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COMPETITION OF SERVICE MARKETPLACES – DESIGNING GROWTH IN SERVICE NETWORKS

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Abstract

The cloud computing paradigm gives rise to Web service marketplaces where complex services are provided by several modular vendors. Recently more and more intermediaries are pushing onto the market, thereby driving competition. Offering innovative business models which are capable of attracting service providers and consumers is a reasonable strategy to beat competitors and to take advantage of network effects. We develop a mechanism that introduces a novel way of distributing revenues among service providers – the power ratio. Its underlying presumption is not only to compensate service providers who actually contribute to a complex service offered at a time, but also to pay out partners who are on standby – i.e. vendors that support the network's variety and stability, but actually do not contribute to the complex service delivered. We show that a payment function that is based upon the power ratio is a promising approach to draw in service providers as it outperforms a payment function that rewards vendors merely based on their actual allocation in terms of expected payoffs for different types of service vendors.

Keywords: Service networks, Service mashups, Revenue distribution, Network effects

1 INTRODUCTION

Today's shift from a product- to a service-oriented economy has strong implications on technical and organizational best practices. A clear trend towards tremendous simplification and a high degree of standardization driven by the cloud computing paradigm blurs the roles of service producers, intermediaries and consumers. The "living Web" becomes reality and consumers experience the benefit of participating in value creation processes. Amazon announced that the bandwidth consumed by their Web service offerings such as the Elastic Compute Cloud (EC2)[1] or the Simple Storage Service (S3)[2] firstly exceeded the bandwidth consumed by all global Amazon shopping Web sites[3] in 2007 for the first time. Adapting this consumer trend, Amazon started to outsource even more complex core competencies such as their payment process as the Flexible Payment Service (FPS)[4] to be consumed by end users or seamlessly integrated in situational applications by software developers. From a technical perspective, dynamic Web services are increasingly used in the context of service mashups and situational applications facilitating lightweight approaches such as RESTful architectures (Fielding 2000) and slim messaging formats such as JSON (Crockford 2006). The service mashup platform ProgrammableWeb[5] reported that 66% of all listed APIs expose REST interfaces, foretelling the trend to an internet of interoperable (Web) services. From an organizational and economic perspective, value is created by the fruitful interplay of various distributed service providers that jointly contribute to an integrated solution that meets individual customers' needs.

In summary, these trends foster a rapid growth of Service Value Networks (SVNs) that are formed in a short-term fashion in order to provide customized complex services to multifaceted service consumers. To face customer requirements, service providers leverage their core competencies SVNs in order to offer joint complex services. Such complex services typically involve the assembly and invocation of several component services offered by a multitude of partners in order to complete a multi-step business functionality (Papazoglou 2007). The actual complex service requested by the buyer is thus dynamically created from the offerings of a pool of sellers. Value creation in SVNs is mostly coordinated by a central mediating entity such as today's leading service platforms: Salesforce[6] with the Web service market place AppExchange[7] and its development platform force.com[8], Xignite[9] with the Splice Mashup Platform[10], and StrikeIron with the StrikeIron service integration platform[11], just to name a few. This recent development drives competition between different service platforms and Web service market places. Service intermediaries have to stay competitive by differentiating their business model. A reasonable strategy in this context is to attract market participants (service providers as well as consumers) by offering novel and innovative pricing models that leverage competitive advantages. In order to boost network growth and foster increasing returns, it is inevitable to attract a critical mass of participants. Speaking of service providers, these participants do not necessarily have to be the most competitive ones – as long as the mass of vendors attracted make sure that a sufficiently large number of consumers enter the platform. If such an SVN is capable of attracting a good share of potential customers, previously not attracted providers might also feel impelled to join the SVN due to network effects (Shapiro and Varian 1999). The more service consumers join the platform, the more attractive

[1] http://aws.amazon.com/ec2/
[2] http://aws.amazon.com/s3/
[3] http://aws.typepad.com/aws/2008/05/lots-of-bits.html
[4] http://aws.amazon.com/fps/
[5] http://www.programmableweb.com/
[6] http://www.salesforce.com/
[7] http://sites.force.com/appexchange/apex/home
[8] http://www.salesforce.com/platform/
[9] http://www.xignite.com/
[10] http://splice.xignite.com/
[11] http://www2.strikeiron.com/Solutions/Overview.aspx

the market becomes for service providers since both sides of the market positively value the number of participants on the other market side. We seek to initiate such network effects by compensating all available vendors in the SVN that are able to fulfill a specific customer request, not only the ones that are actually allocated in a specific service composition. These payments are realized by radically shifting the traditional notion of purely allocation-based revenues towards a re-distribution among all vendors that are able to provide value.

This paper proceeds as follow: In the next section we motivate service value networks and formally model them. Section 3 provides our novel mechanism to distribute revenues in service networks that is able to trigger network effects as described above. Subsequently, the mechanism is benchmarked analytically and numerically in order to outline its ability to foster network growth. We conclude with a summary and implications.

2 SERVICE VALUE NETWORKS

As introduced in Section 1, our application scenario are service value networks which we define as follows (Blau et al. 2009b).

Definition 2.1. Service value networks. *Service value networks are business networks which provide business value through the agile and market-based composition of complex services from a registered, but open pool of complementary as well as substitutive standardized service modules through a ubiquitously accessible network orchestration platform.*

A service value network is described by means of a simplified state chart model (Harel and Naamd 1996) and is aligned with the representation in Zeng et al. (2003). State charts have proven to be the preferred choice when specifying process models. They expose well-defined semantics and provide flow constructs offered by established modeling languages such as WS-BPEL. Therefore, they allow for simple serialization in standardized formalisms. Using a formal notation, a service value network is represented by a directed, k-partite, and acyclic graph. Each partition or candidate pool ω represents a specific class of required (business) functionality. Without loss of generality we assume that each service is owned by a different service provider. Thus, the set of nodes $V = \{v_1, \ldots, v_N\}$ equals the set of service providers[12] that act in the network. Source (v_s) and sink (v_f) formalize complex services as an end-to-end connection and are not considered vendors in the network. An edge $e_{ij} \in E$ denotes a composition relationship between services v_i and v_j. That is, a link between two nodes denotes the technical feasibility of connecting two services (interoperability) on the one hand and the vendors' willingness to cooperate on the other hand. Edges are only possible between nodes of adjoing candidate pools.

Each service v_j exhibits a service configuration $\mathcal{A}_j$ that is characterized by a vector $\mathcal{A}_j = \{a_j^1, \ldots, a_j^M\}$ where a_j^m is an attribute value of attribute type m of service v_j. 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 p_{ij} attached to e_{ij} denote the price[13] for service v_j when being allocated as successor of service v_i.

[12] The terms *service*, *service provider* and *vendor* are used interchangeably.

[13] We do not allocate prices to the incoming edges of the sink since v_f is not considered a vendor. Consequently, links $e_{if}, v_i \in V$ are not included in E

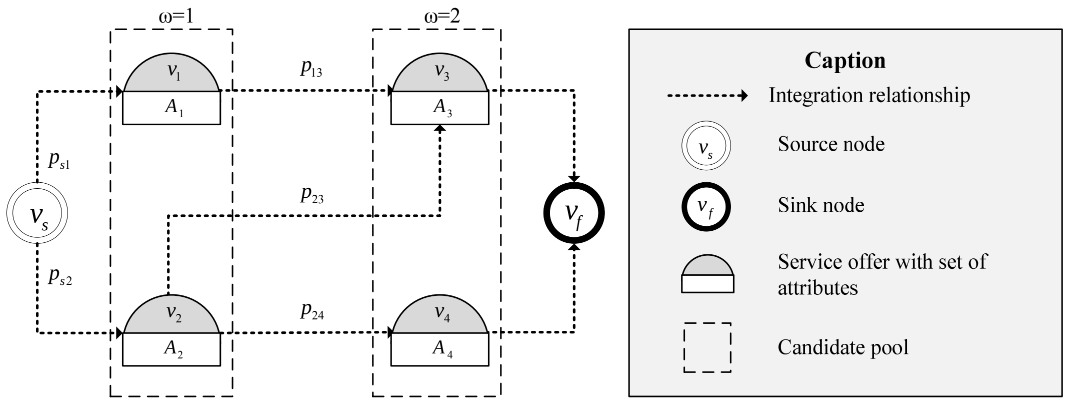

Figure 1. Exemplary formalization of a service value network

Accordingly, G is assembled as follows: $G = (\{V \cup v_S \cup v_f\}, \{E \cup e_{if}\})$. We are particularly interested in formalizing *instantiable* composite service instances as they symbolize a value creating output of G. This set of feasible paths from source to sink is denoted $F := \{F_1, ..., F_L\}$, $F_i := G \setminus \{v_s, v_f, e_{i,f}\}$. $F^* \in F$ shall denote the allocated path in the network.

Figure 1 shows an exemplary formalization of a service value network with $|\omega| = 2$ functionality clusters as a result of a customer's requirement specification. There are three paths in G. Every feasible path from source to sink represents a possible realization (instance) of a complex service. For instance, such a path is $F_1 = (\{v_1, v_3\}, \{e_{s1}, e_{13}\})$.

3 ALLOCATION AND REVENUE DISTRIBUTION

In order to implement our core idea to value distribution, we need to define a measure to capture a player's contribution to the overall network (which we will call the power ratio). When defining a mechanism that incorporates such a measure, one needs to keep in mind desired properties to be fulfilled. In markets, self-interested service providers act according to their private preferences for different outcomes. We consult mechanism design to implement the desired system-wide solution to our decentralized optimization problem (Parkes 2001). Fairness properties firstly introduced by Shapley (1953) and to establish a distribution logic which considers more than the allocated providers are essential and met by the power ratio (Conte et al. 2009). However, these fairness axioms shall not be the focus of this paper. Instead, we concentrate on motivating and evaluating another crucial design desideratum: the mechanism's ability to trigger network entry and growth.

3.1 Distributing Value in Service Networks: A Literature Review

In contrast to traditional mechanisms that distribute revenues merely among allocated service providers as e.g. discussed in Parkes (2001), the power ratio re-allocates monetary flows to any service provider that accounts for a positive value for the network. Academic literature already started to investigate efficient allocation and pricing in such service networks (cp. e.g. Blau et al. 2009a), however, did not yet consider peculiarities of network formation in the growth phase of such ecosystems that suggest to implement alternative logics of distributing value amongst participants.

Such alternative distribution logics compared to traditional mechanism design can be retrieved from cooperative game theory. Considering coalition games (V, χ) with a finite set of players $V = \{v_1, ..., v_N\}$ and a characteristic function χ which maps a coalition of players $T \subseteq V$ to a real numbered value, well-known approaches are, for example, the core and stable sets. Most importantly, both concepts assign a *set of payments* to players which are oftentimes *empty* or *ambiguous* (Mas-Colell et al. 1995). The Shapley value differs from above-mentioned approaches. It always provides a *unique solution*, i.e. a single payment to each player which is based on the average marginal contribution she or he yields to a coalition (Shapley 1953). Hence, it denotes the average power or significance of a player $v_i \in V$. However, the basic assumption in a coalition is that a player $v_i \in V$ is able to cooperate with any player $v_j \in V$. This does not hold true, though, for networks where due to functional or strategic restrictions links between players are of prime importance. Myerson (1977) extended the Shapley value to network structures. The range of possibilities to form coalitions is reduced to a given network topology G, resulting in the following allocation function $Y_i(G,\chi)$ for a player $v_i \in V$:

(1) $$Y_i(G,\chi) = \sum_{T \subset V \setminus \{v_i\}} \left(\frac{|T|!(|V|-|T|-1)!}{|V|!} \right) \cdot (\chi(T \cup \{v_i\}) - \chi(T))$$

An assumption inherited from the use of characteristic functions is superadditivity, requiring that a cooperation among more players must always be more fruitful than cooperations including fewer members. The fact that larger cooperations might not create any additional value is taken care of in Jackson (2005), replacing characteristic functions by monotonic covers $\hat{\chi}$ of the value function[14] for all $G' \subseteq G$ with $\hat{\chi}(G) = \max_{G' \subseteq G} \chi(G')$.

In this article we base our payment function upon Jackson (2005), include the characteristics of SVNs into the measure, and stress the overall network perspective as we show in the subsequent section.

3.2 Mechanism Implementation

In order to prepare service provisioning, information needs to be exchanged between the involved parties. Besides the requested service functionality *fnc* stated in a standardized format most possibly induced by the platform, the customer's service request is defined by the configuration $\mathcal{A}_{F_l}$ of the complex service. The latter evolves as the aggregation of all attribute values of contributing services on the path F_l such that $\mathcal{A}_{F_l} = (\mathcal{A}_{F_l}^1, \ldots, \mathcal{A}_{F_l}^M)$, $\mathcal{A}_{F_l}^m = \oplus_{e_{ij} \in F_l} a_j^m$. The aggregation operation $\oplus$ of attribute values depends on the characteristics of the respective attribute. The requester's valuation for the offered service configuration is idiosyncratic. Likewise, the coherence between price and attribute qualities depends on the requester's individual preference. Both weightings are depicted in the requester's scoring function Sc for a complex service F_l (Asker and Cantillion 2008):

(2) $$Sc(\mathcal{A}_{F_l}) = \sum_{m=1}^{M} \lambda_m \Psi(\mathcal{A}_{F_l}^m)$$

The scoring rule is specified by a set of weights $\Lambda = \{\lambda_1, \ldots, \lambda_M\}$ with $\sum_{m=1}^{M} \lambda_m = 1$ defining the requester's preferences for each attribute type. Attributes are normalized such that $\Psi : \mathcal{A}_{F_l}^m \to [0;1]$. A score of 0 induces a customer utility of zero and a score of 1 denotes maximum utility. Furthermore, the service requester needs to indicate his maximum willingness to pay α for a service yielding a score of 1.

Subsequently, the requested functionality is being forwarded to the potential pool of service providers by the platform operator. Thereupon, vendors willing to participate submit their service offers to the platform operator. Besides above-defined fnc, service offers consist of a bid $b_{ij}(e_{ij}) \subseteq \mathcal{B}$ including a service configuration $\mathcal{A}_j$ and a price bid p_{ij} submitted for a service v_j as successor of v_i as introduced in Section 2.

[14] Jackson (2005) introduced value functions as a richer object than characteristic functions incorporating both costs and benefits.

After the submission of the service request and the service offers, the platform operator dynamically builds the ad hoc service value network G that fulfils the customers' needs (cf. Section 2). Now, the platform operator has to solve the problem of allocating a path F^* and distributing payoffs in a manner that is in line with the design desiderata. This problem shall be solved by the mechanism implementation $m=(o,t)$ with o being the allocation function and t being the transfer function.

Let $\mathcal{P}_{F_l} = \sum_{e_{ij} \in F_l} p_{ij}$ represent the sum of the internal price bids submitted that constitute the complex service F_l . Further, let $\mathcal{U}_{F_l}$ denote the overall utility of path F_l based on the submitted bids. $\mathcal{U}_{F_l}$ is represented by its score for the customer net of the sum of the submitted prices for the edges included in F_l:

(3) $$\mathcal{U}_{F_l} = \alpha \cdot Sc\left(\mathcal{A}_{F_l}\right) - \mathcal{P}_{F_l}$$

Definition 3.1. Allocation function. *The allocation function $o: \mathcal{B} \rightarrow F$ maps the service providers' bids to a feasible complex service $F_l \subseteq F$ that maximizes the overall utility:*

(4) $$\forall \mathcal{U}_{F_l} > 0: \; o := \underset{F_l \subseteq F}{\operatorname{argmax}} \, \mathcal{U}_{F_l} = \underset{F_l \subseteq F}{\operatorname{argmax}} (\alpha \cdot Sc\left(\mathcal{A}_{F_l}\right) - \mathcal{P}_{F_l})$$

Let us now turn to the monetary transfers distributed. The transfer function t is composed of two components. The first component is directly associated with the winner path determination. That is, analogue to a first price auction, each allocated service provider receives its price bid p_{ij} .

The second component shall be the lever to implement the design desiderata such as network growth by monetizing the providers' contribution to the overall SVN. To approach such contributions, we adopted the concept of value functions from cooperative game theory (cp. Section 3.1). In line with Jackson (2005), we interpret value functions as objects representing costs and benefits, considering prices and service attributes as central indicators for the value that is generated by the network or sub-networks, respectively.

As introduced in Section 2, paths from source to sink represent feasible complex services. Only those are considered when assigning a value to a set of service providers and their corresponding links $S_i = (V_i^S, E_i^S) \in S$ with S being the set of all cooperations theoretically possible in G. A cooperation that does not include a feasible path is assigned a value $\chi(S_j) = 0$. As soon as a cooperation yields more than one path through G, the path providing the highest value is decisive for the calculation of the value function. We consult the overall utility function introduced in (2) and define the value function for cooperations $S_j \in S$ as a function $\chi: S \rightarrow \mathbb{R}$ as follows:

(5) $$\chi(S_j) := \begin{cases} \max\limits_{F_l \subseteq S_j} \mathcal{U}_{F_l}, & \text{if } \exists F_l \subseteq S_j, F_l \in F, S_j \in S, \; \alpha \cdot Sc\left(\mathcal{A}_{F_l}\right) > \mathcal{P}_{F_l} \\ 0, & \text{otherwise} \end{cases}$$

In order to determine the power ratio of the players in the network, we define an allocation rule as a function $Y: S \times \mathrm{X} \rightarrow \mathbb{R}^n$. Each service provider that generates a positive value (i.e. $\alpha \cdot Sc\left(\mathcal{A}_{F_l}\right) > \mathcal{P}_{F_l}$ holds true for at least one complex service the respective provider is a part of) is considered a vital vendor. Incorporating (5) and the concept of considering the overall network we get (6) as a direct extension of (1). For all cooperations v_i can theoretically join (6a), term (6c) takes a positive value whenever v_i is pivotal to it. This value is then weighted by the probability of the underlying cooperation to form assuming that the sequence of the players to join this cooperation is equally likely (6b).

The power ratio of service provider v_i is calculated as follows:

$$\varphi_i = Y_i(S_G, \chi) = \sum_{S_j \text{ with } V_k^S \subset V \setminus \{v_i\}} \left(\frac{|V_j^S|!(|V| - |V_j^S| - 1)!}{|V|!} \right) \cdot (\chi(S_j \cup \{v_i, E_{S_j i}\}) - \chi(S_j)) \tag{6}$$

(a) (b) (c)

The set of all incoming edges of a node v_i within a cooperation S_j is denoted $E_{S_j i}$. As soon as a player v_i enters a cooperation S_j, $E_{S_j i}$ is also added. Based upon the circumstance that the path F^* yielding the maximum overall utility $\mathcal{U}_{F^*}$, is being chosen, its value $\chi(F^*)$ will be distributed via the power ratio. Consequently, the overall transfer function assembles as follows:

Definition 3.2. Transfer function. *The power ratio-based transfer function (PRTF) consists of two components. The first component is directly dependent on the allocation in analogy to a first price auction. The second component accounts for the overall network view drawing on Shapley-style calculus:*

$$t_j^{PR} := \begin{cases} p_{ij} + \varphi_j, & \text{if } v_j \in F^* \\ \varphi_j, & \text{otherwise} \end{cases} \tag{7}$$

By distributing $\mathcal{U}_{F^*}$, the mechanism is budget balanced, i.e. outside payments are not required to realize the payment scheme. Budget balance is said to be compulsory since the platform operator cannot subsidize the mechanism in the long run by constantly leveling out side payments (Parkes 2001). In spite of budget balance, the PRTF fosters network growth as we show in the next section that.

4 NETWORK GROWTH

In this section we analyze the PRTF's ability to incentivize service providers to join the service value network. As a suitable benchmark to evaluate the growth incentives implemented by a market using PRTF ($m_{PRTF} = (o, t^{PR})$), a market $m_{ETF} = (o, t^{EQ})$ implementing an equal transfer function t^{EQ} is consulted. The equal transfer function (ETF) distributes the system's surplus $\chi(F^*)$ equally among all allocated service provider as follows:

$$t_j^{EQ} = \begin{cases} p_{ij} + \frac{1}{C}\mathcal{U}_{F^*}, & \text{if } v_j \in F^* \\ 0, & \text{otherwise} \end{cases} \tag{8}$$

with C being the number of candidate pools present in the SVN. That is, the ETF distributes the surplus in equal shares to each allocated service provider. The ETF represents a neutral payment scheme compared to PRTF as it equally distributes the same surplus, however, does not implement particular incentives. To summarize, both mechanisms implement the same allocation function o as outlined in Definition 3.1. However, they differ in respect to the transfer function which distributes payments among service providers.

4.1 Analytical Considerations

In order to determine which market is better suited to incentivize network effects, a comparison of expected payoffs for service providers when deciding upon entering m_{PRTF} or m_{ETF} is required. As both mechanisms are obviously individually rational, i.e. service providers do not have to be forced to participate in the market as they are never worse-off by doing so, their decision solely depends on the expected payoff they gain in each market. Basically, expected payoffs assemble as follows:

(9) $$E(\pi_j^{PRTF}) := prob_j(o) \cdot \left(p_{ij} + \delta_j^o U_{F^*} - c_{ij}\right) + prob_j(\overline{o}) \cdot \left(\delta_j^{\overline{o}} U_{F^*}\right)$$

(10) $$E(\pi_j^{ETF}) := prob_j(o) \cdot \left(p_{ij} + \frac{1}{C} U_{F^*} - c_{ij}\right) + prob_j(\overline{o}) \cdot \left(\delta_j^{\overline{o}} U_{F^*}\right)$$

while π_j^m denotes vendor v_j 's profit in market m. The probability $prob_j(o)$ indicates the probability of service v_j being allocated, while $prob_j(\overline{o})$ denotes the probability of the respective service being not allocated. δ_j^o denotes the percentage of the surplus that is distributed to vendor v_j if allocated, analogously, $\delta_j^{\overline{o}}$ stands for the percentage of the surplus granted if v_j is not allocated. Finally, c_{ij} symbolizes the costs for service v_j to be delivered.

For simplicity, we assume that the costs c_{ij} equal the internally bid price p_{ij}. Further we assume that an arbitrary service provider can choose which market to enter without additional cost. That is, v_j can choose from two actions $\mathfrak{a} = \{m_{PRTF}, m_{ETF}\}$ out of its action space. Depending on the interoperability and the bid price and service configuration, it is then – given the customer's preferences and the network topology - either allocated or not allocated. In case of m_{PRTF}, v_j realizes a profit of $\delta_j^o U_{F^*}$ if allocated or $\delta_j^{\overline{o}} U_{F^*}$ if not allocated. Accordingly, choosing m_{ETF}, the payment amounts to $\frac{1}{C} U_{F^*}$ if allocated while v_j leaves empty-handed if not allocated.

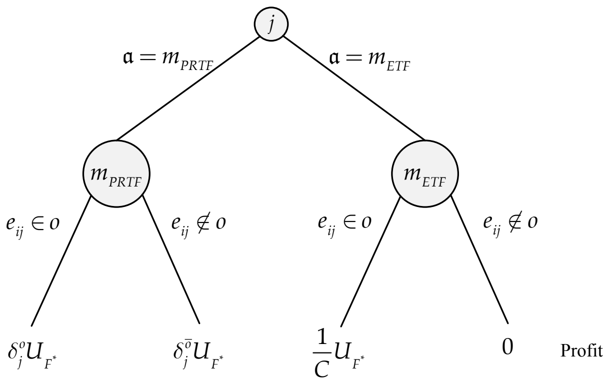

Figure 2. Action space of an arbitrary service provider

An analytical comparison of PRTF and ETF is not trivial. The complexity of the calculation of the set of internal cooperations as required in (6b) is exponential in their input as there are 2^N sub-graphs in a graph G with $|V| = N$ nodes[15]. Therefore, formal proofs are only possible to a limited extent including a large number of restrictions as shown in the following theorem.

Theorem 1. *Assuming a fully intermeshed network[16] which features exactly K service providers in each candidate pool and identical prices and qualities (i.e. $p_{ij} \to \mu$, $\mathcal{A}_j \to \eta \ \forall v_j \in V$), the expected*

[15] Our application of the power ratio in emerging SVNs narrows the importance of an efficient (i.e. polynomial) calculation of the transfer. Sizes of realistic networks (cp. Table 2) and larger are small enough to tackle the calculation using the logic proposed in (6) on the time scale of seconds.

[16] According to the rules stated in Section 2: Links are only permitted between adjoing clusters.

payoff for an arbitrary service provider in m_{PRTF} *equals the expected payoff in* m_{ETF}, *i.e.* $E(\pi_j^{PRTF}) = E(\pi_j^{ETF})$.

Proof. Since all vendor in the SVN are alike, their allocation probability is directly connected with the number of service providers K present in each candidate pool as outlined in (11):

(11) $$prob_j(o) = \frac{1}{K}$$

Hence, the probability of not being allocated assembles as follows:

(12) $$prob_j(\bar{o}) = \frac{K-1}{K}$$

Taking (11) and (12) as a basis, the expected payoff in m_{PRTF} can be calculated. The power ratio for all present vendors is identical since they take over analog roles in the SVN.

(13) $$E(\pi_j^{PRTF}) = \frac{1}{K} \cdot \frac{1}{N} U_{F^*} + \frac{K-1}{K} \cdot \frac{1}{N} U_{F^*} = \frac{1}{N} U_{F^*}$$

According to (8), the ETF leads to the following expected payoff:

(14) $$E(\pi_j^{ETF}) = \frac{1}{K} \cdot \frac{1}{C} U_{F^*} = \frac{1}{N} U_{F^*}$$

But how do the payoffs evolve in case of different bid prices, quality attributes, and/or interoperability relationships? Let us consider two simple variations of the assumptions made in Theorem 1:

- We start with service provider v_i with $p_{hi} \rightarrow \mu + \varepsilon$ ceteris paribus. That is, this vendor creates less utility than any other vendor in the SVN. Thus, $prob_i(o) = 0$. Nevertheless, in the PR-based market, v_i is pivotal to certain cooperations as long as paths including v_i yield a positive utility. Based on (9) and (10), this vendor faces the following expected profits in m_{ETF} and m_{PRTF}: $E(\pi_i^{ETF}) = 0 < E(\pi_i^{PRTF}) = prob_i(\bar{o}) \cdot \left(\delta_i^{\bar{o}} U_{F^*}\right)$ if $\varepsilon < \mu$. Since the surplus distributes is identical in both the ETF and the PRTF market, some other participants must lose a portion of their payment.
- On the other hand, one can construct a situation where a service provider v_j offers a price bid of $p_{ij} \rightarrow \mu - \varepsilon$ ceteris paribus. In this case, $prob_i(o) = 1$ since v_j creates a utility that is higher than the utility created by any other vendor. Based on (9) and (10), this leads to $E(\pi_j^{ETF}) = 1 \cdot \frac{1}{C} U_{F^*}$ and $E(\pi_i^{PRTF}) = 1 \cdot \left(\delta_j^o U_{F^*}\right)$. According to the vendor's contribution to the network, i.e. in this case, dependent on ε, $\delta_j^o \in [\frac{1}{N}, 1)$ can be either greater or less than $\frac{1}{C}$, such that a comparison of $E(\pi_j^{ETF})$ and $E(\pi_j^{PRTF})$ is not possible by implication.

Generally, above-stated considerations still require various restrictive assumptions such as, for instance, a fully intermeshed network and identical prices and quality attributes. A relaxation of these assumptions leads to a multitude of dependencies within the analytical considerations which do not allow formal proofs within reason. Therefore, we present a numerical approach to study the effects of a PR-based transfer function in order to derive more general results that also allow for strategic recommendations.

4.2 Numerical Approach

In this section we seek to numerically show that the market implementing a power ratio-based transfer function attracts more service providers than the ETF-based market as stated in the following hypothesis.

Hypothesis. *m_{PRTF} attracts a greater number of service providers than m_{ETF}.*

To do so, we apply an agent-based simulation, modeled as an N-person game. Purpose of the numerical approach is to relax the assumptions made in Section 4.1. That way, we are able to vary the network topology, the density of the network (i.e. the degree of interoperability relations in the SVN), bid prices and service configurations, and customer requirements. For each of the different network topologies, we simulated $M = 25,000$ rounds, in each of which a random network density ($\in [0.5;1]$) and random price bids and service configurations were drawn from a uniform distribution in the interval $(0;1]$. The service attributes are aggregated via an average function, i.e. $\mathcal{A}_{F_l} = \frac{1}{C} \cdot \sum_{v_j \in F_l} a_j$. Further, in each simulation round, different customer types $R = \{low,\ medium,\ high\}$ were drawn with variable willingness to pay $\alpha \in (0;1.5 \cdot C)$[17]. The three different customer types represent different customer valuations for service quality; $r_1 = low$ represents a rather undemanding customers whereas $r_3 = high$ represents a premium customer. $r_2 = medium$ is situated right in the middle of r_1 and r_3.

As shown in Figure 2, an arbitrary agent v_j is drawn in each round. This service provider is then classified according to its bid price and its service configuration in one of nine classes $D = (d_1,...,d_9)$ as depicted in Table 1.

Price bid / Service quality	$q_j \in (0;0.33]$	$q_j \in (0.33;0.67]$	$q_j \in (0.67;1]$
$p_{ij} \in (0;0.33]$	$d_1 = (low, low)$	$d_2 = (low, med)$	$d_3 = (low, high)$
$p_{ij} \in (0.33;0.67]$	$d_4 = (med, low)$	$d_5 = (med, med)$	$d_6 = (med, high)$
$p_{ij} \in (0.67;1]$	$d_7 = (high, low)$	$d_8 = (high, med)$	$d_9 = (high, high)$

Table 1: Classification of service provider types

After classifying the arbitrarily chosen service provider according to Table 1, its (hypothetical) payoffs π_j^{PRTF} and π_j^{ETF} are calculated in each of the $25,000$ simulation rounds. Table 2 shows the results of the simulation runs by comparing the expected payoffs in m_{PRTF} and m_{ETF} for all agent classes. The hypothesis is divided into nine sub-hypotheses stating that m_{PRTF} attracts a greater number of service providers than m_{ETF} for agent class d. These sub-hypotheses are tested using a one-tailed matched-pairs t-test as the large number of observations ($M = 25,000$) assures robustness of the t-test to violations of the normality assumptions. We performed analyses for multiple topologies as listed below: $Z = \{z_1 = (C = 2, K = 3), z_2 = (3,3), z_3 = (3,4), z_4 = (4,4), z_5 = (5,3)\}$.

[17] A sensitivity analysis of different upper bounds α^U of α showed that its effect follows the same direction, however, is more distinct with a slightly larger upper bound. For small upper bounds $\alpha^U \leq C$, the customer utility is oftentimes too low for a transaction to complete, i.e. such that a path provides positive value.

D	$E(\pi_d^m)$, z_1		$E(\pi_d^m)$, z_2		$E(\pi_d^m)$, z_3		$E(\pi_d^m)$, z_4		$E(\pi_d^m)$, z_5	
	m_{PRTF}	m_{ETF}	m_{PRTF}	m_{ETF}	m_{PRTF}	m_{ETF}	m_{PRTF}	m_{ETF}	m_{PRTF}	m_{ETF}
d_1	0.137**	0.125	0.158**	0.146	0.117**	0.104	0.125**	0.113	0.173*	0.169
d_2	0.244	0.290	0.226	0.267	0.179	0.210	0.176	0.202	0.226	0.268
d_3	0.350	0.421	0.298	0.366	0.239**	0.307	0.230	0.294	0.275	0.346
d_4	0.091**	0.056	0.109**	0.066	0.078**	0.036	0.089**	0.042	0.135**	0.077
d_5	0.158**	0.134	0.168**	0.144	0.118**	0.094	0.122**	0.086	0.170**	0.134
d_6	0.231	0.229	0.215**	0.198	0.160**	0.146	0.156**	0.131	0.210*	0.204
d_7	0.042**	0.021	0.070**	0.029	0.042**	0.016	0.053**	0.012	0.094**	0.035
d_8	0.082**	0.047	0.121**	0.088	0.073**	0.040	0.072**	0.043	0.124**	0.074
d_9	0.124**	0.089	0.155**	0.135	0.088**	0.060	0.100**	0.063	0.147**	0.101

*Table 2: Expected payoffs of service provider classes in m_{PRTF} and m_{ETF} subject to different topologies. * denotes significance at the level of p=0.1, ** denotes significance at the level of p=0.01. If there is no asterisk, significance is not given.*

It is now relevant how many of the service provider classes prefer m_{PRTF} over m_{ETF}. If all classes of service providers appear in equal shares, presuming that service provider types are equally likely, the underlying simulation shows that at least 66.7% (in case of $z_1 = (2,3)$) of the service providers significantly prefer m_{PRTF} (since $E(\pi_d^{PRTF}) > E(\pi_d^{ETF})$, for all other tested topologies, 77.8% of the service providers choose m_{PRTF}. That is, the sub-hypotheses can be accepted for at least six out of nine service provider classes. Vice versa, not all of the service providers are attracted. This is straight forward, since both PRTF and ETF distribute the same surplus U_{F^*}. Therefore, if some of the service providers receive a larger share of it, others must be worse off. It is obvious that the most competitive service providers (d_2 and d_3) expect a higher payoff in m_{ETF} than in m_{PRTF}. However, service providers with intermediate price and quality tend to choose the PRTF market, likewise vendors that offer higher prices but lower quality. The latter class of agents can still be beneficial to an SVN as long as they contribute to the overall welfare. Furthermore, such providers contribute to the variety of the network, making it more attractive for service customers. This larger number of service providers in m_{PRTF} can be interpreted as the kind of variety, multitude, and stability (in a sense of reliability) customers value and honor when deciding on which market to enter (Church et al. 2008). To summarize, the hypothesis stated in this section can be accepted given the assumption that service provider types occur uniformly distributed in an SVN. Furthermore, we assume that customers' preferences are equally distributed and that customers generally prefer networks yielding a greater variety over networks offering only little alternative services. Our simulation cannot claim to be complete. Therefore, the accepted hypothesis should be interpreted as an indication of the PRTF's potential to network growth.

5 SUMMARY AND IMPLICATIONS

Addressing the question of how growth of service ecosystems can be fostered by adequate coordination, novel mechanism design desiderata come to attention. Complementary to the traditional objectives in mechanism design, the work at hand pursues the goal of implementing a mechanism which supports the development of healthy service value networks (SVNs) while accounting for network effects. With the presented power ratio-based transfer function (PRTF), we reward parties that are willing and ready to contribute their core competencies to value creation if needed and therefore increase the network's variety and flexibility. Our evaluation showed that a service marketplace implementing the PRTF is potentially able to foster high-volume network growth compared to a traditional approach by leveraging the power of network effects. The quantity of attracted service providers leads to the attraction of service consumers that base their decision to enter a market upon the expected future size of the network (Shapiro and Varian 1999), thereby activating network effects which provide additional value for vendors. As a consequence, service providers that chose a different platform so far are also likely to be forced to join the PRTF-based market. Furthermore, the defined classes are not given basic knowledge – especially in newly emerging market segments, a self-assessment of service providers is not trivial. Risk-averse vendors are likely to systematically undervalue their competitiveness which generally makes them tend towards the market that yields a more secure payment. In this connection, offering a service on a specific platform involves sunk investments. Uncertain revenues compared to these initial investments might prompt sellers not to join an SVN. Knowing that there will be a recurring payment even if one's service is not regularly allocated might lower the entry barrier for service vendors, somewhat providing security through reconciliation of interests, at least in the initial phase of the platform. Our PRTF for revenue distribution in SVNs is a promising approach to tackle the well-known chicken-egg-problem to attract both sides of a market – consumers as well as providers (Gandal 2002).

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