A NETWORKED ANALYSIS APPROACH FOR THE SELECTION OF SERVICE PROVIDERS IN P2P SON MULTI-PROVIDER ENVIRONMENTS

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ABSTRACT

This paper implements and evaluates a multi-criteria approach involving a particular data analysis method to select appropriated Service Providers (SPs) in a large scale multi-provider environment. This approach applies the Analytic Network Process (ANP) method in a Peer-to-Peer Service Overlay Network (P2P SON) composed of several different multi-domain SPs. Such approach aims to select the most suitable SPs in order to compose a Virtual Organizations (VOs). The proposed data analysis model for the ANP method take into account several SP's performance indicators to accomplish that. The performed evaluation presents simulation results regarding the SP's selection. The results achieved point out the effectiveness of the use of ANP as a method to select the best SPs, thus resulting in better distributed selections.

KEYWORDS. Virtual Organizations, Service aggregation, P2P.

1. Introduction

In a current highly connected world, service transactions foster great business opportunities. Most of these opportunities are related with the communication facilities that the enterprises can take advantage of when collaborating together. Particularly, these communication facilities leverage collaboration in order to cope with the competitive challenges imposed by even more opportunistic consumer needs (Busi e Bititci, 2006).

Several approaches have been employed by organizations to handle these issues (Camarinha-Matos e Afsarmanesh, 2008). One of the most relevant approaches is to create organization networks that are associated to each other by means of multilateral interests, for instance, a Virtual Organization (VO) type of network (Mowshowitz, 1997). This collaboration aims to attend a particular – or even cyclic but not permanent – Collaboration Opportunity (CO). A CO is therefore, the motivational cornerstone that brings together enough organizations to tackle the challenge of ultimately deliver a particular service, product, appliance, among others (Concha et al., 2008).

One of the issues regarding VOs that have to be faced refers to how they are created and, more specifically, how their partners are selected. Regarding this work, a VO is composed by a set of SPs that have previously agreed to collaborate in satisfying a CO. The composition and delivery of the final service depends on the appropriate selection of individual SPs to be arranged in a networked organization. Nevertheless, depending on the CO, it is necessary to perform a selection process in order to choose among all the potential CO attendees (e.g., SPs). In this case, the selection process plays a cornerstone role comprising the VO formation (Camarinha-Matos et al., 2005).

It is worth noting that the SPs search and selection process should not be performed based only on individual SPs' characteristics. A careful analysis must be performed in order to make those processes less time-consuming and improve the quality of the SPs' selection. Moreover, this analysis should be complemented with the support of decision methods, which can systematize this process so providing more agility and transparency in creating a new VO (Junior e Rabelo, 2013).

The main contribution of this paper is to propose a method that uses a multi-criteria analysis to satisfy a CO, i.e., to select the most suitable SPs to compose VOs. It is easy to note that the outcome of the SPs' selection is tightly tied to the chosen criteria. Thus, the use of a multi-criteria approach to select SPs leverages the quality of the process. Also, this paper proposes a correlation model of dependent SP's performance indicators to be applied on the SPs' selection problem. This approach selects the best SPs from a previously proposed Peer-to-Peer Service Overlay Network (P2P SON) architecture (Fiorese et al., 2012) taking into account previously defined performance indicators.

This paper is organized as follows: Section 2 presents some background. Section 3 describes the proposed method while Section 4 shows the method evaluation and discusses the results. Finally, Section 5 concludes the paper and outlines some future work.

2. General Background

2.1. Service Providers Integration

The purpose of the SP integration is to create a group of SPs that collaborate to accomplish a mutual goal. The accomplishment of this aim leads to cost sharing and eventually better outcomes with increasing profits. Several paradigms have been proposed to deal with the appropriate group creation. One of the most well-known is the Virtual Organizations (VO) strategy (Camarinha-Matos e Afsarmanesh, 2008). A VO is a temporary and dynamic collaboration of selected partners (SP for this paper). These partners may be autonomous and geographically distributed organizations that may have different ideas and objectives, but can collaborate to address a common interest (business collaboration opportunity). This advanced collaboration is achieved by means of interactions between their business processes supported by a network infrastructure (Mowshowitz, 1997).

Other well known initiative to deal with SPs integration is the Service Overlay Network (SON) (Tran e Dziong, 2010) concept. Likewise the VO, the aim of a SON is to provide a shared environment in which SPs can collaborate to achieve a common objective. When a SP is a member of a SON, it can make its services available more efficiently. The SON provides an infrastructure where SPs can publish/offer their services and clients can access it to select and use these services (Fiorese et al., 2010). So, a federation of SPs (or a VO) can create a SON that utilizes the Internet communication infrastructure to offer services to a broader range of clients that otherwise cannot be accessible by a single SP.

A SON can be built by using the Peer-to-Peer (P2P) technology (Fiorese et al., 2012; Zhou et al., 2005). This technology allows to create a self-organized overlay network and to share the creation and maintenance costs among the SPs. Moreover, the combination of P2P and SON facilitates the integration of the SPs. Particularly, this work uses the P2P SON infrastructure developed by the same authors (Fiorese et al., 2012) to organize all the SPs committed with the eventual VO formation. This means that all SPs that feel able to attend a possible CO shall be consorted in a first-level SON in order to be selected to compose a VO. In this case, for instance, SPs belonging to a particular geographic domain can be first-level grouped in a P2P SON meaning they are offering their services and being able to be chosen to compose a VO.

2.2. Service Provider Selection

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 (i.e., an infrastructure designed to provide services) to organize all the SPs committed with the eventual VO formation. It is also considered that the SP's search and selection procedures is performed by the OMAN (Fiorese et al., 2010) service management architecture, which provides an environment to offer services through the Internet. This environment supports some functionalities, such as a) creation of a P2P SON composed of several SPs from different network domains; b) search for services and SPs; c) selection of the best SP.

In this paper, the emphasis is given on a specific module of OMAN (named BPSS), which is responsible for performing the selection of the most appropriate SPs in a P2P SON. Figure 1 details the BPSS module. P2P SON, shown as the elliptic curve, is created covering domains (clouds in Figure 1) 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 then sends a service request to the AgS, which forwards the request to the peers in the aggregation overlay. The result of this request is a list of all SPs that can offer the requested service. Thus, the SP selection consists on the application of a suitable selection method by the

BPSS on the returned SPs list.

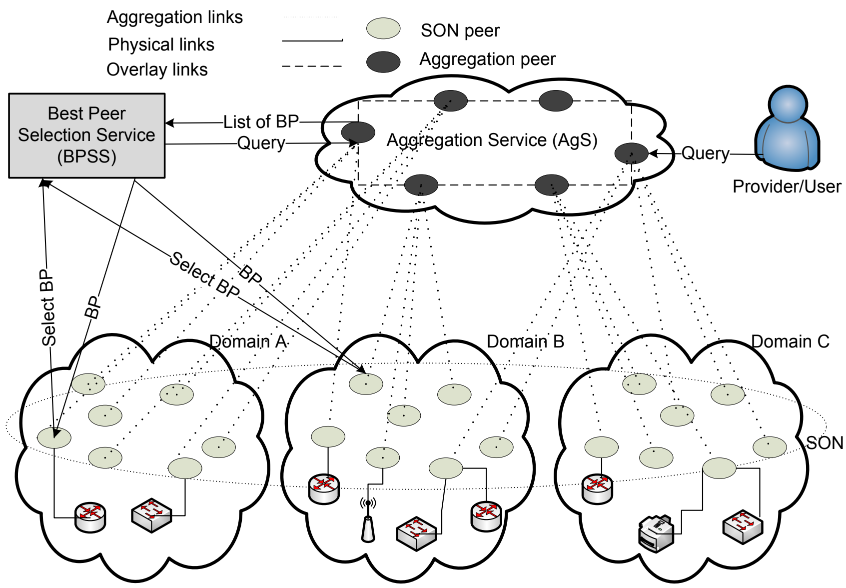


Figura 1. BPSS Architecture

2.3. Decision Making Supported by Data Analysis Methods

The initial premise took into consideration in this paper is that the SPs selection problem addressed is, in fact, a multi-criteria decision making problem (MCDM) (Korhonen et al., 1992), since it is necessary to choose one among the possible alternatives. Several analysis methods addressing MCDM problems have been proposed. Among them, on one hand, the Analytic Hierarchy Process (AHP) (Saaty, 1990) is a multi-criteria hierarchy method that performs qualitative and quantitative analysis of performance indicators, also known as attributes. For each performance indicator (qualitative), the AHP associates a numerical value (quantitative) to it. Basically, at the end of the AHP method a general score is calculated using weights, which are assigned by the user, for the attributes. Thus, by means of this general score, alternatives (i.e., SPs) can be compared with each other.

On the other hand, Analytic Network Process (ANP) (Saaty, 2001) deals with interdependent attributes providing an integrated environment for the evaluation of the existent relationships in complex systems. ANP is an advanced version of AHP that can model the interdependent relationships by relaxing the hierarchical and unidirectional assumptions. The network name comes from the fact that the ANP models do not have to show a hierarchical structure, which means they do not have to be linear from the top to bottom. In fact, ANP uses a network for which it is not necessary to specify levels, as in a hierarchy; therefore the term level in AHP is replaced by the term cluster in ANP. The network model has cycles connecting its clusters of elements and loops that connect a cluster to itself.

This paper uses the ANP method taking as second premise the performance indicators used to support the decision about which SP to select are interdependent.

3. The Proposed Method

The approach proposed in this work uses the ANP method to select SPs by means of the performance analysis of each SP. More particularly, ANP is used by the BPSS module to analyse and select the SPs. Due to the fact that the selection process is meant for choosing SPs of networked services only (particularly on the Internet), the performance indicators used in this work must proper qualify a network SP. For this reason, the following performance indicators were chosen:

- **Distance:** represents the Euclidean distance between the requester and the provider. It is based on the Internet delay model, which was built with real data (Caida, 2014).
- **Delay:** the time it takes to transmit a data packet from the source through routers and network links towards the destination;
- **Jitter:** statistical variation of the delay.

The ANP initial set up consists of the identification and structuring the elements belonging to three basic groups: goal (G), criteria (C) and alternatives (A). In this work, the goal or objective is to select the most appropriate SP (SP) to form a VO according one or more criteria. The criteria are represented by the set $C = \{C_1, C_2, C_3\}$ of performance indicators, where C_1, C_2 and C_3 represent the indicators of Euclidean distance, delay and jitter, respectively. The alternatives are represented by the set $A = \{A_1, A_2, ..., A_n\}$ comprising all the n SPs. Figure 2 depicts the network structure, which comprises the objective (goal), criteria, alternatives, and the relationships represented by the arrows, which are specified at the Section 3.1.2 (Step 2).

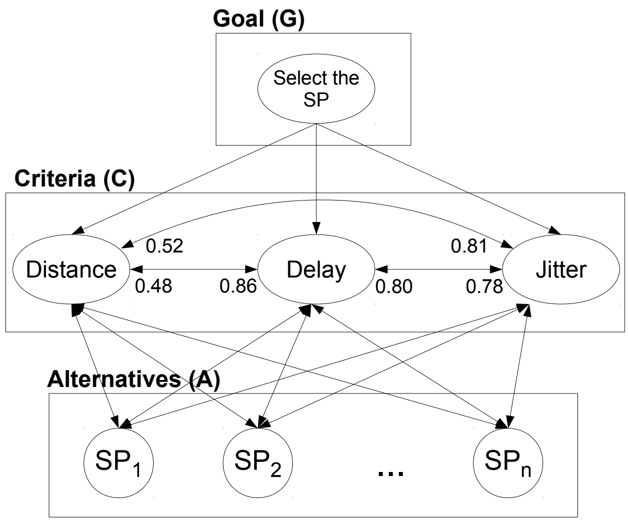


Figura 2. ANP method structure.

Having structured the problem of selecting the SPs in terms of the three ANP clusters, the calculation of the method can be summarized in four steps, as follows:

3.1. Step 1: Define relationship weights

At this stage, all the relationships between criteria (C), alternatives (A) and the goal (G) are weighted. These relationships, when normalized, represent the influence of an element on the other. However, they can be, initially, defined in raw values (not normalized). At this work, these relationships are split into four types as follows:

3.1.1. Relationships from goal to criteria

They correspond to the importance level assigned to each of the three performance indicators considered in this work to select a SP. These values are represented by the column matrix R_1 (Equation 1).

$$R_1 = \begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \end{array} \begin{array}{c} G \\ \begin{bmatrix} gc_1 \\ gc_2 \\ gc_3 \end{bmatrix} \end{array} \tag{1}$$

3.1.2. Relationships from criterion to criterion

The relationships between criteria represent the level of influence that an indicator enforces over the other. The value of this influence is assigned to the matrix R_2 (Equation 2) meaning the indicator of the line i has influence over the indicator of the column j, for $i \neq j$. For instance, it is worth noting in Equation 2 that the Euclidean distance indicator (C_1) has higher level of influence over the delay (C_2) and jitter (C_3) indicators (0.86 and 0.81, respectively), whereas the delay and jitter indicators do not enforce significantly high influence over the Euclidean distance indicator (0.54 and 0.49, respectively).

$$R_2 = \begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \end{array} \begin{array}{c} \begin{array}{ccc} C_1 & C_2 & C_3 \end{array} \\ \begin{bmatrix} 0.00 & 0.86 & 0.81 \\ 0.48 & 0.00 & 0.78 \\ 0.52 & 0.80 & 0.00 \end{bmatrix} \end{array} \tag{2}$$

The criterion used to design the dependence (or influence) level between the three considered performance indicators (and consequently to define the matrix R_2) is based on the calculation of a correlation for each pair of indicators, named Pearson Product Moment Correlation (PPMC). Basically, the PPMC calculates the linear relation between two variables. In this case, given a dataset for each the two indicators (e.g., a list of values for the jitter and delay corresponding to some SPs) then it is applied the PPMC in order to verify how correlated are these indicators.

In order to apply PPMC, the dataset used in this case is the set of SPs in a simulation environment, where each SP can be evaluated regarding any of the three aforementioned indicators. Therefore, the resulting correlation values are presented in the Equation 2.

3.1.3. Relationships from criteria to alternatives

They represent the influence that an SP plays over a performance indicator. They are represented by the matrix R_3 (Equation 3). In this work, the non normalized influence is defined as the absolute value of the indicator for the particular SP being analysed. For instance, if the SP_1 (A_1) has jitter (C_3) equals to 0.5, then $ca_{13} = 0.5$. Equation 3 shows the R_3 matrix for this paper.

$$R_3 = \begin{array}{c} \\ A_1 \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{ccc} C_1 & C_2 & C_3 \end{array} \\ \begin{bmatrix} ca_{11} & ca_{12} & ca_{13} \\ \vdots & \vdots & \vdots \\ ca_{n1} & ca_{n2} & ca_{n3} \end{bmatrix} \end{array} \quad (3)$$

3.1.4. Relationships from alternatives to criteria

They represent the influence of an indicator over an SP, i.e., how much an indicator is considered regarding an SP. The values correspond to the elements of the matrix $R_4 = (R_3)^T$ (Equation 4).

$$R_4 = \begin{array}{c} \\ C_1. \\ C_2. \\ C_3. \end{array} \begin{array}{c} \begin{array}{ccc} A_1 & ... & A_n \end{array} \\ \begin{bmatrix} ac_{11} & \dots & ac_{1n} \\ ac_{21} & \dots & ac_{2n} \\ ac_{31} & \dots & ac_{3n} \end{bmatrix} \end{array} \quad (4)$$

Finally, in order to determine the real influence between the elements (criteria, alternatives and goal) it is necessary that, after the construction of the matrices R_1, R_2, R_3 e R_4, all their column values are normalized in accordance to the Equation 5 (Montgomery e Runger, 2011). Thus, each value x_{ij} will represent the percentage of influence the element from the i_{th} line exerts over the element of the j_{th} column.

$$x_{ij} = \frac{x_{ij}}{\sum_{k=1}^{d} x_{kj}} \quad (5)$$

where $x_{ij} \in R_t$, for $t \in [1..4]$, corresponds to the value of a relationship, and d is the size of the columns of the matrix R_t. This normalization guarantees that the sum of all elements for each column at the matrices R_1, R_2, R_3 e R_4 is equal to 1.

3.2. Step 2: Build an unweighted supermatrix

At this step, the normalized values obtained in the Step 1 are added to the unweighted supermatrix S_U. This supermatrix models the inter-relationships between all the elements of the system and it represents the importance of each element (indicators and SPs) within its own clusters. The supermatrix S_U has dimension $d \times d$, where $d = |A|+|C|+|G|$, i.e., the sum of SPs, indicators and the goal. Moreover, the supermatrix is composed of the four aforementioned (see Step 2) matrices (R_1, R_2, R_3 and R_4), as can be seen in the Equation 6:

$$
S_U = \begin{array}{c} \\ A_1 \\ \vdots \\ A_n \\ C_1 \\ C_2 \\ C_3 \\ G \end{array}
\begin{array}{c}
\begin{array}{cccccccc} A_1 & ... & A_n & C_1 & C_2 & C_3 & G \end{array} \\
\begin{bmatrix}
0 & \ldots & 0 & ca_{11} & ca_{12} & ca_{13} & 0 \\
\vdots & \ddots & \vdots & \vdots & R_3 & \vdots & \vdots \\
0 & \ldots & 0 & ca_{n1} & ca_{n2} & ca_{n3} & 0 \\
ac_{11} & \ldots & ac_{1n} & 0.00 & 0.86 & 0.81 & gc_1 \\
ac_{21} & R_4 & ac_{2n} & 0.48 & 0.00 \; R_2 & 0.78 & gc_2 \; R_1 \\
ac_{31} & \ldots & ac_{3n} & 0.52 & 0.80 & 0.00 & gc_3 \\
0 & \ldots & 0 & 0 & 0 & 0 & 0
\end{bmatrix}
\end{array}
\tag{6}
$$

The relationships between alternatives and the relations between alternatives and goal are not considered in this work, and hence, their values are assigned to zero in the supermatrix shown in Equation 6.

3.3. Step 3: Build an weighted supermatrix

Given the unweighted supermatrix S_U obtained in Step 2, this 3^{rd} step performs the specification of a weighted supermatrix S_W, i.e, a stochastic matrix that represents the general importance of each element considering all clusters (G, C and A) simultaneously. To make this possible, another normalization procedure is performed (similar to the normalization shown in Equation 5), where for each column, each element is divided by the sum of all its elements, as shown in Equation 7.

$$
(S_W)_{ij} = \frac{(S_U)_{ij}}{\sum_{k=1}^{d} (S_U)_{kj}} \tag{7}
$$

3.4. Step 4: Calculate limit supermatrix

The last step on the ANP execution consists in to calculate a limit supermatrix S_L, raising the weighted supermatrix S_W to power ($S_L = (S_W)^k$ for $k = 1, 2, ...$) until the convergence of its values, such that every column $(S_L)_i$, $(S_L)_i = (S_L)_{i+1}$. This convergence always occurs since the stochastic nature of the supermatrix S_W. Hence, the final results are represented by a column matrix X that is generated from any column $(S_L)_i$. The matrix X aims to related the weights of each SP regarding the goal, as can be seen in Equation 8:

$$
X = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_n \end{array}
\begin{array}{c} G \\ \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix} \end{array}
\tag{8}
$$

Thus, at ordering the matrix column X it is given the ranking of all SPs. The selected SP is the one that has the biggest value for the goal.

4. Evaluation Framework

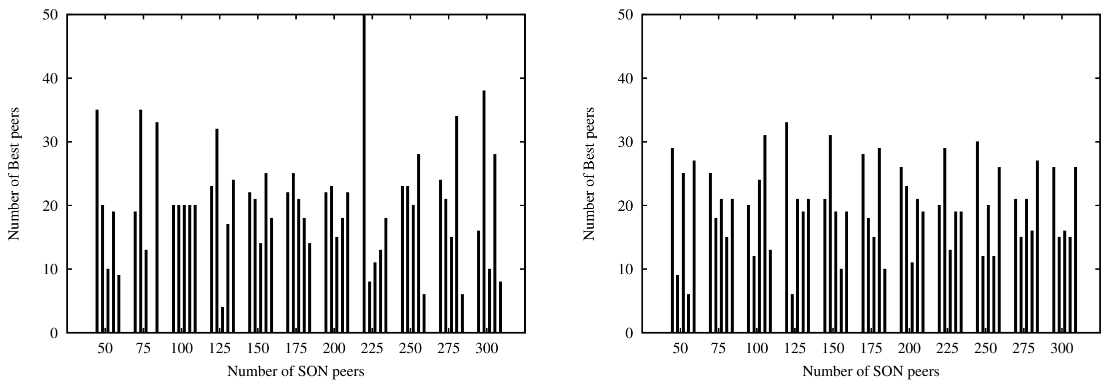
In order to carry out the tests, the PeerfactSim.KOM (Kovacevic et al., 2007) simulation tool was adopted. Real delay, jitter and Euclidean distance data was used in the simulation. This dataset was obtained from CAIDA (Caida, 2014) and MaxMind GeoIP (GeoIP, 2014). The SPs are represented by a set of 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 among the five domains.

Regarding to the ANP method specification, the weights of relationships between the three criteria (distance, delay and jitter) and the goal (select the best SP) were defined in order to do not prioritize any criterion, i.e., each criterion has the same importance (0.33) comprising the goal. The technical system specifications are as follows: computer Intel Core i5 3.1GHz, 4.0GB of RAM and Linux Mint 14.1 64-bit distribution. Next subsections present the achieved results.

4.1. Results

The analysis of SPs selection was performed by comparing the results obtained from the tests that used the ANP method against those from tests that used the Euclidean distance indicator as the only metric (see (Fiorese et al., 2012)).

The results of the best SPs using the Euclidean distance are presented in Figure 3(a) while Figure 3(b) presents the results using the ANP method. There are eleven 5-bar clusters, each one corresponding to one of eleven simulated scenarios (horizontal axis), which range $[50..300]$ SPs in steps of 25 SPs. In each scenario, each of the five bars represents the number of best SPs occurrences (vertical axis) in each of the geographical domains, namely Portugal, Spain, France, Italy, and Germany, respectively. Moreover, each cluster represents the execution of 100 search/selection operations, thus selecting 100 SPs in total.



(a) Euclidean Distance without ANP

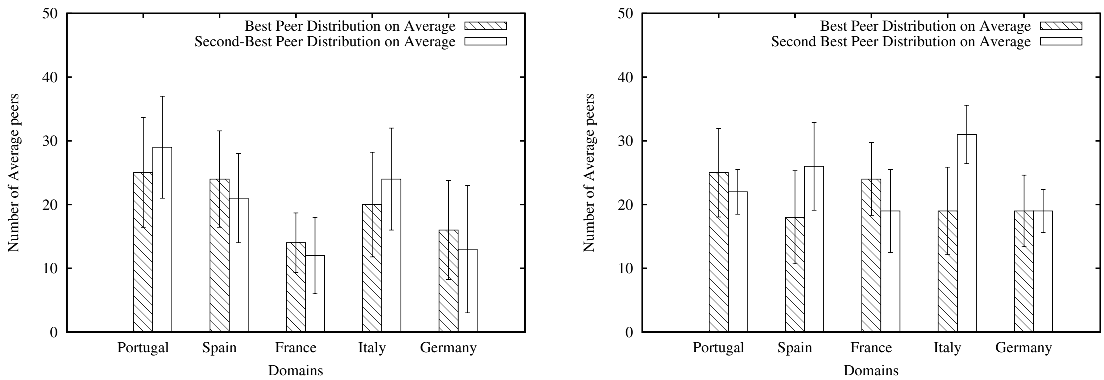
(b) Using ANP with jitter, delay and Euclidean Distance

Figura 3. Best Service Providers Distribution by Amount of Service Providers

The results shown in Figure 3(a) and 3(b) depicts a significant variability between the number of SPs selected using the Euclidean distance as the only indicator (Figure 3(a)) and the number of SPs selected via ANP (Figure 3(b)). Particularly in Figure 3(a), a higher variability occurs because it is taking into account a single indicator (distance), thus prioritizing the results for the closest SPs from the requester, does not necessarily those that provide appropriate quality of service.

On the other hand, the results obtained by means of the ANP method also shown Portugal as the domain with most SPs occurrences. Nevertheless, this is due to the fact the level of influence that the Euclidean distance has over the other performance indicators (delay – 0.86; jitter – 0.81) is quite higher than the level of influence of delay and jitter indicators have over the distance indicator (0.48 and 0.52, respectively). In this sense, the results obtained from ANP tend to give greater importance to the SPs with shorter distance, but at the same time take into consideration the relationships among all three indicators, so offering a more critical choice of which SPs are more suitable to compose a VO.

In order to improve the analysis of the results, the standard deviation of each simulation was calculated. In the context of this work, the higher the standard deviation, the larger the variation in the number of selected SPs when compared to the mean number of SPs selected in a particular domain. The experiments also had chosen second-best SPs (Figure 4(a) and 4(b)). The second-best SPs can aid in the validation of the used metric by measuring the average improvement of the best SP over the second-best SP, an indication of the metrics effectiveness can be obtained. It is worth mentioning the results rely on and are presented based on a confidence interval of 95% for the mean number of best and second-best SPs selections on each geographical domain.



(a) Using the Euclidean Distance without ANP

(b) Using ANP with jitter, delay and Euclidean Distance

Figura 4. Best and Second-best Service Providers Distribution by Geographical Domain

According to average results presented in Figure 4(a) and 4(b) (relying on a confidence interval of 95%), SPs belonging to Portugal domain presented standard deviation of 8.64% when selected as best SPs through Euclidean distance metric against 6.96% for using ANP method; followed by Spain (7.55% against 7.30%), France (4.68% against 5.74%), Italy (8.21% against 6.86%) and Germany (7.76% against 5.61%). For the SPs selected as second-best, the standard deviations results are as follows: Portugal (8.73% against 3.51%), Spain (7.06% against 6.88%), France (6.03% against 6.49%), Italy (8.32% against 4.58%) and Germany (10.05% against 3.35%).

From the simulation results, almost all simulations that used the ANP method presented a standard deviation lower than those that used the Euclidean distance indicator only. It was also clear to see that by using the ANP method, the number of SPs selected from each domain in every scenario did not vary greatly. On the other hand, in the simulations that did not use the ANP method (only Euclidean distance), this variation was much more considerable. Since the ANP method can perform a more consistent analysis by allowing the use of multiple criteria (i.e., distance, jitter and delay), the simulations that used the proposed method showed more balanced results between the domains, thus resulting in low standard deviation values. Therefore, the use of the ANP method increases the flexibility of the search and selection processes, which allows selecting SPs that have not been selected so far.

5. Conclusion

This paper addressed the importance of the SP's search and selection process in the process of composing VOs, and then proposed an approach to select SPs associated to a P2P SON by using the ANP multi-criteria method. In the P2P SON environment, SPs can offer their services in order to attend a certain demands (also reffered as Collaboration Opportunity – CO). Thus, according to some criteria, the appropriate SPs must be selected.

The criticality of the process for search and selection SPs within the life cycle of a VO is related to the fact that SPs that comprise it are independent, geographically dispersed and have different cultures. However, they share resources and information in order to reach common goals and consequently profit. In this sense, the selection process must consider some additional aspects among SP to carry a wisely analysis, i.e, it should be feasible to be applied to all SPs.

In the context of this work, the following performance criteria were used: Euclidean distance, jitter and delay. It was also proposed a correlation model of dependent performance indicators based on the ANP method to be applied on the SPs selection problem to compose a VO. The results of the simulation showed that: a) The selection process becomes more flexible and dynamic, due to the manipulation of the network of relationships between the indicators; b) The results variability are lower when using a method that takes into account the existent relationships between the indicators used as the selection criteria.

One can also note that with the obtained results, it is clear advantage of the ANP method over the selection criterion, which is based just on the distance between SPs. It occurs because not always the closest SP will bring greater benefit, and the ANP method systematized this analysis, considering others performance indicators thus providing more reliable and balanced results.

As future work, it will be planed the comparison of results using other multi-criteria decision making (MCDM) methods such as the Analytic Hierarchy Process. Moreover, it will be also plan to compare, whenever possible, also the worst case scenario where indicators have no relationships.

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