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INCENTIVES IN SERVICE VALUE NETWORKS – ON TRUTHFULNESS, SUSTAINABILITY, AND INTEROPERABILITY

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Completed Research Paper

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Abstract

The concurrence of technical and behavioral trends – such as lightweight approaches for service composition and a rising demand for customized services – fosters the emergence of a novel organizational paradigm: Service Value Networks (SVN). Distributed and highly-specialized service providers contribute to an overall value proposition. SVNs provide means for the ad-hoc composition of services that satisfies individual customers' needs. However, the distributed nature of these environments and the opportunistic behavior of participants require a purposeful design of incentives. Our contribution is threefold: We (i) provide an auction mechanism – the Complex Service Auction – to coordination value creation in SVNs which is incentive compatible in dominant strategies (truthful). To restore budget balance – the prerequisite for a mechanism's sustainability – and to implement incentives that increase a network's degree of interoperability, we (ii) present the Interoperability Transfer Function (ITF). Applying an agent-based simulation method, we (iii) numerically show that this payment scheme limits strategic behavior of service providers and strengthens interoperability endeavors compared to a benchmark transfer function.

Keywords: Mechanism Design, Auction, Service Engineering, Service Science

Introduction

Since the end of the 1990s, the software industry has undergone tremendous changes. Driven by maturing Web services technologies and the wide acceptance of the service-oriented architecture paradigm, the software industry's traditional business models along with business strategies have already heavily started to erode – with far-reaching consequences: Software vendors turn into service providers. While traditional software products are installed on customer site, including prepaid perpetual-use licenses, so-called software-as-a-service (SaaS) or on-demand software is hosted and maintained by the service provider and offers usage- or subscription-based pricing models. While the success story of on-demand software is already sealed, a second wave of innovation has great potentials to shake the software industry's foundations once again. Exploiting the capabilities of Internet standards and interoperability, joint value creation of service providers has emerged. Open standards and service-oriented architectures constitute important building blocks for innovative Web service networks, tying together the competencies of specialized contributors while customer value is created via the *interplay of complementary service providers*.

The adaptiveness of the partners fits to the development of software customers' demanding more sophisticated as well as more specialized solutions and, at the same time, more flexible service provisioning (Bovet and Martha 2000). One of the most powerful approaches to handle complexity is modularity that is composing the whole from smaller subsystems that are designed independently, yet function together as a whole (Baldwin and Clark 2000). Along those lines, vendors concentrate on their core activity while leveraging knowledge and assets of complementary partners. That way, they are able to stay agile and to flexibly adapt their services to changes in the environment, be it customer-, competition-, or regulation-driven. Such joint value creation in terms of Web services is mostly coordinated by a mediating entity as conceivable in today's leading service platforms: Salesforce.com offers its on-demand service market place AppExchange and its development platform force.com, Xignite operates the Splice Mashup Platform, and StrikeIron has ready the IronCloud Web services delivery platform, just to name a few.

However, besides above-mentioned increase in customers' demands and the resultant agility of service providers, other concrete economic factors drive this second innovation wave of the software industry: Requirements for functional and non-functional characteristics of electronic services are much more pronounced and specific than in other domains. If a service customer can choose between a Web service that perfectly fits her needs and a Web service that is programmed to capture the mass appeal, she will most probably purchase the former – if priced appropriately. What is more, modular services can be combined and configured into what is known as service mashups which have the potential to meet virtually every conceivable customer requirement, giving rise to a new level of customization. Such complex services involve the assembly and invocation of several specialized service modules offered by a multitude of specialized partners in order to complete a multi-step business functionality (Papazoglou 2007). Re-combining the service modules, new functionality is created "off-the-shelf" which is potentially able to meet a multitude of customer demands.

From a technical perspective, dynamic Web services are increasingly used in the context of service mashups, facilitating lightweight approaches such as RESTful architectures and slim messaging formats such as JSON (Crockford 2006; Fielding 2000). The service mashup platform ProgrammableWeb reported that by middle of 2009, 66% of all listed APIs expose REST interfaces, foretelling the trend to an internet of interoperable Web services.

Economically, value is created through the interplay of various distributed service providers in ecosystem-like environments that jointly contribute to an individual, integrated solution. However, such environments will also include substitutive services and vendors. Thus, service providers find themselves in the fruitful state of co-opetition, breeding both complementary opportunities and competitive threads (Brandenburger and Nalebuff 1996). While cooperation enables advanced value creation and the access to partners' assets and knowledge, the competitive component diminishes adverse effects of market power and spurs improvements and innovation (Bengtsson and Kock 2000).

The above-introduced second innovation wave of the software industry, most notably the combinatorics in service mashups, can be optimally catalyzed by ubiquitously accessible service orchestration platforms – the service value networks (SVNs) – which are the underlying organizational form to this article (Blau et al. 2009).

Definition 1 (Service Value Networks). *Service Value Networks are Smart Business Networks, which provide business value by automated on-demand composition of complex services from a steady, but open pool of complementary as well as substitutive standardized service modules through an ubiquitously accessible network orchestration platform.*

Economic considerations in SVNs are in their infancy. A multitude of challenges need to be tackled when coordinating services in SVNs. Embedded in the contradictory context of efficient outcomes and efficient computation, a suitable or desired solution to the allocation problem of service consumers' preferences and offered services needs to be found. Mechanism design has proven to be a powerful instrument to solve problems involving self-interested individuals with private information (Mas-Colell et al. 1995; Parkes 2001). Well-known from impossibility results in mechanism design, a suitable trade-off between different mechanism properties such as efficiency and budget-balance – or sustainability in a broader sense – needs to be identified and implemented by the design of incentives in SVNs.

In this article, we provide an auction mechanism – the Complex Service Auction – to coordination value creation in SVNs which is incentive compatible in dominant strategies (truthful). To restore budget balance and to implement incentives that increase a network's degree of interoperability, we present the Interoperability Transfer Function (ITF). Applying an agent-based simulation method, we numerically show that this payment scheme limits strategic behavior of service providers and strengthens interoperability endeavors compared to a benchmark transfer function.

The remainder of this article is structured as follows: In Section 2, the design goals of a suitable mechanism for the coordination in SVNs are described and related research in this context is discussed. The section furthermore presents the SVN model and the mechanism implementation comprehending the bidding language, the allocation function, and the transfer function. In Section 3, the Interoperability Transfer Function (ITF) is presented that restores budget balance, implements incentives for service providers to increase their services' degree of interoperability, and limits strategic behavior. The section outlines related approaches and discusses their shortcomings. Addressing the limitation of strategic behavior, Section 4 analyzes the strategic behavior of service providers under the presence of the presented mechanism implementation by means of an agent-based simulation. Finally, Section 5 summarizes the contribution and points out future research.

The Model

Our approach to design an auction mechanism to coordinate the composition of complex services – the Complex Service Auction (CSA) – is based on the discipline of *mechanism design*. Mechanism design is a subfield of game theory that pursues the idea of designing institutions that determine decisions as a function of the information that is known by the individuals in the economy in order to achieve a desired outcome (Myerson 1988). Mechanisms serve as a unifying conceptual structure, which allows for analyzing and comparing economic institutions with respect to their properties and suitability in order to foster certain outcomes.

Design Goals

The objective of mechanism design is to implement a social choice function in equilibrium strategies that yields desired properties. Such properties are often referred to as mechanism properties. Nevertheless, mechanisms do not directly expose these properties but they implement social choice functions that do so. The properties of a social choice are also referred to as mechanism properties. For an extended introduction to mechanism and social choice properties, the interested reader is referred to Parkes (2001).

Design Goal 1 (Allocative Efficiency). *A mechanism is allocatively efficient if its social choice function always determines an outcome such that there is no other outcome which yields a higher valuation for all agents, i.e. an allocative efficient mechanism maximizes the sum of all agents' utilities.*

Put differently, a mechanism is allocatively efficient if it maximizes the total value over all agents. The total value matches the welfare of the system. Such allocative efficiency is not always desirable, e.g. if the objective is revenue maximization of the auctioneer. In this case, the mechanism design problem is re-formulated as optimization problem (Parkes 2001) which maximizes the utility of a particular agent (Dash et al. 2003). However, *optimal auction design* will not be discussed in depth in this article – the interested reader is referred to Myerson (1981).

Design Goal 2 (Budget Balance & Sustainability). *A mechanism is said to be budget-balanced if no outside payments are required to realize the outcome rule. In addition, the net transfers between the agents for all types need to be zero. In other words, the system is financially autarkic and sustainable.*

So, budget balance denotes the situation where the amount of money remains unchanged after the outcome has been determined. However, the money is being re-distributed.

Design Goal 3 (Individual Rationality). *A mechanism is individually rational if it makes sure that agents are not worse-off by participating than by waiving participation.*

In other words, the agents do not suffer any loss by participating. Therefore, this property is also called *voluntary participation*. For simplification, the utility of the outside option is oftentimes assumed to be zero. This is a desirable property since more participating agents lead to a greater variety of paths as to SVNs which can be a prerequisite for allocative efficiency.

As mentioned before, a central element of mechanism design is the question of how to incentivize agents to reveal their private preferences (i.e. types) truthfully. In order to prevent agents from "cheating", that is, agents find it advantageous to conceal their true type, a mechanism needs to be compatible to the incentives of the agents (Hurwicz 1972a). Such *incentive compatibility* is said to be the key to overcome selfish behavior. Rational agents will only choose the strategy of reporting their type truthfully to the mechanism if and only if their own profit is maximized in doing so. Furthermore, if truth revelation is an equilibrium in dominant strategies, agents want to reveal their true type no matter which strategies are played by other participants. A mechanism that implements a social choice which yields such an equilibrium implements *truthfulness*.

Design Goal 4 (Truthfulness). *A mechanism is said to implement truthfulness if it is a direct revelation mechanism in which truth-telling is a dominant strategy for all agents.*

Truthfulness is also a desirable property of a mechanism as to its complexity. Agents do not have to reason about other agents' strategies since every agent decides to reveal its true type out of its own self-interest (Parkes 2001). Therefore, the agents' strategy spaces are considerably simplified. Based on the impossibility results that are well-known in mechanism design theory (Green and Laffont 1987; Hurwicz and Walker 1990; Myerson and Satterthwaite 1983; Walker 1980), there is an inherent trade-off between design goals that has to be considered when constructing the mechanism's components. Hence, there are strong limitations regarding the design goals that can be simultaneously pursued. Despite of "traditional" mechanism design desiderata, design goals from a network perspective embody a crucial factor for the success of SVNs.

The formation of networks drawing on a multitude of approaches has been extensively discussed in economic theory. A standard objective pursued is *stability* which can be formalized and analytically verified. Depending on the links type and formation assumption, *pairwise stability* can be a desirable target. In respect to networks with directed relationships, *individual stability* is a more substantial than considering both linked agents in order to make statements on its stability.

When considering network formation, closely connected to stability is network efficiency. In networks with transferable units, it equals pareto efficiency. Therefore, network efficiency denotes the maximal total value of a network in terms of value distributed to the agents (Dutta and Mutuswami 1997; Jackson and Wolinsky 1996). However, as Jackson and Wolinsky (1996) found, such efficiency and pairwise stability are conflicting under quite weak assumptions. In respect to one-sided link formation and individual stability, Dutta and Mutuswami (1997) showed that incompatibility with network efficiency still holds unless some (quite useful) requirements are waived.

In line with such trade-offs to be made when designing a certain manifestation of a network, other target settings in respect to link formation come into consideration. If links are interpreted as *interoperability*, or *compatibility* relationships, respectively, such as in the SVN environment, an as high as possible number of connections in the network can be a desirable goal. Links in SVNs denote the linkage of complementary services, therefore it is compatibility that actually enables complementarity (Economides 1996). In this connection, aiming at a fully intermeshed network that features all feasible links can be a design goal. If a complete network is unrealistic, a target setting that formulates the number of compatibility relationships in relative terms is an alternative to above-mentioned measures. Such a relatively verbalized objective requires a comparison to suitable benchmarks.

Design Goal 5 (Interoperability). *Assuming links in SVNs are interpreted as* interoperability*, or* compatibility *relationships, respectively, an as high as possible number of connections in the network is desirable.*

Service Value Network

This section provides a SVN model that captures its main aspects in a comprehensive technical manner and lays the foundation for the design of the auction mechanism.

A SVN is described by means of a simplified statechart model (Harel and Naamad 1996, cp. Figure 1) and is aligned with the representation in Zeng et al. (2003). Statecharts have proven to be the preferred choice for specifying process models as they expose well-defined semantics and they provide flow constructs offered by prominent process modeling languages (e.g. WS-BPEL) and therefore allow for simple serialization in standardized formalisms.

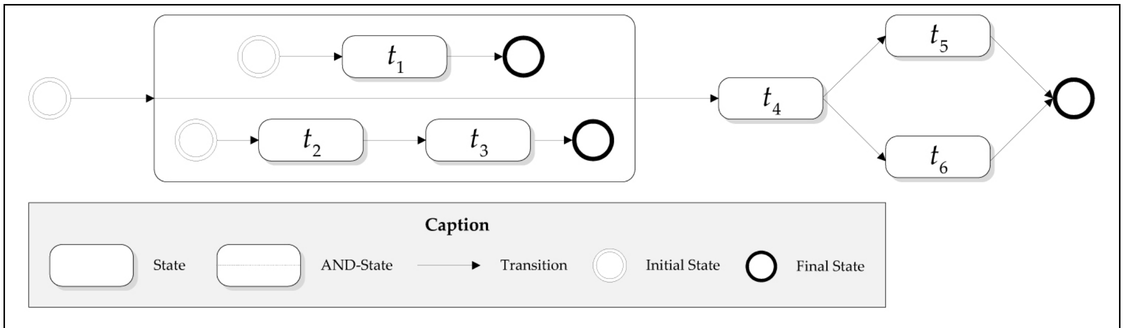

Figure 1. Statechart Model

Hence, a SVN is represented by a k -partite, directed and acyclic graph $G=(V,E)$. Each partition $Y_1,\ldots,Y_K$ of the graph represents a *candidate pool* that entails service offers that provide the same (business) functionality. The set of N nodes $V=\{v_1,\ldots,v_N\}$ represents the set of *service offers* with u,v,i,j being arbitrary service offers. There are two designated nodes v_s and v_f that stand for source and sink in the network and are not part of any partition $\mathrm{Y}=(Y_1,\ldots,Y_K)$, hence $V=Y_1\cup\ldots\cup Y_K\cup\{v_s,v_f\}$. Services are offered by a set of Q *service providers* $S=\{s_1,\ldots,s_Q\}$ with s being an arbitrary service provider. The *ownership information* $\sigma:S\rightarrow \mathrm{P}(V\ ,\ \{v_s,v_f\})$ that reveals which service provider owns which services within the network is public knowledge. The reverse ownership information $\sigma^{-1}:V\ ,\ \{v_s,v_f\}\rightarrow S$ maps service offers to single service providers that own that particular service. The set of edges $E=\{e_{ij}\mid i,j\in V\}$ denotes technically feasible service composition such that e_{ij} represents an interoperable connection of service $i\in V$ with service $j\in V$. If two services are not interoperable at all, they are not connected within the network.

Definition 2 (Service Configuration). *A service configuration* A_j *of a service* $j\in V$ *selects a value* a_j^l *for each attribute type* $l\in \mathrm{L}$ *of a service and thereby unambiguously defines all relevant service characteristics. The choice of configuration might affect the functional and non-functional aspects of a service and is a major determinant of the price.*

A *service configuration* A_j of service offer $j\in V$ is fully characterized by a vector of attributes $A_j=(a_j^1,\ldots,a_j^L)$ where a_j^l is an attribute value of attribute type $l\in \mathrm{L}$ of service offer j 's configuration. Attribute types can be either functional attribute types or non-functional attribute types (e.g. availability or privacy). A service's configuration represents the quality level provided and differentiates its offering from other services.

Furthermore let c_{ij} denote the *internal variable costs* that the service provider that owns service j has to bear for that service being interoperable with service i and for the execution of service j as a successor of service i. The representation of a detailed cost structure of service providers is intentionally omitted which serves a better understanding and does not restrict the generalization of the model. It is assumed that the representation of internal variable costs reflects the service providers' valuations for their service offers being executed in different composition-related contexts. The instantiation of a complex service is represented by a path from source to sink within the SVN. Let F denote the set of all feasible paths from source to sink. Every $f \in F$ with $f \subset E$ represents a possible instantiation of the complex service. Focusing on the presence or absence of a particular service $i \in V$, F_{-i} represents the set of all feasible paths from source to sink in the reduced graph G_{-i} without node i and without all its incoming and outgoing edges. In contrary, let F_i be the subset of all feasible paths from source to sink that explicitly entail node i.

Definition 3 (Service Value Network). *A service value network model is an acyclic, k-partite and directed graph such that*

$$G = (V, E) \tag{1}$$

with the set of nodes V representing service offers and the set of edges E that denotes technically feasible service compositions. G contains two designated nodes v_s and v_f representing source and sink such that every feasible path $f \in F$ connecting both nodes is a possible instantiation of the complex service.

For illustration purpose, Figure 2 shows the model of a SVN with service offers $V = \{v_1, \ldots, v_4\} \cup \{v_s, v_f\}$ and service providers $S = \{s_1, \ldots, s_3\}$. Every feasible path $f \in F$ connecting source node v_s and sink node v_f represents a possible realization of the overall complex service.

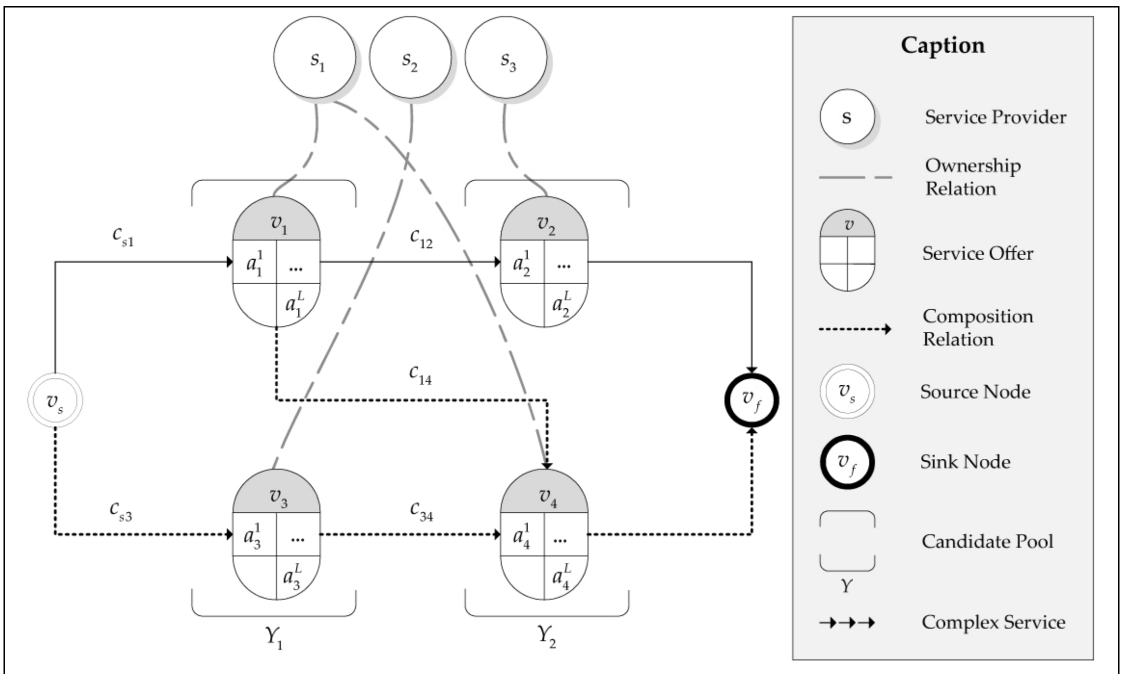

Figure 2. SVN Model

Bidding Language

As a formalization of information objects which are exchanged during the auction conduction a bidding language is introduced that is based on bidding languages for products with multiple attributes as discussed in Engel et al. (2006). The formalization is aligned to multiattribute auction theory as presented in Parkes and Kalagnanam (2002); Ronen and Lehmann (2005) and assures compliance with the WS-Agreement specification (Andrieux et al 2004) in order to enable realization in decentralized environments such as the Web.

A complex service – represented by a path f – is characterized by a configuration A_f. The importance of certain attributes and prices of a requested complex service is idiosyncratic and depends on the preferences of the requester. The requesters' preferences are represented by a scoring function $\mathrm{S}(\mathrm{A}_f)$. The scoring function represents the requesters' preferences for a configuration A_f of the complex service represented by f analog to the definition of scoring rules in Asker and Cantillon (2008). It maps the configuration of a complex service to a value representing the requester's score

Having defined how the score for certain outcomes is computed based on the requester's preferences, a specification of the willingness to pay is introduced that determines the rate of substitution between score and price. Let $\mathrm{T}_f = \sum_{s \in S} t^s$ represent the sum of all monetary transfers to service providers, i.e. the overall price of the complex service denoted by f. Hence, the requester's utility gained from purchasing a complex service specified by a path f with a configuration A_f evolves as follows:

$$\mathrm{U}_f^R(\alpha, \Lambda, \mathrm{A}_f, \mathrm{T}_f) = \alpha \mathrm{S}(\mathrm{A}_f) - \mathrm{T}_f \tag{2}$$

The factor α represents the requester's willingness to pay for a "perfect" configuration A_f with score $\mathrm{S}(\mathrm{A}_f) = 1$ based on reported preferences. In other words α defines the individual substitution rate between quality and price such that the requester is indifferent between an increase of 1 score unit and α monetary units. Incorporating that information, a service request for a multidimensional complex service is defined as follows:

Definition 4 (Multidimensional Service Request)**.** *A multidimensional service request for a complex service is a vector of the form:*

$$R := (\mathrm{Y}, \alpha, \Lambda) \tag{3}$$

such that $\mathrm{Y} = (Y_1, \ldots, Y_K)$ *represents all candidate pools with the SVN, i.e. necessary information for each service provider about preceding service offers. The maximum willingness to pay for a configuration that yields a score of* 1 *is denoted by* α *. The set of weights* Λ *represents the requesters' preferences for different attribute types* $l \in \mathrm{L}$.

Having specified the bidding language for requesters we define a notation for the provider side. A multidimensional service offer consists of an announced service configuration A_j and a corresponding price p_{ij} that a service provider wants to charge for the service j being invoked depending on the predecessor service i. An offer bid $b_{ij} = (A_j, p_{ij})$ is a service offer for invocation of service j as a successor of service i. A service provider s announces a matrix of bids $B^s \in \mathrm{B}$ for all incoming edges to every service it owns:

Definition 5 (Multidimensional Service Offer). *A multidimensional service offer is a matrix of bids of the form:*

$$B^S := \begin{cases} b_{ij} = (A_j, p_{ij}), & i \in \tau(j), j \in \sigma(s) \\ (\bar{A}_j, -\infty), & \text{otherwise} \end{cases} \tag{4}$$

with $\tau(v)$ *denotes the set of all predecessor services to service* v *with* $\tau : V \rightarrow V$ *and* $\sigma(s)$ *the set of all services owned by service provider* s *.* $\bar{A}_j$ *is an arbitrary service configuration.*

Allocation

Let U_f denote the overall utility of path f based on the reported types. Let further P_f be the sum of all price bids for allocated service offers on the path f such that $\mathrm{P}_f = \sum_{e_{ij} \in f} p_{ij}$. The allocation function $o : \mathrm{B} \to F$ maps the service providers' bids $B \in \mathrm{B}$ – their reported types – to a feasible path from source to sink $f^* \in F$ such that:

$$o(B) := argmax_{f \in F} \mathrm{U}_f = argmax_{f \in F} \left(\alpha \mathrm{S}(\mathrm{A}_f) - \mathrm{P}_f \right) \tag{5}$$

For the sake of simplicity, the expression "allocated service offer" means that this service offer has an incoming edge that is entailed in the allocated set of edges f^*. Analogously, the expression ``allocated service provider'' means that a service provider owns at least one "allocated service offer"

Having defined an allocation function to perform a desired social choice that selects a set of edges within G that determine the instance of the complex service, a function that specifies monetary transfers to service providers has to be designed.

Let U^* denote the overall utility of the allocated path meaning the utility of the path f^*, which maximizes the overall utility. Furthermore, let U^*_{-s} denote the overall utility of a path f^*_{-s} that yields the maximum welfare in a reduced graph G_{-s} without every service owned by service provider s and without incoming and outgoing edges of these service offers, i.e. the complex service instance that maximizes welfare in an SVN without service provider s's participation.

Definiton 6 (Critical Value)**.** *The* critical value $\Delta t^{crit,s}$ *of a service provider* s *represents its contribution to the system as the difference between the overall utility* U^* *in the complete graph and the overall utility in the reduced graph* U^*_{-s} *without service offers owned by service provider* s *and incoming and outgoing edges of these services such that*

$$\Delta t^{crit,s} = \mathrm{U}^* - \mathrm{U}^*_{-s} \tag{6}$$

Transfer

Every service provider s receives a monetary transfer t^s for all services s owns that are allocated by $o(B)$. Analogue to the idea of a second-price auction, a monetary compensation $t^s - \sum_{e_{ij} | e_{ij} \in o,\, j \in \sigma(s), i \in \tau(j)} p_{ij}$ for service provider s that owns service offers $j \in \sigma(s)$ corresponds to the monetary equivalent of the utility gap between the allocated path and the allocated path in the reduced graph without s and all its incoming and outgoing edges, i.e. the critical value of service provider s. In other words the additional payment $t^s - \sum_{e_{ij} | e_{ij} \in o,\, j \in \sigma(s), i \in \tau(j)} p_{ij} \geq 0$ is a monetary equivalent to the utility service provider s contributes to the overall utility of the system. Thus, the transfer t^s represents the price that service provider s could have charged without losing its participation in the winning allocation. Consequently, the transfer function t^s for service provider s is defined as

$$t^s := \begin{cases} \sum_{i \in \tau(j)} \sum_{j \in \sigma(s)} p_{ij} + (\mathrm{U}^* - \mathrm{U}^*_{-s}), & \text{if } \mathrm{e_{ij}} \in \mathrm{o} \\ 0, & \text{otherwise} \end{cases} \tag{7}$$

Incentivizing Interoperability Endeavors and Achieving Budget Balance

The mechanism implementation of the CSA consists of a transfer function that pays each service provider z that owns allocated service offers the corresponding price bid and the *critical value* $\Delta t^{crit,z}$ in addition. The critical value represents a monetary equivalent to the provider's utility contribution to the whole system such that $\Delta t^{crit,z} = \mathrm{U}^* - \mathrm{U}^*_{-z}$. Price bids of each service offer that is allocated by the mechanism plus the corresponding critical value have to be paid by the service requester to the service providers. A provider's critical value compensates the individual contribution to the system which depends on the contributions of the other participants. Hence, the payments, the service requester has to distribute among service providers depend on multiple factors (e.g. the network topology). In case the payments exceed the requester's willingness to pay in the CSA, budget balance cannot be achieved by the mechanism.

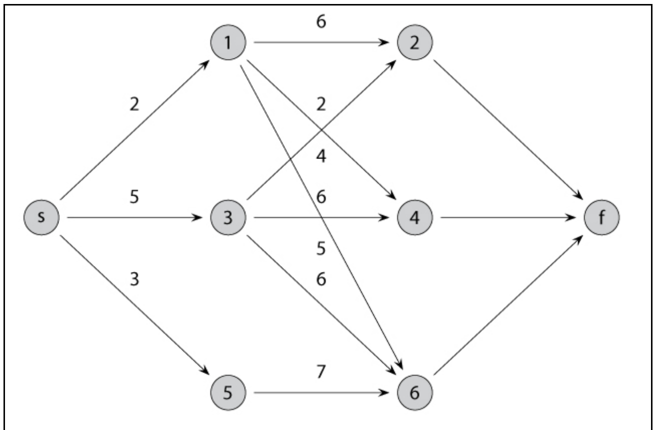

Figure 3. Non-Budget-Balanced Outcome of the CSA

Example 1 (Achieving Budget Balance). *This example illustrates a non-budget-balanced outcome of the CSA. Figure 3 shows a SVN with service offers* $V = \{1,2,3,4,5,6\} \cup \{s, f\}$. *For simplicity it is assumed that each service provider* $s_1,\ldots,s_6$ *only owns a single service within the network such that* $\sigma(s_i) = \{i\}$ *with* $i = 1,\ldots,6$. *Furthermore it is assumed that the requester's willingness to pay is* $\alpha = 12$.

The mechanism allocates the path $f^* = \{e_{s1}, e_{14}, e_{4f}\}$ *as it yields the highest overall utility of* $\mathrm{U}_{f^*} = 12 - (2+2) = 8$. *According to the transfer function, each service provider that owns allocated service offers receives a payment consisting of the corresponding price bid and the critical value such that* $t_1 = 2 + (8-3) = 7$ *and* $t_4 = 2 + (8-4) = 6$. *The sum of transfers which are distributed among the service providers exceeds the service requesters willingness to pay as* $\mathrm{U}^R = 12 - (7+6) = -1$. *Thus, an amount of* 1 *unit has to be externally subsidized in order to obtain the efficient allocation maximizing welfare.*

This section introduces an extension to the CSA that restores the desideratum of budget balance by sacrificing truthfulness to a certain degree. The extension is based on the design of a transfer function – the Interoperability Transfer Function (ITF) – that limits overpayments to satisfy budget balance constraints. The ITF implements incentives for increasing services' interoperability with adjacent offers to foster the growth of agile SVNs with an increased level of feasible complex service instantiations.

Related Work

In incentive compatible mechanisms, agents are incentivized to choose the strategy of revealing their true type. Incentive compatible mechanisms such as the celebrated Vickrey-Clarke-Groves (VCG) mechanism are firstly introduced and extensively investigated in Vickrey (1961); Clarke (1971); Groves (1973); Green and Laffont (1978).

In VCG-based mechanisms, the transfers are indeterministic and can be arbitrarily high (Archer and Tardos 2007). These so called *overpayments* or a mechanism's *frugality* is a central characteristic of a mechanism implementation. This phenomenon is extensively analyzed in mechanism design research especially in the context of graph-based implementations (Archer and Tardos 2007; Elkind et al. 2004; Karlin and Kempe 2005; Talwar 2003). A frugality ratio that measures the payments in a truthful mechanism compared to a non-truthful implementation is a ratio that ``characterizes the cost of insisting on truthfulness" (Karlin and Kempe 2005). Approaches to predict overpayments that occur in truthful graph-based mechanisms have been developed in Karger and Nikolova (2004) in the context of random graphs and in Karger and Nikolova (2005) for large-scale networks.

Addressing this shortcoming of VCG-based mechanisms, an approximately efficient and budget-balanced solution to overpayment issues in VCG-based combinatorial auctions is introduced in Parkes et al. (2001) while focusing on solving linear problems subject to budget balance that yield approximate incentive compatible solutions. Another approach to counteract the loss of budget balance by sacrificing efficiency is introduced in Archer and Tardos (2007) in the context of path auctions. In their work they replace the efficient allocation function by a class of "minimum functions" that yield lower overpayments in certain scenarios. Nevertheless they show that it is always possible to construct worse case scenarios in which minimum functions perform as bad as the efficient variant.

The Interoperability Transfer

As we have shown in Example 1, the transfer function as introduced in Equation (7) is not budget-balanced and can be subject to serious overpayments. However, it is oftentimes stated that budget-balance and individual rationality are compulsory characteristics of a mechanism to make it sustainable in practical application (Mas-Colell et al. 1995; Parkes 2001). Individual rationality is vital since agents are not willing to voluntarily participate if they expect to incur losses. On the other hand, a mechanism cannot be continuously subsidized by its operator or some set of the agents in the long run. Taking the impossibility constraints by Myerson and Satterthwaite (1983) into account, allocative efficiency must be sacrificed to guarantee a mechanism's sustainability in the long run.

Classic mechanism design, as Parkes (2001) calls it, seeks for efficient outcomes, therefore requiring that agents reveal their private information truthfully. If the welfare of the system shall be maximized, agents *must* reveal their true types. It is certainly possible to construct inefficient, but incentive-compatible mechanisms (Myerson 1982; Feigenbaum et al. 2001). On the other hand, mechanisms that are not incentive-compatible cannot be allocatively efficient per definition (Parkes et al. 2001). If utility maximization is conducted over types that are not necessarily truthful, statements on the “true” welfare cannot be made.

However, *non-incentive-compatible mechanism design* can be reasonable – in this case truthful bidding is not an equilibrium strategy for agents (Parkes et al. 2001). In other words, incentive-compatibility is not a requirement, but rather a desideratum that can be approached as close as possible. Certainly, mechanism design in the narrow meaning does not require such a variation: technically, non-incentive-compatible mechanisms can be subsumed under the class of incentive-compatible ones. According to the revelation principle any social choice function achieved with a non-incentive-compatible mechanism can be transferred in an equivalent incentive-compatible direct-revelation mechanism (Myerson 1979; Gibbard 1973). However, computational assumptions of the revelation principle are unrealistic. First, it assumes that agents in the non-incentive-compatible mechanism are generally capable of computing their equilibrium strategies. Second, for the submission of agents' strategies and the computation of the outcome by the mechanism operator, the revelation principle postulates unlimited computational resources (Parkes 2001; Ledyard 1993). Yet, from an economic standpoint, in some cases, it might not be the ultimate goal to achieve a truthful revelation of the agents' types. This can be the case, for instance, if the mechanism's allocation function maximizes reported surplus instead of actual surplus resulting from truthful information revelation of the agents. Sacrificing truthfulness in favor of other properties can be reasonable in order to obtain a “good (enough)” result.

Summarized, implied by Myerson and Satterthwaite (1983), if budget balance and individual rationality are to hold, one must sacrifice allocative efficiency no matter if incentive-compatibility is present or not. On the other hand, if incentive-compatibility subject to budget balance and individual rationality is to be enforced, inefficient solutions are deliberately being accepted – and such inefficiency can be enormous as truthful and budget balanced mechanism implementations give proof of (cp. e.g. McAfee (1992); Barbera and Jackson (1995)). Less inefficient allocations can, though, be reached without insisting on truthful information revelation (Parkes et al. 2001). We follow such a non-incentive-compatible mechanism design approach by maximizing the *reported welfare* of the network participants.

The actual design of a budget-balanced payment scheme presented in this article is based on the work of David Parkes (Parkes et al. 2001). We extend his approach by adding incentives to strengthen a network's degree of interoperability which is a valuable property in the context of SVNs.

Let T denote the sum of all incoming edges to service offers V, $\{v_f\}$. Furthermore let τ_i be the number of incoming edges to service offer i such that $\sum_{i\in V,\ \{v_f\}} \tau_i = T$. The ratio $r_i = \frac{\tau_i}{\mathrm{T}}$ denotes the incoming-edge-ratio for each node. Recall, e_{ui} represents an interoperable connection of service $i \in V$ with service $u \in V$, meaning that service i is capable of interpreting service u's output, i.e. service i is interoperable with service u. Thus, the more incoming edges to a service offer, the higher its feasible interoperability with its predecessor services. Hence, the incoming-edge-ratio r_i represents the degree of interoperability of service i with its predecessor services in comparison to all other services. Focusing on all service offers owned by a service provider s, the ratio $r^s = \frac{\sum_{i\in\sigma(s)} \tau_i}{\mathrm{T}}$ denotes the incoming-edge-ratio of service provider s.

Let $\Delta t^{crit,s}$ denote the critical value of service provider s. The idea to construct a transfer function that accounts for budget balance constraints is based on the work in Parkes et al. (2001) and focuses on choosing adequate discounts Δ^s for each service provider $s \in S$ instead of paying every allocated service provider the critical value. The decision on how to choose adequate discounts is formulated as a general optimization problem subject to budget balance constraints.

$$L_\tau(\Delta, \Delta t^{crit,s}) = \sum_{s\in S} r^s(\Delta t^{crit,s} - \Delta^s) \qquad (8)$$

L_τ represents the weighted distance function that measures the distance between the service providers' critical values and computed discounts with respect to the incoming-edge-ratio. The goal is to distribute the surplus $\mathsf{S}^* = \alpha \mathrm{S}(\mathrm{A}_{f^*}) - \mathrm{P}_{f^*}$ in a way that it minimizes the distance function L_τ. In other words, the goal is to transfer discounts Δ^s to service providers, which together minimize the overall weighted distance $\sum_{s\in S} r^s(\Delta t^{crit,s} - \Delta^s)$ and do not exceed the surplus S^*. Minimizing the distance function L_τ subject to budget balance, individual rationality and the critical values as upper boundaries leads to the following special optimization problem:

$$\min_\Delta \sum_{s\in S} r^s(\Delta t^{crit,s} - \Delta^s) \qquad (9)$$

$$\text{s.t. } \sum_{s\in S} \Delta^s \le \mathsf{S}^* \qquad \text{(BB)}$$

$$\Delta^s \le \Delta t^{crit,s}, \forall s \in S \qquad \text{(CV)}$$

$$\Delta^s \ge 0, \forall s \in S \qquad \text{(IR)}$$

Based on the optimal solution Δ^* of the Lagrangian problem, the complete interoperability transfer function evolves accordingly:

$$t^{ITF,s} := \begin{cases} \sum_{i\in\tau(j)} \sum_{j\in\sigma(s)} p_{ij} + \Delta t^{crit,s}, & \text{if } \mathrm{e_{ij}} \in \mathrm{o}, \mathrm{C}_\tau < \mathrm{r^s} \\ \sum_{i\in\tau(j)} \sum_{j\in\sigma(s)} p_{ij} + \tilde{\Delta}^s, & \text{if } \mathrm{e_{ij}} \in \mathrm{o}, \mathrm{C}_\tau = \mathrm{r^s} \\ \sum_{i\in\tau(j)} \sum_{j\in\sigma(s)} p_{ij}, & \text{if } \mathrm{e_{ij}} \in \mathrm{o}, \mathrm{C}_\tau > \mathrm{r^s} \\ 0, & \text{otherwise} \end{cases} \qquad (10)$$

Example 2 (Achieving Budget Balance (Continued)). *Recalling Example 1, this continuation illustrates how budget balance can be retained by implementing the interoperability transfer function. In order to determine an optimal threshold parameter* C_τ*, each service provider that owns allocated service offers is decreasingly ordered by its incoming-edge-ratio* r^s*. The number of possible edges within* G *is denoted by* $\mathrm{T} = 10$*. Consequently, the incoming-edge-ratio* r *for service providers that own allocated service offers evolves as* $r^{s_1} = \frac{\sum_{i \in \sigma(s_1)} \tau_i}{\mathrm{T}} = \frac{1}{10}$ *and* $r^{s_4} = \frac{2}{10}$*. The vector of the ordered incoming-edge ratios is* $(\frac{2}{15}, \frac{1}{10})$*. The optimal threshold equation is satisfied by* $C_\tau^* = \frac{1}{10}$ *with* $k^* = 2$ *which is the solution that satisfies the conditions* $\sum_{i=1}^{k^*} \Delta t^{crit,i} \leq \mathrm{S}^* \wedge \sum_{i=1}^{k^*+1} \Delta t^{crit,i} > \mathrm{S}^*$*. The value* $\tilde{\Delta}$ *for service provider* s_1 *is* $\tilde{\Delta}^{s_1} = \frac{8-4}{1} = 4$*. Payments for allocated service offers evolve accordingly such that* $t^{ITF,s_1} = 2 + 4 = 6$ *and* $t^{ITF,s_4} = 2 + 4 = 6$*. As* $\mathrm{U}^R = 12 - (6+6) = 0$*, the outcome of the extended CSA is budget-balanced and does not have to be subsidized externally. It is important to notice that the interoperability transfer function rewards service provider* s_4 *for the high degree of interoperability – i.e. the incoming-edge-ratio* r^{s_4} *– which increases the variety of feasible complex service compositions.*

Utility of the ITF Mechanism

In summary, the ITF utilizes the available surplus, i.e. *budget-balanced (Design Goal 2)*, and assures its distribution to contributing service providers in a way that *rewards interoperability endeavors (Design Goal 5)* – it implements incentives to increase ones interoperability to other providers – and at the same time *limits strategic behavior (Design Goal 4)*. However, the assurance of budget balance and the payment of rewards for interoperability endeavors come at the price of losing truthfulness in a strictly analytical sense. Nevertheless, the ITF is designed to limit non-truthful behavior as far as possible considering the surplus constraints which is extensively shown by the numerical analysis in the remainder of this work.

From a platform provider perspective, the ITF mechanism embodies an attractive pricing model as it is sustainable – i.e. it does not require external (platform) subsidizations. Secondly, the fact that interoperability is increased within the SVN leverages the power of combinatorics within the long-tail of business as it exponentially increases the number of sellable complex services (solutions) which in turn attracts new customer groups. Thirdly, the mechanism design limits strategic behavior of service providers, that is, it makes non-truthful information revelation less favorable to a certain degree (assuming rational behavior). Consequently, the SVN becomes a trust-worthy environment for all participants, which is an important aspect in anonymous distributed structures.

Manipulation Robustness of the Interoperability Transfer

Recalling that in the basic CSA, allocated service providers are paid their price bid plus their critical value compensating their contribution to the whole system. This critical value is designed to implement a dominant strategy equilibrium in which every service provider reports its multidimensional type truthfully to the auctioneer.

Nevertheless, incentive compatibility comes at the price of losing budget balance, i.e. the sum of service providers' transfers may exceed the service requester's willingness to pay which results in a negative budget that has to be subsidized externally. As a possible remedy to retain budget balance, the ITF extending the basic CSA was introduced. The ITF distributes the available surplus in a way that additionally to their bid, allocated providers are paid their critical value in the priority of their degree of interoperability subject to budget balance. It is obvious that in order to restore budget balance, incentive compatibility has to be sacrificed to a certain degree. Incurring this trade-off, the set of possibly beneficial bidding strategies of service providers increases and from a pure analytical perspective truthfulness does not hold under the presence of the ITF extension. Although the primary goal from an incentive engineering perspective of the ITF is to reward interoperability endeavors, the design of the ITF gives a good indication that bid manipulation is only beneficial to a certain level which strongly depends on the level of competition (Hurwicz 1972b; Jackson 1992; Roberts and Postlewaite 1976). We analyze strategic behavior of service providers in the CSA with the ITF extension following a simulation-based approach.

Simulation Model

To analyze the manipulation robustness, a simulation is conducted as follows: A random SVN topology is created with density 1.0 (complete graph) and – depending on the degree of competition – with a predefined number of service offers and candidate pools. For simplicity and without loss of generality it is assumed that each service provider owns only a single service offer within the SVN. The competition rate results from the number of alternative complex service instances (number of feasible paths) without the participation of a single service provider. The number of feasible paths depends on the number of service offers within the network as well as on the number of candidate pools and the density of the graph, i.e. the ratio between the number of edges and the number of all possible edges in the graph. The ratio between the number of service offers and the number of candidate pools is also responsible for the number of possible service compositions.

Each problem set is characterized by a random network topology with random costs c_{ij} assigned to each incoming edge of service offers drawn from $U(0,1.0)$. Furthermore, the requester's willingness to pay α is analogously drawn from $U(0,\frac{1}{2}K)$ with K being the number of candidate pools. $\frac{1}{2}K$ denotes the mean price of a complex service in a network with K candidate pools and internal costs of service providers drawn from $U(0,1.0)$ under the presence of truthfulness.

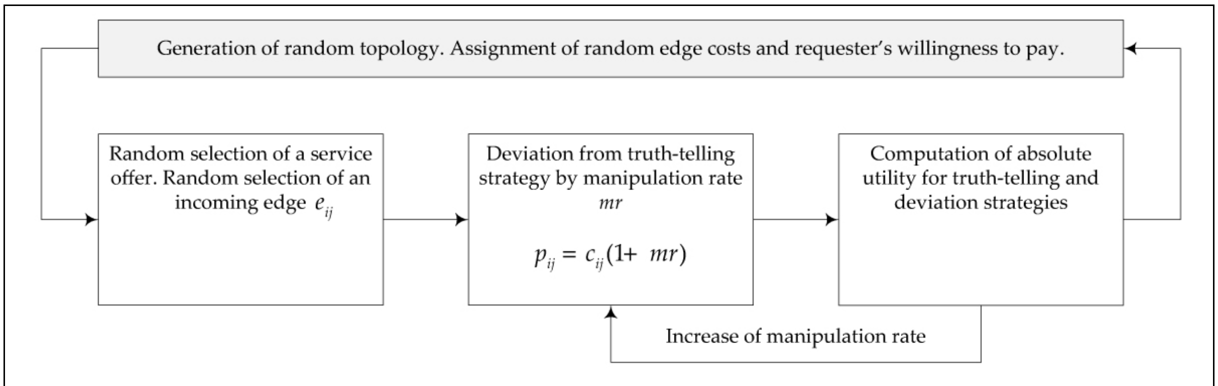

Figure 4. Simulation Model for the Evaluation of the Manipulation Robustness of the ITF

For each problem set, a single service offer's incoming edge e_{ij} is randomly selected. The bid price p_{ij} is manipulated stepwise from 50% to 150% in steps of 10% of the true valuation c_{ij}. For each manipulation rate the auction is conducted and the service provider's utilities for the deviation and the truth-telling strategies are computed based on the ITF and on the critical value transfer function which serves as a benchmark. Figure 4 depicts the stepwise procedure of the simulation. As the number of variable parameters and their interdependencies are high, heavy statistical noise is likely to be generated. To counteract the high volatility of the simulation model, a large number of problem sets of 5000 (identified by a sensitivity analysis) is evaluated for each degree of manipulation and the mean results are reported. In order to identify the degree of manipulation for which a deviation from the truth-telling strategy is beneficial for service providers, the statistical significance is tested using a one-tailed matched-pairs t-test analyzing the alternative hypothesis that service providers benefit from manipulation, that is, the mean difference in utility is greater than zero. The large size of the analyzed problem sets for each observation assures robustness of the t-test to violations of the normality assumption (Bridge and Sawilowsky 1999; Ramsey 1980; Sawilowsky and Blair 1992).

Results

For participating service providers in the CSA with the ITF extension, possible strategies and corresponding outcomes are illustrated in Figure 5. The decision tree evaluates possible bidding strategies in comparison to a truth-telling strategy. Focusing on a single service provider, two fundamental cases must be considered in order to evaluate the result of different strategies:

1. Having followed a truth-telling strategy, the service provider s would have been allocated by o. In this case, *overstating* the true valuation by announcing a price $\tilde{p}_{ij} > c_{ij}$ leads to a payoff $\tilde{\pi}^s \geq \pi^s$ if the service provider stays allocated and to a payoff $\tilde{\pi}^s < \pi^s$ if it is dropped out of the allocation. The monotonicity of the allocation function assures that the service provider still gets allocated by understating the true valuation such that $\tilde{p}_{ij} < c_{ij}$ which leads to a payoff $\tilde{\pi}^s \leq \pi^s$.
2. Having followed a truth-telling strategy, the service provider s would not have been allocated by o. In this case, by *overstating* the true valuation announcing a price $\tilde{p}_{ij} > c_{ij}$, the service provider is not allocated due to monotonicity of the allocation function which leads to a payoff $\tilde{\pi}^s = \pi^s$. *Understating* the true valuation results in a payoff $\tilde{\pi}^s < \pi^s$ if the service provider gets allocated and to a payoff $\tilde{\pi}^s = \pi^s$ if it is not allocated.

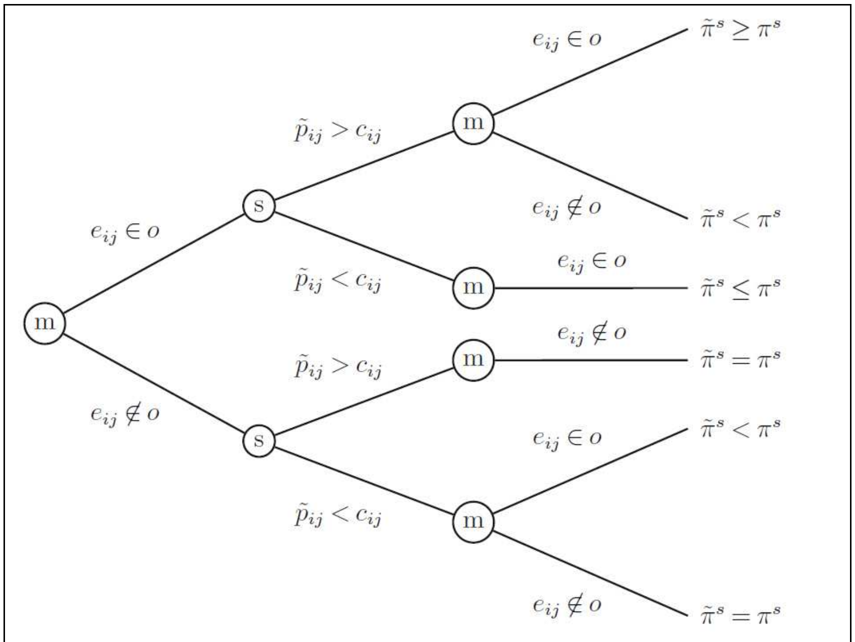

Figure 5. Decision Tree of Service Providers Robustness of the ITF

The effect of a bid manipulation strategy of service providers is highly dependent on the level of competition in the SVN as this increases the risk of dropping out of the allocation by overstating ones true valuation. As market size increases, participants become price takers and strategic considerations converge towards a truth-telling strategy (Hurwicz 1972b; Jackson 1992; Roberts and Postlewaite 1976). In the CSA, the level of competition results from the number of alternative paths in the absence of a single service provider. Therefore a good indication for the level of competition can be derived from the number of feasible paths in the network. The lower the level of competition, the higher the benefit for service providers that deviate from their truth-telling strategy. Table 1 shows the utility of a single manipulating service provider in a low competition setting with 12 service offers in 4 candidate pools. Understating one's true valuation results in a negative utility gain compared to a truth-telling strategy. However, service providers that overstate their true valuation significantly benefit from a deviation up to 100% of their true valuation.

Table 1. Utility for a single manipulating service provider with 12 service offers in 4 candidate pools. *abs* denotes the mean absolute utility and *rel* the ratio of means of the utility with manipulation and the utility following a truth-telling strategy. *sd* is the standard deviation of the mean absolute utility. * denotes significance at the level of $p = 0.1$, ** at $p = 0.05$, and * at $p = 0.01$.**

	Critical Value Transfer			Interoperability Transfer		
Manipulation Rate	abs	rel	sd	abs	rel	sd
-50%	0.0423	0.5865	0.0793	-0.0209	-0.6871	0.1022
-40%	0.0562	0.7789	0.0506	-0.0009	-0.0308	0.0714
-30%	0.0631	0.8741	0.0334	0.0113	0.3645	0.0478
-20%	0.0693	0.9603	0.0136	0.0194	0.6763	0.0264
-10%	0.0715	0.9904	0.0050	0.0250	0.8795	0.0144
0%	0.0722	1.0000	0.0000	0.0302	1.0000	0.0000
10%	0.0715	0.9906	0.0050	0.0317	1.0688***	0.0125
20%	0.0705	0.9771	0.0097	0.0327	1.0968***	0.0199
30%	0.0703	0.9738	0.0102	0.0393	1.1380***	0.0283
40%	0.0696	0.9638	0.0137	0.0384	1.1776***	0.0355
50%	0.0673	0.9320	0.0261	0.0379	1.1774***	0.0435
60%	0.0640	0.8870	0.0383	0.0384	1.1016***	0.0445
70%	0.0627	0.8691	0.0424	0.0377	1.0866***	0.0486
80%	0.0603	0.8354	0.0508	0.0355	1.0535***	0.0449
90%	0.0596	0.8251	0.0521	0.0362	1.0233*	0.0475
100%	0.0591	0.8181	0.0533	0.0351	1.0581***	0.0508
110%	0.0578	0.8006	0.0560	0.0378	1.0091	0.0537
120%	0.0554	0.7670	0.0632	0.0354	0.9652	0.0524
130%	0.0550	0.7613	0.0639	0.0314	0.9824	0.0543
140%	0.0534	0.7395	0.0672	0.0317	0.9529	0.0576
150%	0.0526	0.7285	0.0685	0.0344	0.9557	0.0581

In the setting with 20 service offers in 4 candidate pools as shown in Table 3, service providers do not significantly gain from deviation of more than 20%. Although, the CSA with the ITF extension is not incentive compatible in a strict theoretical sense, service providers cannot significantly benefit from deviation from reporting their true valuation, i.e. the truth-telling strategy is a best (or equally good) strategy compared to any manipulation strategy.

Providing an overview over multiple settings with different levels of competition, Figure 6 illustrates the relative utility gain following a manipulation strategy compared to truth-telling.

Implications

In summary our results lead to the several implications. As the attraction of SVNs is subject to network externalities, the value that service requesters gain from initiating a CSA highly depends on the number of participating service providers and the number of feasible complex service instances that can be provided through the network. Hence, especially in an early growing stage of a SVN, it might be desirable for platform providers to implement a mechanism that rewards service providers for offering multiple services with a high degree of interoperability, such as the CSA with the ITF extension does. Especially in settings with a low level of competition, critical values of service providers can be relatively high and unpredictable for the platform provider. Hence, a budget-balanced variant might be favorable in such an early stage as well. Reaching a critical mass of participants the network's inherent competition increases and critical values of service providers tremendously decrease. Assuring complete truthful behavior of service provider, the CSA with the critical value transfer might be beneficial for both service providers and the service requester. Service providers do not have to reason about the other participants' behavior and the service requester trustfully receives a tailored complex service instance. This variant always assures a welfare maximizing solution accounting for the providers' and the requester's side.

Table 2. Utility for a single manipulating service provider with 20 service offers in 4 candidate pools. *abs* denotes the mean absolute utility and *rel* the ratio of means of the utility with manipulation and the utility following a truth-telling strategy. *sd* is the standard deviation of the mean absolute utility. * denotes significance at the level of $p = 0.1$, ** at $p = 0.05$, and * at $p = 0.01$**

	Critical Value Transfer			**Interoperability Transfer**		
Manipulation Rate	Abs	rel	sd	abs	rel	sd
-50%	0.0025	0.1122	0.0630	0.0111	0.7315	0.0741
-40%	0.0107	0.4870	0.0425	0.0003	0.0187	0.0495
-30%	0.0173	0.7854	0.0231	0.0090	0.5533	0.0292
-20%	0.0208	0.9444	0.0089	0.0137	0.8251	0.0146
-10%	0.0219	0.9916	0.0020	0.0150	0.9434	0.0063
0%	0.0220	1.0000	0.0000	0.0167	1.0000	0.0000
10%	0.0219	0.9920	0.0017	0.0169	1.0298***	0.0059
20%	0.0215	0.9748	0.0051	0.0168	1.0227***	0.0086
30%	0.0205	0.9300	0.0108	0.0157	0.9929	0.0111
40%	0.0195	0.8849	0.0156	0.0150	0.9266	0.0143
50%	0.0191	0.8662	0.0169	0.0149	0.9129	0.0163
60%	0.0189	0.8562	0.0176	0.0150	0.8881	0.0166
70%	0.0185	0.8387	0.0197	0.0148	0.8794	0.0187
80%	0.0183	0.8324	0.0201	0.0153	0.8847	0.0201
90%	0.0182	0.8246	0.0207	0.0149	0.8776	0.0218
100%	0.0179	0.8125	0.0217	0.0149	0.8526	0.0220
110%	0.0176	0.7988	0.0235	0.0148	0.8480	0.0234
120%	0.0174	0.7888	0.0243	0.0154	0.8303	0.0266
130%	0.0168	0.7602	0.0270	0.0139	0.7904	0.0270
140%	0.0165	0.7474	0.0285	0.0139	0.7947	0.0293
150%	0.0163	0.7397	0.0293	0.0139	0.7869	0.0279

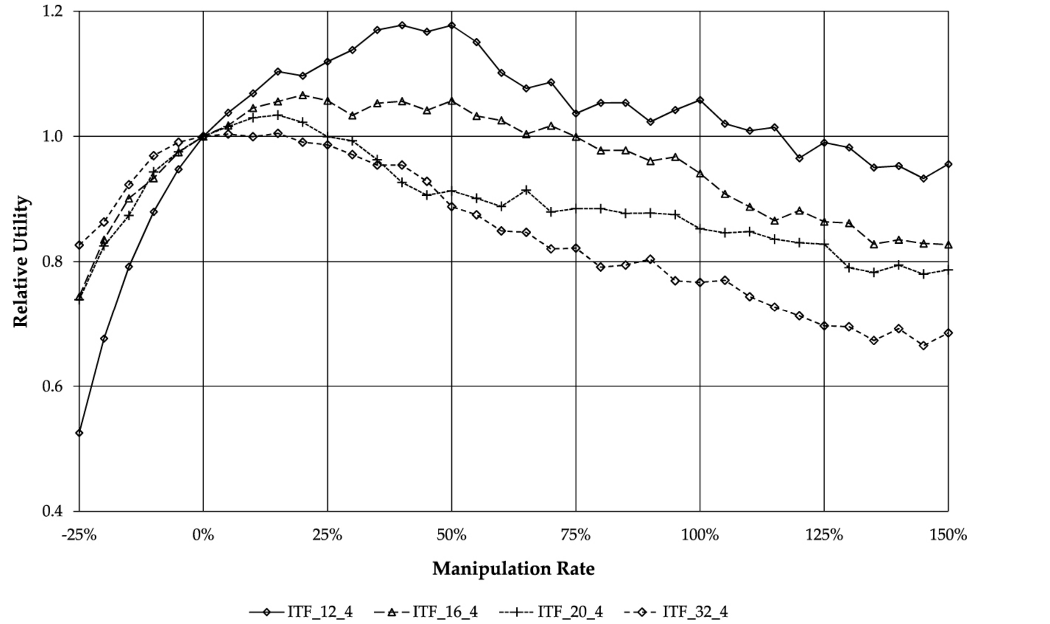

Figure 6. Utility for a single manipulating service provider in different competition scenarios. $\mathrm{ITF}\_|\tilde{V}|\_K$ **denotes the setting with** $|\tilde{V}|$ **service offers in** K **candidate pools, where** $|\tilde{V}| = V$, $\{v_s, v_f\}$

Conclusion

In this article, we provided an auction mechanism – the Complex Service Auction (CSA) – to coordination value creation in Service Value Networks (SVNs). The CSA implements a truth-telling equilibrium in weakly dominant strategies, i.e. service providers cannot benefit from misreporting their true valuation satisfying Design Goal 4. This is a valuable property for a mechanism and the implemented social choice as it assures truthful behavior of all participants which allows for an efficient allocation that maximizes welfare among service providers and the service requester which meets Design Goal 1. Truthfulness comes at the price of budget balance. As a remedy for this shortcoming, the Interoperability Transfer Function (ITF) was developed. The ITF sacrifices truthfulness and efficiency to a certain degree in order to retain budget balance. The ITF furthermore rewards service providers that offer highly interoperable services within the SVN, which increases the number of feasible service compositions that can be offered to requesters. Thus, the ITF implements incentives to increase a services' interoperability and therefore fosters the growth of vital and more agile SVNs satisfying Design Goal 5.

Using the CSA with the critical value transfer as a benchmark, the robustness of the ITF extension was analyzed with respect to bid manipulation of service providers (deviation from the truth-telling strategy). The simulation-based results showed that in scenarios with a low level of competition, implementing the ITF extension opens up strategic behavior to a certain degree. Service providers can significantly benefit from misreporting their true valuation. Nevertheless, in settings with a slightly higher level of competition, the set of beneficial manipulation strategies is decreased tremendously. Although the CSA with the ITF extension does not implement truthfulness in a strict analytical sense, service providers cannot significantly benefit from misreporting their true valuation in settings with a still relatively low level of competition.

Service components that are traded in service marketplaces such as the CSA also require low level resource services (utility services) to enable their deployment and assure scalability during run-time. Focusing on the infrastructure layer, it is also reasonable to trade utility services themselves independent from mechanisms to allocate and price complex services in SVNs. Nevertheless, utility services expose different characteristics and therefore impose different requirements upon suitable market mechanisms. Combining the trade of utility and complex services, the question arises of *how a multi-layered market can be designed in order to enable a seamless allocation and pricing of complex services and corresponding utility service which are required by the layer above.*

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