

Enabling Service Networks Through Contribution-Based Value Distribution

Tobias Conte

FZI Research Center for
Information Technology
conte@fzi.de

Gerhard Satzger

KSRI Karlsruhe Service Research
Institute, Universität Karlsruhe (TH)
satzger@de.ibm.com

Benjamin Blau

Institute of Information Systems and
Management (IISM), Universität Karlsruhe (TH)
blau@iism.uni-karlsruhe.de

Clemens van Dinther

FZI Research Center for
Information Technology
vandinther@fzi.de

ABSTRACT

Products increasingly turn into services. A prime example for this trend is the software industry. Specialized vendors leverage their core competencies in service value networks that offer joint complex services to customers. Such service value networks are in their infancy, yet both academics and practitioners lack approaches to formalize and economically analyze them. Our objective is to reward service providers not only for their inclusion in a particular service rendered, but also for their mere presence in the network. Purpose of such a scheme is to incentivize vendors to join the network and to enforce certain network characteristics from an operator's point of view. To this end, we introduce a metric to express the contribution of service providers to the whole network – the power ratio. We conduct a simulation to study the evolution of service value networks if vendors maximize their utility based on their power ratio.

Keywords

Revenue distribution, service networks, network formation, network evolution.

INTRODUCTION

Customers increasingly demand holistic and tailored solutions. In order to handle these changing requirements, companies start to re-organize their value creation processes towards joint provisioning of goods and services in ecosystem-like environments. Once serving the whole value chain, celebrating what has become famous as vertical integration, companies now focus on their core competencies. In related but non-core activities, assets of partners are leveraged. That way, the network has the ability to “rapidly pick, plug, and play” business processes (van Heck and Vervest, 2007).

A prime example for this trend is the software industry. Vendors do not only turn into service providers, benefitting from the capabilities of Internet standards and interoperability. They increasingly modularize their core competencies in *service value networks* (SVNs) in order to offer joint complex services which meet specific customer requests. 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 customer is dynamically created from the offerings of a pool of provider candidates. Increasingly, service platforms and marketplaces emerge that assemble and manage SVNs – with significant business impact, at this stage already observable in the software industry.

When preparing the market entry of an SVN, its operator needs to “get on board” both buyers and sellers in order to establish a successful business (Rochet and Tirole, 2003). The key challenge is to find a way to exploit so-called network effects, i.e. capitalizing the dependency of a network's value and the number of participants connected to it (Shapiro and Varian, 1999). Service consumers benefit from the quantity and complementarity of service providers on the platform¹, leading to greater variety and more competitive prices. However, sellers are only willing to register if they expect to come across a sufficient number of buyers in the market (Caillaud and Jullien, 2003).

¹ In two-sided market theory, the term *platform* is used for platforms in the wider sense like common hardware or common standards. In this article, platform denotes both the marketplace itself and the standards imposed by the platform operator.

Thus, a successful SVN requires measures to incentivize participants to join. We present an approach that explicitly concentrates on incentivizing the service provider side. Its underlying novelty is to not only compensate those who actually contribute to the complex service offered at a time, but also to pay out service providers that are on standby, i.e. partners supporting the network's variety, but actually do not contribute to the complex service rendered. That way, we seek to lower the entry barrier for service vendors that face initial costs when developing services compliant to the platform requirements.

Let p_i denote the price a service provider i announces to the platform operator. φ_i denotes the individual percentage of its contribution to the network. δ shall be a surplus that is additionally distributed according to φ_i . Basically, such a scheme r could be designed as follows:

$$(1) \quad r_i := \begin{cases} p_i + \varphi_i \cdot \delta, & \text{if player } i \text{ is allocated} \\ \varphi_i \cdot \delta, & \text{otherwise} \end{cases}$$

Certainly, the surplus has to be sponsored by one of the network participants. Therefore, (1) can only be suitable as a temporary measure in the initial phase of an SVN.

In this article we assume that the platform operator grants the surplus. This assumption is built upon several rationales. On the one hand, to reach a profitable mass of participants, the platform operator needs to invest in monetary incentives to draw in service providers. On the other hand, a payment as described in (1) can be a lever for the platform operator to push the network structure to a certain direction. Customers are expected to prefer purchasing services in networks yielding alternative offerings such that other providers can dynamically pitch in if an allocated service vendor goes out of business. Hence, the platform operator is willing to push the network structure to a situation where, preferably, as many service providers as possible are linked with each other. Furthermore, promoting alternative paths through the network leads to a more balanced network without single providers having monopolistic positions. In such balanced networks, the platform operator is no longer dependent on powerful service providers which could impose pressure by bullying the market or by threatening the network with termination of membership.

In the following, we do not examine the very impact of such a payment scheme to the formation of SVNs. Rather we analyze if such a payout rule can, from the platform operator's point of view, positively affect the network's structure.

This paper proceeds as follows: After a literature review and the formalization of service value networks, we propose the *power ratio* as a measure to capture a service provider's marginal contribution to the SVN. Thereafter, we transfer the power ratio to a payment rule and set up research hypotheses concerning its behavior. The subsequent section outlines the simulation design, its settings, and the evaluation of its results. We conclude with a summary.

REWARDING VENDORS' CONTRIBUTIONS IN SERVICE VALUE NETWORKS

As stated in the introduction, our objective is to compensate all available sellers in an SVN that are able to fulfill a customer request.

Literature Review

Cooperative game theory offers a multitude of concepts to deal with the distribution of value among individuals. Considering coalition games (V, χ) with a finite set of players $V = \{v_1, \dots, v_N\}$ and a characteristic function χ which maps a coalition of players $T \subseteq V$ into real numbers, well-known approaches are, for example, the core and stable sets. Most importantly, both concepts assign a *set of payments* to players which is oftentimes *empty* or *ambiguous*.

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 $v_i \in V$ as a direct extension of the Shapley value:

$$(2) \quad Y_i(G, \chi) = \sum_{T \subseteq V \setminus \{v_i\}} \left(\frac{|T|!(|V|-|T|-1)!}{|V|!} \right) \cdot (\chi(T \cup \{v_i\}) - \chi(T))$$

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. But what if a smaller cooperation of players is able to obtain a certain goal more efficiently? The application of proper characteristic functions does not cover this issue. This extension is, in turn, provided by Jackson (2005). He replaces characteristic functions by monotonic covers $\hat{\chi}$ of the value function² for all $G' \subseteq G$ with $\hat{\chi}(G) = \max_{G' \subseteq G} \chi(G')$.

Another closely related field of research is network formation. Jackson and Wolinsky (1996) analyzed the evolution of social and economic networks where self-interested individuals form or sever links. Jackson and Watts (2002) dynamically based network formation upon players' individual improvements resulting from changes in the network topology. Traditionally, breaking relationships can be done unilaterally while the formation of links requires consent from both players (Jackson and Wolinsky, 1996). Bala and Goyal (2000), however, stated that links can be formed by individual decision under certain circumstances. This is also the case in SVNs since service providers cannot influence which other services process their outputs.

To summarize, we base our payment function upon Jackson (2005), include the characteristics of SVNs into the measure, and stress the overall network perspective. The formation of SVNs is evaluated given our contribution-based payment.

Service Value Networks – A Formal Model

Before economically analyzing SVNs, we need to define an abstract model to formalize them. Importantly, we focus on the core process of realizing a complex service without going into process-related details such as parallel or cyclic components. The logic of the services' interaction is depicted in a process model.

An SVN is represented by a k -partite, directed, acyclic graph $G = (\{V \cup v_s \cup v_f\}, \{E \cup e_{i,f}\})$. For simplicity we assume that each service is owned by a different service provider. Thus, the set of service providers $V = \{v_1, \dots, v_N\}$ equals the set of services present in network G . Two auxiliary nodes v_s (source) and v_f (sink) serve to formalize complex services as an end-to-end connection. These nodes are not considered service providers in the network.

An edge $e_{i,j} \in E$ denotes an integration relationship between two service providers v_i and v_j (i.e. interoperability of offered services and their willingness to cooperate). A service configuration A_j of service v_j is fully characterized by a set of M attributes $A_j = \{a_j^1, \dots, a_j^M\}$ where a_j^m is an attribute value of attribute type m . Each $e_{i,j} \in E$ is annotated with the price $p_{i,j}$ of service v_j when being allocated as successor of service v_i . We do not allocate prices to the incoming edges of the sink as v_f is not considered a vendor. Consequently, the links $e_{i,f}$ with $v_i \in V$ are not included in E .

Each partition ω represents a specific class of functionality. Vendors belonging to the same cluster provide a service of the same type. Only possible realizations of complex services, i.e. complete paths from source to sink, create value. Since v_s and v_f are not considered vendors, the set of paths shall be denoted $F := \{F_1, \dots, F_L\} \subseteq G \setminus \{v_s, v_f, e_{i,f}\}$. Let $F^* \in F$ denote the allocated path in the network.

Figure 1 exemplarily formalizes a service value network. The graph illustrates the network of providers and their connections which meet the requirements specified by a service requester.

² Jackson (2005) introduced value functions as a richer object than characteristic functions incorporating both costs and benefits.

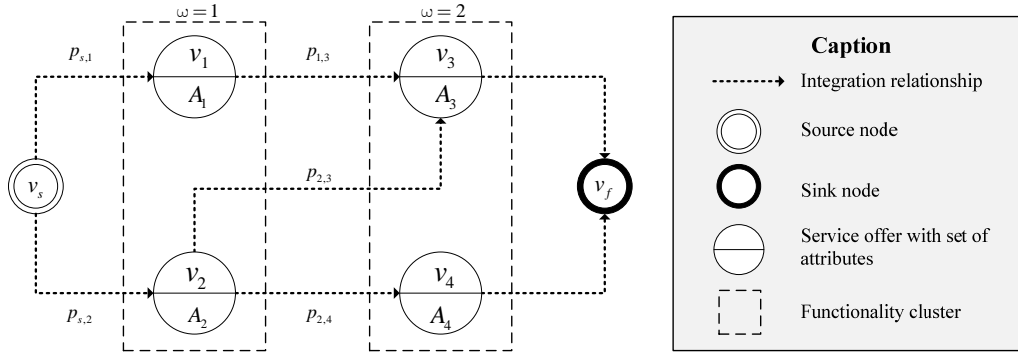


Figure 1. Formalization of a service value network

The Power Ratio: Measuring a Vendor's Marginal Contribution to a Service Value Network

In analogy to Jackson (2005), we interpret value functions as objects representing costs and benefits. As above-mentioned, paths denote feasible complex services. Therefore, the value of paths is the crucial factor when assigning value to a cooperation $S_k = (V_k, E_k) \in S$, $S \subseteq G \setminus \{v_s, v_f, e_{i,f}\}$. That is, a cooperation S_j with $\neg \exists F_l \subseteq S_j \forall F_l \in F$ is assigned a zero-value $\chi(S_j) = 0$. For cooperations $S_k \in S$ with $\exists F_j \subseteq S_k$ we implement a valuation that is directly dependent on the network characteristics that create value. As we consider SVN from an overall perspective, its best path is to create the same value as the cooperation that includes the whole network. We suggest waiving the strong assumption of a superadditive value function in favor of a weaker constraint. That is, we accept:

$$(3) \quad \chi\left(\bigcup_{i=1}^K S_i\right) \geq \max(\chi(S_1), \dots, \chi(S_K)) \text{ , } S_i \in S$$

In order to meet (3), we only incorporate vendors that provide additional value when determining χ . That is, as soon as there is a cooperation that yields at least one path through G , the path providing the highest value is consulted for the calculation of χ . For example, consider a vendor v_i that joins a cooperation $S_1 \supseteq F_1$, thereby accounting for a cooperation S_2 yielding an additional path F_2 . If $\chi(F_1) < \chi(F_2)$, then $\chi_{\max}(S_2) = \max\{\chi(F_1), \chi(F_2)\} = \chi(F_2)$. On the other hand, if $\chi(F_1) > \chi(F_2)$, then $\chi_{\max}(S_2) = \chi_{\max}(S_1) = \chi(F_1)$. In the latter case, v_i does not provide additional value to S_2 .

We consider prices $p_{i,j}$ and service attributes A_j as the central indicators for the value that is generated. The price of a complex service P_{F_i} is determined by aggregating the prices $p_{i,j}$ of services situated on F_i , that is $P_{F_i} := \sum_{e_{i,j} \in F_i} p_{i,j}$. For simplification, we assume equal service attributes A_j of all services. Consequently, value functions are only driven by prices. Therefore, we introduce the value function as a function that is monotonically decreasing with rising prices, i.e. a quasi-linear approach using $\chi_{\max}(S_k) = \alpha - \max_{F_l \subseteq S_k} P_{F_l}$, if $\exists F_l \subseteq S_k, F_l \in F, S_k \in S$ with α being the service requester's willingness to pay. To further simplify our model, we assume a universal service requester, i.e. α is sufficiently high and identical for all requesters. Thus, we can again simplify χ as a function $\chi: S \rightarrow \mathbb{R}$ that reciprocally accounts for the prices of services included in the complex service for cooperations $S_k \in S$ as follows:

$$(4) \quad \chi_{\max}(S_k) := \begin{cases} \max_{F_l \subseteq S_k} \frac{1}{\sum_{F_l} P_{F_l}}, & \text{if } \exists F_l \subseteq S_k, F_l \in F, S_k \in S \\ 0, & \text{otherwise} \end{cases}$$

Let X be the set of all possible value functions. In order to determine the service providers' power ratios, we define a function $Y: S \times X \rightarrow \mathbb{R}^n$. Recall that the basis for our consideration is always the cooperation S_G that includes the full graph G . Incorporating (4) and the concept of considering the overall network we get (5) as a direct extension of (2). For all cooperations v_i can theoretically join (5a), term (5c) 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 (5b).

$$(5) \quad Y_i(S_G, \chi) = \underbrace{\sum_{S_k \text{ with } V_k \subset V \setminus \{v_i\}}}_{(a)} \underbrace{\left(\frac{|V_k|! (|V| - |V_k| - 1)!}{|V|!} \right)}_{(b)} \cdot \underbrace{(\chi_{\max}(S_k \cup \{v_i, E_{S_k, i}\}) - \chi_{\max}(S_k))}_{(c)}$$

The set of incoming edges of a node v_i within a cooperation S_k is denoted $E_{S_k, i}$. As soon as v_i enters a cooperation S_k , $E_{S_k, i}$ is also added. Based on (5), we calculate a service provider's relative share in the overall productivity of the network which we interpret as its power ratio (PR) φ_i relative to the overall network, i.e. $\varphi_i \in [0;1]$:

$$(6) \quad \varphi_i(S_G, \chi) = \frac{Y_i(S_G, \chi)}{\sum_{j \in V} Y_j(S_G, \chi)} = \frac{Y_i(S_G, \chi)}{\chi_{\max}(S_G)}$$

The individual power ratios $(\varphi_1, \dots, \varphi_N)$ sum up to 1. Hence, we do not directly distribute the value created via Shapley-style calculations, but rather extract the influence of a single service provider relative to the topology of the whole network.

A Payment Rule Based on the Power Ratio: Objectives and Research Hypotheses

Based on (1) and (6), we propose the *PR-based payment (PRP) rule* as a distribution scheme:

$$(7) \quad r_j^{PRP} := \begin{cases} p_{i,j} + \varphi_j \cdot \delta, & \text{if } v_j, e_{i,j} \in F^* \\ \varphi_j \cdot \delta, & \text{otherwise} \end{cases}$$

The determination of the allocated complex service F^* shall not be coupled with the PR and is based on an allocation function that picks the most favorable complex service available in the network available from a consumer's point of view. Importantly, we vary the payment rule and concentrate on evaluating the usability of applying a payment scheme that considers the whole network structure as presented in (7). Hence we do not yet consider the bidding strategies of service providers.

The design of our PRP rule aims to support the goals pursued by the platform operator. Firstly, a more distributed compensation shall incentivize participants to join the SVN (*O1*). Such incentives will be reinforced if there is not only a recurring payment, but also a greater alternation of allocated service providers. Thus, the platform operator is willing to foster network agility (*O2*). Eventually, from a platform operator's perspective, it is beneficial to foster variety (*O3*) within the network to prevent single service providers from winning too much bargaining power. Furthermore, the more intermeshed the SVN, the greater the number of alternative paths which increases reliability by enabling failovers through re-allocation. At first sight, it seems favorable for vendors to be linked to as many other service providers as possible when payments are made based on (7). Having more connections, a service provider is situated on more paths and is thus more often a vital participant when it comes to cooperation formation. However, vendors with a high PR might be reluctant to establish links to service providers with less power. Since the power ratios of all network participants are relative, strengthening others can result in weakening one's own position.

To study the suitability of PR-based revenue distribution, we investigate on how service providers in the SVN maximize their utility based on their PR. That is, they are considered as self-interested individuals that form or sever relationships to maximize their benefits. Whether services are connected depends on two factors: functional and strategic criteria. Functional integration is given due to common standards imposed by the platform. However, the platform operator cannot dictate how sellers are to connect their services to complementary ones. Thus, *each service provider can choose its linkage strategy to directly antecedent service providers*.

In order to compare our PRP rule to more traditional notions of distributing payments, we consider a simple payment exclusively rewarding allocated service providers, that is a purely *allocation based payment (AP) rule*:

$$(8) \quad r_j^{AP} = \begin{cases} p_{i,j}, & \text{if } v_j, e_{i,j} \in F^* \\ 0, & \text{otherwise} \end{cases}$$

The payment function as shown in (8) is analogue to a first price auction. The sellers providing the component services that are situated at F^* receive their announced price.

Above-stated considerations lead to the following research question: *Is a payment scheme incorporating the power ratio feasible to diminish concentration and to foster agility and variety in SVNs?*

Derived from this research question, we state the following *hypotheses*:

- H1: PR-based payments account for diminished concentration of distributed payments compared to a purely allocation-based payment (cf. O1).
- H2: PR-based payments account for increased dynamics and agility in the network compared to a purely allocation-based payment (cf. O2).
- H3: PR-based payments account for a higher degree of variety compared to a purely allocation-based payment (cf. O3).

After evaluating above-mentioned hypotheses in a simulation with a relatively high δ , we vary the level of the surplus in order to verify how different levels of δ influence H1-H3.

SIMULATION

We apply a simulation approach to verify the hypotheses stated in the last section. Agents form or sever links based on their utility improvement or deterioration resulting from their action accomplished.

Simulation Model

The problem is modeled as an N -person game. Let v_i^ω denote that vendor v_i belongs to cluster $\omega \in \{1, \dots, K\}$. V^ω denotes the set of nodes in cluster ω . Edges are only possible between nodes of consecutive clusters. Generally, each $v_i \in V$ must at least have one incoming and one outgoing edge to be situated on a path $F_i \in F$.

In each period $t \in \{1, \dots, T\}$ each provider v_i chooses an action out of its action set B_i . B_i is defined as all possible combinations of links to service providers of the preceding functionality cluster. That is, assuming $|V^{\omega-1}| = 2$ and $V^{\omega-1} = \{v_h, v_j\}$, the action set B_i of vendor $v_i \in V^\omega$ contains four entries: No links, link to v_h , link to v_j , and links to both preceding services. We binary code B_i as follows: $B_i = \{00, 01, 10, 11\}$.

The payment r_i^t of vendor v_i at time t is dependent on the network topology, the vendor's action, and the actions taken by all other participants in the network.

We apply reinforcement learning to evaluate and evolve actions over time. Each node v_i assigns a fitness value $\phi_{i,b}$ to each possible action $b \in B_i$. The fitness of the *chosen action* at t is updated at the end of each period according to the following update rule which depends on the feedback r_i^t of the chosen action: $\phi_{i,b}^t = (\beta - 1) \cdot \phi_{i,b}^{t-1} + (\beta) \cdot r_i^t$. The learning rate $\beta \in [0, 1]$ controls the impact of the current feedback on the fitness of the chosen action. For simplicity, switching costs are disregarded.

Actions are chosen according to a probability choice rule q based on the action's fitness and the fitness of each other action:

$$q_{i,b}^t(\phi) = \frac{\phi_{i,b}^t}{\sum_{B_i} \phi_{i,b}^t}.$$

After each node has decided upon its action based on $q_{i,b}^t(\phi)$, the payments are computed and fed back to the nodes which then update their fitness³.

³ If a vendor drops out of the network on behalf of another vendor's action, the feedback (i.e. a zero-payment) is disregarded.

Simulation Setting

We create networks with $|\omega|=3$ and $|V^\omega|=4$. The prices per link are drawn from a uniform distribution in the interval $[0.1;1]$ and are assigned to all possible links in the network except for incoming edges of the sink. The number of initially activated links is determined by the initial link density. The density is set to 0.5 (50% link activation). Other levels of density (varying from 0.25 to 1.0) were tested, however, did not yield different results. The learning rate is set to $\beta=0.1$. In order to eliminate side effects caused by a small β , we perform a sufficiently high number of simulation rounds as described in the paragraph below.

The simulation is divided into a training phase to pre-evaluate the actions of the vendors and a simultaneous⁴ run phase. For the PR-based payment, the starting value of the fitness function is simply defined by $\phi_{i,b}^{mit} := r_i^{PRP}$, given each possible action of service provider v_i and its impact on the links activated in the starting topology G^{mit} . This result is comparable to a sufficiently long training phase. For AP, each node goes through a training phase of $T=200$ runs, given the remaining nodes and their incoming edges are held constant according to G^{mit} . We then conduct $T=4000$ simultaneous runs⁵. Each simulation includes PRP and AP in parallel, starting with the same topology and initially activated links. Per round, each vendor v_i chooses a $b \in B_i$. To rule out learning effects that go beyond the learning phase due to the simultaneous choice of actions, we merely consult the last 2000 runs for the interpretation of the results. Altogether, we conduct 30 of the above described simulations, each with a different starting topology.

To basically asses our results, we set $\delta = \varepsilon \cdot P_{F^*}$, $\varepsilon=1.0$, that is the amount totally distributed is twice the price of the complex service allocated. However, as indicated in the first section, δ needs to be sponsored by the platform operator as a network development measure. Therefore we re-ran the simulation using a simplified setting with halved number of simulation series (i.e. 15) and halved numbers of simulation runs ($T=2000$, consulting the last 1000 runs for the interpretation of the results) and additionally considered lower $\delta = \varepsilon \cdot P_{F^*}$ with $\varepsilon = \{0.01, 0.05, 0.1, 0.15, 0.2, 0.25, 0.3, 0.5, 0.75\}$.

We are aware that the underlying assumptions of the simulation model and setting are simplified and can cover the complexity of real world SVNs only to some extent. However, the interval chosen for the initialization of prices in connection with the consideration of a relative δ allows for a high degree of generalizability of our simulation approach.

Assessment of Results and Implications

In this section, we elaborate our research hypotheses. We consult characteristic measures to analyze each of the three statements.

H1 states that PRP promotes diminished concentration. To evaluate H1, we consider statistical measures of concentration. On the one hand, the Herfindahl-Hirschman index (HHI)⁶ shall shed light on a vendor's payment in relation to the overall distributed payments. On the other hand, we utilize the Gini coefficient (GC)⁷ as a measure of inequality of wealth. By H2 we state that PRP accounts for increased dynamics in the SVN. To investigate this question, we consider the amount of switches of F^* , i.e. a provisioning of the allocated complex service in t by a different set of vendors than in $t-1$. Finally, H3 postulates an increased degree of variety in case of PRP. Transferred to our formalization of SVNs, a high degree of variety is reflected by a large number of links in relation to all possible links. We therefore measure the degree of variety by the density of the resulting graphs of the SVN. The density puts the actual number of existing links in relation to the maximum possible number of links. Table 1 shows the descriptive and inductive results of the simulation conducted. For all characteristic measures, we firstly calculated the mean within one simulation phase and then aggregated these 30 values to

⁴ That is, service providers choose their actions simultaneously.

⁵ However, tests incorporating a varying number of simulation runs showed that the network converges to stable results after approximately 2000 runs.

⁶ $HHI \in \{1/n, 1\}$, whereas $HHI > 0.18$ denotes a high degree of concentration and $HHI < 0.1$ indicates little concentration.

⁷ The closer the Gini coefficient converges to 1, the greater the inequality of distributed values. A coefficient close to 0 denotes a perfectly equal distribution.

one average mean (μ) and its corresponding standard deviation (σ) for both the PRP and the AP setting. In order to verify our hypotheses, we performed a single-sided Wilcoxon rank-sum test⁸.

	PRP		AP		Hypothesis	Wilcoxon rank-sum test
	μ	σ	μ	σ		
Herfindahl index	0.105	0.009	0.308	0.059	H1	p << 0.02
Gini coefficient	0.262	0.049	0.729	0.047	H1	p << 0.02
Number of F^* switches	1316.2	113.7	634.7	411.3	H2	p << 0.02
Density of network	0.775	0.002	0.719	0.022	H3	p << 0.02

Table 1. Simulation Results

Concerning H1, PR-based payment leads to a *HHI* of 0.105, which is very close to the assumption of little concentration whereas allocation-based payment leads to a highly concentrated wealth. In analogy to the *HHI*, the Gini coefficient for PRP $GC^{PRP} = 0.2347$ indicates a much more balanced wealth distribution than for AP, where $GC^{AP} = 0.7344$ signalizes a highly uneven revenue distribution. Both results significantly support H1 – which coincides with the nature of PRP as the power ratio is to broadly reward contributions to the network topology. Thereby, PRP fosters competition. Service providers that are (temporarily) not situated on the best path are more likely to retain in the network and represent competitors for frequently allocated vendors. In case of allocation-based payments, service providers that are never allocated play arbitrary actions each round (i.e. $\phi_{i,b} \rightarrow 0$ for each $b \in B_i$). So, if these providers are offered an outside option yielding positive value, they will walk away.

H2 can be accepted as well since the number of switches of F^* is significantly higher in the case of PR-based payment. On average, the best path alters every 3.5 rounds in case of AP. Applying PRP, the switching rate is 1.5. Generally, the network using AP is more static. PR-based payment promotes dynamic allocation of different paths over time which lets more different service providers be part of the actual service provided.

In terms of H3, the density of the network topology is on average 77.5% in case of PRP and 71.9% when the payment is merely based upon allocation. We can conclude that above-described behavior occurs systematically since the Wilcoxon rank-sum test shows significance with $p << 0.02$. Therefore, PRP is a suitable measure to promote highly interconnected networks. These interconnections increase interaction by incentivizing service providers to pursue a cooperation strategy that involves the creation of more links than in environments based on AP.

We additionally considered $\delta = \varepsilon \cdot P_{F^*}$ with $\varepsilon = \{0.01, 0.05, 0.1, 0.15, 0.2, 0.25, 0.3, 0.5, 0.75\}$ to analyze the behavior of PRP subject to varied surpluses. Interestingly, H3 is invariant in respect to ε . The resulting density applying PRP is constantly between 77.2% and 78.8%. We can state that H3 applies for $\varepsilon \geq 0.01$. However, H1 and H2 are closely linked to the level of ε . H1 cannot be supported for $\varepsilon < 0.15$. Also, we cannot state higher agility (H2) using PRP for $\varepsilon < 0.25$. In connection with the larger number of links (cp. H3), we conclude that these must not necessarily be the ones to promote H1 and H2. With increasing ε , the number of path switches as well as the tendency towards equal distribution rises. For $\varepsilon = 0.3$, H2 shows significance to a 5% level. Taking these settings as a basis for a judgment of the required level of ε in order to reach objectives O1, O2, and O3, the platform operator needs to grant at least an additional 30% surplus to be distributed via PR-based payments.

We infer from above-mentioned results that PR-based payments are a promising instrument to diminish concentration (O1) and foster agility (O2) and variety (O3) in SVNs if the PR-based surplus is set sufficiently high. Due to the application of concepts from cooperative game theory, the PRP rule is particularly suitable to deal with coordination in ecosystem-like environments like SVNs. Participants are both self-interested, but also depend on the performance of the whole system.

⁸ We performed Kolmogorov-Smirnov tests showing that the underlying data significantly deviates from the Gaussian distribution with a 99% probability. Therefore, t-tests (that require normally distributed data) are not applicable.

CONCLUSION

In this paper we argued that the fundamental change from a product-oriented to a service-oriented economy fosters the formation of service value networks, as for example, is evident in the software sector. For such SVNs, we presented a model to express the power ratio (PR) of vendors. This model then served as the basis for a PR-based payment (PRP) rule that distributes generated revenue to all network participants dependent on their overall contribution to the network topology. This payment scheme was introduced as a lever for the platform provider to push the network towards a more variable and dynamic structure and to diminish concentration of revenues. In order to evaluate the effects of PRP, we conducted a simulation and compared PRP to a simply allocation-based payment (AP) rule. We were able to show that PRP can foster the desirable goals mentioned above. Generally, these effects were shown with striking significance for a high surplus. However, variety and agility effects decreased with lower surpluses. We conclude that, especially in launching and consolidation phases of SVNs, a payment scheme based upon participants' contribution to the networks' infrastructure is a promising alternative to traditional performance-based revenue distribution if set sufficiently high.

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