisting of nodes and edges between them, and an Application Layer. The network used for simulation experiments consists of 100 nodes that are connected not heavy-weighted and not long-tailed. The mean distance between the nodes is about 3.26 with an maximum distance between two nodes of six hops.

For the following simulation experiments, 200 SP agents and 200 SC agents will be deployed at the beginning of the simulation experiment. In order to introduce dynamics, participants are substituted by newcomers during the simulation experiments. The time range for the substitution process is set to a value that in average the complete population of agents is replaced once during one simulation experiment of 100,000 time ticks. Depending on the payment model 10% SP cheaters or 10% SC cheaters are deployed. This rate might fluctuate due to the dynamic character of the system.

For each simulation setting, the products that are negotiated are fixed by a certain functional attribute definition. This attribute combination is assumed to be defined by an underlying service description. The one and only attribute that is negotiated is denoted by the price. The negotiation protocol is determined by a (M+1)st price Double Auction.

4.2.2 Metrics

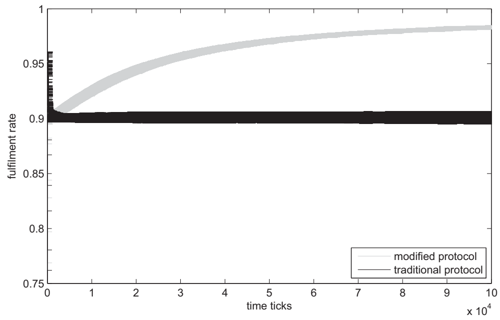
As the simulation scenario has been defined, the metrics for the simulation experiments are introduced now. The fulfilment rate and the negotiation rate are plotted in dependence of the simulation time.

The concrete implementation of the fulfilment depends on the payment model of the simulation experiment. If the service has to be payed in advance, the fulfilment rate considers the service fulfilment: $fr = \sum_i^{|SCs|} \frac{services_i^{received}}{services_i^{paid}}$. For each participant the rate of successful services against failed services are noted. Without any reputation system, one would expect that the service fulfilment rate corresponds to the rate of cheaters in the system. If the service has to be payed after it has been fulfilled, the fulfilment rate considers the payment fulfilment. Then, for each SP the rate of successful payments against failed payments are plotted over time.

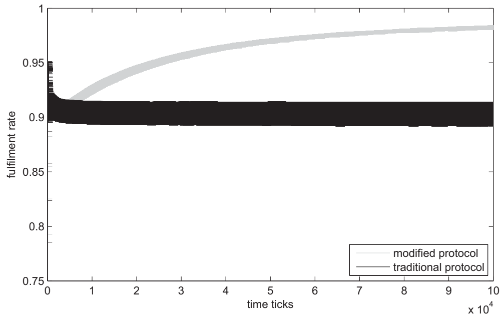
The negotiation rate is defined very close to the fulfilment rate. While the latter focuses on the service and payment fulfilment, the negotiation rate focuses on the rate of negotiation processes that have been finsihed successfully: $nr = \sum_i^{|SCs|} \frac{negotiation_i^{finished}}{negotiation_i^{started}}$. The outcome of the fulfilment afterwards is not relevant for this metric. In a system with a well-working reputation system the negotiation rate of defecting agents will fall down as soon as they are identified, and the other participants will not be willing to negotiate with them any more. If the trust and reputation system does not work properly, the rates might not differ at all between honest and cheating participants. The definition when a negotiation begins, depends on the negotiation protocol: in a Double Auction as soon as a bidder submits a bid to the Auctioneer is assumed as the negotiation start.

Finally a metric that covers indicators that base on the ne-

[1]For more information see http://simis.sourceforge.net

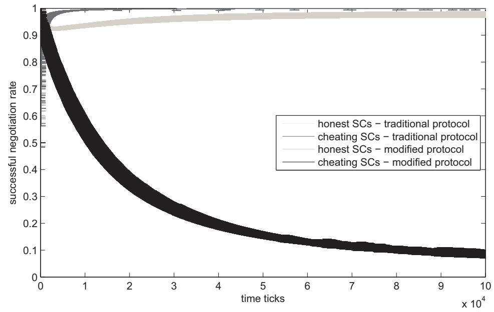


(a) Service Consumer negotiation rate (pay-later)

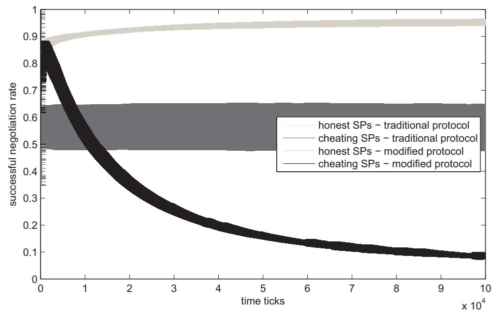


(b) Fulfilment Rate (pay-before)

Figure 4: Double Auction Fulfilment Rate



(a) Service Consumer negotiation rate (pay-later)



(b) Service Provider negotiation rate (pay-before)

Figure 5: Negotiation Rates in modified Double Auction

gotiation and trustworthiness will be introduced: fairness. While the negotiation and fulfilment rate will be plotted over time, this metric will analyse the agent population at the end of each experiment. When plotting the investments or revenues against the amount of services, fairness can be defined in a distribution close to the bisecting line (assuming similar valuations) [32]. The gradient of the bisecting line is determined by the valuation. To ensure the applicability of this metric in both trustor/trustee relationships, we will evaluate the deviation of a population by the root mean square deviation to the expected bisecting line. A deviation value of 0 for the whole polulation would denote a complete "fair" system, whereas a high deviation value denotes an "unfair" system. The deviation is calculated by the root mean square error that measures the differences of the measured values against the expected (fair) values.

4.2.3 Simulation Results

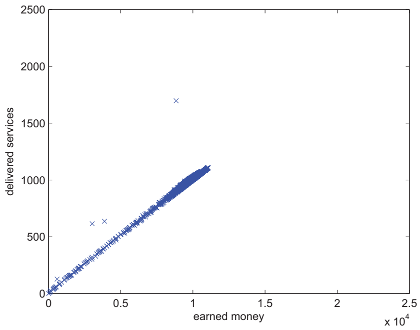
In the following simulations each single experiment is repeated for 30 times using different random valuations and makes use of the modified Double Auction Protocol. With 30 replications and uniformly distributed input parameters, the simulation experiments are expected to satisfy common statistical requirements. During the data analysis the 0.95 confidence interval of the time series are taken for further analysis. The simulation outcome is further compared to the case that uses the initial Double Auction protocol. In both cases, $AVALANCHE_{dec}$ is used as decentralized trust and reputation model for all participants (SPs and SCs).

Figure 4 illustrates the overall fulfilment rate of the scenario's simulation experiments. The figure denotes the payment fulfilment in the pay-later and the service fulfilment in the pay-before model. As we have again 10% of cheating agents, the fulfilment rate is expected at about 90%. As we have seen above, the reference case (initial Double Auction protocol) fulfils the expectation with a constant fulfilment rate of about 90% (dark area).

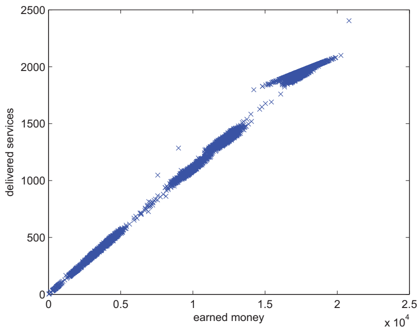
The grey areas illustrate the service or payment fulfilment rates when using $AVALANCHE_{dec}$, combined with the modified protocol. The service fulfilment rate increases significantly compared to the simulation outcome with the initial Double Auction protocol. Both payment models lead to analogous results.

A value of approximated 100% is unrealistic due to the following reasons: during the settlement phase of the simulation run the reputation system has to be filled with information. Within this settlement phase some interactions fail, such that the rate can not reach the 100% value. Further, during the simulation runs the implemented dynamics lead to a continuous arrival of unknown agents.

As we stated above, a working reputation system has to lead to a spreading of negotiation rates between honest and dishonest participants. Figure 5 illustrates the negotiation rates when using the initial or the modified Double Auction protocol. Subfigure 5a considers the pay-later case where the SCs are acting as trustees. Determined by the payment model, these agents are able to cheat the corresponding SPs. Following, with a well-working trust and reputation model the negotiation rate of cheating and honestly acting SCs

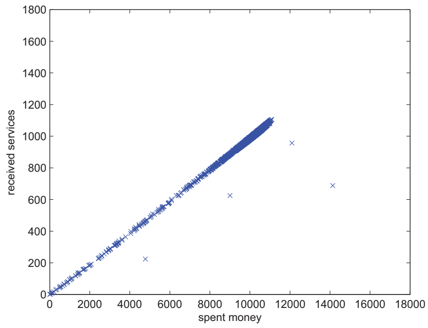


(a) modified protocol

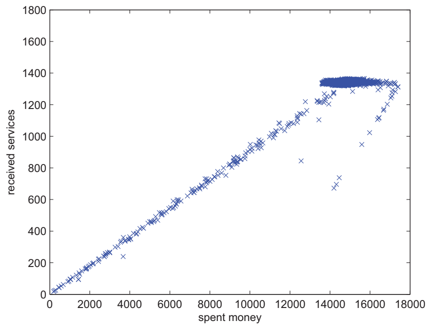


(b) initial protocol

Figure 6: Fairness between Service Providers in Double Auctions (pay-later)



(a) modified protocol



(b) initial protocol

Figure 7: Fairness between Complex Service Agents in Double Auctions (pay-before)

should spread.

The initial Double Auction protocol does not differentiate regarding the negotiation rate between honest and dishonest SCs. As soon as we implement the modified Double Auction protocol, the negotiation rate of dishonest SCs decreases over time and spreads compared to the rate of honest SCs (dark area vs. light grey area). This case (modified Double Auction, pay-later and $AVALANCHE_{dec}$) is now a well-working case regarding the trustworthiness.

The pay-before case is illustrated in figure 5b. Like in the pay-later case, an implementation of the modified protocol leads to a spreading of negotiation rates. Honest SPs, which represent the trustees now, are more often able to finish a negotiation process compared to cheating SPs (dark area vs. light grey area). As soon as the initial Double Auction protocol is used to coordinate the services, the negotiation rates of both SP groups do not differ at all. Demand and supply are not balanced in the scenario, such that the negotiation rates differ between SC and SP.

Figures 6 and 7 will now consider the fairness metric when coordinating the services in an IoS environment by the different Double Auction protocols.

Based on the findings before, figure 6a denotes a well-working combination of the modified Double Auction protocol with the pay-later payment model and $AVALANCHE_{dec}$ as reputation model. This combination leads to less negotiations with fraudsters involved. In consequence, a smaller amount of SPs are cheated. The root mean square error to the expected bisection (completely fair system) is denoted by 22.27.

Figure 6b illustrates the result of the same experiment, but with the initial Double Auction protocol. Compared to the simulation experiment with usage of the modified specification, we can immediately see that the reputation information of $AVALANCHE_{dec}$ does not influence the results. SPs receive less money in relation to the services they delivered. These cheated agents can be found above this imaginary bisection. The root mean squared error in this case is with 145.9 higher than in the same experiment using the extended protocol version.

Based on the findings before, figure 7a illustrates the second well-working combination of the modified Double Auction protocol: this time with the pay-later model. Here, the usage of $AVALANCHE_{dec}$ leads to less negotiations with fraudsters involved. In consequence, a smaller amount of SPs are cheated. The root mean square error to the desired bisection is denoted by 20.01. If we use the initial approach in the pay-before case, the simulation outcome decreases in its fairness metrics (see figure 7b). The simulation experiment leads to a root mean squared error of 149.1.

Additional sensitivity analyses show that the model is very robust against changes in the cheaters rate (up to about 40%) and regarding the amount of services (with more than

50 SPs and SCs). Running simulations for 100,000 ticks ensures that stable system states are reached. Neither increasing the simulation duration, nor changing the reputation model (for example by using the proposal by Abdul-Rahman [1]) affect the simulation outcomes.

Summarizing the results of the modified Double Auction experiments, we can state that both initial hypotheses regarding the Double-sided Auction can be confirmed: when using the original Double Auction protocol, the instantiation of $AVALANCHE_{dec}$ does not increase the trustworthiness of the system compared to the expected trustworthiness based on the cheating probability of trustees. This statement is unversally valid for both possible payment models and following both trustee/trustor relationships. As soon as we use the modified Double Auction protocol, which has been proposed in this paper, the impact of $AVALANCHE_{dec}$ renders the system more trustworthy and fairness between agents can be ensured.

If we consider this modification again in detail, we can notice that through the additional confirmation an additional decision point for SCs and SPs has been introduced. For these participants this additional decision point leads to the possibility to decide based on trust and reputation information. In terms of the introduced reputation roles, the trustors become Beneficiary of the reputation system, such that the reputation role overlapping determines a working system.

In order to close the section on the Demonstration and Evaluation of the modified protocol combined with the decentralized reputation model $AVALANCHE_{dec}$, we are going to review the deducted requirements.

- R 0 *Trusting relationship between Sellers and Buyers:* The proposed mechanism adresses the trust relationship between the group of sellers (SPs) and buyers (SCs). This fact becomes obvious when changing the behaviour regarding the honesty of agents during the evaluation step. In both payment models, cheating trustees are detected and indirectly excluded. Further, the modified protocol is still denoted as Double Auction protocol, such as both groups, sellers and buyers, are bidding on services or demand within the same protocol.
- R 1 *The trustor is able to use its reputation information:* With the modification of the protocol an additional decision point has been added. All participants can now decide if they accept the corresponding opponent. Through this additional possibility the agents are not confronted with an anonymous amount of agents. Instead they are already clearly allocated to a specific partner. Now they are able to use trust and reputation information to make the decision whether to confirm the matching or not. In terms of the reputational roles, SCs and SPs are now Beneficiaries of the reputation system.
- R 2 *Mechanism that covers both payment models:* Such as for both sides, buyer and seller, this additional decision point has been introduced, the protocol is still a symmetric one. The fact that the protocol works well with both models could be shown within the evaluation.
- R 3 *Decision on acceptance must not depend on price information:* This requirement can also be denoted as fulfilled. The "Ask-if-opponent-is-Ok" message does not include any price information. Instead it includes the name of the opponent, such that the agent is able to decide based for example on the opponent's past behaviour. The price information (in our simulation the (M+1)st price) is conveyed with the "Sold" message after both partners have confirmed the matching. This split into two steps avoids an influence of strategic economic behaviour at this point.

5. CONCLUSIONS AND FUTURE WORK

The paper identified trusting problems between autonomous services in the IoS vision. The IoS envisions a service ecosystem where services are traded without human interactions and even beyond company boundaries. The conflicting interests between participants lead to strategic behaviour of single actors.

In literature, trust and reputation models are proposed to set incentives to act honestly. But when using Double Auctions to match buyers and sellers, these trust and reputation models fail to close this "trusting gap". A theoretical investigation of the problem has led to the idea to introduce additional decision points. A modified Double Auction protocol fulfils the deducted requirements. Simulation experiments show that the usage of this modified protocol leads to increased trustworthiness for the participants. Concluding, the paper shows that it is possible to close the trusting gap in Double Auction Markets as soon as the protocol is modified as proposed. With a traditional Double Auction protocol, closing this trusting gap is not possible.

Future work should focus on the independence of the proposed mechanism from the used trust and reputation model. Even if first investigations have been positive, this question needs further investigations in future. Especially side-effects between Double Auction configurations and reputation model configurations should be investigated. Further, a detailed economic investigation of common Double Auction requirements, like truthful bidding is still to be done.

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