Ad Hoc Networks 72 (2018) 68–80

Contents lists available at ScienceDirect

Ad Hoc Networks

journal homepage: www.elsevier.com/locate/adhoc

A heterogeneous network selection algorithm based on network attribute and user preference

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ARTICLE INFO

Article history:
Received 21 August 2017
Revised 11 January 2018
Accepted 30 January 2018
Available online 31 January 2018

Keywords:
Heterogeneous networks
Network selection
Entropy
FAHP
TOPSIS

ABSTRACT

Mobile terminals are often in the dynamic environment of heterogeneous networks. For some reasons, they need to switch between different networks, namely vertical handover. At this moment, it is a very crucial issue for the mobile terminal to select the best suitable one rapidly from all detected alternative networks on condition that the selection result can avoid the ping-pong effect as much as possible. This paper proposes a heterogeneous network selection algorithm based on the combination of network attribute and user preference. Taking full account of user preferences for each candidate network and the actual situation of heterogeneous networks, the algorithm combines three typical MADM methods, namely FAHP, Entropy and TOPSIS. We first use FAHP to calculate the subjective weights of network attributes and the subjective utility values of all alternatives for four typical traffic classes, and then use Entropy and TOPSIS to respectively get the objective weights of network attributes and the objective utility values of all alternatives. Finally, according to the comprehensive utility value of every candidate network and a threshold, the most appropriate network, whose comprehensive utility value is maximum and greater than the corresponding value of the current network of the mobile terminal, is selected to access. The proposed algorithm not only avoids the one-sided nature of a single algorithm, but also dynamically adjusts the proportion of each algorithm in the final result according to the actual requirements. Simulation results indicate that the proposed algorithm can accurately select the optimal access network, significantly reduce the number of vertical handovers and provide the required QoS and QoE in terms of the quantified benefit from vertical handoff, compared with three existing hybrid algorithms.

1. Introduction

Since standards of 4G communication were issued, many research institutions in the world have been researching the next generation of communication standards 5G and relevant technology. For the equilibrium among operators, suppliers and users, various heterogeneous wireless networks (2G, 3G, 4G and WLAN and so on) will coexist and complement for a long time [1,2]. Hence, the trend of heterogeneous networks integration is increasingly evident especially with the advent of Internet of Things [3,4]. How to select a target access point to ensure efficient communication between two terminals or nodes in the system has become a basic requirement for many practical application scenarios, for example Scale-Free Wireless Sensor Networks [5], Social Internet of Vehicles [6,7]. In order to be always best connection (ABC) to obtain a high Quality of Experience (QoE) for users, mobile terminal needs to switch between different networks [8]. This switching behaviour is known as vertical handover. Necessary vertical handovers can bring profit to end users and network operators, while unnecessary vertical handovers can degrade QoE of user and overall network performance [9–11]. Consequently, it has become an interesting and challenging research topic to choose an optimal one from several candidate networks.

Generally, the issue of heterogeneous wireless network selection can be formulated as a problem of multiple attribute decision making (MADM) [12,13]. With respect to attributes considered in this area, there are the following three categories: (1), the QoS characteristics of candidate networks, such as received signal strength (RSS), network load, available bandwidth, data transmission rate, latency, delay jitter, packet loss ratio and bit error rate. (2), the attributes relevant to mobile terminal, such as rate of movement, the angle formed between the direction of movement and the access point (or base station), and remaining power [14]. (3), the user preferences, such as the overall level of personal preference for each network [15].

The typical MADM algorithms available currently are Simple Additive Weighting (SAW), Hierarchical Analysis Process (AHP), Fuzzy Analytic Hierarchy Process (FAHP), Technique for Order Pref-

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https://doi.org/10.1016/j.adhoc.2018.01.011

erence by Similarity to an Ideal Solution (TOPSIS), Entropy, Grey Relational Analysis (GRA), Markov Process [16], Weighted Markov Chain (WMC), and VIseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) [17], etc. Each algorithm has its own advantages and disadvantages. Undoubtedly, none of these algorithms can solve all MADM problems perfectly so far. Hence, in the context of heterogeneous network selection, there are two intuitive ways: making improvements on one of the algorithms above (e.g., [18] and [19]) or combining a variety of algorithms so as to get a better comprehensive result. The former only uses a single algorithm and thus can quickly get the final results by some simple operations, but the improvements are very limited. Therefore it has not been used gradually. Whereas the latter uses no less than two kinds of algorithms and thus increases the computation complexity and latency unavoidably, but it can bring together the advantages of the related algorithms, effectively overcome the one sidedness of a single algorithm, and show a strong ability to meet the environment. Hence it is more popular and widely used [20].

It should be noted that in addition to these schemes based on MADM, many intelligent algorithms have also been applied for this issue, such as Artificial Neural Network (ANN), Genetic Algorithm (GA), Ant Colony Optimization (ACO), Particle Swarm Optimization (PSO), Simulated Annealing (SA), Q-Learning [21,22], GA-SA (a hybrid of GA and SA) [23]. However, all these so-called intelligent algorithms must be iterated many times by probabilistic and heuristic rules, and then the optimal results are gradually obtained. Without enough iteration, undesirable or even bad results are usually yielded. That's to say, adequate iterations are required before the desired results are obtained. Otherwise, any intelligence of algorithms will not be reflected. As we all know, the time of the vertical handoff decision process should be as short as possible from the viewpoints of both end-user and network operator. Hence, it limits the application of these algorithms in the context of network selection.

Unlike the above-mentioned intelligent algorithms, the MADM algorithms are simple and straightforward and without random factors in the whole runtime. Since there are no stochastic factors, they can obtain the definite result almost directly, relying on their corresponding formulas rather than multiple loops. Although the results may be less intelligent, they can quickly complete the vertical handoff decision process and select the best target network. Therefore, these MADM algorithms still have very good advantages and provide a promising prospect in this field.

It's true that various MADM based methods have been studied in the context of network selection to rank the alternatives, but there is still a lack of a scheme based on hybrid MADM methods getting the rank list of all alternatives from the points of view of network attribute and user preference. Meanwhile, the relative importance of each relevant algorithm in calculating the final result can also be changed flexibly. Hence, this paper integrates three simple MADM algorithms (improved FAHP, Entropy and TOPSIS) and optimizes the flow of operation so as to get the comprehensive utility values of all candidate networks from the points of view of network attribute and user preference, then with the help of a threshold determines whether the mobile terminal should switch to the new network with the maximum utility value or still stay in the current one.

In summary, the major contributions of this paper are as follows.

(1) Propose an algorithm combined with FAHP, Entropy and TOPSIS to calculate the comprehensive utility value of each candidate network from the points of view of network attribute and user preference. Meanwhile, use a threshold to avoid some unnecessary vertical handoffs further.
(2) When constructing the fuzzy consistent matrix of FAHP, we make full use of its hierarchy model and adopt a novel 0.5–0.95 scale method and a formula to get the corresponding vectors.
(3) The adjustment coefficients can be flexibly adjusted according to specific traffic class or actual need. Moreover, with the change of these coefficients, the proportion of each algorithm in the final result can also be adjusted accordingly.

The rest of this paper is organized as follows. Section 2 reviews the related work on hybrid MADM methods for network selection. Section 3 describes the specific composition of the heterogeneous networks simulation scenario and the whole algorithm flow. And then the detailed process of calculating the comprehensive utility value of each network is presented. Moreover, an optimal network is selected with the help of a threshold. In Section 4, we set all parameters (network parameters and adjusting coefficients for four traffic classes) for the related simulation experiments, then test and evaluate our algorithm. Finally, conclusions and some future extensions of this proposed work are provided in Section 5.

2. Related work

For the heterogeneous network selection problem, various schemes have been proposed in the existing literature. Since the MADM methods are simple and straightforward in comparison with other non-MADM ones, many methods based on MADM are viewed as a promising direction and have been extensively studied. In this paper, we primarily focus on these MADM methods.

Chandavarkar et al. [24] propose a selection approach named SI-MAAR (Simplified and Improved Multiple Attributes Alternate Ranking) to overcome the rank reversal problem of many classical MADM methods, thereby obtaining perfect network selection reliability. On the whole, this approach itself is similar to TOPSIS. Its salient features different from TOPSIS are as follows:

(1) Use the original decision matrix and the expectation of each attribute (related to network, user, mobile device and the traffic class) to form closeness index (utility) matrix, which is equivalent to the weighted normalization decision matrix of original TOPSIS. Hence, both attribute normalization and weight calculation are removed.
(2) Each element in the positive and negative ideal solutions is 1 or 0, rather than the value in the weighted normalization decision matrix, thereby convenient to compute the Euclidean distances from each alternative network to positive or negative ideal solutions.

It can be seen that the expectation of each attribute considered in the approach for specific traffic class plays a vital important part in constructing the closeness index matrix. The performance of SI-MAAR can be affected or even degraded by the expectation of each attribute. However, opinions about the proper expectation value of each attribute obviously vary from person to person. Consequently, it means that the end-user must be very proficient with each attribute and its corresponding unit before getting a group of proper expectations for all attributes.

To our best knowledge, improvements in a single algorithm are limited after all. Meanwhile, the current heterogeneous network selection algorithms, widely used in the model of MADM, often consist of two or more simple algorithms to determine the optimal network. After giving an above example of improving single MADM method, we mainly focus on reviewing some existing hybrid MADM methods.

In [25], the authors use AHP and GRA in turn to get subjective weights of criteria and rank the networks. Similarly, a selection scheme comprising AHP and TOPSIS is proposed in [26]. The