An Instance-based Approach for the Quantitative Assessment of Key Value Network Dependencies*

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Abstract. Entailed from challenges in industries which are characterized by competitive economics of scale, like for instance network interconnection, the interest in Value Networks (VN) has significantly grown recently. While most of the related work is focussing on qualitative VN analysis, in this paper we describe an enhanced model of a VN quantification concept and argue for the instance-based orthogonalization of key VN dependency indicators. As a result, the reduced set of such independent indicators is organized around the axes of customers and suppliers in order to form manageable quantification algorithms.

Keywords: Value Networks; Quantification; Dependency Analysis; Factor Analysis; Interconnection

1 Introduction

The economic challenges in highly competitive industries such as network Interconnection (IC)—stagnating revenues[4] being opposed by tremendous demand growth rates[5]—require conceptual (non-linear) inter-firm supplements to Business Models [1, 2], i.e., *Value Networks* (VNs) [3–5]. However, related work focuses on qualitative mechanisms for comparing and analyzing available VN options such as [6], while to the best of our knowledge, hardly any approach providing quantitative support for assessing VN options has been proposed so far.

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[4] DrPeering International—Internet Transit Prices – Historical and Projected: `http://drpeering.net/white-papers/Internet-Transit-Pricing-Historical-And-Projected.php`, last accessed: Jan 31, 2012

[5] Cisco Visual Networking Index Forecast Projects 26-Fold Growth in Global Mobile Data Traffic From 2010 to 2015: `http://newsroom.cisco.com/press-release-content?type=webcontent&articleId=5892556`, last accessed: Jan 30, 2012

Therefore in the compagnion paper [7], we have introduced a quantified dependency quantification method for VNs. With this concept, the dependency of an entity e on the VN, i.e., on all other entities, can be calculated on the basis of six relative dependency indicators (mainly derived from Porter's five forces on firms [8]): Bargaining power of suppliers (δ_1^e) and customers (δ_2^e), substitutes (δ_3^e), potential market entrants (δ_4^e), industry rivalry (δ_5^e), resource type dependency—i.e., fungibility of resources (δ_6^e). These indicators are supposed to measure forces in VNs which might cause structural changes of businesses and related VNs in the future. The six dependency indicators δ_i^e are aggregated to form a single dependency factor Δ^e,

$$\Delta^e = \sum_{i=1}^{6} w_i * \delta_i^e \quad , \tag{1}$$

for entity e by the usage of weighting factors w_i. While the dependencies themselves are extracted from entity-specific data, e.g., price and cost values (for details we refer to [7]), we have abstained from discussing the role of the weighting factors in detail so far.

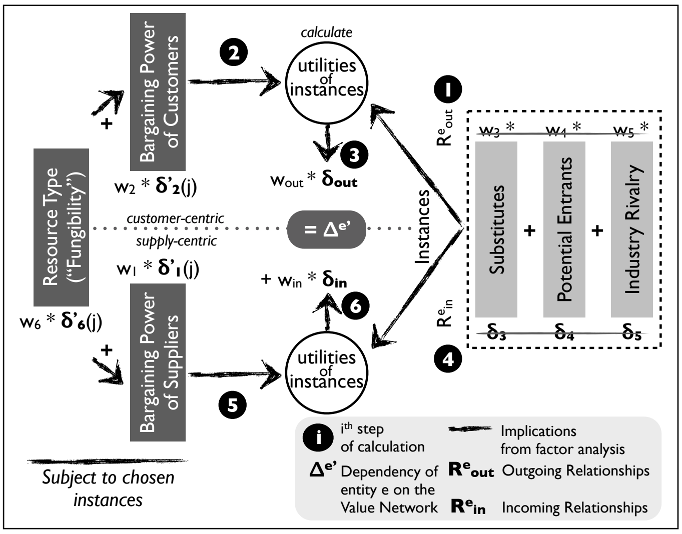

Fig. 1. Orthogonalization of initial dependency indicators from [7]

By applying a more fine-granular instance-based perspective, in this paper we aim at rendering several of these weighting factors obsolete (dependency from substitutes, potential entrants, and industry rivalry—see Figure 1), while we consider the orthogonalization of key VN dependency indicators and the explicit modelling of substitution to be additional novel contributions of this work. For this purpose, we extend the concept described in [7] by revisiting the dependency indicators $\delta^e_{\{3,4,5,6\}}$ while $\delta^e_{\{1,2\}}$ are left untouched. For further details on our VN quantification concept, the reader is strongly refered to [7] as starting point for the subsequent discussion and extension.

The remainder of this paper is structured as follows: We first identify required VN quantification assumptions in Section 2, which are then used as conceptual basis for an instance-based VN dependency indicator orthogonalization concept in Section 3. In Section 4, an evaluation discussing potential interpretations and limitations is given. We conclude in Section 5 with a summary of key findings.

2 Assumptions

For the construction of our fine-granular entity dependency model, we apply a series of assumptions and interpretations followed throughout the work.

Monopoly. Our model relies on the monopolistic decisioning case fully eliminating resource scarcity and competition for resources. Hence, all alternatives are assumed to be available when bearing a certain investment effort. Competitive games for resources may have to be considered in future work.

Stationarity. The core of the quantified VN options are assumed to remain stationary throughout the analysis, i.e., prices, costs, players (entities and their instances), relationships, substitutes, investments costs etc. remain constant. Hence, all substitution options can be explicitly modeled a priori.

Dynamicity. The dynamicity of real-world VNs is captured through modeling player entrance and potential player exits, as well as the analysis of substitutes.

Utility. Added values are used in the sense of utility gains—based on the Von Neumann-Morgenstern utility theorem [9]—already incorporating values, costs, risks, chances, and further impairments.

Time. Utilities are standardized for a predefined *time span* with a clearly defined *starting time*. This is required in order to sufficiently integrate investment costs that may be required in order to switch to a substitutive alternative. This concept strongly relates to depreciation mechanisms used in accounting.

Complete Knowledge. The information required in order to allow a sufficient dependency reasoning process (complete knowledge) is taken as given.

Individual Rationality. We assume individual rationality of demanding customers (i.e., only positive utilities for buying a product may trigger a purchase) and involved entities, i.e., always the individually best VN option is chosen.

Entity. The identification of the best VN configuration is subject to the perspective of an entity or a group of entities minimizing its dependency towards the VN.

3 New Model Features

The present work further details the VN dependency quantification as proposed in [7] by orthogonalizing the key VN dependency indicators. So far, the dependencies $\delta^e_{\{3,4,5\}}$ resulting from industry rivalry, substitutes, and potential market entrance have been treated as individual and mutually independent indicators. In order to make them quantitatively comparable in a unified representation, we transfer the entity-based perspective of VN quantification to a finer-granular instance-based analysis. Basically, we consider each individual relationship instance as an *option* for providing a certain resource (due to either industry rivalry, substitution or market entrance), and calculate its utility. In this way, the dependency of one instance from all other (instance-based) alternatives is quantified. To this purpose, the representation of VNs is slightly enhanced as basis for further specifying the calculation of VN dependencies.

3.1 Substitution & Market Entrance

So far, the Value Network Dependency Model (VNDM) [7]—an approach for visually sketching VNs—has not captured substitutes. In principle, *substitutes* may be represented in form of separate VNDMs. For a better overview, we however have opted for directly integrating them in a single VNDM.

Visualization mechanisms immanently face a trade-off between their complexity and their expression power. Thus, the set of relationship alternatives are represented by the most beneficial (utility maximizing) instance choice—especially also integrating instances from potential *market entrance*—for the VN (in terms of resource values, costs, etc.). Each available substitution is visually marked in the model in order to reflect required investments.

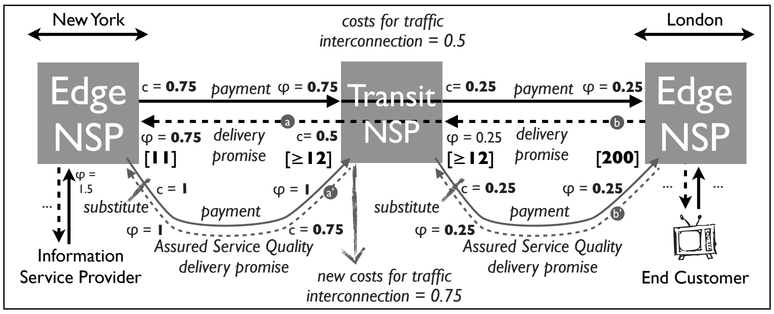

Fig. 2. Partial view on a Video-on-Demand VNDM ([7] Fig. 3) extended with ASQ traffic delivery as substitute

In the example of Figure 2, a simple Video-on-Demand (VoD) interconnection (IC) scenario is sketched (an excerpt of the example used in Figure 3 in [7]). A movie platform from New York is delivering a movie to an end customer's television set in London. For this purpose, the platform provider pays for the Best-Effort delivery ($1.5) in order to receive a delivery promise from its access provider, i.e., an Edge Networks Service Provider (NSP). This NSP (similar to [7] we assume there are 11 Edge NSP instances) is then responsible for establishing the IC via a Transit NSP ($\geq$ 12 instances [7]) to the Edge NSP (200 instances) delivering the content to the customer, i.e., it pays the chain of Transit and Edge NSP (cost $c = \$1$). In addition, we have added in Figure 2 Assured Service Quality (ASQ) traffic interconnection as substitute for the chosen Best-Effort solution. For ASQ, we assume higher costs c (labelled at the source of the edge), but also higher revenues/value φ (at the tip of the arrow).

3.2 Dependencies from Alternatives

The revised entity dependency calculation proposed in this section addresses two dimensions: (i) the available relationships, and (ii) the utility of available instances for each relationship. These dimensions are targeted by forming a detailed utility model, which incorporates dependencies from inter-relationship factors. We further distinguish customer-side and supply-side dependencies.

Customer-side Dependencies. For the purpose of quantifying the customer-side dependencies, we enumerate and order the available instances for each entity (competition), market entrance options, and available substitutes by incorporating the required investment and other effort compensations in the utility assessment of an option (adjusted to the chosen time span). We call each of the corresponding alternatives an *option*, and will subsequently use these options to analyze the available alternatives for each relationship of a VN or its VNDM representation—i.e., the set of options $O(r)$ for each relationship r of an entity. Methodologically, we are taking recourse to the existing dependency calculation approach based on the *Gini coefficient* [10] as introduced in [7], while at the same time we aim at the harmonization of information on the stated forces.

In our case, the Gini coefficient indicates the fairness of utility distribution among available options for instantiating a relationship, i.e., other entities providing the same good or technical alternatives. Unfortunately, this parameter does not consider whether the second best options is dramatically worse than the optimum etc. This, however, is a requirement for assessing the dependency of one relationship (and its entity) on the availability of one particular instance. We assume that the utility divergence of options—ordered by their utilities—is intensified by an exponential spreading factor, i.e., the utility decreases from one option to the next-best one by a constant multiplicative factor < 1. Therefore, we define the exponential spreading factor $y(j)$ for the utility calculation, where $o(j)$ is the j^{th} best relationship option of all n_r available options of relationship r of an entity e and $y(j)$ continuously decreases with growing j:

$$y(j) := \frac{1}{n_r} * e^{\frac{ln(n_r)}{n_r - 1} * (n_r - j)} \tag{2}$$

where $y(j) \in [1/n_r, 1], j \in \{1, 2, ..., n_r\}$, and $n_r = |O(r)|$.

Note that $y(1) = 1$ and $y(n_r) = \frac{1}{n_r}$, hence these marginal values match those obtained for instance also by a model of linearly decreasing utilities.

In order to make the available options quantitatively comparable, impairments such as necessary investment costs i or inherent risks—e.g., the risk of weak customer relationships—need to be incorporated in the utility calculation of options. By taking depreciation during the calculation of the utilities into account (adjusted to the chosen time span) their utilities can be directly compared, i.e., additional weighting factors are no longer required. In addition, the integration of alternative options (substitution, market entrance) entails the possibility of changing resource types, values or costs, hence rendering each option conditional to dependencies from resource types δ_6^e and the bargaining power of customers δ_2^e. The vague description of δ_6^e given in [7] is further detailed in Equation (3) for the j^{th} best option. Explicitly, an exchanged resource may be used for a subset $k(j)$ of all possible business relationships M of the VN, $0 \leq k(j) \leq |M|$. The higher $k(j)$, the lower is the dependency on the VN—and vice versa.

$$\delta_6'^e(j) := 1 - \frac{k(j)}{|M|} \tag{3}$$

The overall utility $\mathcal{U}(j)$ incorporating all relevant dependency indicators for the j^{th} best option $o(j)$ is calculated according to (4):

$$\begin{aligned} \mathcal{U}(j) := y(j) * [\varphi(o(j)) - c(o(j)) - i(o(j))] * \\ * w_{2'} * [1 - \delta_2^e(j)] * w_{6'} * [1 - \delta_6^e(j)] \quad , \end{aligned} \tag{4}$$

where $\varphi(o(j))$ is the value, $c(o(j))$ is the operation cost, and $i(o(j))$ the investment cost (optional) of the j^{th} best option for relationship r. In contrast to $w_{\{2,6\}}$ in (1), the revised weights $w'_{\{2,6\}}$ are integrated in the calculation of $\mathcal{U}(j)$ for a chosen j in (4). Hence, for every j both forces are calculated beforehand (step 2—cf. Figure 1), as if the j^{th} option would have been the used (best available) variant—for all other relationships the best option is kept stationary. Thereafter, δ_{out}^e can be computed, which may imply a disproportional complexity increase with the number of relationship options. By using the utility calculation of (4), the adapted dependency calculation can be formulated as follows:

$$p(j) := \frac{\mathcal{U}(j)}{\sum\limits_{k \in \{1,\ldots,n_r\}} \mathcal{U}(k)} \quad , \tag{5}$$

$$gini(r) := \sum_{j \in \{1,\ldots,n_r\}} [p(j)]^2 \quad , \tag{6}$$

$$gini(R^{e,out}) := \frac{1}{|R^{e,out}|} * \sum_{r \in R^{e,out}} gini(r) \quad , \tag{7}$$

$$\delta_{out}^e := \frac{gini(R^{e,out})}{\max\limits_{k \in E} \{gini(R^{k,out})\}} \quad , \tag{8}$$

where $e \in E; r \in R^{e,out} \subseteq R^e \subset R,$ and $gini(R^{e,out}) \leq 1$.

(5) and (6) calculate the Gini coefficient for each option of all available options $O(r)$ for a relationship r. This captures whether the utilities $\mathcal{U}$ are evenly distributed over alternatives, i.e., measuring whether the entity requiring this relationship has valuable options. Accordingly, the dependency of each instance increases with every valuable option to be replaced. In (7), the average Gini factor of all outgoing relationships $R^{e,out}$ of entity e is calculated. This is finally turned to a relative indicator for entity e's dependency on the VN in (8)—in respect to the highest dependency measured in the VN.

Supply-side Dependencies. The dependencies δ^e_{in} resulting from incoming edges (supply) are quantified in analogy to the customer side—see (8). However, $\delta_2(j)$ is replaced by $\delta_1(j)$ and in lieu of outgoing edges $R^{e,out}$ the incoming edges $R^{e,in}$ are used. Moreover, the dependency calculation is essentially modified in (9), i.e., the dependency decreases with the number of supplier options:

$$\delta^e_{in} := 1 - \frac{gini(R^{e,in})}{\max\limits_{k \in E}\{gini(R^{k,in})\}} \quad . \tag{9}$$

Together δ^e_{in} and δ^e_{out} capture the dependency of entity e on the VN, where weighting factors $w_{\{in,out\}}$ with a sum of 1 are used for aligning the indicators, thus eventually replacing the equation of (1):

$$\Delta'^e := w_{in} * \delta^e_{in} + w_{out} * \delta^e_{out} \quad . \tag{10}$$

4 Interpretations & Limitations

The instance-centric perspective on VN dependencies has led to the formation of two key VN dependency factors eliminating the need to autonomously quantify dependencies from substitutes, market entrance, and industry rivalry. We suggest to denote these new indicators as customer-side and supply-side *dependencies from alternatives*. This modification reduces the complexity for the dependency calculation in practice. On the other hand, the concentration on an instance-based analysis has emphasized the disproportionally growing calculation effort with an increasing number of instances. In addition, the requirement of numeric market data estimations has been inferred from the quantitative methodology.

Rearrangements. Whenever a VN is extensively rearranged, the mapping of one relationship to a successor may require some interpretation. In particular, relationships may be logically merged or costs assigned to several relationships. Precise computational routines for such situations are left for further work.

Dependencies. The almost unlimited fungibility of money [11] entails the lowest possible resource type dependency of the resource exchange on the VN—as captured in the adapted calculation of δ'_6 (see Equation (3)).

Completeness. Although market entrance is captured explicitly in the model, the risk of market exits decreasing the utility of one relationship has only implicitly addressed as further risk. By graph analysis the completeness of the used dependency forces needs to be further confirmed.

5 Conclusions

The present work conceptually argues for the orthogonalization of key indicators for VN dependencies. The initial indicators have been derived from [7], where we have proposed to turn Porter's five forces into quantitative VN dependency indicators, i.e., metrics stating how dependent one entity is on the overall VN. In order to capture the interrelations between these initial indicators, we have formed two key dependency indicators δ^e_{in} (supply-side dimension) and δ^e_{out} (customer-side dimension) as a result of an instance-based analysis. This outcome has rendered several of the initial indicators redundant, which may reduce the complexity of VN dependency quantifications. The indicators δ^e_{in} and δ^e_{out} have been formed around the instance-based dependency arising from the threat of being replaced by another instance (whether through industry rivalry, substitution, or market entrance). Future work will target the confirmation of the initial dependency indicators providing a basis for the advanced dependency quantification Δ'^e shown in (10), as well as the practical quantitative assessment of VN alternatives, e.g., enabling ASQ traffic as depicted in Figure 2.

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