Qualification Evaluation in Virtual Organizations Based on Fuzzy Analytic Hierarchy Process

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Abstract

Conventional grid infrastructure implements CA to ensure security and authentication access control which is not flexible, while peer-to-peer applications are flexible enough but no evaluation system to ensure members in a virtual organization are proper and safe enough to corporate with each other. In this paper, we propose an easily extendable evaluation system using the Fuzzy Analytic Hierarchy Process (FAHP) to quantify the suitability of request initiators who decide to join a virtual organization for file sharing and transferring. Eleven criteria, derived from literatures review and practical applications, are selected to enrich the whole evaluation framework. We have conducted an extensive experimental study to show the impacts of minor change of each criterion on final qualification values. Simulation results show that FAHP is efficient to evaluate fuzzy integrated factors and the system can be easily applied to different scenarios with minor changes.

1. Introduction

1.1 Backgrounds

Grid computing was motivated by enabling wide-area and cross-domain sharing of computational resource [1] which has involved into cyber infrastructure [2] and cloud computing [3, 4, 5] for revolutionizing science and engineering these days. One problem we should not shy away is how to guarantee all members in one Virtual Organization (VO) safe and proper enough to corporate with each other. Traditional CA and the related protocols are safe for authentication verification, access control, etc. But it is not flexible to implement large scale corporation and no measurement can be made about whether it is proper for members of one VO to share resources. P2P content delivery network[6,7], which is widely used for file sharing and transferring, is flexible enough to allow any member to join in and quit any virtual organization at will, but no evaluation or safety model to keep VO from malicious attacks or potential high overload that probably leads to large scale collapse.

Proper measurement should be made to evaluate the qualification and suitability of the request initiator thus lots of different factors should be considered. In the environment of file sharing and exchanging, request initiator with lots of related files are more prone to be the potential candidates. Those highly overload network, such as frequently accessed sites are more concerned of the potential virtual organization load which might collapse the whole system, thus the requests with too large amount of file exchanging are less likely to be welcomed. What's more, those secure transactions such as e-auction or business that probably involves lots of anonymous peers should embed more trust or reputation elements for fair and safe activities. The list goes on, and more criteria should be integrated into the system to gain a complete evaluation.

Concluded from the analysis made above, different environments needs different evaluation criteria or even evaluation models, it is a tough job to qualify reputation because many dynamic factors are involved [8], not less to say total framework to fairly evaluate request initiators. This paper is not intended to provide a method that suitable for all circumstance, rather it implements one method widely used in industrial and social evaluation—FAHP, to give a proper integrated framework to quantify and fairly score request initiators, which is relatively useful in promoting secure and effective cooperation in virtual organizations.

1.2 Previous Related Work

Secure-binding scheme and trust integration are

introduced in [9] to guide the security upgrade of grid sites and predict the grid performance of large workloads. The performance workloads and security problems are factors that we should firstly noticed. Trust management in P2P overlay network is fully investigated in [10, 11, 12, 13], although the list I provide here is by no means exhaustive, the common feature of these work is using values or scores to evaluate the reputation of peers. Feedback system [10] used in e-bay is now widely accepted for e-transactions in real world and e-commerce trust evaluation. Similar feedback to evaluate trust is shown in Li Xiong and Liu Lian's work [13] which develops peer trust models. In [14], similar feedback systems with different parameters are used to schedule remote access to scientific instruments to get a high QoS. Credit evaluation models [15] are used more than we can imagine in C2C and e-commerce. Such factors are also should be reasonably included in the integrated evaluation model. Potential malicious attack or vicious detection should be fully investigated based on their abnormal behaviors. All these criteria are included in my work and their comparative importances are also carefully investigated by referring to experts, related literatures and combining with practical application scenarios. Detailed analysis can be referred to section 3.

Fuzzy Analytic Hierarchy Process (FAHP) [16] is widely used to evaluate multi-criteria decision-making problems that incorporate unquantifiable information, incomplete information, non-obtainable information and partial facts into the decision model [17]. Although FAHP requires tedious computations, it is capable of capturing a human's appraisal of ambiguity when complex factors are considered. It is used in location selection [18], R&D project selection [19], quantitative performance for servo control systems [20], etc. Although the method itself is essentially applicable to these domains, none research have ever been done on the qualification evaluation of members that intend to corporate with members in one virtual organization in grid or peer-to-peer organizations, this paper fully investigate the characteristics for file sharing and transferring, hope to establish fair and proper judgment framework to make qualification evaluation.

The rest of this paper is organized as follows. We present fuzzy theory and analytic hierarchy process in Section 2. Section 3 introduces the criteria we choose and the weight vector. Their impacts on the final score are introduced in Section 4 and the trend of their influence are clearly depicted in the simulation Figure. We conclude the paper in Section 5 and propose some future work.

2. Preliminaries

2.1 Fuzzy theory

Fuzzy theories are used to describe those concepts that are not easily and clearly described. For example, it is difficult to show the clear bound between "cold" and "hot" with traditional definite or exact figures. Fuzzy mathematics gives us good method to analyze those fuzzy concepts.

Definition: Let A be a fuzzy set of domain U, $\forall x \in U$, $\exists \mu_A(x) \in [0,1]$, the value of $\mu_A(x)$ is member- ship g*rade* or *degree of membership*. The corresponding mapping $\mu_A : U \to [0,1]$, which map $\mu_A : x \to \mu_A(x)$ is *membership function*.

For example, U can be viewed as a reasonable region of a common person's age, say, from 0 to 120. x is an actual age value of a special person such as 20, then A can be the fuzzy concept such as "young" or "old". Based on our common sense, a person whose age is 20 should be viewed as "young" much more than that be viewed as "Old". So we can use the related value $\mu_{young}(age = 20) = 0.9$ and $\mu_{old}(age = 20) = 0.2$. Member functions can be implemented to describe the mapping fuzzy concept to its fuzzy value which is between 0 and 1.

Member function $\mu_{\mathrm{A}}(\mathrm{x})$ quantifies the membership's grade of the element x to the fuzzy set A. It can take various forms. In our application, three forms in figure 1 and 2 are shown here. Member functions are the primary cause that describe different values affect the affiliations of each other, the detailed member functions are followed introduced.

Their corresponding member functions can be categorized into two types.

For those factors whose increase results to the final qualification value increase, such as files relevance, average recommendation members, previous average credit score number, and pc or network availability rate, their related member functions are:

$$r_{i1} = \begin{cases} 0, x_i \le s_{i2} \\ (x_i - s_{i2}) \big/ (s_{i1} - s_{i2}), s_{i2} < x_i \le s_{i1} \\ 1, x_i > s_{i1} \end{cases}$$

$$r_{ij}=\begin{cases}\left[x_i-s_{i(j+1)}\right]\Big/\left[s_{ij}-s_{i(j+1)}\right], s_{i(j+1)}<x_i\le s_{ij}\\ \left[s_{i(j-1)}-x_i\right]\Big/\left[s_{i(j-1)}-s_{ij}\right], s_{ij}\le x_i<s_{i(j-1)} \quad j=2,3\\ 0, x_i\le s_{i(j+1)} \quad or \quad x_i\ge s_{i(j-1)}\end{cases}$$

$$r_{i4}=\begin{cases}1, x_i\le s_{i4}\\ \left(s_{i3}-x_i\right)\Big/\left(s_{i3}-s_{i4}\right), s_{i4}<x_i\le s_{i3}\\ 0, x_i>s_{i3}\end{cases}$$

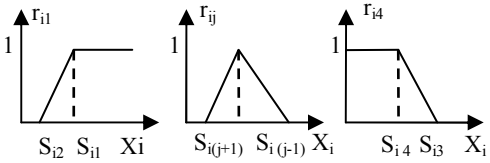


Figure 1. Fuzzy member function of monotonous increasing criteria

For those factors whose increase results to the final qualification value decrease, such as traffic jam rate, abnormal behavior, potential virtual organization load. Their related member functions are:

$$r_{i1}=\begin{cases}1, x_i\le s_{i1}\\ \left(s_{i2}-x_i\right)\Big/\left(s_{i2}-s_{i1}\right), s_{i1}<x_i\le s_{i2}\\ 0, x_i>s_{i2}\end{cases}$$

$$r_{ij}=\begin{cases}\left[x_i-s_{i(j-1)}\right]\Big/\left[s_{ij}-s_{i(j-1)}\right], s_{i(j-1)}<x_i\le s_{ij}\\ \left[s_{i(j+1)}-x_i\right]\Big/\left[s_{i(j+1)}-s_{ij}\right], s_{ij}\le x_i<s_{i(j+1)} \quad j=2,3\\ 0, x_i\le s_{i(j-1)} \quad or \quad x_i\ge s_{i(j+1)}\end{cases}$$

$$r_{i4}=\begin{cases}0, x_i\le s_{i3}\\ \left(x_i-s_{i3}\right)\Big/\left(s_{i4}-s_{i3}\right), s_{i3}<x_i\le s_{i4}\\ 1, x_i>s_{i4}\end{cases}$$

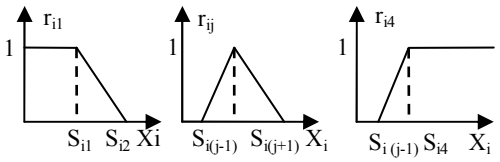


Figure 2. Fuzzy member function of monotonous decreasing criteria

x_i is the characteristic value of the i[th] evaluation factor, s_{ij} is the standard value of the i[th] evaluation value whose rank is j.

2.2 Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) was first proposed by Thomas L. Saaty in the 1970s to help people deal with complex multi-criteria decision problems. The AHP provides a comprehensive and rational framework for structuring a problem, for representing and quantifying its elements, for relating those elements to overall goals, and for evaluating alternative solutions. Nowadays, it is more generalized and applicable to lots of decision making problems.

Its basic idea is dividing a complex problem into several component elements, group and cascade them to form hierarchical laying structure, then make pair wise comparison to get the comparative importance between all pair elements, combing with people's judgments to get total order. Weight vector, eigenvalue and characteristic indices can also be derived.

Four steps are used to implement this method:

(1) Constructing hierarchical structure to simplify complex problems.

(2) Constructing single element pair comparative weight matrix.

(3) Consider consistency of weight matrix

(4) Evaluate element compound weight to form order.

Suppose our initial single element pair comparative weight matrix is $A=\left(a_{ij}\right)_{n\times n}=\frac{a_i}{a_j}$, n is the number of elements. a_i and a_j are the importance of elements i and j respectively and a_{ij} is the pair comparative importance of i to j. The weight of all elements is computed like this:

(1) Get initial weight of all elements by $\omega_i^*=\sqrt[n]{\prod_{j=1}^{n}a_{ij}}, i=1,2,\cdots,n$

(2) Normalize initial weight to get normalized weights by $\omega_i=\omega_i^*\Big/\sum_{i=1}^{n}\omega_i^*, i=1,2,\cdots,n$

In the evaluation system, it is impossible to calculate the exact value $\frac{a_i}{a_j}$ precisely, what we can do is to provide an estimate of it. Consequently, the error is unavoidable. We can use the following steps to get if the matrix A is proper for us to do further analysis.

(1) Get column elements sum

by $S_j = \sum_{i=1}^{n} a_{ij}, j = 1, 2, \cdots, n$

(2) Compute the maximum eigenvalue by $\lambda_{\max} = \sum_{i=1}^{n} \omega_i S_i$

(3) Compute Consistency Index (CI) by $CI = \frac{\lambda_{\max} - n}{n-1}$.

(4) Compute more reliable index (CR) by $CR = \frac{CI}{RI}$, RI is the rectified value in figure 3.

If CR is less than 0.1, the weight is not well and thus an adjustment of initial matrix A should be implemented until the condition is satisfied. On the other hand the computed weight is ok and next analytical steps can be furthered.

n	1	2	3	4	5	6
RI	0	0	0.58	0.96	1.12	1.24
n	7	8	9	10	11	12
RI	1.32	1.41	1.45	1.49	1.52	1.54

Figure 3. RI of n dimension matrix

Detailed steps of FAHP can be referred to some related papers.

3. Evaluation criteria and models

The evaluation model of qualification values is fully investigated in this section to evaluate the suitability that whether current request of joining one virtual organization is allowable. Together with that, we should predefine some basic concepts used in our criteria.

(1) Files Relevance: The request initiator who wants to join one VO should provide the typical files it needs and resources that it offers back to the VO. So the files or resource relevance is one factor needs considering. Logs on request initiator's historical files sharing information are clearly recorded and should be explicited provided just like the credit that will be introduced in the following criterion. Request initiators with higer files revelence are prone to get higher acceptance rate since they can also provide lots of related files in retuen. The units of this criterion can be derived from the percentages of related files that logs describe.

(2) Credit: It describes the trustability of all members in the environment, which ranges from 0 to 10 and dynamically changeable after a request initiator joining one VO based on the VO credit. Detailed algorithm of the credit change is depicted in lots of related papers, which are omitted here.

(3) Previous Credit Condition: As described in (2), Credit of one member is dynamically changed and the previous credit value shows the history credit information of one initiator and should be clearly considered as one factor of its qualification.

(4) PC or Network Availability Rate: To ensure consistent and stable environment in VO for file sharing and accessing, availability rate of request initiator and its network situation is also a factor should be considered. Together with that, another two factors, bandwidths and network traffic jam rate are also should be included and considered.

(5) Abnormal Behavior: Malicious attempts of invading or hacking VO should be detected and excluded outside which is essential to make sure secure and safe network environment. Querying Frequency, especially those that of a relatively high rate are more reasonable considered as malicious attempts and should be negatively considered as factors to assist initiator's request.

(6) Potential Virtual Organization Load: Too much load is harmful to the consistent flow of one VO. Thus the more resources the initiator requires, the less qualification value it is prone to get in the end.

All these criteria should be fully considered to evaluate whether the current member is appropriate to join a current VO. However, the significance or importance of them are relatively different and should be judged fairly. Firstly initial judgment is made pair wisely to get matrix $\left(a_{ij}\right)_{7\times7}$, then based on the method provided above in AHP, we should check if the matrix $\left(a_{ij}\right)_{7\times7}$ proper for us to calculate the normalized weight. Thus our result are

$$\lambda_{\max} = 7.264, CI = 0.044, CR = 0.033 < 0.1$$

which shows the matrix is appropriate enough. Then the total normalized weight of all seven criteria could be calculated below. Figure 4 shows the weight of seven criteria of the elements we choose. Together with that, their significance are also ranked by ordering their weights, which shows that previous credit information of the request initiator is of the most important factor since its weight is much larger than others. The reason is obvious that trustability is the first criterion we should consider in our practical environment. Furthermore, recommendation information, which demonstrates the "relationship" between the request and the members of the VO is also important since it is another profile to show trustability. What's more, PC status, which gives the availability rate, should also reasonably be treated as one important factor since frequently join and quit VO is really burdensome and consumes too much resource, which is one cause of potential VO load in criteria 7.

The hierarchical structure of the elements and their weights in our AHP analysis are provided in figure 5. We could figure out that credit information of the request initiator's together with recommendation information are of the most dominant factor since they totally account for over 0.6 weight of the whole. This conclusion could be made in that current environment needs secure and trustworthy members that in our VO to cooperate with each other. What's more, PC Status, which demonstrates the situation of the request initiator is also important since corporation needs stable availability of all members. If otherwise, in generally P2P environments that stress more on the files sharing and transferring, the potential benefit together with PC and network status are the most important factor since effective and efficient file sharing should be guaranteed. To evaluate different kinds of environments, we need not change the framework of the whole structure; instead we can only change the pair wise comparison to get the appropriate weight to evaluate the related scores.

Criteria	Weight	Rank
1. Potential Benefit	0.065	5
2. Recom. Info	0.221	2
3. Prev. Credit Info	0.382	1
4. PC Status	0.151	3
5. Network Status	0.041	6
6. Abn. Behavior	0.110	4
7. Pot. VO Load	0.030	7

Figure 4. Weights and ranks of the seven criteria

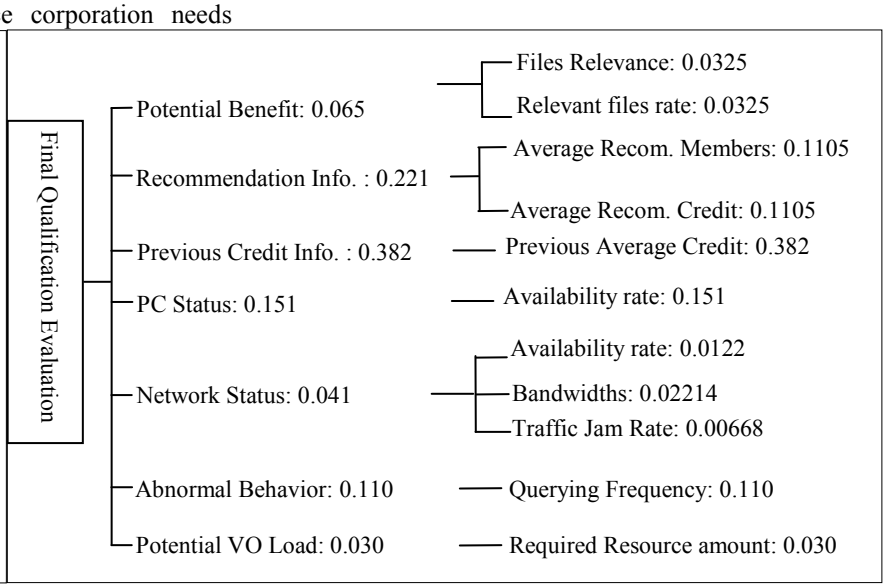
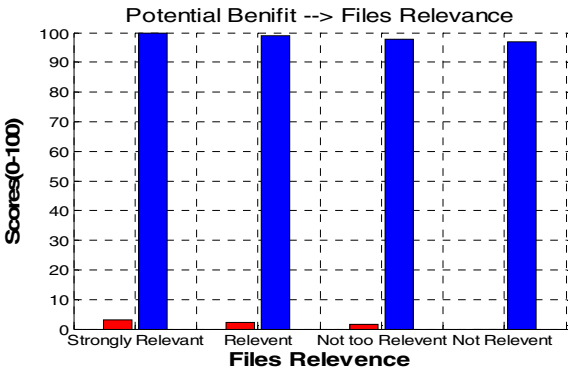


Figure 5. Normalized weights of all criteria

4. Simulation Results

Normalized weights calculated above shows us the general importance of all different criteria, which is our fundamental base to analyze the final score and judgments. We choose every second rank index as our basic unit to show the impact of which on the final score. There are totally 11 groups of results. One group contains two graphs; the first shows the comparison of the worst result with the best result. The red star lines are the results that we assume all other conditions are worst, which is easily spotted that the results are in a very close narrow range that more than zero. On the contrast, the blue round lines are results that corresponds to all other conditions that are best, which is the same easily spotted from the facts that they are in a very close narrow range that less than one hundred. Also, we can also see the red and blue lines are the same pattern; the reason is very obvious that all member functions that we select to determine the fuzzy concept are linearly, which does not change the structure of the lines. That is also the same reason why the second graph in every group is piecewise continuous. We have to stress that the blank space between the red star line and blue round line is fully occupied, since the two lines are two end extremes of each graph.

The second graph in the same group shows the detail characteristics of the score that change with the value of the current index. 11 groups correspond roughly to the 11 second rank index and the values that out of the range of the given x axis are either 0 or 100, thus they are omitted here.



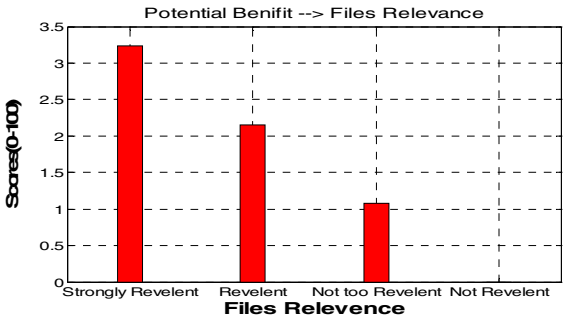


Figure 6. Impact of file relevence

Figure 6 above shows the impact of the files relevance to the total scores. It corresponds roughly to our final normalized weight that the potential benefit of it is 0.065. Files relevance share 0.5 of the weight that should have maximized impact value is 3.25 theoretically. From our simulation result, the exact value is 3.232 which is very close to the estimated value.

The same rule applies to figure 7 that the estimated value theoretically is 3.25 and practically from our simulation result it comes to 3.232 which is completed the same as in figure 5. The reason is that they share the same first rank weight 0.5.

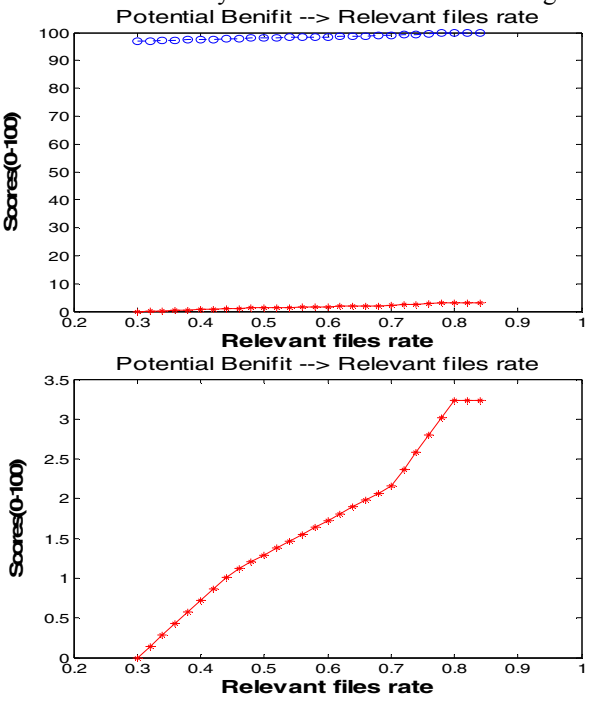


Figure 7. Impact of relevant files rate

Figure 8 shows the impact of recommendation members rate. It is the percentage of the recommendation members to the total members in one VO. Theoretically the value is 11.05 since the weight of recommendation information is 0.221 and the recommendation members' rate occupied half of it. In our simulation the score is 11.495. The little margin is stem from the round off of the normalized weight 0.221.

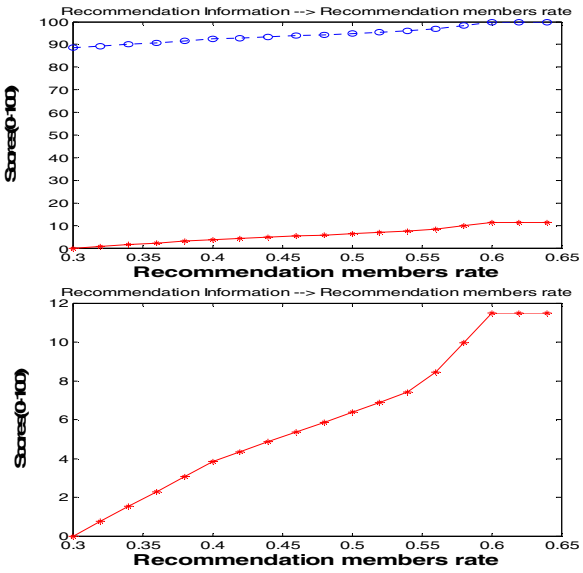


Figure 8. Impact of recommendation members rate

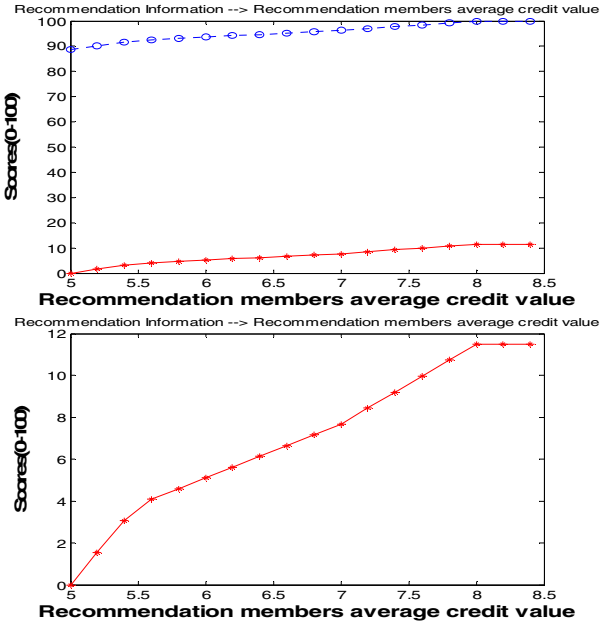
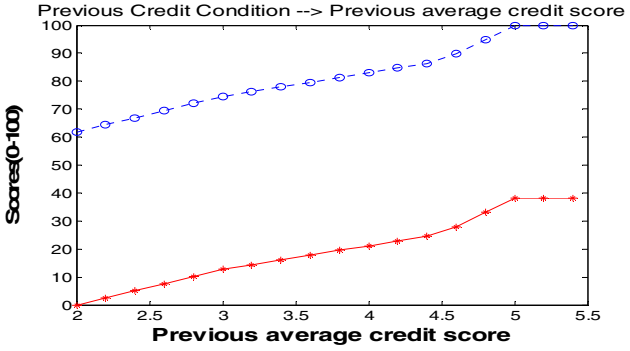


Figure 9. Impact of recommendation members' average credit value

The same analysis applies to figures from 10 to 16.



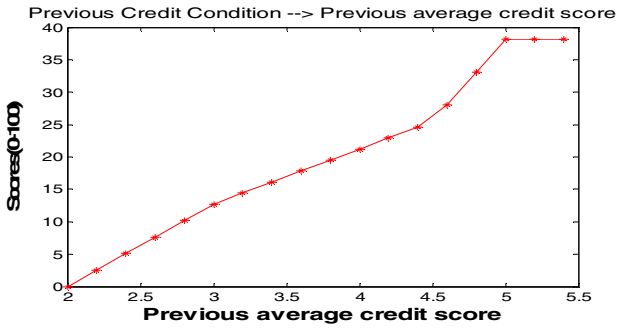
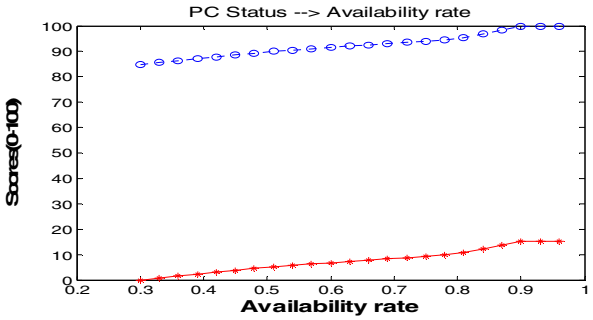


Figure 10. Impact of previous average credit score



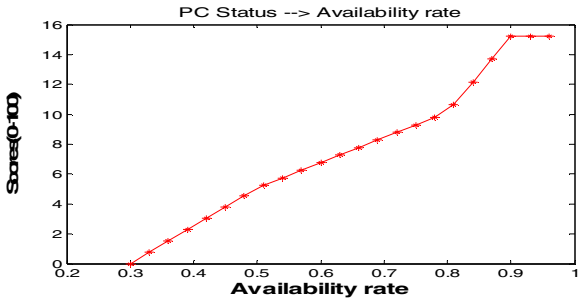
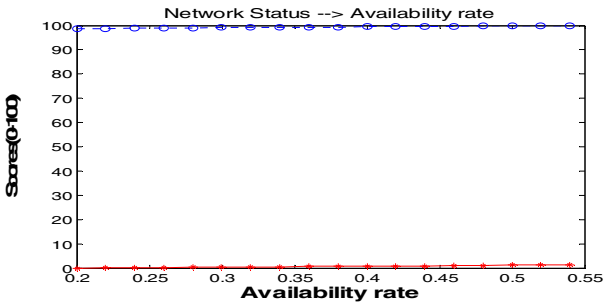


Figure 11. Impact of pc availability rate



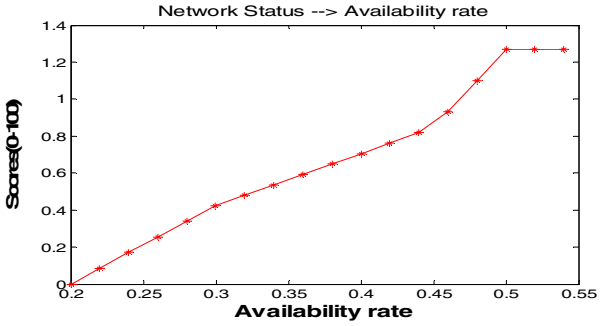
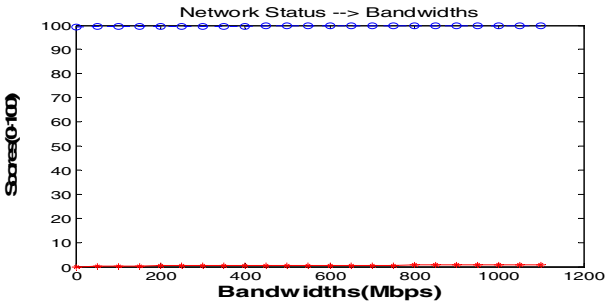


Figure 12. Impact of network availability



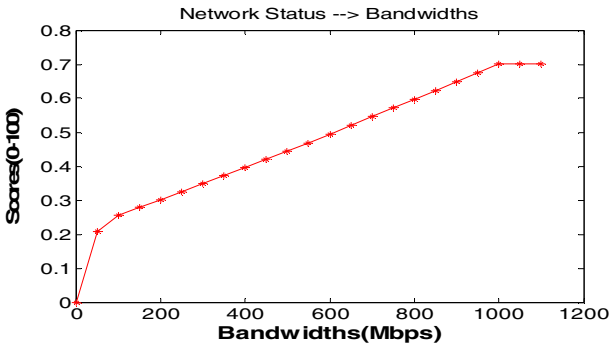
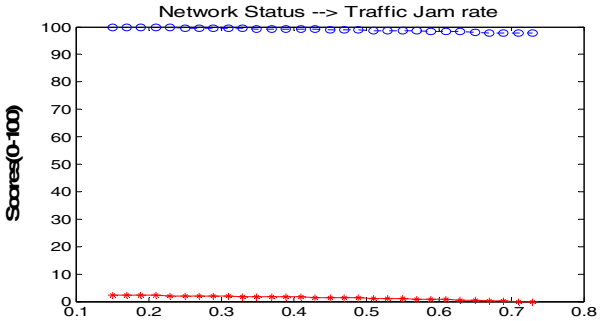


Figure 13. Impact of network bandwidths



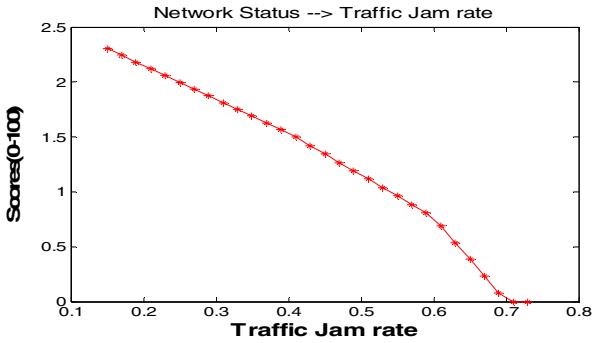
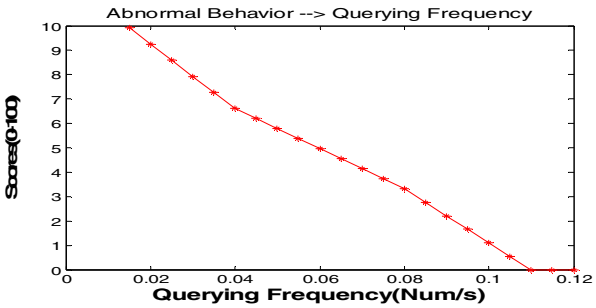


Figure 14. Impact of traffic jam rate



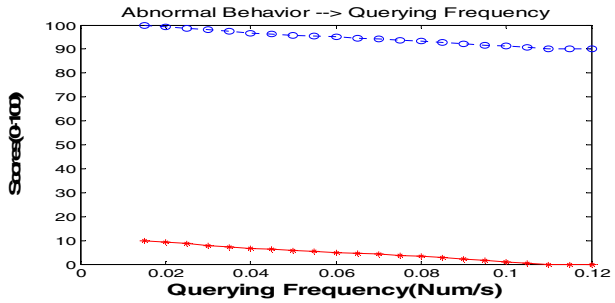


Figure 15. Impact of querying frequency

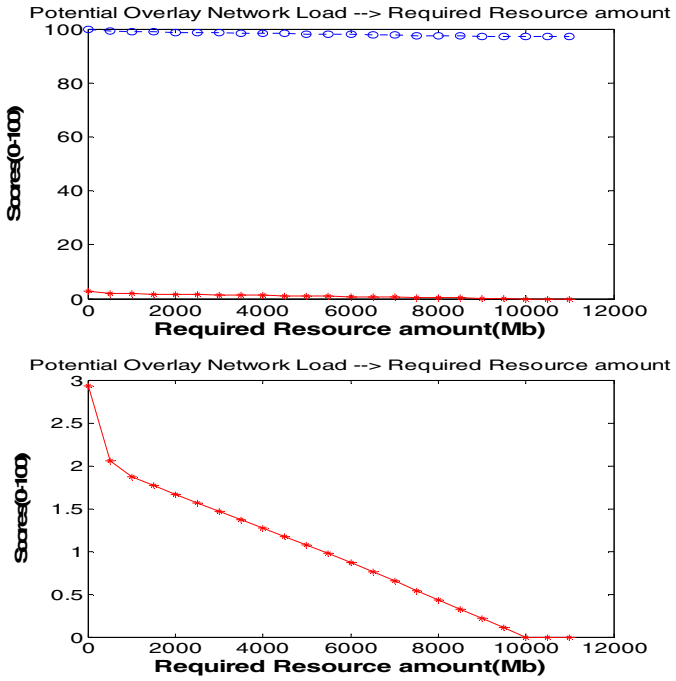


Figure 16. Impact of potential virtual organization load

The trend of figure 14 to 16 are different from previous figures in that the factors we consider here, such as traffic jam rate, querying frequency and required resource amount are factors that negatively affect the total scores.

5. Conclusions

The main contribution of this paper is implementing fuzzy analytical hierarchy process into evaluating and qualifying the score of all request initiator's values, which is used effectively in multi-VO overlay content network, especially in P2P environment when one member belongs lots of overlay network. Different VOs have their own evaluating standard and important criteria, thus we can easily transfer one application to another by redefining the pair wise weight introduced above, so it is easily extendable. Fuzzy analytical hierarchy process is easily carried out to satisfy all these applications.

Further, algorithm to compute the credit value of all members in the environment is simplified to fit for the FAHP application. It can be more complicated if we consider global credit and local credit [9], but the essence is more or less the same.

Future work can be done from the following three aspects.

(1) More complicated features or criteria ought to be considered to satisfy all different situation.

(2) Independence of all criteria we considered are presumably to be satisfied in advance. More analysis can be taken from whether two or more factors, say, the credit of the recommendation members' and request initiators' are inter-related.

Malicious attack or potential cheating is considered in this paper, more ways of cheating should be also considered to ensure a secure and safe environment for file sharing and transferring.

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