A Network Selection Algorithm Based On Combined Weights

Hongbing Wu, Yunfei Mao, Wenjian Wu and Wei Zhang

China Satellite Maritime Tracking and Controlling Department, 103# Jiangjin Jiangsu, China
Email: 170536390@qq.com, myf4494@163.com

Abstract. Heterogeneous network selection is a typical multiple attribute decision making problem. This paper studies the determination method of parameters weight in the network selection process and proposes a network selection algorithm based on combined weights. The algorithm respectively used the GI method and entropy method to determine the subjective weights and objective weights of judgment index, through a linear combination of the subjective and objective weights to get the optimal combination weights. At the same time, make use of network evaluation model based on improved TOPSIS to conduct comprehensive ranking for each candidate network and choose the best one. Simulation results show that the algorithm can obtain lower average latency, jitter, packet loss rate and etc., compared to a typical network selection algorithm based on single weights.

1. Introduction
The determination methods of common parameter index weight can be divided into two categories: subjective methods of weighting and objective methods of weighting. Subjective methods of weighting refers to user according to their own subjective demand to determine the importance of different parameters index, and then determine the index weight of each parameters, GI method is belong to the subjective methods of weighting. Objective methods of weighting refers to user according to the degree of change of different parameters index of candidate network to determine the weight of each index, such as entropy method [1]. Subjective weight method can fully consider the subjective feeling of users, but care few of the objective reality of the network, however, objective weight method can fully consider the objective reality of network performance index, but failed to care about customer experience. Therefore, this paper studies the determination method of parameters weight in the network selection process and proposes a network selection algorithm based on combined weights.

On this basis, proposes a network selection algorithm based on combined weights (NSABCW, Network Selection Algorithm Based on Combined Weights). The algorithm respectively used the GI method and entropy method to determine the subjective weights and objective weights of judgment index, through a linear combination of the subjective and objective weights to get the optimal combination weights. At the same time, make use of network evaluation model based on improved TOPSIS to conduct comprehensive ranking for each candidate network and choose the best one. Simulation results show that the algorithm can obtain lower average latency, jitter, packet loss rate and etc., compared to a typical network selection algorithm based on single weights (NSABIT, Network Selection Algorithm Based on Improved TOPSIS).
2. Brief introduction of G1 method and entropy method

2.1. G1 method

G1 method is a subjective evaluation method, which was an improvement on AHP Method and was proposed by Professor Guo Yajun. The steps of G1 method to determine the judgment index weight are as follows [2]:

(1) Divide each judgment index hierarchy and determine the relative importance between each judgment index. Divide relevant judgment index hierarchy of candidate and analyze the relative importance of the relationship between each judgment index. Create the set about the first layer judgment index \( \{X_1, X_2, \ldots, X_n\} \), mark the most important judgment index as \( X'_1 \), then in the remaining \( n-1 \) judgment index, choose the most important one it thinks and marks it as \( X'_2 \). And so on, complete the ranking of index importance of the first level judgment index set. In the same way, create the set of judgment index of other levels and rank the importance.

(2) Judge the importance of the ratio of \( X'_1 \) and \( X'_n \). Set the importance of the ratio of the judgment index \( X'_1 \) and \( X'_n \) as \( r_n \). Among them \( r_n = \frac{w_{n-1}}{w_n} \), \( w_n \) is the weight of the \( n \) judgment index.

(3) Calculate the weighted value of each judgment index

G1 method to calculate the weighted value of each judgment index, which is completed by step-by-step calculation. Firstly, calculate the weight of the judgment index of the first layer, and calculate the weight of the judgment index of other layers in the same way. For example, calculate the weight of the judgment index of the first layer, if the assignment of \( r_n \) has been obtained, then the weight \( w_m \) of the \( m \) judgment index is:

\[
    w_m = \left(1 + \sum_{k=2}^{m} \prod_{i=k}^{m} r_i \right)^{-1}
\]

If there are a total of \( m \) judgment, we can calculate \( w_m \) firstly, then calculate the weight of other judgment index of this layer by \( w_m \), the formula is:

\[
    w_{k-1} = r_k w_k \quad (k = m, m-1, m-2, \ldots, 3, 2)
\]

Similarly, we can also calculate the weight of the judgment index of the other layers. Finally, the subjective weight vector of each judgment index is combined as:

\[
    W_i = [w'_1, w'_2, \ldots, w'_n].
\]

2.2. Entropy method

The entropy method is a method to determine the index weight, according to the degree of change of the parameter index among the candidate schemes. The concept of entropy comes from information theory, which is a measurement of disorder degree in a system. The specific steps of the entropy method to determine the index weight of parameter are as follow [3]:

(1) Calculate the entropy of the parameter index

The formula of the entropy of each parameter index is:

\[
    e_j = -\frac{1}{\ln n} \sum_{i=1}^{n} f_{ij} \ln(f_{ij})
\]

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Among them, \( n \) represents the number of the candidate schemes, \( e_j \) represents the entropy of the \( j \) parameter index, \( x_{ij} \) represents the normalized value of the observation data of the \( j \) parameter index of the \( i \) candidate schemes, \( f_j \) represents the proportion of the \( i \) candidate network in all candidate schemes, under the \( j \) parameter index.

(2) Calculate the difference coefficient of each parameter index among the different candidate schemes.

The difference coefficient between the \( j \) index and the different candidate schemes is:

\[
f_j = 1 - e_j \quad (5)
\]

It is observed that, for the \( j \) parameter index of the different candidate schemes, if the difference of \( x_{ij} \) is smaller, then the \( e_j \) is larger, and \( h_j \) is smaller, the influence of the parameter index on the result of judgment is smaller. On the other hand, if \( h_j \) is larger, then the influence of the parameter index on the result of judgment is greater. If \( x_{ij} \) are all equal, then \( h_j \) is 0, indicating that \( j \) parameter index will not have an impact on the result of judgment.

(3) Calculate the weight of each parameter index

For the normalized processing on \( h_j \) is the weight of each parameter index:

\[
w_j^* = \frac{h_j}{\sum_{j=1}^{n} h_j}, \quad j = 1, 2, \ldots, n
\]

Finally, the objective weight vector of the parameter index is: \( W_2 = [w_1^*, w_2^*, \ldots, w_n^*] \).

### 3. Network selection algorithm based on combined weights

#### 3.1. Algorithm Principle

The algorithm proposed in this paper firstly determines the subjective weight of QoS parameters of different services according to G1 method. Then, the entropy method is used to determine the objective weights of the QoS parameters of the network. Then, the above-mentioned subjective weight and objective weight are linearly combined to obtain the optimal combination weight. Finally, based on the improved TOPSIS network evaluation model, the candidate network is evaluated synthetically and the best target network is selected. The specific process was shown in Figure 1 algorithm.

#### 3.2. Determine the combined weight of judgment index

(1) G1 method to determine the subjective weight

The selection of time delay, delay jitter, packet loss rate, guaranteed bit rate and maximum bit rate are taken as QoS parameter index. The subjective weight vector is:

\[
W_1 = [w_{D_t}^*, w_{D_j}^*, w_{PLR}^*, w_{GBR}^*, w_{MBR}^*] .
\]

The calculation method of G1 method is used to determine the subjective weight of each parameter index, and the weight vector of QoS parameter index of four different types of service is shown as follows:
Conversational services: [0.2917, 0.2917, 0.2430, 0.1013, 0.0723]
Stream class services: [0.1836, 0.2387, 0.2625, 0.1576, 0.1576]
Interactive services: [0.2981, 0.1554, 0.2981, 0.0856, 0.1628]
Background services: [0.1866, 0.1866, 0.2611, 0.1261, 0.2396]

\[ W_i = \begin{cases} 
\text{Conversational services:} & [0.2917, 0.2917, 0.2430, 0.1013, 0.0723] \\
\text{Stream class services:} & [0.1836, 0.2387, 0.2625, 0.1576, 0.1576] \\
\text{Interactive services:} & [0.2981, 0.1554, 0.2981, 0.0856, 0.1628] \\
\text{Background services:} & [0.1866, 0.1866, 0.2611, 0.1261, 0.2396] 
\end{cases} \] (7)

(2) The entropy method to determine the objective weight
According to the theory of entropy method, when the objective weight of the QoS parameter index is determined, all the parameters index need to be standardized. Specific steps are as follows:

**Figure 1.** Algorithm process.

(a) Establish the decision matrix
According to the QoS parameter index, the corresponding decision matrix is established

\[ R = \begin{bmatrix} 
  r_{11} & r_{12} & \cdots & r_{1m} \\
  r_{21} & r_{22} & \cdots & r_{2m} \\
  \vdots & \vdots & \ddots & \vdots \\
  r_{n1} & r_{n2} & \cdots & r_{nm} 
\end{bmatrix} \] (8)

\( n \) represents the number of candidate network, \( m \) represents the number of parameter index considered by the user in the network selection process(In this case, it’s 5), \( r_{ij} \) represents the objective value of the \( j \) parameter index of the \( i \) candidate network.

(b) QoS parameter index classification and processing
QoS parameter index are divided into two categories: forward and reverse index. A forward index is the larger the better index. While the reverse index is the smaller the better index. The forward and reverse indexes are normalized to get the standard decision matrix:

\[ R = (r_{ij})_{n \times m} \]  

Among:

\[ r_{ij} = \begin{cases} \frac{r_{ij}' - \min_n(r_{ij}')}{\max_n(r_{ij}') - \min_n(r_{ij}')}, & r_{ij} \text{ is forward index} \\ \frac{\max_n(r_{ij}') - r_{ij}'}{\max_n(r_{ij}') - \min_n(r_{ij}')}, & r_{ij} \text{ is reverse index} \end{cases} \]

(c) Determine the weight of the QoS parameter index

According to calculation method of the entropy method, the objective weight of each index is calculated, and the weight vector is

\[ W_o = [w_{D}, w_{DJ}, w_{PLR}, w_{GBR}, w_{MBR}] \]  

(3) The linear combination of subjective weight and objective weight will be expressed as the linear combination of \( w_i^* \) and \( w_i^{**} \), that is

\[ w_i = \lambda w_i^* + (1 - \lambda)w_i^{**} \]

\[ i = D, DJ, PLR, GBR, MBR \]

In which, \( \lambda \) is proportional coefficient of Qos index weight determined by G1 method.

In order to obtain the optimal combination weight, the subjective weight and the objective weight are equalized to minimize the deviation from the optimal weight. The specific process is as follows:

\[ \min z = \sum [(w_i - w_i^*)^2 + (w_i - w_i^{**})^2] \]

\[ w_i = \lambda w_i^* + (1 - \lambda)w_i^{**} \]

\[ i = D, DJ, PLR, GBR, MBR \]

Further calculation can get the best combination weight:

\[ w_i = 0.5w_i^* + 0.5w_i^{**} \]

\[ i = D, DJ, PLR, GBR, MBR \]

Here, the optimal combination weight vector is marked as \( W = [w_{D}, w_{DJ}, w_{PLR}, w_{GBR}, w_{MBR}] \).

3.3. Based on the improved TOPSIS network evaluation model

The improved TOPSIS is used to construct the network evaluation model. The decision matrices of the network parameters index are established, and the normalization matrixes \( R \) are obtained by normalizing the elements of the decision matrix.
According to the current service type of the user, choose the QoS parameter index of the corresponding service type, then obtain the combination weight vector: \( W = [w_D, w_{dj}, w_{plr}, w_{gbr}, w_{mbr}] \).

The weighted decision matrix is calculated:

\[ U = R \cdot \text{diag}(W) = (u_y)_{5 \times 5}. \]

From formula (6) and (9), we know that "ideal solution" and "negative ideal solution":

\[
A^+ = \{\text{max} \ u_y \mid j = d, dj, plr, gbr, mbr\} \\
= \{u_d, u_{dj}, u_{plr}, u_{gbr}, u_{mbr}\}
\]

\[ A^- = \{\text{min} \ u_y \mid j = d, dj, plr, gbr, mbr\} \\
= \{u_d, u_{dj}, u_{plr}, u_{gbr}, u_{mbr}\}
\]

The distance \( S^+ \) between each candidate network and the "ideal solution" and the distance \( S^- \) between each candidate network and the "negative ideal solution" are calculated:

\[
S^+_i = \sqrt{\sum_{j=1}^{5} (u^+_j - u_y)^2} \\
i = 1, 2, \cdots, m, \ j = d, dj, plr, gbr, mbr
\]

\[
S^-_i = \sqrt{\sum_{j=1}^{5} (u^-_j - u_y)^2} \\
i = 1, 2, \cdots, m, \ j = d, dj, plr, gbr, mbr
\]

Then the proximity \( C_i \) of the candidate network \( N_i \) to the "ideal solution" is calculated:

\[
C_i = S^-_i / (S^+_i + S^-_i); i = 1, 2, \cdots, m
\]

Finally, the relative similarity degree of correction is obtained:

\[
C^*_i = C_i \times G_i
\]

According to the value of \( C^*_i \), sort each candidate network, then the network of maximum value is the best target network.

4. The simulation and analysis of algorithm
The use of sections to divide the text of the paper is optional and left as a decision for the author. Where the author wishes to divide the paper into sections the formatting shown in table 2 should be used.
This chapter uses the heterogeneous simulation scenario, which is shown in figure 2. The simulation scene includes three candidate networks: N1 (WiMAX), N2 (UMTS) and N3 (WLAN). Assumes that the using user terminal have the function of accessing variety of wireless, and be able to collect the performance metrics parameters of the network around. In the process of network selection, the user terminal can launch four types of services defined by 3GPP.

User terminal use the algorithm of NSABCW to select network between domain of C and D (N1, N2, N3 three available network). This result and the network selection based on the algorithm of NSABIT were compared and analyzed.

In the simulation process, the user terminal respectively launched four different services. While launching some services, increase time delay, time delay jitter and subjective weight of packet loss rate respectively (increased from 0.1 to 0.9, step length is 0.1). At the same time, adjust the weight of the other parameters in equal proportion. Conduct 100 network selections for the terminal under each given weight value. Figure 3, Figure 4 and Figure 5 show the influence of parameter weights on average time delay, average time delay jitter and average packet loss rate under different algorithm conditions respectively.

Figure 3 shows that when the terminal initiates conversational services, interactive services and background services, the average time delay obtained by the NSABCW algorithm is less than the average time delay obtained by the NSABIT algorithm. Since the stream class service didn’t require much on time delay, when the weight of time delay is less than 0.3, the average time delay obtained by the NSABCW algorithm is not ideal. The result of NSABCW algorithm is better than that of NSABIT algorithm by increasing the weight of time delay.

Figure 4 shows that the average time delay jitter obtained by the NSABCW algorithm is less than the average time delay jitter obtained by the NSABIT algorithm, when the terminal initiates the conversation service and the background service. For the stream class service, when the weight value of time delay jitter is less than 0.6, the average time delay jitter obtained by the NSABCW algorithm is not ideal. With the further increase of the weight value of the time delay jitter, the NSABCW algorithm is superior to the NSABIT algorithm. Similarly, there is a similar situation in interactive services. When the weight value of time delay jitter is less than 0.3, the average time delay jitter obtained by the NSABCW algorithm is not ideal. With the further increase of the weight value of time delay jitter, the average time delay jitter obtained by the NSABCW algorithm is significantly less than the average time delay jitter obtained by the NSABIT algorithm.

Similar to Figure 3 and Figure 4, Figure 5 shows that when the user terminal initiates stream class services, interactive services, and background services, the average packet loss rate obtained by the NSABCW algorithm is less than the average packet loss rate obtained by the NSABIT algorithm. For the conversation services didn’t require much on the packet loss rate. When the weight value of the packet loss rate is less than 0.4, the average packet loss rate obtained by the NSABCW algorithm is not ideal. With the further increase of the weight value of the packet loss rate, the NSABCW algorithm obtains a lower average packet loss rate.
Figure 3. The trend of the average time delay following the change of the weight of time delay

Figure 4. The trend of the average time delay jitter following the change of the weight of time delay jitter.
Figure 5. The trend of the average packet loss rate following the change of the weight of the packet loss rate

5. Summary

Against the existing problems of the most of the available network selection algorithm to calculate the index weight, research on the determination method of parameter index weight, a network selection algorithm based on combined weights is proposed. The algorithm respectively used the G1 method and entropy method to determine the subjective weights and objective weights of judgment index, through a linear combination of the subjective and objective weights to get the optimal combination weights. On this basis, make use of network evaluation model based on improved TOPSIS to conduct comprehensive ranking for each candidate network and choose the best one. Finally, analyze the performance for the algorithm. Simulation results show that the algorithm can obtain lower average latency, jitter, packet loss rate and etc., compared to NSABIT.

6. References

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