A Risk Analysis Method for Selecting Service Providers in P2P Service Overlay Networks

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Abstract: In an increasingly competitive market place, the development of collaborative networked environments has become a key factor to companies successfully leverage their business activities. Nevertheless, when these companies get involved in more volatile strategic networks, it is necessary to deal with additional risks that need to be identified, measured, and mitigated through a well defined process. In this sense, this paper aims to specify a method for risk analysis comprising a set of service providers (SPs) in a P2P Service Overlay Network (SON). In this applied, qualitative and essentially exploratory work, the proposed method assesses the level of risk present in a set of previously selected SPs using key performance indicators (KPIs), and measures the viability of a Virtual Organization (VO) formation using those selected SPs. A computational prototype was also specified and used to execute a set of tests to assess the proposed risk analysis method.

1 INTRODUCTION

Services are becoming a major source of revenue on the Internet. Fundamental developments in network technologies, particularly the advent of Peer-to-Peer Service Overlay Networks (P2P SON) (Duan et al., 2003; Fiorese et al., 2012), are providing an advantageous environment for companies make their services available to the global user community. 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 (Zhou et al., 2005).

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 (Mowshowitz, 1997; Camarinha-Matos and Afsarmanesh, 2008). In this sense, the P2P SON acts as infrastructure that provides an environment for VO formation and, additionally, enhances benefits to SPs, i.e. sharing costs, bandwidth and others (Fiorese et al., 2010).

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 (Alawamleh and Popplewell, 2010). For this reason, the service provisioning is not guaranteed and needs the support of methods that encompass one or more criteria, supporting a set of key performance indicators (KPIs). These methods seem well suited especially when dealing with complex service chain networks (Junior and Rabelo, 2013).

In a previous work, the same authors designed a three-layer architecture for services management in P2P SONs, named OMAN (Fiorese et al., 2010). 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 (Fiorese et al., 2012). 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 (Fiorese et al., 2012) and (Junior and Rabelo, 2013), 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, 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 indi-

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vidually 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 provides a numerical example to illustrate the proposed method. Section 5 presents the set of experiments conducted to evaluate the proposed method and also presents the final results. Finally, Section 6 concludes and discusses future directions.

2 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, also referred to as Collaboration Opportunity (CO). 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 (Camarinha-Matos and Afsarmanesh, 2008). Regarding to the classical main phases of a VO life cycle (creation, operation, evolution and dissolution phases) (Camarinha-Matos and Afsarmanesh, 2005), this paper focuses on the creation (or formation) phase, which is seen in Figure 1. Within the creation phase, this analysis is carried out during the Partner's Search and Selection step (left circle).

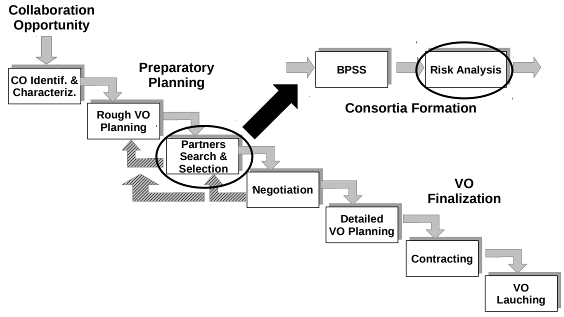


Figure 1: Framework for the VO Formation Process. Extended from (Camarinha-Matos and Afsarmanesh, 2005).

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 particular Virtual Breeding Environment (VBE) (Afsarmanesh and Camarinha-Matos, 2005). It is also considered that the SP's search and selection procedures is performed by the OMAN (Fiorese et al., 2010) service management architecture, with particular emphasis on its specific module (named BPSS), which is responsible for performing the selection of the most appropriate SPs in a P2P SON.

Figure 2 details the BPSS module. P2P SON, shown as the elliptic curve, is created covering domains (clouds in Figure 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 (Camarinha-Matos and Afsarmanesh, 2005). 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.

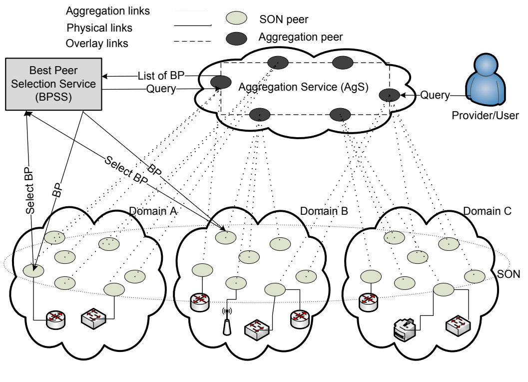


Figure 2: BPSS Model (Fiorese et al., 2012).

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. (March and Shapira, 1987) provide an overview of risk definition, as a variation in the distribution of possible outcomes, their probabilities, and their subjective values. (Moskowitz and Bunn, 1987) associate 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 its impact in the case of its occurrence (Vose, 2008).

In the state of the art review, some works related to risk analysis for VOs have been identified. In (Alawamleh and Popplewell, 2012; Alawamleh and Popplewell, 2010), thirteen KPIs were identified as general risk sources in VOs, further identifying the importance of each one. In (Grabowski and Roberts, 1998), the problem of risk mitigation in VO was discussed, and four processes were identified to improve the level of VOs performance reliability. In (Li and Liao, 2007) 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. (Min et al., 2007) and (Fei and Zhixue, 2010) considered the fuzzy characteristics and the project organization mode of VOs to propose Multi Strategy Multi Choice (MSMC) risk programming models.

In spite of these reviewed works and the insights we have been taken from them, none have somehow formalized how the proposed KPIs should be used nor provided means to quantity VO partners risks before the VO formation. Moreover, from the best of our knowledge, it was not identified proposals that specify a method or procedure that aims to systematize the process of risk qualification/quantification involved in the SP's Search and Selection for the VO formation. Therefore, this paper presents as a contribution a way to specify KPIs together with a mathematic method that enable measuring the risk in the VO formation.

In this sense, the VO formation process depicted in Figure 1 was extended by proposing two sub-steps in the Partner's Search and Selection step. The first sub-step comprises the BPSS model (as seen in Section 2.1). It is used to provide an environment for SP's search and selection. Next, the second sub-step introduces an additional process in order to embrace also risk analysis (right circle in Figure 1). Thus, given a VO in formation (composed by SPs), a set of adequate *performance indicators* are firstly used and, ultimately the SP selection also considers the risk perspective.

The way the risk is represented should be aligned with the organization's 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 (Vose, 2008). Therefore, there are four main sources of risks regarding VOs: *trust*, *communication*, *collaboration* and *commitment* (Alawamleh and Popplewell, 2010). In this work they are modeled as KPIs and their values are calculated and provided by the methodology developed in (Junior and Rabelo, 2013):

- **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

This section aims at describing the proposed method, named MARTP (*Multi criteria Risk Analysis method applied to P2P Service Overlay Networks*).

3.1 MARTP Overview

The devised method for risk analysis is generally presented in Figure 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 (Camarinha-Matos and Afsarmanesh, 2008), the so-called VO Manager is seen as the main decision-maker.

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, VO manager has the following role: quantifies the level of risk (acceptable range) for VOs before creating them. 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.

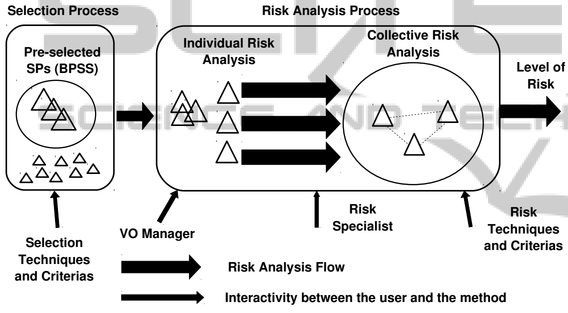


Figure 3: Overview of MARTP.

3.2 MARTP Architecture

The MARTP method itself is illustrated in Figure 4. Inspired in (Mosleh et al., 2004), 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 Fault Tree Analysis (FTA) method (Ericson, 2005; Vose, 2008).

3.2.1 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 (Ericson, 2005). It uses a visual representation based on a logical binary tree structure, known as Event Tree (ET), as shown in Stage 1 of Figure 4.

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 (Ericson, 2005). 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 Figure 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 (Pidduck, 2006; Goranson, 1999). 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) (Montgomery and Runger, 2011). The EWA is formally defined by Equation 1:

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

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 EWA results. The MQI is used as a performance reference (threshold) for all others SPs that will be assessed. In this sense, considering i the number of used KPIs (*four*) and n the number of SPs associated for each KPI (*three*), Equation 2 shows the MQI calculation procedure:

$$MQI_i = max_i\,(\bar{X_n}) \tag{2}$$

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

The value of the MQI (left circle in Figure 5) assigned for this KPI would have been set up as 6.7 (this

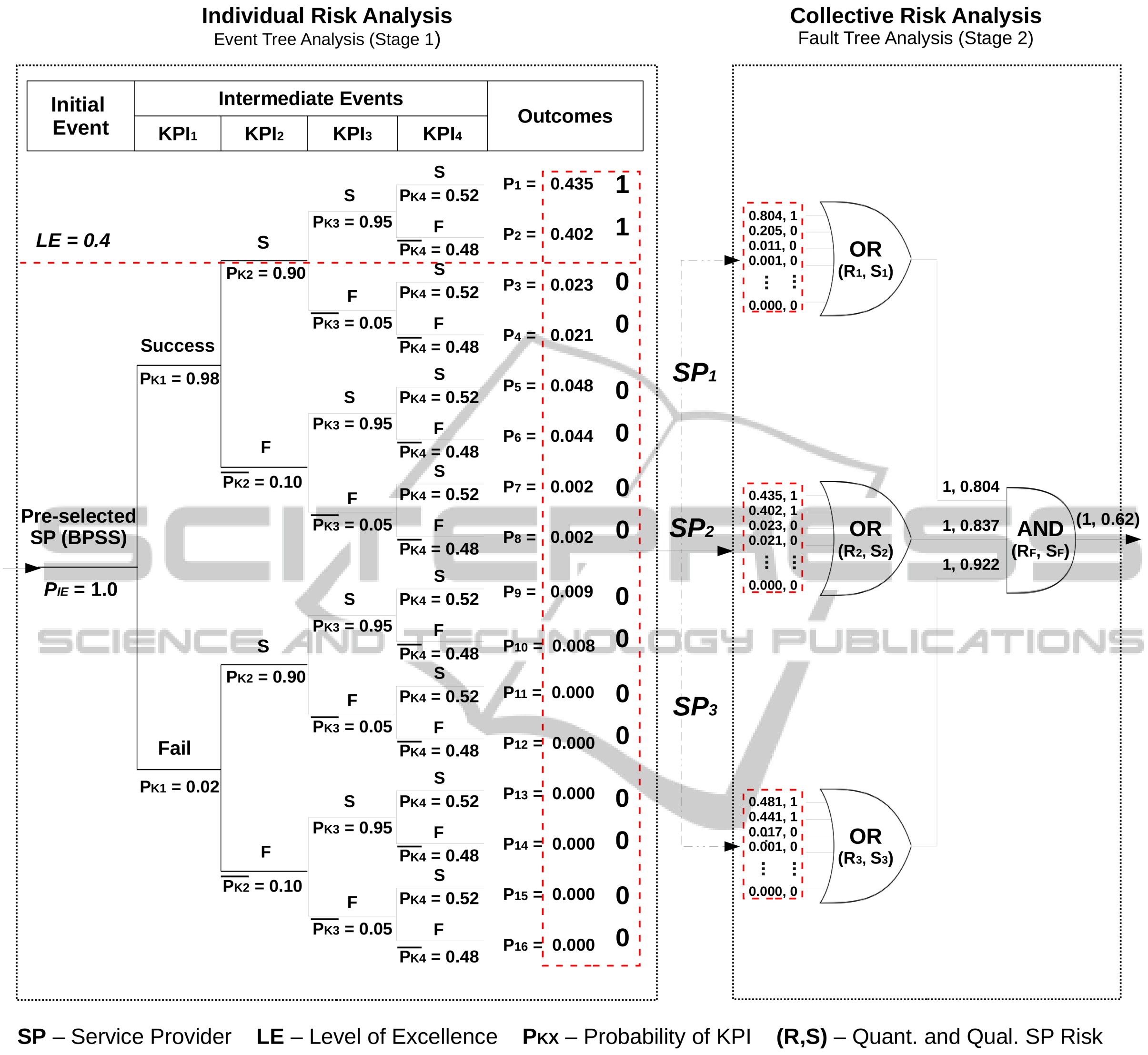


Figure 4: MARTP Architecture.

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 Figure 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 $MQI-SD$ (with an * in Figure 5), Equation 3 calculates the KPI success probability for the current participation.

$$Pr(K)=\frac{n_R}{n_{PA}} \tag{3}$$

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

$$Pr(\bar{K})=1-Pr(K) \tag{4}$$

According to Figure 4, the success and failure probability rates are calculated for all KPIs that compose the ET of a SP, which are presented by the four intermediate (and independent from each other) events $KPI_{1:4}$ that populate the ET. Event KPI_2, for instance, would be related to KPI communication, with success and failure values of 0.90 and 0.10, respectively.

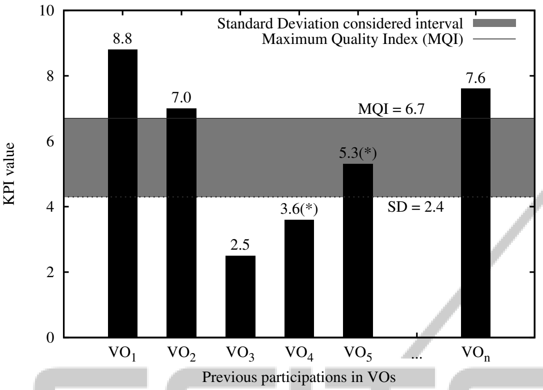


Figure 5: Trust KPI historical values for a given SP.

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. The results greater than a Level of Excellence (LE) are then selected to be part of the Stage 2 of MARTP. LE is set by the VO manager and corresponds to a minimum acceptable probability that qualifies/enables a SP to compose a VO. The LE values can be classified as follows: $[0.0; 0.2]$: *regrettable*; $[0.2; 0.4]$: *bad*; $[0.4; 0.6]$: *regular*; $[0.6; 0.8]$: *good*; $[0.8; 1.0]$: *superior*.

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 business. Let $K = \{K_1, K_2, ..., K_m\}$ be a set of m KPIs associated to a SP_n, and $\rho(K)$ the probability function associated with each event in K (as defined in Equation 3). ETA events occur independently, i.e., where the occurrence of an event does not affect the occurrence of other event. This situation can be represented by the equalities defined in Equation 5 and Equation 6:

$$\rho(K_m | K_{m-1} | ... | K_1) = \rho(K_m) \tag{5}$$

$$\rho(K_1 \cap \cdots \cap K_m) = \rho(K_1) \cdot \rho(K_2) \cdots \rho(K_m) \tag{6}$$

Now consider $P = \{P_1, P_2, ..., P_{|K|}\}$ 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) (Bentley, 1975), which travels $2^{|K|}$ different paths and assigns a value to each element of P, as shown in Equation 7:

$$P = \bigcup_{k=1}^{2^{|K|}} \left[P_{IE} * \prod_{l=1}^{|K|} \omega(i, j, k, l) \right] \tag{7}$$

where P_{ie} is the initial probability of the SP. The function ω, as shown in Equation 8, corresponds to a 4-dimensional vector which 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 Figure 4.

$$\omega(i, j, k, l) = \begin{cases} Pr(K_l); j = c, & k \leq c \\ 1 - Pr(K_l); i = c, & k > c \end{cases} \tag{8}$$

where $c = (i + j)/2$. After defined all possible outputs P for a SP and calculated their probabilities, the method applies a constraint variable Q, which checks, for each element of P, whether its value is greater than or equal to LE. Only the results that are greater than LE are considered, and the other are discarded. Thus, $Q = \{Q_1, Q_2, ..., Q_n\}$ is a subset of P:

$$Q = \{q \in P \mid q \geq LE\} \tag{9}$$

The final probability values obtained by Equation 9 will be used to measure and analyze the SP's risk collectively.

3.2.2 Collective Risk Analysis

The second phase of the MARTP method aggregates the results provided by the first phase (i.e., 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).

This phase applies FTA (Fault Tree Analysis) method (Ericson, 2005). FTA uses a logical diagram called Fault Tree (FT) - which is a graphical representation of failure logical events that can occur in a system among all other possible event combinations. The graphical model can be translated into boolean logic using logic gates to calculate failures. Events are associated with input lines from the logic gates

(0-*failure*, 1-*success*) and must be analyzed to determine the logical connection between underlying failure events that might cause them. On the other hand, FTA also performs probabilistic analysis for the underlying failure events, by calculating the probability of the top event (VO overall risk), given the FT and the probability of occurrence of the basic events (risk level of SPs) (Ericson, 2005).

This paper performs both qualitative risk analysis (boolean values) and quantitative analysis (probability associated to the boolean values). To make this possible, first is considered that the risk level of each SP is defined by a pair $\langle R,S\rangle$. R represents a condition of the SP to compose a VO (using boolean logic), while S represents the success probability of the SP associated with the condition R. So $SP_i = \langle R_i,S_i\rangle$ for the i-th selected SP and the i-th S associated with the i-th R. The R value is calculated checking if the set Q has some element (Equation 10), i.e., if there is at least one outcome value greater than LE. A value 1 corresponds to the presence of elements, so enabling the SP to compose a VO. The S value (Equation 11) is calculated summing all elements of Q, obtaining the success probability rate for a SP.

$$R_i = \begin{cases} 0 & , \quad |Q| = 0 \\ 1 & , \quad |Q| \neq 0 \end{cases} \tag{10}$$

$$S_i = \sum_{i=1}^{|Q|} q_i \quad , \quad q_i \in Q \tag{11}$$

In this sense, next step consists of taking all the results from ETA (first phase) and set them as the input (see Figure 4) of the FTA method. A logic gate OR with $2^{|K|}$ entries is associated with each SP, meaning that the number of logic gates OR changes according to the number of SPs. In this case, the OR operation among all inputs will result in a pair $\langle R_i,S_i\rangle$ for each SP.

Resulting values from logic gates OR are then aggregated to an AND logic gate, which verifies if all SPs are able to compose the VO. This gate returns a pair $\langle R_F,S_F\rangle$ where $R_F = 1$ means success, i.e., the VO formation is considered feasible from the risk analysis point of view, and $R_F = 0$ means failure, i.e., VO is discarded and the procedure is restarted with other SPs (with the other possible VO compositions). If all members are considered able to, the VO as a whole is considered able to go for operation. It is necessary to mention that S_F quantifies the value of R_F, i.e., even though the R_F determines the criterion to assigned success or failure in a given VO, the S_F will show how risky is the VO formation process itself.

The calculation for R_F with all SPs is performed aggregating all R_i in order to verify if each SPs is able to compose the VO. This process is formalized as follows (Equation 12):

$$R_F = \bigwedge_{i=1}^{|SP|} SP\langle R_i\rangle \tag{12}$$

The quantitative risk can be also found by S_F, which shows the final success VO probability. In this case, the logic port AND presented in FTA acts multiplying all S_i results acquired in the OR logic gate, as seen in Equation 13.

$$S_F = \prod_{i=1}^{|SP|} SP\langle S_i\rangle \tag{13}$$

4 A NUMERICAL EXAMPLE

This section presents a numerical example to better understand the proposed method operation. Suppose that a CO was created and three SPs ($SP = \{SP_1,SP_2,SP_3\}$ were selected (using the SPs selection method developed in a previous work (Fiorese et al., 2012)). Therefore, the goal is to measure the risk of every pre-selected possible SP for the given VO. Following the proposed method, the individual risk of every SP is measured and the overall VO risk is calculated.

The assessment criteria K of each SP are defined by a set of four KPIs: Trust (K_1), Communication (K_2), Collaboration (K_3) and Commitment (K_4). Table 1 shows hypothetical historical values assigned to KPIs of SP_1, SP_2 and SP_3 for its participations in the last four VOs (V). Equation 3 (see Section 3) calculates the success probability of these KPIs. The MQI value for KPIs$_{1:4}$ are also computed and subtracted of their respective SDs values, based on the procedures presented in Equations 1 and 2.

In order to individually measure the risk level of the SP_1, SP_2 and SP_3, they are submitted to the first stage of MARTP, applying ETA method. It should also consider the success and failure probabilities of each KPI that composes the intermediate events so to add them as parameters in the ET. The ET graphical representation can be viewed in Stage 1 of Figure 4. According to Table 1 and using Equations 3 and 4, the success and failure probabilities associated with all KPIs of each SP are calculated (Table 2) and the respective ETs are formed.

Now, let $P_i = \{P_1,P_2,...,P_{16}\}$ a set of all combinations among K_1, K_2, K_3, K_4 for each SP_i and, for example, $LE = 0.4$ (a regular level). Table 3 presents this result after applying Equation 7. It represents

Table 1: Quantitative values of KPIs according historical values of SP_1, SP_2 and SP_3 in VOs.

K	Service Providers (Past VOs)												
	SP_1				SP_2				SP_3				MQI−SD
	V_1	V_2	V_3	V_4	V_1	V_2	V_3	V_4	V_1	V_2	V_3	V_4	
K_1	0.50	0.74*	0.89*	0.82*	0.84*	0.85*	0.93*	0.86*	0.48	0.90*	0.81*	0.96*	$0.71(SP_3)$
K_2	0.84*	0.90*	0.96*	0.70	0.94*	0.80*	1.00*	0.79*	0.85*	0.77*	0.90*	0.78*	$0.75(SP_2)$
K_3	0.87*	0.95*	0.91*	0.77*	0.57	0.80*	0.96*	0.85*	0.75*	0.98*	0.85*	0.74*	$0.72(SP_2)$
K_4	0.99*	1.00*	0.95*	0.73	0.99*	0.97*	0.89*	0.69	1.00*	0.89*	0.94*	0.77*	$0.74(SP_3)$

*KPI values greater than $(MQI-SD)_i$ are considered in the risk analysis

Table 2: Success and failure probabilities for SP_1, SP_2, SP_3.

K	Service Providers					
	SP_1		SP_2		SP_3	
	Suc	Fail	Suc	Fail	Suc	Fail
K_1	0.75	0.25	1.00	0.00	0.75	0.25
K_2	0.75	0.25	1.00	0.00	1.00	0.00
K_3	1.00	0.00	0.75	0.25	1.00	0.00
K_4	0.75	0.25	0.75	0.25	1.00	0.00

Table 3: Results from event combinations for SP_1, SP_2, SP_3.

P	Service Providers (Outcomes)		
	SP_1	SP_2	SP_3
P_1	$0.422^* \rightarrow 1$	$0.562^* \rightarrow 1$	$0.750^* \rightarrow 1$
P_2	$0.141 \rightarrow 0$	$0.187 \rightarrow 0$	$0.000 \rightarrow 0$
P_3	$0.000 \rightarrow 0$	$0.187 \rightarrow 0$	$0.000 \rightarrow 0$
P_4	$0.000 \rightarrow 0$	$0.062 \rightarrow 0$	$0.000 \rightarrow 0$
P_5	$0.141 \rightarrow 0$	$0.000 \rightarrow 0$	$0.000 \rightarrow 0$
P_6	$0.047 \rightarrow 0$	$0.000 \rightarrow 0$	$0.000 \rightarrow 0$
P_7	$0.000 \rightarrow 0$	$0.000 \rightarrow 0$	$0.000 \rightarrow 0$
P_8	$0.000 \rightarrow 0$	$0.000 \rightarrow 0$	$0.000 \rightarrow 0$
P_9	$0.141 \rightarrow 0$	$0.000 \rightarrow 0$	$0.250 \rightarrow 0$
P_{10}	$0.047 \rightarrow 0$	$0.000 \rightarrow 0$	$0.000 \rightarrow 0$
P_{11}	$0.000 \rightarrow 0$	$0.000 \rightarrow 0$	$0.000 \rightarrow 0$
P_{12}	$0.000 \rightarrow 0$	$0.000 \rightarrow 0$	$0.000 \rightarrow 0$
P_{13}	$0.047 \rightarrow 0$	$0.000 \rightarrow 0$	$0.000 \rightarrow 0$
P_{14}	$0.012 \rightarrow 0$	$0.000 \rightarrow 0$	$0.000 \rightarrow 0$
P_{15}	$0.000 \rightarrow 0$	$0.000 \rightarrow 0$	$0.000 \rightarrow 0$
P_{16}	$0.000 \rightarrow 0$	$0.000 \rightarrow 0$	$0.000 \rightarrow 0$

*Values greater than $LE = 0.4$

the $2^{|K|}$ combinations of K, corresponding to all the probabilities (sixteen) associated with each event. For each value of P, the respective binary representation are added (1 – values *equal* to or *greater* than LE; 0 – values *less* than LE) as seen in Stage 1 of Figure 4.

The second stage of the method consists in to aggregate all the individual results from the SP team and to analyze them as a whole. This is done using ET results (the set with P_1, P_2, ..., P_{16}) as input to verify whether that VO coalition, collectively, is feasible or not. So, it will be firstly assigned a S_i score and a R_i boolean result for each SP (Equations 11 and 10) that are calculated through a logic gate OR present in FTA method. For each SP is also defined a constraint Q_i (Equation 9), corresponding a set with the values greater than LE (these procedures are seen as follows):

$$Q_1 = \{0.422\}$$

$$Q_2 = \{0.562\}$$

$$Q_3 = \{0.750\}$$

Note that the number of elements in all Q are equal to 1. It happens because only one value of P associated with both SP_1, SP_2 and SP_3 was reached 0.4. Therefore, applying the values of constraint Q, Table 4 summarizes all these informations:

Table 4: Values of $\langle R,S \rangle$ associated with SP_1, SP_2, SP_3.

$\langle R,S \rangle$	Service Providers		
	SP_1	SP_2	SP_3
R	1	1	1
S	0.422	0.562	0.750

Given the values of R and S for all three SPs, Equations 12 and 13 are applied considering the provided values (Table 4) using the $SP_i(R)$ and $SP_i(S)$ as follows:

$$R_F = SP_1(R) \wedge SP_2(R) \wedge SP_3(R) = 1 \wedge 1 \wedge 1 = 1$$

$$S_F = SP_1(S) * SP_2(S) * SP_3(S) = 0.422 * 0.562 * 0.750 = 0.177$$

As explained in Section 3, considering $R_F = 1$ would mean that the combination of those three SPs has an acceptable level of risk. Hence, they could become members of the VO, i.e., the VO could be created. Considering quantitative levels (calculated by S_F), the VO as a whole has 17.7% chance of success.

5 EVALUATION FRAMEWORK

This section presents results of an ongoing and exploratory research, through MARTP method evaluation. A computational simulation is conducted based on the preliminary results of (Fiorese et al., 2012) research, in order to add the risk analysis context. Next subsections present the results obtained.

5.1 Computational Prototype

The developed prototype was split into two modules: BPSS (Best Peer Selection Service) (Fiorese et al., 2012) and DFRA (Decision Framework for Risk Analysis). The first module implements the BPSS model developed by (Fiorese et al., 2012; Fiorese et al., 2010) (view Section 2.1) by using the PeerFactSim.KOM discrete event simulator (Stingl et al., 2011) 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 methods 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 Figure 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.

5.2 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 (Caida, 2013). 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 risk analysis data setup, 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 firstly because companies are often very variable and the implementation of the four chosen KPIs (trust, communication, collaboration and commitment) in real scenarios to cope with risks in VO also 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. The LE (Level of Excellence) is defined as 0.6, which represents a *good level* of quality, as seen in Section 3.

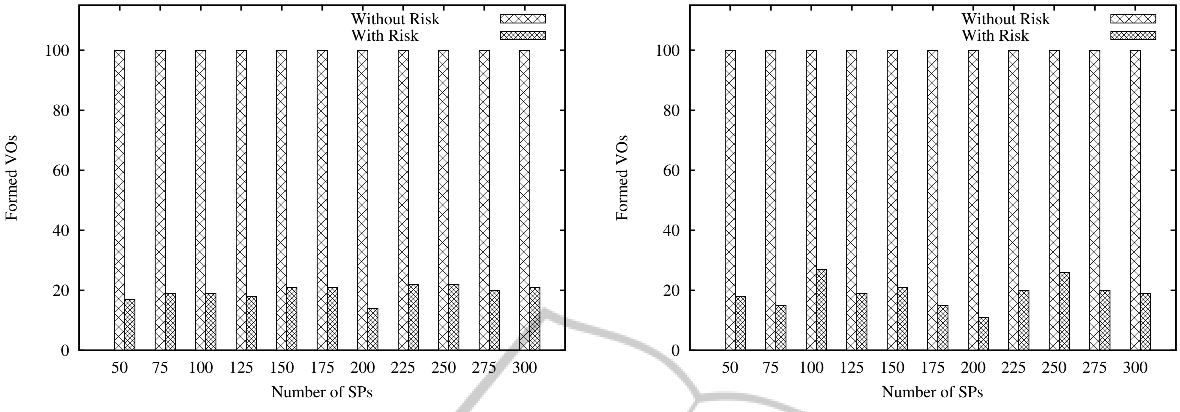
5.3 Results

5.3.1 VO Risk Analysis

The results presented in this section aims to evaluate the efficiency of MARTP (regarding the number of VO formed) in choosing SPs when comparing the selection process. 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 (Fiorese et al., 2012). 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.

The process for comparison between the number of formed VOs without risk analysis (i.e., only grouping the three SPs acquired in the first phase into a consortia for forming a new VO) and with risk analysis (analyzing the risk of the previous formed consortia) for the best SPs is depicted in Figure 6a. 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 2-bar clusters, which one varying from 0 to 100. This scale are represented by the vertical axis and shows, in percentage, the number of formed VOs regarding the two bars.



(a) (b)

Figure 6: Clustering VO Formation for: (a) Best SPs; (b) Second Best SPs.

It is worth mentioning that the selected SPs in the first phase (i.e., without risk analysis; first-bar cluster), will form VOs (since if does not have other criteria to block the formation). Nevertheless, there is a significant decrease on the percentage of VOs formation under risk analysis (MARTP) results. The method is primarily behaving just as a filter, where from selected SPs, it checks whose are able to compose VOs, regardless of whether they have been rated as the best or the worst according to other criteria.

The comparison between VO formation also took into account the second best SPs (selected by the BPSS), as shown in Figure 6b. This comparison can aids the validation of the MARTP method by measuring the average improvement of two distinct scenarios (in this case, the difference of the best SPs over the second-best SPs).

Considering average results (and based on a confidence interval of 95%), the reduction in the number of formed VOs when adding the risk filter for the "best" SPs was 80.54%, and for the second offering better services, the reducing dropped 80.81%. The results show that there was not significant variations between the average of percentage reductions of the best and second best SPs.

It is important noting that forming the VO based on choosing only the best SPs accordingly the best rates of KPIs is not a very good choice. A wiser decision is to submit the chosen SPs to a risk evaluation. This is what MARTP does. More importantly, it does it considering also the odds of SPs working together. This is the reason of the high drops in the number of VOs formed after the risk analysis.

5.3.2 Estimation of VO Acceptance Rate

The results presented in Section 5.3.1 showed the amount of formed VOs when considering $LE = 0.6$. However, it is necessary to consider that such results are calculated based on static values of LE, i.e., that were previously defined by VO manager and give only a partial view of the method functionality.

Accordingly, there was performed an evaluation regarding the relation between the amounts of formed VOs while LE varies. This evaluation aims to show how the LE variation can impact in the number of formed VOs, and additionally, to obtain an equation that best define this behavior.

The evaluation was carried out by a regression analysis, where equations were found that describe how the number of formed VOs behaves in accordance with the increase in LE for 100 simulated scenarios (each scenario represents a simulation performed with LE varying from 0.00 to 1.00, with intervals of 0.01). Figure 7 presents two curves, each one generated by applying a regression calculation in the dataset obtained through the 100 simulated scenarios. The minimum and maximum ranges $[0, 100]$ represented on the vertical axis was defined according to the limit in the number of formed VOs. This means that for values lower or higher than the adopted

Table 5: Polynomial coefficients for the best and becond-best SPs regression analysis.

	a	*b*	*c*	*d*	*e*	*f*	*g*	*h*
Eq 1	1.008e+2	-7.312e+1	9.128e+2	-2.912e+3	-2.534e+3	1.581e+4	-1.727e+4	5.972e+3
Eq 2	9.976e+1	-5.416e+1	7.972e+2	-3.161e+3	4.502e+1	1.011e+4	-1.211e+4	4.273e+3

range, the number of VOs formed remains constant at 0 or 100. In contrast, the horizontal axis represents the variation in the LE value. It ranges from 0 to 1 with intervals of 0.01 (100 possible results), according defined in Section 3.

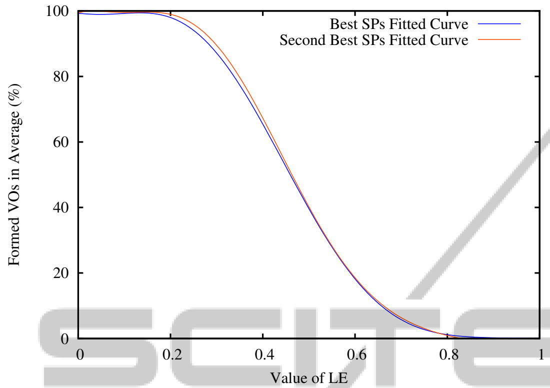


Figure 7: Regression analysis for VO formation in relation to LE variation.

The curve is better adjusted by a polynomial equation, where the approximate polynomial coefficients are shown in Table 5. In the analysis performed through Figure 7, it was found the correlation coefficient (which verify the correlation degree between LE and the VO formation percentage) $r_a = -0.999$ for the best SPs and $r_b = -0.999$ for the second-best SPs scenario. It means that the LE values have a strong negative correlation with the number of VOs formed, i.e., the more increases the value of LE, the smaller becomes the number of VOs, with a success rate higher than 99.999% for both cases.

One can also see that even maintaining a lower LE value, often the SPs cannot become able to compose VOs (for instance, the results presented in Section 5.3.1 shows that the number of formed VOs when LE is 0.6 is approximately 20%). It primarily occurs because how the ETA method (which makes up the individual risk analysis) in this work is designed to deal with independent events, so it is sufficient that just one of all KPIs present a low value for significantly reduce the SP success probability as a whole.

In this sense, it can be concluded that the method favors a more rigorous evaluation when is encompassed an increased number of indicators, what is desirable when analyzing the risk in the VO as a whole. Moreover, for all SPs that will compose a VO, it is necessary that all their indicators have reasonably acceptable values. Otherwise, they can compromise the proper working of the VO.

6 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 analyses the global risk considering all SPs together. It applies FTA method to accomplish that.

In order to assess the MARTP behavior, four distinct KPIs (trust, communication, collaboration and commitment) are assigned for each SP. Moreover, these indicators are combined with real geographical data in a simulation environment. The performed simulations involved sets of pre-selected SPs, which have been taken in (Fiorese et al., 2012).

The achieved results seem promising about the suitability of the method regarding its purpose. The level of competence required for each SP to compose a VO is higher and it is strongly influenced by LE, which is decisive for this choice. Thus, the VO manager should increase the quality of the SPs by increasing the LE value, which result in a more restrict set of SPs that are able to compose a 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.

Therefore, future work includes testing the method in near-real scenarios as well as creating a framework for risk analysis regarding VOs formation as a whole. The next steps also include extend the evaluation to an expert panel, in order to improve the quality of the method as well as the comparison with other decision support methods like Bayesian Networks (Heckerman, 1996), Genetic Algorithms (Holland, 1973) and Data Envelopment Analysis (DEA) (Cooper et al., 2007).

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