Analyzing Virtual Organizations' Formation Risk in P2P SON Environments

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Summary. Virtual Organizations (VOs) have emerged as a powerful enterprising strategy to leverage the activities of Small and Medium sized Enterprises, by providing a way of sharing their costs and benefits when attending to particular demands. Along with their numerous advantages, VOs also pose several challenges, including additional risks that need to be considered to ensure its correct operation. Proper risk analysis provides more solid means for managers to evaluate and further decide about the most suitable VO composition for a given business. Therefore, this paper aims to develop a mathematical method that analyzes and measures the risk in a set of partners, synthesized in the form of Service Providers, which will compose a VO in a P2P SON environment. By means of validation of the proposed method, a set of simulations were carried out and the results are presented in this paper.

Key words: virtual organization, risk analysis, P2P SON

1 Introduction

The fundamental developments in network technologies, particularly the advent of Peer-to-Peer Service Overlay Networks (P2P SON) [1, 2], provided an advantageous environment for companies make their services available to the user community at large. The joining of the SON and P2P fields offers a high potential for handling services, by creating dynamic and adaptive value chain networks across multiple Service Providers (SPs). Moreover, a wide range of services can be made available, as well as an environment where price and quality can be competitive differentials [3].

The P2P SON concept applies to a broad range of network architectures. This paper deals particularly with the Virtual Organization (VO) type of network. A VO is a temporary and dynamic strategic alliance of autonomous, heterogeneous and usually geographically dispersed companies created to attend very particular business opportunities [4, 5]. In this sense, the P2P SON acts as infrastructure that provides an environment for VO formation and, additionally, enhances benefits to SPs, e.g., sharing costs, bandwidth and others [6].

Although the mentioned advantages of using P2P SON can improve the VO formation process, the natural VO networked structure faces additional risks than other general forms of organization. These additional risks come, in part, from the increasing sharing of responsibilities among companies and their dynamic nature of relationships [7]. The problem is that there is a lack of more systematic and integrated methods to handle the several dimensions of risk, which includes both intra-organizational and inter-organizational aspects of the VO. Since the analysis of these risks is key to ensure the VO's proper operation, it should be complemented with the risk analysis support methods that can provide more agility and transparency when creating new VOs [8].

In a previous work, it was designed a three-layer architecture for services management in P2P SONs, named OMAN [6]. The OMAN offers an efficient search and selection process of most suitable SPs in a multi-provider environment. Authors also presented results of SP selection by using a geographical location criteria [2]. However, the VO risk aspects in the context of P2P SONs were not addressed.

This paper presents an exploratory work, which complements the proposals of [2] and [8], and looks for answering how SPs can be properly selected when considering risks. This work consists in adding an additional risk management level in the search and selection process and conceiving a new risk analysis method, named MARTP (Multi criteria Risk Analysis Method applied to P2P Service Overlay Networks). In the proposed method, the SPs are two-stage evaluated, both individually and collectively. The goal of the method is to measure the level of risk and identify which SPs are most risky for the VO formation. This will allow decision-makers to decide wisely about which SPs should be effectively discarded for a given business collaboration opportunity, and additionally, the identified risks can be managed and hence mitigated throughout the VO formation process.

The remainder of this paper is organized as follows: Section 2 addresses the problem of SPs search and selection in P2P SONs and contextualizes it within the VO risk analysis proposal. Section 3 describes the proposed method for VO risk analysis. Section 4 presents the set of experiments conducted to evaluate the proposed method and also presents the final results. Finally, Section 5 concludes the paper and outlines some future work.

2 General Background

2.1 Service Provider Integration

As cited in Section 1, different SPs can be grouped in a given VO in order to accomplish a mutual goal, the so-called collaboration opportunity. These SPs might range from non-governmental organizations to autonomous software entities, by sharing costs, benefits and risks, acting as they were one single enterprise [5]. Regarding to the classical main phases of a VO life cycle (creation, operation, evolution and dissolution phases) [9], this paper focuses on the creation (or formation) phase, which is seen in Fig. 1. Within the creation phase, this analysis is carried out during the *Partner's Search and Selection* step (left circle).

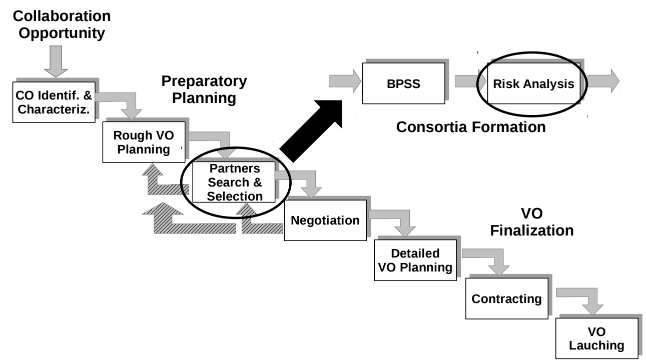


Fig. 1. Framework for the VO Formation Process. Extended from [9].

The process of collaboration among the SPs in a VO is accomplished through interactions between their business processes, which are usually supported by a network infrastructure. Particularly, this work addresses the use of P2P SON to organize all the SPs committed with the eventual VO formation. A P2P SON is an infrastructure designed to provide services and, in the context of this work, it can be seen as a breeding environment for the creation of VOs [10]. It is also considered that the SP's search and selection procedures are performed by a service management architecture developed in [6], particularly through its BPSS module, which aims to select one SP from the set of SPs that fulfill a required service according a particular metric.

Fig. 2 details the BPSS module. P2P SON, shown as the elliptic curve, is created covering domains (clouds in Fig. 2) that contain SPs. Every peer in the P2P SON runs service(s) from the corresponding SPs. The AgS is created in a higher level inside the P2P SON, where each AgS peer maintains an aggregation of services published by the SON peers (providers at the P2P SON level). In order to select a SP (peer), the BPSS sends a service request to the AgS, which forwards the request to the peers in the aggregation overlay. In the context of this work, this means the begin of a new Collaboration Opportunity (CO) that will trigger the formation of a new VO [9]. The result of this request is a list of all SPs that fulfill a required service according a particular, or a set of, application metrics.

2.2 VO Formation Risk Analysis

The problem in choosing the most appropriate SPs to compose a VO is critical. The concept of risk can be handled at a number of perspectives. [11] provides an overview of risk definition, as a variation in the distribution of possible outcomes, their probabilities, and their subjective values. [12] associates risk with the likelihood of an unfavorable outcome. When applied on this research context, the risk can then be viewed as a composition of three basic elements: the general environment where it can happens; its occurrence probability; and the scope of

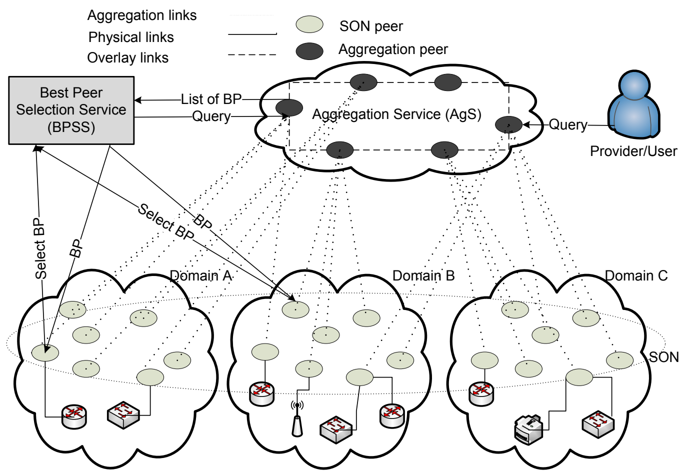


Fig. 2. BPSS Model [2].

its impact in the case of its occurrence [13]. Specifically, a risk is characterized by the potential of an SP – that in principle is able to be a member of a VO – to do not perform correctly its assigned task regarding the associated CO's requirements and hence hazarding the VO success.

In the literature review, a number of risk analysis methods has been identified as potentially suitable for VOs, namely FMEA (Failure mode and effects analysis), FTA (Fault Tree Analysis), AHP/ANP (Analytic Hierarchy/Network Process), ETA (Event Tree Analysis), Bayesian Networks, CNEA (Causal Network Event Analysis) and Ishikawa Diagram [13, 14, 15, 16, 17]. Some requirements can be pointed out for the tackled problem: events can be treated as independent from each other; the deterministic relation between events can be known; events analysis can be both qualitative and quantitative; a risk can be globally quantified after a succession of events. Regarding these requirements, ETA and AHP techniques were selected to be used and combined in the proposed method.

In that same reasoning line, there is a number of works related VO's sources of risk and its analysis. In [18, 7], thirteen KPIs were identified as general risk sources in VOs, further identifying the importance of each one. In [19], the problem of risk mitigation in VO was discussed, and four processes were identified to improve the level of VOs performance reliability. In [20] two sources of risks were specified (external and internal), and risk occurrence likelihood in the life span of a VO was calculated based on them. [21] and [22] considered the fuzzy characteristics and the project organization mode of VOs to propose Multi Strategy Multi Choice (MSMC) risk programming models.

In addition, [23] presented a competence model to support efficiently the process of partner's selection, which works in the context of Service-Oriented Virtual Organization Breeding Environments. When dealing with SP as the type of partners, the same authors have proposed a hybrid DEA-Fuzzy method for analyzing the risk in the process of VO partners search and selection [24]. The method is strongly based in the concept of SPs importance and efficiency within the VO, where aspects like SPs historical performance and relative efficiency are considered in the analysis and therefore in the calculation performed.

All the reviewed works in the literature have proposed contributions to isolated elements of the whole tackled problem of this research. Nevertheless, none have somehow formalized how the proposed KPIs should be used nor provided means to quantity VO partners risks before the VO formation. Moreover, it was not identified proposals that specify a method or procedure that aims to systematize the process of risk qualification/quantification involved in the SPs' Search and Selection for the VO formation, while focusing in the SP type of partner. Therefore, this paper presents as a contribution a way to specify KPIs together with a mathematical method that enable measuring the risk in the VO formation.

The way the risk is represented should be aligned with the organization goals so that the most important ones can be determined for further and more proper management. Identifying risk sources is the first and most important step in risk management [13]. Therefore, there are four main sources of risks regarding VOs that were considered the most critical ones: *trust*, *communication*, *collaboration* and *commitment* [7]. In this work they are modeled as KPIs and their values are calculated and provided by the methodology developed in [8]:

- **Trust**: SPs who are going to compose a VO do not necessarily have prior knowledge about each other before starting collaborating. Thus, trust is crucial to bear in mind, which in turn involves commitment in doing the planned tasks. When trust among providers is not enough established there is a hesitation to share risks and so the VO can be jeopardized;
- **Communication**: Communication among VO's SPs is a key factor for its proper operation. They should provide correct information about parts, products and services, collaborating in solving conflicts, sharing practices, etc. However, this can be complicated by the fact SPs are heterogeneous, independent, geographically dispersed and usually have distinct working cultures. The insufficient communication can put a VO on risk;
- **Collaboration**: Collaboration is characterized when the sharing of risks, costs and benefits of doing business are agreed and fairly distributed among partners. However, when a collaboration agreement is not clearly defined, i.e., when there is no clear definition of its main objectives, the VO risk increases;
- **Commitment**: Commitment is related to the attitude of VO members with each other, i.e., it considers the contributions and agreements made by and among them for a business. This is important as partners have complementary skills and so it is important they feed the whole environment with the right and timely information. The VO risk gets higher when partners fail in that attitude.

3 The Proposed Method

3.1 MARTP Overview

The devised method for risk analysis is generally presented in Fig. 3. It starts having as input a pre-selected and ranked list of most adequate SPs (through BPSS simulation) registered in a P2P SON environment. The main goal of the proposed risk analysis method is to add another support dimension for decision-making, identifying and measuring how risky is each of those SP candidates involved in the VO formation process. In this work, considering VO reference theoretical foundations [5], the so-called VO Manager is seen as the main decision-maker.

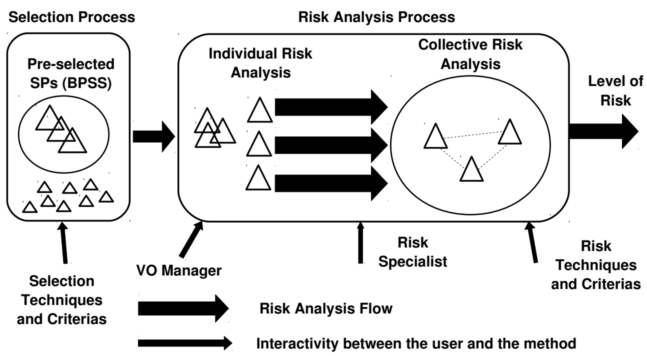


Fig. 3. Overview of MARTP.

The method splits the problem into two stages. In the first stage, it starts measuring the risks individually, for each possible SP, and after and based on that, collectively, for the entire SP team for the given VO. In this context, the VO manager has the following role: to quantify the level of importance of each SP in the VOs before creating it. There is also a risk specialist, who is in charge of auditing the SPs historical KPI metrics. The risk techniques and criteria are applied to assess the risk according to the VO manager guidelines.

3.2 MARTP Architecture

The MARTP method itself is illustrated in Fig. 4. It divides the problem into two phases: the first phase does the individual risk analysis applying the Event Tree Analysis (ETA) method for that. The second phase does the risk analysis taking the group of SPs as a whole into account, applying the Analytic Hierarchy Process (AHP) method [14, 15].

Individual Risk Analysis

In the first phase of MARTP, it is performed an individual risk analysis for pre-selected SPs. ETA is particularly suitable for risk analysis of systems where there are interactions between several types of probabilistic events, whether dependent or independent [14]. It uses a visual representation based on a logical binary tree structure, known as Event Tree (ET), as shown in Stage 1 of Fig. 4.

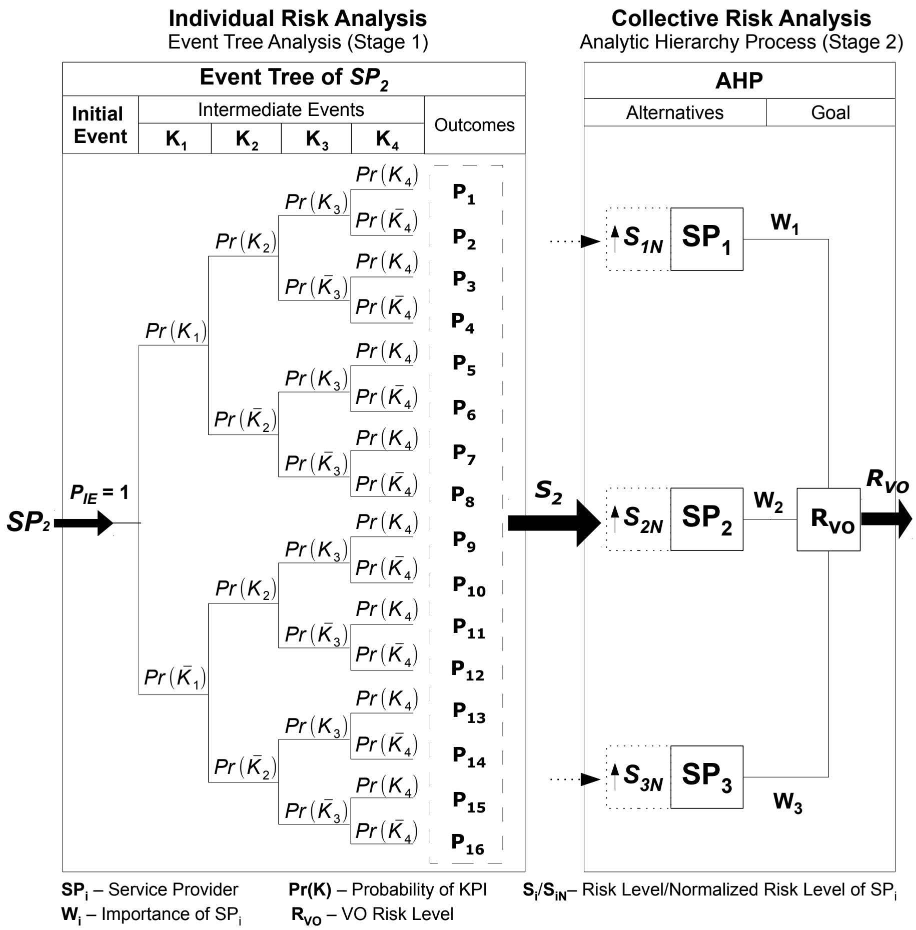


Fig. 4. MARTP Architecture.

An ET is a probability tree, which provides two possible conditions: success and failure. It also has three basic components: initial event; intermediary events; and outcomes. The initial event begins the ET creation process. In this work, it corresponds to one pre-selected SP, and the assigned probability (P_{IE}) is always 1 (or 100%) in the beginning [14]. Next step consists in specifying the (four) intermediary events, which are represented by the (four) KPIs: *trust*, *communication*, *collaboration* and *commitment*.

These events are used to quantify the effectiveness of a particular SP, i.e., if it is able or not to compose a VO, and to generate an ET by assigning success and failure probabilities to each of them as shown in Stage 1 of Fig. 4. The criterion to assign the KPI success probability to each SP takes the historical values analysis of the KPI that were assigned to it in past VOs participations [25, 26]. This analysis is fundamentally based on statistical inferences by quantifying both the central trend and variability of historical values.

The central trend analysis is performed by calculating an exponentially weighted average index (EWA) for each set of historical KPI values of a given SP. The EWA is currently used in financial risk analysis and supply chain management being popular in practice due to its simplicity, computational efficiency and reasonable accuracy (giving more importance for the most recent values in an exponential factor) [27]. The EWA for a KPI k of a SP p is formally defined by Eq. 1:

$$\bar{X}_k(p) = \frac{\sum_{i=1}^{n} x_i w_i}{\sum_{i=1}^{n} w_i} \tag{1}$$

where $x = \{x_1, x_2, ..., x_n\}$ means a non-empty set of historical KPI values and w represents a normalized exponential decay constant (note that this paper aims to calculate a success probability by KPI historical analysis; the determination of optimal values for central trend analysis is not within its scope). After calculating the EWA for each SP, the Maximum Quality Index (MQI) value is assigned as the higher value among all the results obtained with the EWA results of a given K_k for different SPs (that is, for $p = 1, 2, ...n$). The MQI is calculated for each KPI and used as a performance reference for all others SPs that will be assessed. In this sense, considering k the number of used KPIs (in this case *four*) and p the number of SPs associated for each KPI, Eq. 2 shows the MQI calculation procedure:

$$MQI_k = max_k \left(\bar{X}_k(p)\right) \quad \forall p \in SP \tag{2}$$

For instance, Fig. 5 shows a graph with hypothetical KPI values about *trust* (intermediate event KPI_1 according to Stage 1 of Fig. 4) associated to a SP.

The value of the MQI (left circle in Fig. 5) assigned for this KPI would have been set up as 6.7 (this value is the highest EWA value calculated for SPs using the KPI trust). Nevertheless, it is obvious that, when taking into account only the highest MQI value, a few KPIs will reach an acceptable success probability. For this reason, a variability metric is well-suited in this scope. The metric used is the standard deviation (SD) of MQI. Therefore, the acceptable interval will range not only values above 6.7, but also includes the SD interval, which are 2.4 (right circle in Fig. 5). So, the acceptable range turn to $6.7 - 2.4 = 4.3$.

The values assigned to each KPI can vary from 0 to 10 and are associated with a probability success rate which varies from 0 to 1, respectively. Assuming that each SP has participated in n_{PA} past VOs and since that n_R represents the number of SP's previous participation in VOs where its KPIs values are higher than $MQI_k - SD_k$ (those values with an * in Fig. 5), Eq. 3 calculates the KPI success probability for the current participation.

$$Pr\left(K_k\right) = \frac{n_R}{n_{PA}} \tag{3}$$

The failure rate for a given KPI is represented as $Pr\left(\bar{K_k}\right)$ by the following equation:

$$Pr\left(\bar{K_k}\right) = 1 - Pr\left(K_k\right) \tag{4}$$

According to Fig. 4, the success and failure probability rates are calculated for all KPIs that compose the ET of an SP, which are presented by the four intermediate (and independent from each other) events $K_{1:4}$ that populate the ET. Event K_2, for instance, would be related to KPI communication, with success and failure values of $Pr(K_2) = 0.90$ and $Pr\left(\bar{K_2}\right) = 0.10$, respectively.

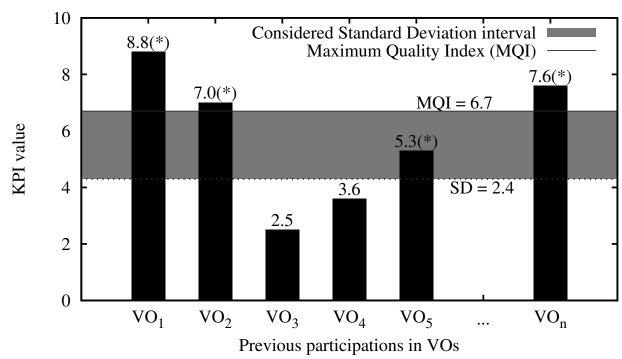


Fig. 5. Trust KPI historical values for a given SP.

After assigning all probabilities for all ET branches, it is necessary to identify if the SPs are minimally qualified to compose a VO. For this, a calculation is performed to obtain the final probabilities for all event combinations composing the ET. They are determined for each of the $2^{|K|}$ branches of ET and are got by multiplying the probabilities of events that compose each path. Following, it is applied the Harmonic Weighted Average (HWA) calculation over the set of results obtained in the ET, in order to obtain the level of risk for each SP.

The presented concepts can be formalized as follows:

Let $SP = \{SP_1, SP_2, ..., SP_n\}$ be a set of n SPs previously selected, where each element in this set is associated with a different type of service activity that is being requested in a CO. Let $K = \{K_1, K_2, ..., K_m\}$ be a set of m KPIs associated to a SP_n, and $Pr\left(K_k\right)$ the probability function associated with each event K_k (as defined in Eq. 3). ETA events occur independently, i.e., where the occurrence of an event does not affect the occurrence of the other.

Now consider $P = \{P_1, P_2, ..., P_{2^{|K|}}\}$ as a set of all possible outcomes from the $2^{|K|}$ ET events combinations. The procedure for obtaining this set was performed using a Binary Search Tree (BST) [28], which travels $2^{|K|}$ different paths and assigns a value to each element of P, as shown in Eq. 5:

$$P = \bigcup_{k=1}^{2^{|K|}} \left[P_{IE} * \prod_{l=1}^{|K|} \omega(i,j,k,l) \right] \tag{5}$$

where P_{IE} is the initial probability of the SP. The function ω, as shown in Eq. 6, performs a binary search in the tree, returning a path element from each iteration. Values i and j correspond, respectively, to the beginning and ending of the search, and have $i = 0$ and $j = 2^{|K|}$ as initial values. The value k corresponds to the index of the sought element (an element of P) and l, the current level of the tree. The sequence of events can be viewed in Stage 1 of Fig. 4.

$$\omega\left(i,j,k,l\right) = \begin{cases} Pr\left(K_l\right); j = c, \quad k \leq c \\ 1 - Pr\left(K_l\right); i = c, \ k > c \end{cases} \tag{6}$$

where $c = (i + j)/2$. After all the possible outputs of P for a SP p are defined, the method calculates the value S_p, which represents its quantitative risk level, as formalized in Eq. 7. The procedure for calculating the S_p takes into account performing a Harmonic Weighted Average (HWA) over all elements of P. The HWA comprises a particular type of average where the weights follow a sequence of harmonic numbers (i.e., the sequence harmonically converges to zero at each new number).

$$S_p = \sum_{j=1}^{k} \left(\frac{1}{j}\right) P_j \tag{7}$$

Therefore, from the set of S_p obtained results (i.e., the risk of each partner), the proposed method will be able to measure and analyze the SP's risk collectively.

Collective Risk Analysis

The second phase of the MARTP method aggregates the results provided by the first phase (that is, the risk level of each pre-selected SPs) to calculate the VO success probability as a whole (if the VO formation can succeed or not). To perform this, it is used the Analytic Hierarchy Process (AHP) [15], as seen in Stage 2 of Fig. 4. The AHP method arranges the problems resolution in a hierarchy, starting from the more general element (usually the goal) to the most specific elements (often alternatives). In this paper, the problem to be solved using AHP is specified by two components: the goal and the alternatives. The goal of AHP is to determine the overall VO risk. The alternatives consist in the individual risk levels for each SP (S_p) obtained through the individual risk analysis (Stage 1 of Fig. 4).

The first step to perform the AHP evaluation consists in defining a normalized level of risk S_{pN} for each SP p. The normalization procedure is necessary as a way to enable the collective risk analysis step. The level of risk of each SP (S_p) is normalized in a scale that varies from 0 to 1 as seen in Eq. 8:

$$S_{pN} = \frac{S_p}{|S|max(S)} \tag{8}$$

where $max(S)$ represent the highest value of S and $|S|$ the number of elements in S.

After normalizing the risk level of each SP, it is applied a correspondent weight W_p, which determines the degree of importance of each SP_p regarding the VO. In this work, the degree of importance of each SP is determined by an external entity named VO Manager [5], which is seen as the main decision maker. Therefore, the VO Manager plays a key role in the process of evaluating the VOs since he will inform which SPs have greater or lesser importance, so prioritizing some specific SPs in relation to the other ones.

For example, given a VO in the formation process, composed by three SPs (as illustrated in Fig. 4), each SP will have a level of importance (weight). The importance of each SP can be classified as follows: $[0.0; 0.25]$: very low; $[0.25; 0.50]$: relatively low; $[0.50; 0.75]$: relatively high; $[0.75; 1.00]$: very high. In this sense, the VO manager can change the weights W_p according to the degree of importance that is assigned to each SP_p. This feature increase the robustness of the method when compared to other techniques, by determining collectively the influence that each SP has within the VO and the level of risk of each one will impact overall VO risk level.

Accordingly, let be $W_1, W_2, ..., W_n$ the weight of each alternative $S_{1N}, S_{2N}, \cdots, S_{pN}$ associated the goal. The overall goal, i.e., to measure the VO risk level, is represented by R_{VO}, whose simplified calculation procedure is shown in Eq. 9:

$$R_{VO} = 1 - \sum_{i=1}^{p} W_i S_{iN} \tag{9}$$

From the calculation presented in Eq. 9, is obtained the overall level of risk in the VO formation, considering the importance of each SP in the process.

4 Evaluation Framework

This section presents results of the MARTP method evaluation. A computational simulation is conducted based on the preliminary results of [2] and [24] researches, in order to add the risk analysis context and also analyze the impact in the process of selecting SPs. Next subsections present the results obtained.

4.1 Computational Prototype

The developed computational prototype was split into two modules: BPSS (Best Peer Selection Service) [2] and DFRA (Decision Framework for Risk Analysis).

The first module implements the BPSS model developed by [2, 6] (view Section 2.1) using the PeerFactSim.KOM discrete event simulator [29] to support the creation of the P2P SON infrastructure and additionally make available the process for SPs search and selection. On the other hand, the DFRA module focuses specifically on the risk analysis method simulation. This model was integrated with BPSS in order to group the pre-selected SPs into a new potential VOs and to perform a MARTP evaluation (see Fig. 3).

Regarding technical system specifications, the prototype was built and the tests were developed in a computer Intel Core i5 3.1GHz, 4.0GB of RAM and Linux Mint 14.1 64-bit distribution.

4.2 Simulations setup

The initial configuration for the risk scenario follows the same rules used for the SP's selection. The data was taken from the CAIDA project and MaxMind GeoIP database [30]. The SPs are represented by a set of pre-selected SON peers whose identifiers (IPs addresses) belong to five geographical domains, corresponding to the five countries (Portugal, Spain, France, Italy and Germany). They are also equally distributed between the five domains.

Taking into account the data setup for the risk analysis, the KPIs values assigned to each SP follows a linear distribution (varying from 0 to 1) during the simulation. The linear distribution strategy for generating the KPIs values is primarily used because companies are often very variable and the implementation of the four chosen KPIs (trust, communication, collaboration and commitment) in real scenarios depends on the culture and working methods currently applied by the involved organizations. In the same way, it is also considered that each SP has participated at 10 previous VOs (in average) when it was selected.

4.3 Results

The results presented in this section aims to present a comparative analysis of the proposed MARTP method that analyses risk of SPs to form a VO with: (a) the selection process proposed by [2]; and (b) the DEA-Fuzzy risk analysis method proposed by [24]. The main goal of this comparison is to verify which of the three procedures present a more critical analysis regarding the risk level of sets of "preformed VOs" (i.e., a set of grouped SPs). The overall procedures for obtaining the selection and risk results are divided into two different phases as follows:

– The first phase basically performs the process of SP's search and selection through the BPSS model [2]. In this paper, the process for VO formation will take into account a set of three distinct SPs that will provide the following services: VPN (SP_1), Billing (SP_2) and Video-Streaming (SP_3). For this reason, the BPSS model should be used three-times in order to provide the three different SPs, each of them providing its particular service.

– The second phase take emphasis on the risk analysis process (MARTP). Thus, this phase uses as input the three SPs acquired at the first phase (SP_1, SP_2 and SP_3) to group them into a consortia to measure the risk of their collaboration in composing a new VO. It is worth to mention that the MARTP and the DEA-Fuzzy risk analysis methods uses the same criteria (KPIs), thus enabling the comparison of the results.

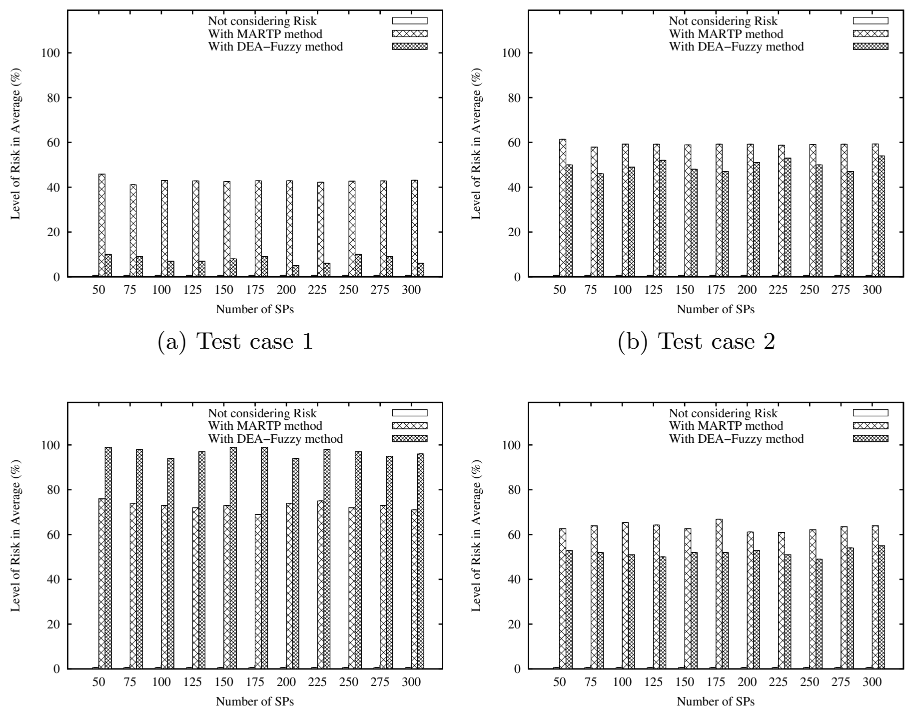
The results comprise four test cases, where each one present a different distribution in the absolute importance of SP_1, SP_2 and SP_3 (that compose a potential VO), as specified in Table 1. It means that there will be evaluated from cases where both the three SPs have little importance in the VO to cases where both the three SPs have great importance at all.

Table 1. Level of importance assigned for each SP in the four test cases.

	SP_1	SP_2	SP_3
Test case 1 (Fig. 6a)	0.30	0.30	0.30
Test case 2 (Fig. 6b)	0.50	0.50	0.50
Test case 3 (Fig. 6c)	0.70	0.70	0.70
Test case 4 (Fig. 6d)	0.30	0.50	0.70

The process of comparison between the level of risk of preformed VOs without risk analysis (i.e., only grouping the three SPs acquired in the first phase into a consortia) and with risk analysis (analyzing the risk of the previous formed consortia with the MARTP and the DEA-Fuzzy methods) is depicted in Figs. 6a – 6d. The simulation comprises 11 sets of individual scenarios divided into clusters that range $[50, 300]$ SPs. For each of the eleven scenarios (50 SPs, 75 SPs, $\cdots$, 300 SPs), the first and second phase early mentioned are performed 100 times, which will result in eleven 3-bar clusters, which one varying from 0 to 100. This scale is represented by the vertical axis and shows, in percentage, the average level of risk of the simulated VOs when: not using any method of risk analysis (just selection), using the MARTP method and using the DEA-Fuzzy method.

It is worth mentioning that the selected SPs in the first phase (i.e., without risk analysis), will always form VOs since there is no criteria to prevent their formation beyond those for selection. In this case, the risk level regarding the first-bar cluster in the results figures will be always assigned to zero. On the other hand, there is a significant increase on the risk percentage in the analyzed VOs under the methods that consider the risk analysis as the formation decision criterion (MARTP and DEA-*Fuzzy*) for all the four simulated test cases. In this sense, it can be pointed out that both methods behave like a VO formation filter, regardless of whether pre-selected SPs have been rated as the best or the worst according to a particular selection criteria.



(a) Test case 1 (b) Test case 2

(c) Test case 3 (d) Test case 4

Fig. 6. Distribution in the number of formed VOs when not using risk analysis (just selection), MARTP method and the DEA-Fuzzy method [24].

Considering average results (and based on a confidence interval of 95%), the greatest increase in the level of risk of the analyzed VOs when using the MARTP method was 77.54%, and for the DEA-*Fuzzy* method, 98.81%. On the other hand, the smallest increase when adding the MARTP method was 41.22%, and for the DEA-*Fuzzy* method, 8.03%,

Taking into account the comparison between the two methods of risk analysis, one can notice a reasonable difference in their VO's level of risk distribution (in average), which can be seen in the Fig. 6a and Fig. 6c. Although analyzing the risk in a similar way (i.e., the more importance have the SPs, the more risky is the VO) the DEA-Fuzzy method presented a very higher and lower VO's level of risk distribution when compared with the MARTP method (41.22% and 77.54% for MARTP, versus 8.03% and 98.81% for DEA-Fuzzy method) while in the Fig. 6b and Fig. 6d there were a similar occurrence of these distributions (59.76% and 62.69% versus 49.04% and 50.54%).

The main factor that contributes to this result is related to the bicriterial facet of the proposed method (MARTP), which takes into account a more critical and balanced analysis regarding its stages of individual and collective risk analysis. This means that MARTP avoids the small oscillations in the calculation of each step that generates large variations in the distribution of VO's level of risk in [24]. It means that the performance of a given SP has more equal – or similar – importance in relation to their relative importance within the VO, what is desirable to ensure the consistency of the proposed method in different kinds of scenarios. In the work presented in [24], these minor variations in the degree of importance of each SP led to huge variation in the distribution of risk (standing near from 0% or near from 100%), as shown in Fig. reffig:result1a and Fig. 6c.

In this sense, one can conclude that the risk analysis compared methods may favour a greater or lesser critical evaluation, where both the individual SP's performance and its importance in the VO plays a decisive role in the final outcome to calculate the final VO level of risk. Therefore, it should be taken great prevention and control by the VO Manager and risk specialists when evaluating the importance as well as the competence of each SP in order to provide confidence in the future operation of the VO, which is the next step further the VO formation.

5 Conclusion

This paper addressed some issues related to VO risk identification and measurement. Overall, risk analysis has become a key element in VO planning since small errors can lead them to impairment as a whole. Therefore, it is proposed a new method to perform a risk analysis in a set of Service Providers (SPs) that are going to compose a Virtual Organization (VO).

The presented method, named MARTP, is composed of two stages. The first stage performs an individual risk analysis for all pre-selected SPs, by basing it on ETA analysis. Having as input the results from the first stage, the second stage calculates and analyzes the global risk considering all SPs together. It applies AHP method to accomplish that.

Most of the works in the literature review have approached the problem of selecting partners via an analysis focused on members competences and capabilities. This work extended this vision incorporating an additional dimension of decision, which is risk. Therefore, besides considering these two dimensions, this work qualifies and quantifies the risk of each possible VO, suggesting to decision-makers a measurable rank of the less risky compositions.

The risk measurement is also based on four chosen KPIs (trust, communication, collaboration and commitment) that seem appropriate regarding the technical literature. Moreover, these indicators are combined with real geographical data in a simulation environment. The performed simulations involved sets of pre-selected SPs (taken in [2]) in order to explore the comparison between the proposed method and the method previously proposed by [24], evaluating which of the two methods presents more criticality in the process of analyzing the risk in VOs.

The achieved results seem promising about the suitability of the method regarding its purpose. There were found that the proposed method may be more or less critical for the assessment of an SP to be part of a VO, where this analysis is equally dependent on both the individual SPs' performance and their importance in the VO, unlike [24]. This particular feature enhances the consistency of the proposed method when dealing with different kind of scenarios, which is very common in VOs. The VO Manager plays a key role in the evaluation since it informs which SPs have greater or lesser importance in the VO.

Likewise, the presented method contributes to a more concrete way to express, measure, assess and deal with the risks in VO forming, both individually and collectively, while focusing only on SPs. Nevertheless, the use of the method in the process of risk analysis provides an evaluation with a lower level of subjectivity, discarding SPs or not, before composing a VO, according to the established criteria. Future work includes testing the method in near-real scenarios as well as extending the evaluation to an expert panel, in order to improve its quality.

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