Multi-Criteria Approach to Select Service Providers in Collaborative/Competitive Multi-provider Environments

Adriano Fiorese†, Fernando Matos††, Omir Correa Alves Júnior† and Ramon Michels Rupeenthal†

†Department of Computer Science, Santa Catarina State University, Brazil
†Department of Systems and Computer, Federal University of Paraíba, Brazil

Summary
This paper implements and evaluates a multi-criteria approach to select appropriate service providers in a large scale multi-provider environment. This approach uses the Analytic Hierarchy Process (AHP) method in a Peer-to-Peer Service Overlay Network (P2P SON) composed of several service providers in order to select the most suitable one to deliver the requested service. The AHP method takes into account several performance indicators to accomplish the task. The performed evaluation compares simulation results regarding the service providers' selection by using and not using the AHP method. The results show that the use of AHP as a method to select the best service providers is effective, thus resulting in better distributed selections.
Key words:* *AHP, provider selection, multi-provider.

1. Introduction

Due to the globalization process, the competition between organizations has increased, as well as the consumer market demanding for better price, delivery time, quality and personalization [1]. Several approaches have been employed by the organizations to handle those issues. One of the most relevant approaches is to create organization networks that are associated to each other by the means of multilateral interests so they can collaborate. These networks allow joining efforts, decreasing costs and increasing the competition along the entire value chain. Moreover, these networks leverage market competition between the networks or associations, rather between the organizations or enterprises [2,3]. Thus, every organization that is a member of a network can focus on its core competence. This results in a service provisioning model in which the service requirements are fulfilled by a combination of competences from distinct organizations (or service providers), i.e. each service provider can meet one or more requirements. In this sense, the composition and delivery of the final service depends on the appropriate selection of service providers to be arranged in a Service Overlay Network (SON).
Tran and Dziong [4] define SON as a virtualized network composed of service providers (peers) that are interconnected. The general purpose of the SON is to meet a demand, also known as a Collaboration Opportunity (CO), with a minimum acceptable Quality of Service (QoS). Thus, in the context of this work, a SON is composed of service providers that have previously agreed to collaborate in satisfying a CO. Moreover, depending on the CO, the outcome of a service providers' selection is a SON where each peer is the best service provider to satisfy a part of the service demand. However, according to [4,5], the search for providers and the selection of the those that can satisfy a CO should not be performed based only on individual providers' characteristics. A carefully analysis must be performed in order to make those processes less time-consuming and improve the quality of the providers' selection step.
The aim of this work is to propose a method to select service providers that uses a multi-criteria analysis to satisfy a CO. It is easy to perceive that the outcome of the service providers' selection is tightly tied to the chosen criteria. Thus, the use of a multi-criteria approach to select providers leverages the quality of the process. The study presented in [6] shows that the Analytic Hierarchy Process (AHP), which was proposed in [7], can be used to perform qualitative and quantitative analysis of the providers' attributes (performance indicators), thus allowing a dynamic selection based on these attributes. In this sense, this paper proposes the use of AHP to select the best service provider from a SON taking into account previously defined performance indicators. The AHP method is implemented in a SON architecture previously proposed [13].
This paper is organized as follows: Section 2 presents some related work. 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.

Manuscript received September 5, 2013
Manuscript revised September 20, 2013

2. Related Work

2.1 Service Providers Integration

The aim of service provider integration is to create a group of providers that collaborate to accomplish a mutual objective. Several paradigms have been proposed to create this group. One of the most well-known is the Virtual Organizations (VO) strategy [8]. VO is a temporary and dynamic collaboration of selected partners (service providers). These partners may be autonomous and geographic distributed organizations that may have different ideas and objectives, but can collaborate to address a common interest (business opportunity). In a VO, the partners must share trust, competences, resource, information, risks and costs, thus allowing them to realize their mutual goals. This advanced collaboration is achieved by the means of interactions between their business processes supported by a network infrastructure.

Likewise the VO, the aim of a Service Overlay Network (SON) [4] is to provide a shared environment in which service providers can collaborate to achieve a common objective. When a provider is a member of a SON, it can make its services available more efficiently. The SON provides an infrastructure where providers can publish/offer their services and clients can access it to select and use these services. Therefore, a federation of providers 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 provider.

A SON can be built by using the peer-to-peer (P2P) technology. This technology allows to create a self-organized overlay network and to share the creation and maintenance costs among the providers. The combination of P2P and SON facilitates the integration of the providers. This statement can be endorsed by the work of Lavinal et al. [9] that used P2P as the base for a SON architecture. In that work, the authors studied the discovery of services considering QoS aspects. Therefore, the work presented in this paper uses our own developed P2P SON infrastructure to select the best peer (service provider).

2.2 Peer Selection

Regarding the fulfillment of a CO, the problem in selecting the appropriate service providers is crucial. Several works have been proposed to tackle this issue.

Aldo and Rabelo [10] claim that the selection phase complexity is due to the need to propose a method that uses one or more analysis criteria and is supported by a set of performance indicators to select high quality providers. Camarinha-Matos and Afsarmanesh [8] show that the processes of search and selection become more complex due to the heterogeneous nature of the providers.

In file sharing systems, incentive mechanisms are used in the selection process. BitTorrent [11] employs fairness between uploads and downloads as the metric to select the best peers. However, the work proposed in this paper is not file (or data) sharing-oriented. Instead, it focuses in selecting the best peers that fulfill the requirements of the service (e.g. content distribution, connectivity, etc). Besides, to best fulfill these requirements, provider performance indicators can be also taken into account during the selection process.

Therefore, the use of a multi-criteria approach can achieve better results. Moreover, differently from file-sharing systems, the proposed approach considers provider selection processes in environments comprising long-term sessions.

2.3 OMAN Architecture

The Overlay Service Management Architecture (OMAN) [12] 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 service providers from different network domains; b) search for services and service providers; c) selection of the best service provider.

According to [12], the OMAN architecture consists of three layers and each layer contains several modules, as presented in Figure 1. Layer 1 is responsible to support communication and service publication functionalities. Layer 2 consists of three modules, where the Aggregation Service module (AgS) is responsible to aggregate the service published by Layer 1. Finally, Layer 3 is responsible to select the best service provider by using the Best Peer Selection Service (BPSS) module [13].

Figure 2 details the BPSS module. P2P SON (shown as the elliptic curve in Figure 2) is created covering domains (clouds in Figure 2) that contain service providers. Every peer in the P2P SON runs service(s) from the corresponding providers. The AgS is created in a higher level inside de P2P SON, where each AgS peer mantains an aggregation of services published by the SON peers (providers at the P2P SON level). In order to select a provider (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 providers that can offer the requested service. Thus, the provider selection consists on the application of a suitable selection method by the BPSS over the returned providers list.

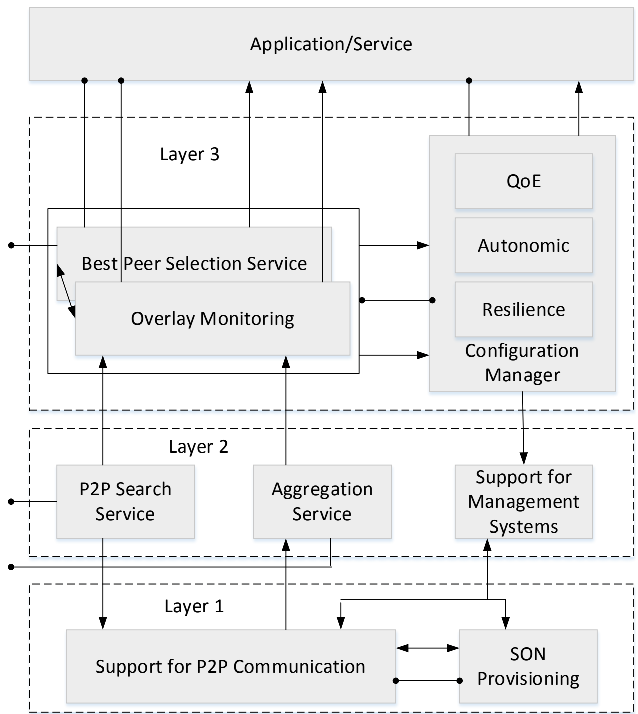

Fig 1. OMAN Architecture

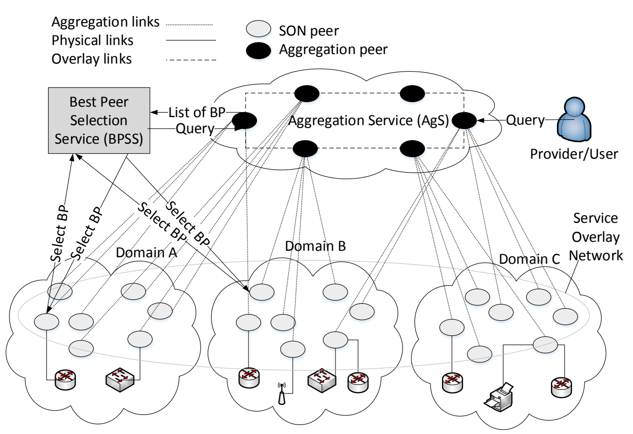

Fig 2. BPSS Architecture

3. Proposed Approach

The approach proposed in this work uses the AHP method to search and select service providers by the means of the performance analysis of each provider. The AHP is implemented in the OMAN architecture. More specifically, AHP is used by the BPSS module to analyze and select the service providers.

According to [7], the AHP 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. This aspect of AHP makes it a good choice for selecting service providers in order to take care of a CO. In this regard, it is proposed a group of four performance indicators for each service provider that can potentially handle the CO. Thus, the process of selecting service providers is performed by analyzing the values of those performance indicators all together.

Due to the fact that the selection process is meant for choosing providers of networked services only (particularly on the Internet), the performance indicators used in this work must proper qualify a network service provider. For this reason, the following performance indicators were chosen:

- Cost: the price of the service offered by the provider;

- Distance: represents the Euclidean distance between the requestor and the provider peer. It is based on the Internet delay model, which was built with real data [14]. In that model, the peers are placed in a Cartesian plane by using network performance metrics along with the geographic coordinates of the peers. This allows to estimate and use the Euclidean distance as an indicator. In this sense, the distance indicator takes into account the geographic distance between peers, as well as, the delay between these same peers. Because of that, the distance between two peers from the same geographic domain may eventually be greater than the distance between two peers from different geographic domains;

- 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.

After the performance indicators were defined, they were placed in the hierarchy structure (Figure 3) used by the AHP method, where the upper layer is the goal of the analysis, the intermediary layer shows the picked indicators, and finally bottom layer consists of several choices.

The next step is to determine the weight (relative importance) of the performance indicators. This weight dictates how the provider selection process is affected by each indicator. To accomplish that, Saaty [7] proposed a scale table comprised of degree of preferences. These degrees specify the extent to which an indicator outweighs the others. They are labeled from 1 to 9, where 9 represents the largest discrepancy between the indicators, and 1 represents the smallest discrepancy between them (i.e. the indicators are equally important). By using this scale table, a comparison matrix is then created to compare pairs of performance indicators. This comparison is performed by the means of a normalization process, which results in the weight of each indicator. Such normalization is obtained by carrying out a sequence of calculations that produce a number between 0 and 1 for each indicator, where the sum of these values must be 1. In this sense, the weights can also be expressed as percentage. More details of the AHP method can be found in [6].

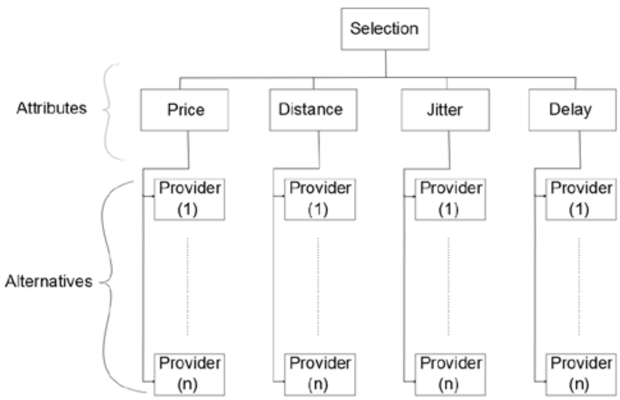

Fig 3. AHP Hierarchy Structure

After the weights of all performance indicators are defined, the general score of each service provider is calculated. The quantitative values of the four indicators of each service provider are normalized (between 1 and 10). The results of the normalization are multiplied by the corresponding AHP weights, and the general score is the sum of these multiplications. Thus, by the means of this general score, providers can be compared with each other. In this sense, the provider that obtains the highest score is considered to be the more qualified to meet the service requirements, so it is chosen to provide the service.
The abovementioned calculation is shown in Equation 1, where *S* represents the general score. *C*, *T*, *J* and *D* represent the quantitative values defined to cost, distance, jitter and delay, respectively, while *W1*, *W2*, *W3* and *W4* represent their corresponding weights.

$$S = (W1 * C) + (W2 * T) + (W3 * J) + (W4 * D) \qquad (1)$$

4. Evaluation Results

In order to carry out the tests, the PeerfactSim.KOM [17] simulation tool was adopted. Real Euclidean distance data was used in the simulation. This data was obtained from CAIDA [15] and MaxMind GeoIP [16] project databases. The quantitative values of cost, jitter and delay were randomly assigned.

4.1 Test Environment

In order to test the AHP method implementation to select the appropriate service providers, eleven scenarios were conceived during the simulations. Each scenario was comprised of a different number of SONs and Aggregation peers (AgS peers). The first test scenario consisted of 50 peers equally distributed between five domains: Portugal, Spain, France, Italy and Germany. In each subsequent scenario, the number or peers increased by 25. All peers were created by using the simulation tool.

Regarding the AgS overlay, it was composed of 10 percent of the number of SON peers in each scenario. The distribution of peers that constitute the AgS is also equally distributed among the five domains. For instance, in the scenario that has 50 SON peers, the AgS contains five peers, where each one belongs to a different domain. It is worth noting that all simulation tests were carried out by considering that the service requestor was always located at the Portugal domain.

4.2 Analysis of the Results

The analysis of service providers' selection was performed by comparing the results obtained from the tests that used the AHP method against those from tests that used the cost indicator as the only metric [18]. Every simulation were performed by executing 100 search/selection operations for each scenario, thus selecting 100 service providers. Each scenario simulation comprises the following processes: search for service providers; identification of service providers; general score calculation; and service provider selection.

During the first simulations sequence, the AHP method implementation was executed by prioritizing the cost indicator. This indicator priority was set to 100% (weight 1) in order to verify whether the same providers are selected when compared to the test that does not use the AHP method and take into account the cost metric only. Figures 4 and 5 present the results of the simulations that do and do not use the AHP method, respectively. The horizontal axis represents the simulation scenarios, where each scenario contains five geographic domains (five distinct countries). The vertical bars in each scenario represent the number of providers selected in each domain (Portugal, Spain, France, Italy and Germany). Figure 4 highlights the order of the domains, which is Portugal, Spain, France, Italy and Germany.

As can be seen, the first two simulations behave as expected. The results of both the simulations were the same, since one of them use the cost indicator only (Figure

5) while the other sets the cost indicator to the maximum weight when applying the AHP method (Figure 4).

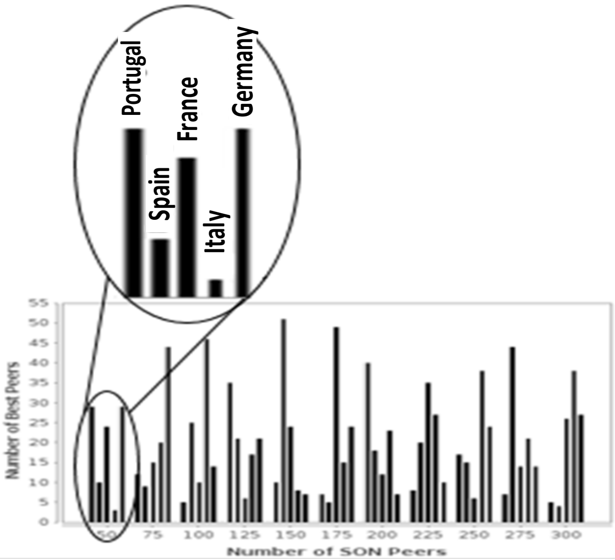

Fig 4. AHP best peers - cost at 100% (simulation 1.1)

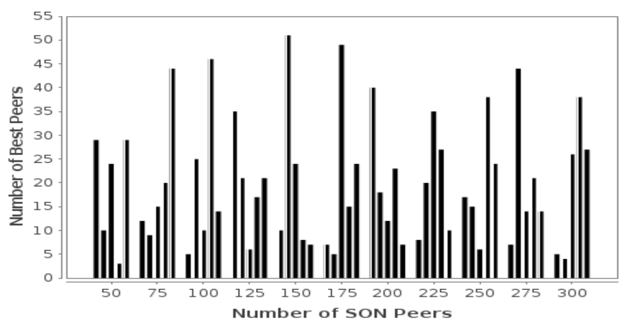

Fig 5. Best peers - cost indicator (simulation 1.2)

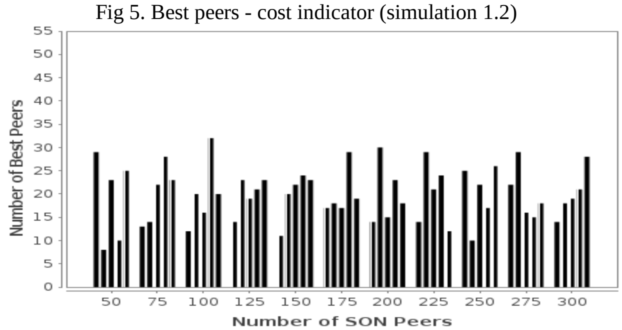

Fig 6. AHP best peers - cost at 90% (simulation 2.1)

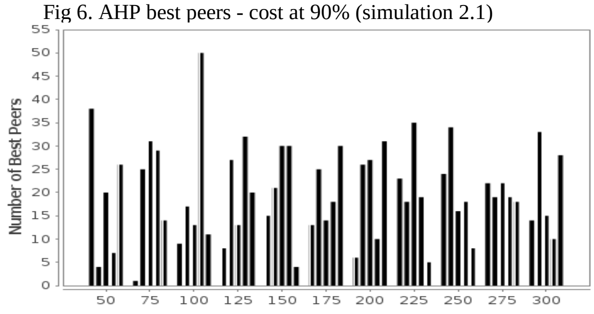

Fig 7. Best peers - cost indicator (simulation 2.2)

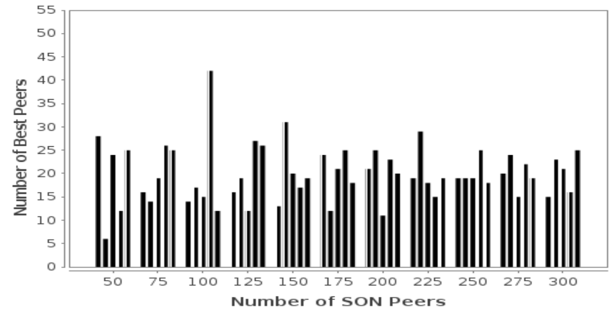

Fig 8. AHP best peers - cost at 80% (simulation 3.1)

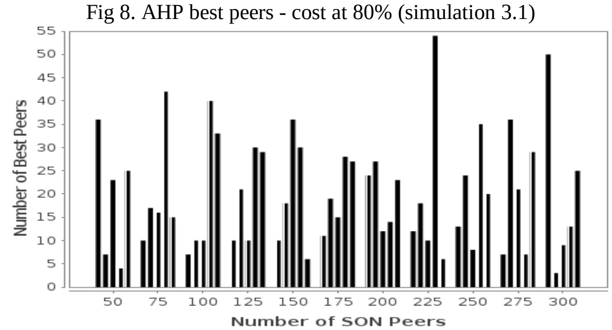

Fig 9. Best peers - cost indicator (simulation 3.2)

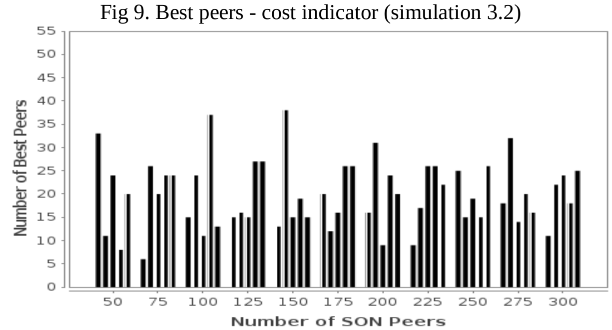

Fig 10. AHP best peers - cost at 70% (simulation 4.1)

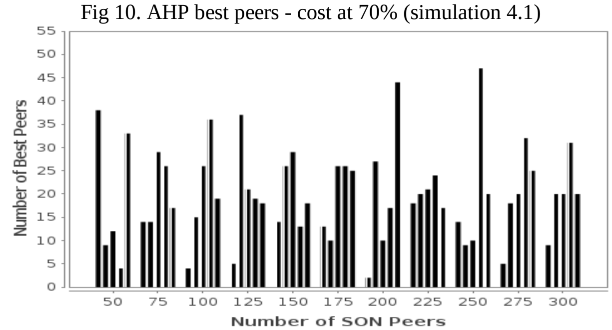

Fig 11. Best peers - cost indicator (simulation 4.2)

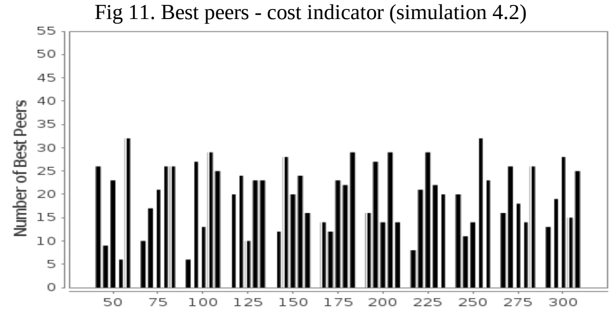

Fig 12. AHP best peers - cost at 60% (simulation 5.1)

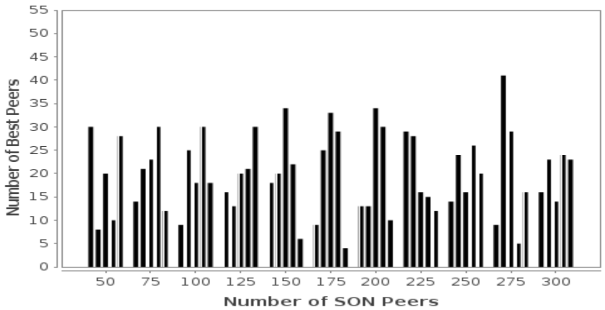

Fig 13. Best peers - cost indicator (simulation 5.2)

During the subsequent simulation sequences (from the second to the fifth), the weight of the cost indicator in the AHP method was gradually decreased by 10%. Thus, during the second simulation sequence, the weight cost was set to 90%, 80% in the third sequence, 70% in the fourth sequence and finally 60% in the last sequence. The remaining weights were equally distributed to the other indicators (distance, jitter and delay) at each simulation sequence. Therefore, the weights for each one of the three indicators (distance, jitter and delay) at the four subsequent simulations were 3.33%, 6.66%, 10% and 13.33%, respectively.

At each new simulation using the AHP method, a simulation that uses the cost indicator only was also performed, where the quantitative values of the cost indicator are randomly generated. However, to fairly compare the two types of simulations, the quantitative values of the cost indicator in both of them are the same. Figure 6 to 13 show the results of these tests.

By comparing and analyzing the graphs presented in Figures 4 to 13, it is possible to identify a significant variability of the number of providers selected during simulations that do not use the AHP method. This situation arises because the randomly assignment of the quantitative values to the cost indicators, which occurs at every simulation scenario. For instance, in the scenario that contains 175 SON providers of the simulation 1.2 (Figure 5), the number of selected providers from the France domain was 50. Meanwhile, in the next scenario, which contains 200 SON providers, of the same simulation, the number of providers selected from the France domain was less than 15.

From the simulation results, it was clear to see that by using the AHP method, the number of providers selected from each domain in every scenario did not vary so much. On the other hand, in the simulations that did not use the AHP method, this variation was much more considerable, as can be seen in the graphs and in [18].

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 of the number of selected providers when compared to the mean number of providers selected in a specific domain. Figures 14 to 23 show these results. The selected service providers were grouped by geographic domains (Portugal, Spain, France, Italy and Germany). As can be seen from Figures 14 to 23, all simulations that use the AHP method present a standard deviation lower than those that use the cost indicator only.

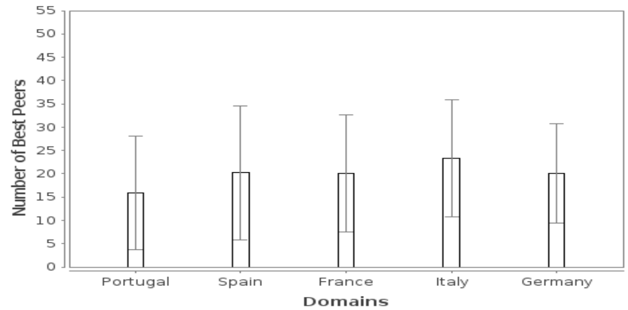

Fig 14. Mean number of providers selected by using AHP - cost at 100% (simulation 1.1)

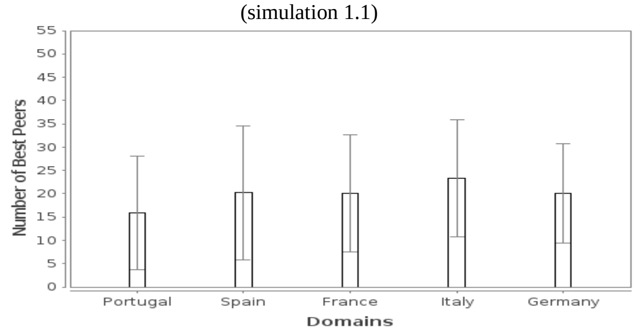

Fig 15. Mean number of selected providers without using AHP (simulation 1.2)

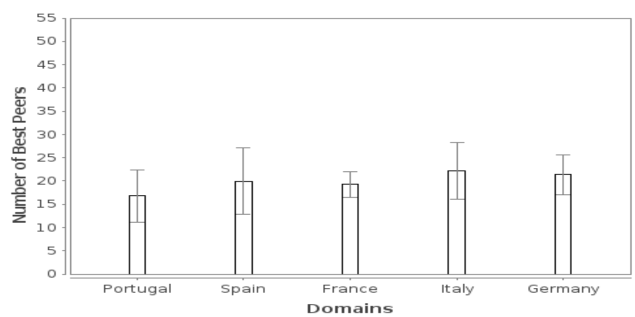

Fig 16. Mean number of providers selected by using AHP - cost at 90% (simulation 2.1)

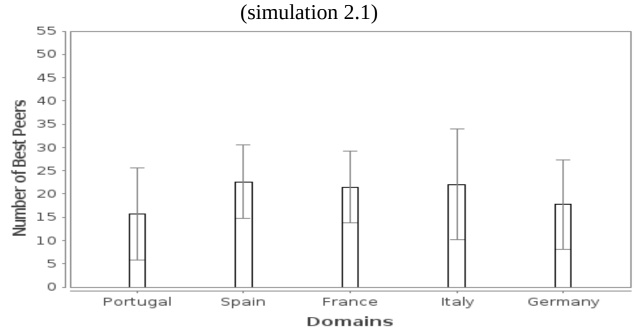

Fig 17. Mean number of selected providers without using AHP (simulation 2.2)

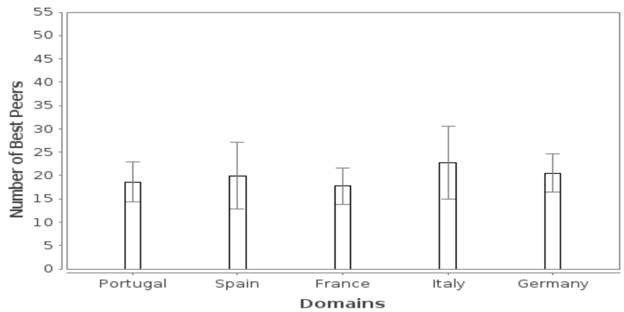

Fig 18. Mean number of providers selected by using AHP - cost at 80% (simulation 3.1)

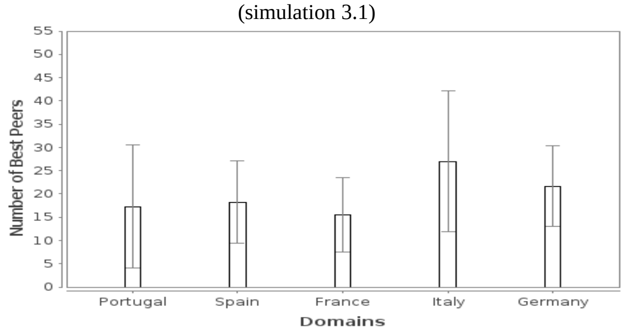

Fig 19. Mean number of selected providers without using AHP (simulation 3.2)

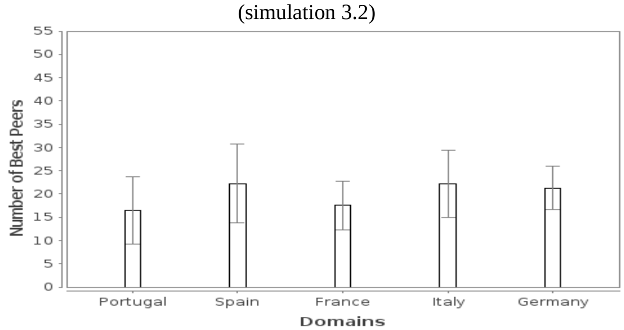

Fig 20. Mean number of providers selected by using AHP - cost at 70% (simulation 4.1)

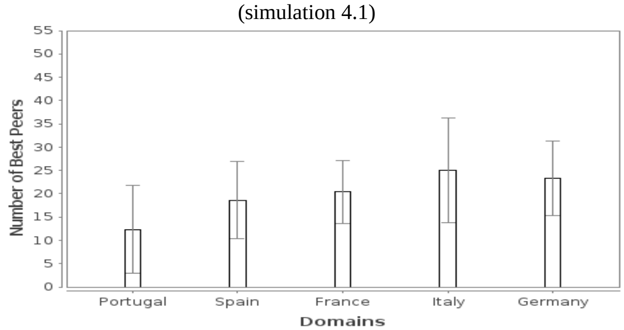

Fig 21. Mean number of selected providers without using AHP (simulation 4.2)

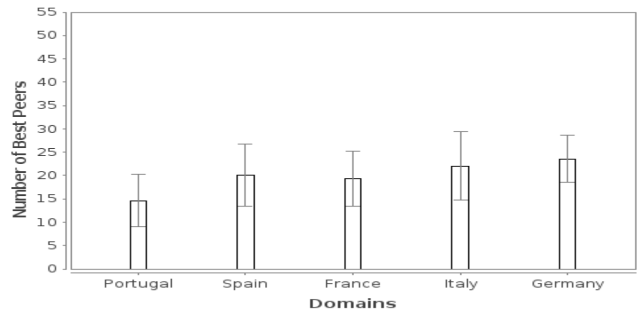

Fig 22. Mean number of providers selected by using AHP - cost at 60% (simulation 5.1)

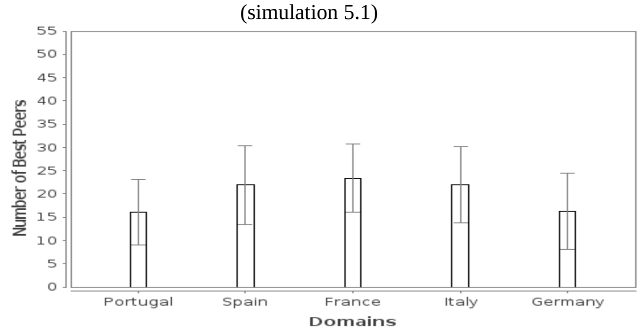

Fig 23. Mean number of selected providers without using AHP (simulation 5.2)

Since the AHP method can perform a more consistent analysis by allowing the use of multiple criteria (i.e. cost, distance, jitter and delay), the simulations that used the proposed method showed more balanced results among the domains, thus resulting in low standard deviation values. Therefore, the use of the AHP method increases the flexibility of the search and selection processes, which allows selecting service providers that have not been selected so far.

5. Conclusion

The contribution of this paper is to propose an approach to select service providers associated to a P2P SON by using the AHP multi-criteria method. In the P2P SON environment, providers can offer their services in order to meet a demand (Collaboration Opportunity - CO). Thus, according to some criteria, the appropriate providers must be selected. In the context of this work, the following criteria were used: cost, distance, jitter and delay.

The results of the simulation showed that: a) The adoption of the AHP method allows to perform a more accurate selection of providers, since it employs quantitative and qualitative analysis by using multiple performance indicators; b) The selection process becomes more flexible and dynamic, due to the possibility of including and excluding performance indicators, as well as, the manipulation of the weights of the indicators, according to the interests of the service requestor.

As future work, we plan to analyze the process behavior in selecting the second best and the worst providers to meet a CO. Moreover, we also plan to develop a risk analysis method that will be executed after the best provider selection step. This step may eventually improve the decision making process when using several service providers to meet a CO.

References

[1] Bititci, U. and Busi, M. "Collaborative performance measurement: a state of the art and future research", International Journal of Productivity and Performance Management, 2006, v. 55 No. 1. p. 7-25.

[2] Gerwin, D. and Ferris, J.S. (2004) "Organizing New Product Development Projects in Strategic Alliances", Organization Science, v. 15, No. 1, p. 22–37.

[3] Provan, K.G., Fish, A; Sydow, J. "A Review of the Empirical Literature on Whole Networks", Journal of Management, 2007.

[4] Tran, C. and Dziong, Z. "Service overlay network capacity adaptation for profit maximization", IEEE Transactions on Network and Service Management, 2010, v. 7 No. 2 p 72 - 82.

[5] Duan, Z., Zhang, Z.-L., Hou, Y. T. "Service Overlay Networks: SLAs, QoS, and Bandwidth Provisioning", IEEE/ACM Transactions on Networking (TON), 2003, v. 11 No 6 p. 870 - 883.

[6] Sari, B., Sen, T., Kilic, S.E. "Ahp model for the selection of partner companies in virtual enterprises", Springer-Verlag London Limited, 2006, p. 367-376.

[7] Saaty, T.L. "How To Make A Decision: The Analytic Hierarchy Process". In: European Journal of Operational Research, 1990, vol. 38, issue 1, pg. 9-26,

[8] Camarinha-Matos, L.M., Silveri, I., Afsarmanesh, H., Oliveira, A.I. "Towards a framework for creation of dynamic virtual organizations", In: L.M. Camarinha-Matos et al. (Eds.) 6th IFIP Working Conference on Virtual Enterprises PRO-VE 2005, 2005, p. 26–28. Springer.

[9] E. Lavinal, N. Simoni, M. Song, e B. Mathieu, "A next-generation service overlay architecture", Annals of Telecommunications, 2009, vol. 64, no. 3, p. 175-185.

[10] Alves Junior, O. C. and Rabelo, J. R. "A Methodology for Logistics Partners Selection to Compose Virtual Organizations Based on KPI". In: 12th IFIP WG 5.5 Working Conference on Virtual Enterprises, PRO-VE 2011, São Paulo, Brazil. Adaptation and Value Creating Collaborative Networks, 2011, v. 362, p. 439-449.

[11] K. Huang, L. Wang, D. Zhang, e Y. Liu, "Optimizing the BitTorrent performance using an adaptive peer selection strategy", Future Generation Computer Systems, 2008, vol. 24, p. 621–630.

[12] A. Fiorese, P. Simões, and F. Boavida. "OMAN - A Management Architecture for P2P Service Ovelay Networks". In: Proceedings of the 4th International Conference on Autonomous Infrastructure, Management and Security (AIMS 2010), Zürich - Switzerland, LNCS v. 6155, p. 14-25, Jun 21-25, 2010.

[13] A. Fiorese, P. Simões, and F. Boavida. "An Approach to Peer Selection in Service Overlays". In: Proceedings of 7thInternational Conference on Network and Services Management (CNSM 2011), Paris, France, October 24-28, 2011.

[14] Kaune, S., Pussep, K., Leng, C., Kovacevic, A., Tyson, G., Steinmetz, R. "Modelling the Internet Delay Space Based on Geographical Locations", In 17th Euromicro Internacional Conference on Parallel, Distributed, and Network-Based Processing, 2009.

[15] Macroscopic topology measurements. http://www.caida.org/projects/macroscopic/.

[16] GeoIP databases and web services - http://www.maxmind.com/en/geolocation_landing.

[17] Kovacevic, A., Kaune, S., Liebau, N., Steinmetz, R., Mukherjee, P.: "Benchmarking platform for peer-to-peer systems". it - Information Technology, 2007,v. 49, n. 5, p. 312–319.

[18] Júnior, R, B. and Fiorese, A. "Seleção Baseada em Preço dos Melhores e Piores Provedores de Serviço em Rede de Sobreposição de Serviços Par-a-Par", In: Computer on the Beach, Anais do Evento, p. 138. Florianopolis, 2012.