Mixed Method: An Aggregated Method for Handover Decision in Heterogeneous Wireless Networks

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Abstract. The next generation of wireless networks is marked by a variety of access networks. A mobile user desires to run a service seamlessly regardless of his access network. This makes the continuity of service during handover and QoS relevant issues to deal with. In this context, Media Independent Handover (MIH) standard was developed to facilitate the interworking between IEEE and non-IEEE Access technologies. This paper suggests an aggregated method for the best access network selection. This method combines Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and VIse Kriterijumska Optimizacija kompromisno Resenja (VIKOR) decision algorithms together with Shannon entropy to assign handover criteria weights. Entropy is an adequate tool to weigh up the handover criteria. Compared with TOPSIS and VIKOR, mixed method performs better in terms of handovers number, packet loss rate, end to end delay, and throughput. Simulations are realized within the scope of MIH using NS3 simulator.

Keywords: Heterogeneous networks · Seamless handover · QoS

1 Introduction

The unification of Heterogeneous wireless Networks (HetNets) affords better QoS. Vertical Handover (VH) happens when a user switches his access network. This mechanism is divided into three phases: The first phase is the network discovery when the Mobile Terminal (MT) recognizes all the available access networks. The second phase is the handover decision, when the MT selects its target network. The third phase is the handover execution, when MT switches to the elected network. Seamless handover [1] allows mobile users to be always connected to the best network. It involves decision making criteria and algorithms. To be always best connected, the handover should start at the suitable time and select the adequate target network. The IEEE organization participates in the provision of interoperability and seamless VH via a standard called MIH [2]. MIH serves to connect IEEE and non-IEEE technologies, and establish handover via a set of protocols and mechanisms.

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To choose a network that meets user needs is a challenge, because some criteria may conflict with each other. The network selection turns into a Multi-Criteria Decision Making (MCDM) problem [3]. This paper proposes an approach, which combines two MCDM methods: TOPSIS and VIKOR. It employs the ranking results of TOPSIS [4,5] and VIKOR [6,7], to re-rank the available access networks. We also propose Shannon entropy to calculate the objective weights of handover criteria. Number and latency of handovers, packet loss rate, end to end delay, and throughput, are measured to evaluate QoS and network performance. Results of the suggested method are compared with those of TOPSIS and VIKOR. Simulations are performed in an IEEE 802.11, IEEE 802.16, and LTE system. The rest of the paper is arranged as follows: Sect. 2 reviews the related work, Sect. 3 introduces MCDM methods. The suggested decision making method is introduced in Sect. 4. Section 5 evaluates the proposed method. Conclusions are given in Sect. 6.

2 Related Work

In the literature, various VH algorithms [8] have been proposed. Radio Signal Strength (RSS) based algorithms [9] employ RSS value and other metrics (cost, bandwidth, power consumption, etc.). They afford low handover latency but a low to medium throughput. Other algorithms determine a cost function for every candidate network [10]. Mainly, cost function algorithms offer the same throughput level as RSS algorithms. Also, delays are higher because of the information collection and cost function computing complexity. Fuzzy logic and artificial neural networks [11], are extensively used in the literature to make handover decisions [12]. The use of these complex algorithms is required by the complexity of handover decisions and wireless networks dynamic conditions. The context-aware [9] handovers depend on informations related to the MT, network, and other contextual factors. MCDM methods integrate informations in a problem decision matrix to select the best from among the possible choices. Some of them have been suggested to make handover decisions [2,4,5,8,10]. MCDM algorithms afford high throughput [5]. However, their complexity raises the handover delay. This is also true for more complex methods like artificial intelligence and context-aware methods. In [4], the author analyses two MCDM approaches: TOPSIS and Simple Additive Weighting (SAW). For many considered criteria, TOPSIS performance is decent. VIKOR, TOPSIS, PROMETHEE (Preference Ranking Organization METHod for Enrichment of Evaluations) and Analytic Hierarchy Process (AHP) [14] are used to seek the most appropriate target network for the MT [7,14]. Authors in [15] found out that the final ranking of the possible network choices differ across MCDM methods. Authors [17] introduced a comparison of SAW, TOPSIS and VIKOR. They noticed the identical ranking of TOPSIS and SAW which is different from VIKOR ranking. They assumed that both TOPSIS and VIKOR are appropriate to give results not far from reality. Authors [16,20] presented a comparative study of TOPSIS and VIKOR. These algorithms adopt different normalization and aggregation methods.

Researchers noticed that in many cases, every MCDM approach gives a different result. To fix this problem, some aggregation methods have been suggested [13]. A decision problem is solved with many MCDM methods. Then, an aggregation of applied methods results gives the final decision. The reason why researchers try aggregation methods for decision making is to improve selection confidence of MCDM methods.

3 MCDM Methods

Handover decision making can be treated as an MCDM problem where there are n candidate networks, and m performance criteria. Rows and columns of the decision matrix present the alternatives A_1 ... A_n and criteria C_1 ... C_m, respectively. a_{ij} defines the quantity of alternative A_i against criterion C_j. Weights w_1 ...w_m have to be positive and designated to all criteria. They define the criterion importance to the decision making.

3.1 TOPSIS

TOPSIS is one of the extensively adopted classical MCDM tools. It is based on the following idea: the best alternative is assumed to have the shortest distance from the positive ideal solution and the longest distance from the negative ideal solution. Appropriately, TOPSIS is a reliable method for risk-avoidance as the decision makers may want a decision that not only augments the profits but also prevents risks. TOPSIS steps are:

step 1: decision matrix normalization

$$p_{ij} = (\frac{a_{ij}}{\sqrt{\sum_{i=1}^{n} a_{ij}^2}}) \tag{1}$$

step 2: weights are multiplied to the normalized matrix as follows

$$v_{ij} = w_j p_{ij} \tag{2}$$

step 3: positive ideal solution is $A^+ = (v_1^+, ..., v_j^+, ..., v_m^+)$, where v_j^+ is the best value of the j^{th} attribute over all the available alternatives. Negative ideal solution is $A^- = (v_1^-, ..., v_j^-, ..., v_m^-)$, where v_j^- is the worst value of the j^{th} attribute over all the available alternatives. They are computed as follows:

$$\begin{aligned} A^+ &= \{(max_i v_{ij} | j \in J), (min_i v_{ij} | j \in J\prime) | i = 1, 2, ..., n\} \\ A^- &= \{(min_i v_{ij} | j \in J), (max_i v_{ij} | j \in J\prime) | i = 1, 2, ..., n\} \end{aligned} \tag{3}$$

$J\{1, 2, ..., m\}$ and $J\prime\{1, 2, ..., m\}$ are the sets of criteria which need to be maximized and minimized, respectively.

step 4: the normalized euclidean distance between alternatives and ideal solutions is applied

$$d_i^+ = \sqrt{\sum_{j=1}^{m} (v_{ij} - v_j^+)^2} \quad and \quad d_i^- = \sqrt{\sum_{j=1}^{m} (v_{ij} - v_j^-)^2} \tag{4}$$

step 5: the relative closeness C_i to the ideal solution is computed

$$C_i = \frac{d_i^-}{d_i^- + d_i^+} \tag{5}$$

The best ranked alternative is the one with the maximum value of C_i.

3.2 VIKOR

VIKOR [20] was created to provide compromise solutions to optimization problems that include conflicting criteria with different units. The compromise ranking of alternatives is accomplished by comparing the measure of closeness to the ideal solution. Any exclusion or inclusion of an alternative could affect VIKOR ranking results. In VIKOR algorithm ν is the strategy weight of the maximum group utility, usually it takes the value 0.5, whereas $1 - \nu$ is the weight of the individual regret. VIKOR aggregate function is always close to the best solution, while in TOPSIS it must be distant from the worst solution even if it is not very close to the ideal solution. This makes VIKOR adequate for obtaining maximum profit. The VIKOR procedure is described below:

step 1: determination of aspired (f_j^+) and tolerable (f_j^-) levels of benefit and cost criteria, respectively where $j = 1, 2, ..., m$

$$\begin{aligned} f_j^+ &= \max_i a_{ij}, \quad f_j^- = \min_i a_{ij} \\ f_j^+ &= \min_i a_{ij}, \quad f_j^- = \max_i a_{ij} \end{aligned} \tag{6}$$

step 2: calculation of utility S_i and regret R_i using the following where $j = 1, 2, ...m$

$$S_i = \sum_{j=1}^{m} w_j \frac{f_j^+ - f_{ij}}{f_j^+ - f_j^-} \qquad R_i = \max_j \left(w_j \frac{f_j^+ - f_{ij}}{f_j^+ - f_j^-} \right) \tag{7}$$

step 3: The index Q_i is calculated. S_{min} and R_{min} are the minimum values of S_i and R_i, respectively. S_{max} and R_{max} are their maximum values, respectively.

$$Q_i = \nu \frac{S_i - S_{min}}{S_{max} - S_{min}} + (1 - \nu) \frac{R_i - R_{max}}{R_{min} - R_{max}} \tag{8}$$

Q_i, S_i, and R_i, are three ranking lists. The alternatives are arranged in a descending order in accordance with Q_i values. They are also arranged in accordance with S_i and R_i values separately. The best ranked alternative A_1 is the one with the minimum value of Q_i. A_1 is the compromise solution if:

Condition 1: $Q(A_2) - Q(A_1) \geq (1/(n-1))$, where A_2 is the second best alternative ranked by Q_i.

Condition 2: A_1 must be also best ranked alternative by S and/or R.

If one of the conditions is not fulfilled, a group of compromise solutions is proposed: A_1 and A_2 if only condition 2 is not satisfied. $A_1, A_2, ..., A_m$ if condition 1 is not satisfied. A_m is defined by the relation $Q(A_m) - Q(A_1) \leq (1/(n-1))$.

4 Mixed Method for Vertical Handover Decision Making

apparently, different decision making methods give different results in accordance with their hypotheses. Since seamless VH decision making is very critical, it is better to employ more than one method. To overcome this problem, we present an aggregate method named mixed or Rank Average method. As it implies other methods results and details, mixed method is capable of being perfect for access network selection. It ranks alternatives based on the average of implied approaches rankings. The ranking $R_{mixed}(i)$ of the i^{th} candidate network is acquired as follow, where k is the number of implied MCDM methods:

$$R_{mixed}(i) = \frac{\sum_{k} R_k(i)}{k} \tag{9}$$

This average ranking is invaluable because it is capable of adding the respective powers of each implied method. In our scenario, TOPSIS and VIKOR rank the alternatives. Then mixed method computes the average of their results for all alternatives. We choose TOPSIS and VIKOR for three reasons: (1) Each of them is advantageous and efficient for handover decision making. (2) They employ different aggregation and normalization functions. So, they give distant results for the same decision problem. For example, a selected alternative as the best by TOPSIS may be considered as the worse by VIKOR. (3) Mixed method can take advantage from their complementary powers regardless of their differences, and make efficient handover decisions.

We employed entropy [18,19] to compute the appropriate weight of each criterion. Entropy has the benefits of computational simplicity and efficiency. It determines the weights through the following steps:

step 1: normalization of the decision matrix using Eq. (1), in order to eliminate the criteria units.
step 2: calculation of the entropy value for each criterion, where k is the *Boltzmann*'s constant

$$E_j = -k \sum_{i=1}^{n} p_{ij} \ln p_{ij} \quad where \quad k = \frac{1}{\ln n} \tag{10}$$

step 3: extraction of objective criteria weights

$$w_j = \frac{1 - E_j}{\sum_{j=1}^{m} (1 - E_j)} \tag{11}$$

5 Performance Evaluation and Results

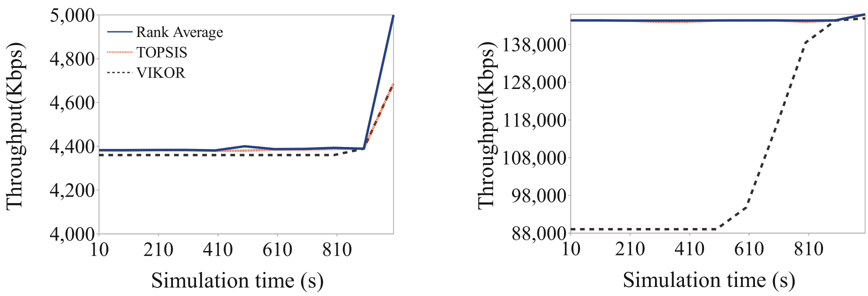
In this section, we assess and compare mixed method, TOPSIS, and VIKOR through some important performance metrics: throughput, end to end delay, packet loss rate, and handover decision delay [21]. We added MIH module to NS3 under which we have run simulations. We have considered WiFi, LTE, and WiMAX HetNets. Two MTs are equipped with three network devices of every access technology, and an MIH interface. MIH is needed to establish a list of local interfaces, obtain states and control the behaviour of these interfaces. MTs are initially connected to Wifi1 network while they are running real time applications: Voice over Internet Protocol (VoIP), and video streaming.

- MT1 starts to run a VoIP application while moving with a constant speed equal to 1 m/s. The VoIP application uses a G.729 codec, with 8,5 Kbps data rate and 60 B packet size.
- MT2 starts to run a video streaming application while moving with a constant speed equal to 1 m/s. The video streaming application sends MPEG4 stream using H.263 codec, with 16 Kbps bit rate.

mixed method, TOPSIS, and VIKOR are implemented in the MTs. Table 1 shows the list of simulation parameters. The measurements are taken every 10 s.

5.1 Throughput

Throughput figures among important QoS statistics. In our context, it is the number of bits received successfully by the MT divided by the difference between the last packet reception time and the first packet transmission time. The results in Fig. 1 shows that the three methods maximize the throughput. Mixed method is able to enhance the transmission throughput of real-time services. It offers a bit higher throughput than TOPSIS and VIKOR.

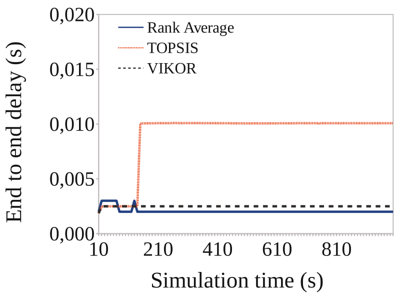


(a) VoIP (b) Video streaming

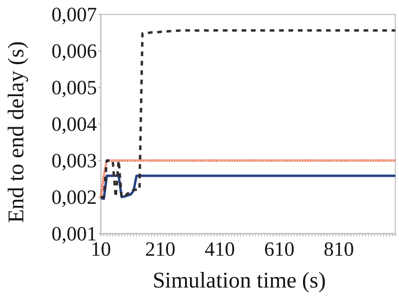
Fig. 1. MTs throughput

Table 1. Simulation parameters

Simulation parameters	Values
IEEE802.11 frequency bandwidth	5 GHz
IEEE802.11 transmission radius	100 m
IEEE802.11 data rate	20 Mbps
IEEE802.16 frequency bandwidth	5G Hz
IEEE802.16 transmission radius	600 m
IEEE802.16 channel bandwidth	10 MHz
Propagation model	COST231_PROPAGATION
IEEE802.16 modulation and coding	OFDM QAM16_12
MAC/IEEE802.16 UCD interval	10 s
MAC/IEEE802.16 DCD interval	10 s
LTE uplink bandwidth	25 resource blocks
LTE downlink bandwidth	25 resource blocks
LTE link data rate	10 Gbps
LTE channel bandwidth	5 MHz
Maximum transmission Power	30.0 dBm
LTE path loss model	Friis propagation
LTE transmission radius	2000 m
Mobility model	constant-position



(a) VoIP

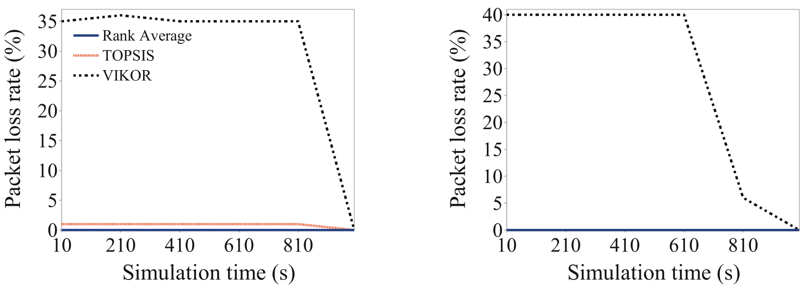


(b) Video streaming

Fig. 2. Packet end to end delay between MT and its correspondent node

5.2 End to End Delay

End to end delay is computed for each received packet. Figure 2 shows that mixed method has a better end to end delay performance than TOPSIS and VIKOR. Since real-time flows such as VoIP and video streaming are very sensitive to delay. We can say that decreased delay is a potential benefit of mixed method.



(a) VoIP

(b) Video streaming

Fig. 3. Packet loss rate

5.3 Packet Loss Rate

To achieve seamless VH in HetNets, it is essential to guarantee service continuity and QoS, which means low latency and packet loss rate during handover. Figure 3 shows that the three evaluated approaches guarantee low packet loss rate. Furthermore, mixed method assures null packet loss. This enhances the QoS for real-time-services.

5.4 Handover Delay

Handover delay is the time taken by the MT to make a decision and select the best access network. Every time we employ mixed method, TOPSIS, or VIKOR. We monitor the MN for 1000 s to get the number of handovers, and measure decision delay for each handover event. Figure 4 shows the obtained results. The number of handovers executed by VIKOR is higher compared to TOPSIS and Rank Average. For VoIP at 10s, the three evaluated methods executed a handover, but mixed method has handover delay greater than TOPSIS and VIKOR. This is because mixed method waits for the ranking results of TOPSIS and VIKOR to compute their average for every alternative. Even if the proposed VH approach requires more delay to decide a handover, it can accomplish better performance than conventional TOPSIS and VIKOR, with respect to end to end delay, packet loss rate, and throughput.

Ping-pong effect is the unnecessary handover to the neighbouring access point that returns to the original network after a very short interval of time. This unnecessary back and forth handover engenders heavy processing and switching loads. For example, mixed method compared to VIKOR reduces the number of unnecessary handovers. Hence, resources are saved and the number of dropped calls is reduced, thereby the VH QoS is improved. Since, mixed method and TOPSIS have less total number of handovers compared to VIKOR, the ping-pong effect is decreased.

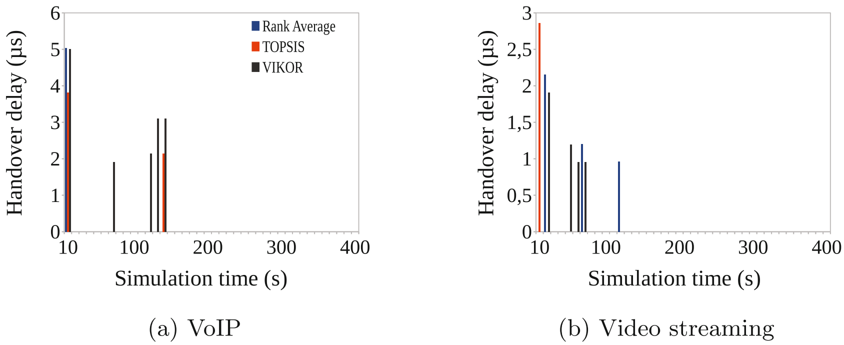


Fig. 4. VH decision delay

6 Conclusions

In this paper, we used mixed method as a VH decision making method in which two powerful but different ranking methods were implied: TOPSIS, and VIKOR. Mixed method is useful to determine which method is close to perfect VH decision, and which one is not. Performance of the three compared methods were assessed under NS3 simulator within MIH scope. The employed criteria are throughput, end to end delay, handover decision delay, and packet loss rate. Mixed method has the best performance in accordance with simulation results, except for decision delay. It can reduce the number of unnecessary handovers, ping-pong effects, end to end delay, packet loss rate, and improve throughput. So, mixed method has the ability to add the powers of applied methods (TOPSIS and VIKOR), and find a compromise between their proposed solutions despite their differences.

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