# Performance Analysis of MADM Algorithms with Different QoS Parameters in Heterogeneous Networks

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*Abstract* – **In current wireless environment the need for an user to be always best connected (ABC) anywhere at anytime leads to execute a vertical handoff decision for guaranteeing service continuity and quality of service (QoS). In Heterogeneous wireless networks main challenge is continual connection among the different networks like WiFi, WiMax, WLAN, WPAN etc. MADM (multiple attribute decision making) is an algorithmic approach suitable to realize a dynamic interface selection with multiple alternatives and attributes. In this paper, we compare the performance of three MADM algorithms e.g. SAW, WP, and TOPSIS. The simulation results show that each algorithm has its own limitations.**

*Keywords* – ***Heterogeneous wireless networks, MADM, TOPSIS,* SAW, WP, Decision making.**

## I. Introduction

In Heterogeneous Networks are expected to support different access technologies and to integrate multiple networks over a common IP (Internet Protocol) platform. They are managed by different operators like WiMax, WiFi, UMTS, est. One of the main goal and most challenged area in fourth generation wireless network (FGWN) was service continuity. Users expect the best connectivity to applications anywhere at anytime, which is most important issue in such environment also known as the Always Best Connected (ABC) concept [1]. ABC requires dynamic selection of the best network and access technologies when multiple options are available simultaneously.

Handover network type has the two types horizontal handover and vertical handover [2]. The homogeneous wireless network performs horizontal handover when the connection just moves from one base station to another within the same network. A vertical handover is the process of changing the mobile connection between different access points belonging to different access technologies. The vertical handover consist mainly in three phases: network discovery, handoff decision and handoff execution. In first step, the mobile terminal (MT) discovers its available neighbouring networks. In the decision phase, the MT determines whether it has to redirect its connection based on comparing the decision factors offered by the available networks and required by mobile user, that is, information gathering in the first phase. The last phase is responsible for the establishment and realise of the connections according to the vertical handoff decision.

MADM (multiple attribute decision making) [3] includes many methods such as SAW (Simple Additive Weighting) [4], WP (Weighted Product Method) [5] and TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) [6]. Saw calculates the overall score of alternatives by the weighted sum of all attribute values. The overall score in WP is a product of the values made across the attributes. The fundamental premise of TOPSIS is that the best alternatives should have the shortest Euclidean distance from the ideal solution (made up of the best value for each attribute regarding the alternatives) and the farthest distance to the negative ideal solution (made up of the worst value of each attribute regarding the alternatives).

In this paper is proposed a comparative study of three MADM algorithms by means of simulations and performance analysis for a heterogeneous network, integrated by WiFI, UMTS and 4G networks, when the user conducts various applications.

This paper is organised as follows. Section II presents related works. In section, III presents MADM methods. Simulation and results are presented in section IV. Section V consists of conclusion.

## II. Related Works

Many handoff decision algorithms are proposed in the literature so far. In [4] a comparison is done among SAW, TOPSIS, Grey Relational Analysis (GRA) and Multiplicative Exponent Weighting (MEW) for vertical handoff decision. In [7] a comparison analysis done between seven algorithms: SAW, MEW, TOPSIS, ELEKTRE, VIKOR, GRA and WMC for vertical handoff in 4G networks. The aim is to understand its performance for different user applications. Another performance comparison is made in [8]. There is presented study about limitations of three MADM algorithms (SAW, WP, TOPSIS) influencing the decision making for interface selection. Performance evaluation and comparison of MADM algorithms for subjective and objective weights is made in [9]. In [10] their goal is to reduce the overload and the processing delay in the mobile terminal so they proposed novel vertical handoff decision scheme to avoid the processing delay and power consumptions. In [12] is proposed a novel ranking algorithm, which combines multi attribute decision making (MADM) and Mahalanobis distance. The main task of this paper is to deal with limitations like ranking abnormality and number of handovers. Proposed algorithm combines two methods such as Fuzzy AHP and Mahalanobis distance.

## III. MADM Algorithms for Vertical Handover

The most known and used MADM Algorithms for vertical handoff are Simple Additive Weighting (SAW), Technique

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for Order Preference by Similarity to Ideal Solution (TOPSIS) and Multiplicative Exponent Weighting (MEW) or still Weight Product Method (WPM). These algorithms have to evaluate and compare the decision factors for each wireless networks, in order to detect and trigger a vertical handover. The factors can be classifies as beneficial, i.e. the larger, the better, or cost, i.e. the lower, the better. In this paper, these algorithms are used Euclidian normalization method. We choose this normalization method since it provides the highest-ranking consistency [11].

MADM problem is set out as follows:

$$A = \{A_i, i = 1, 2, ...., n\} \quad (1)$$

A set of a finite number of alternatives, which represents the possible networks the mobile terminal supports.

$$C = \{C_j, j = 1, 2, ...., m\} \quad (2)$$

A set of attributes which presented a different criteria as an examples signal strength, bit rate, power consumption, price, delay, security est.

TABLE I
MADM MATRIX

| | $C_1$ ($w_1$) | $C_2$ ($w_2$) | · | · | $C_m$ ($w_m$) |
|---|---|---|---|---|---|
| $A_1$ | $x_{11}$ | $x_{12}$ | · | · | $x_{1m}$ |
| $A_2$ | $x_{21}$ | $x_{22}$ | · | · | $x_{2m}$ |
| · | · | · | · | · | · |
| · | · | · | · | · | · |
| $A_n$ | $x_{n1}$ | $x_{n2}$ | · | · | $x_{nm}$ |

The weight vector $\mathbf{w} = \{w_1, w_2, ..., w_m\}$ (3) represents the relative importance of these attributes.

MADM problem can be represented by a matrix as shown in Table I.

### *A. Simple Additive Weighing – SAW*

This is the best known and most widely used scoring method, the score of each candidate network $i$ is obtained by adding the contributions from each attribute $x_{ij}$ multiplied by the weight factors $w_j$. Then the selected network $A^*_{SAW}$ is:

$$A^*_{SAW} = \max_i \sum_{j=1}^{m} x_{ij} \times w_j \quad (4)$$

The weight vector must satisfy $\sum_{j=1}^{N} w_j = 1$. (5)

The new from paper [8] is new way to calculate the results with Euclidian normalization method. The formula, which we used in normalizations for SAW, WP, and TOPSIS, is this:

$$1 - \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}} \quad (6)$$

We used that formula in case we have cost parameters. Cost parameters as an example are jitter, delay and lost. Benefit parameter, in our case, is utilization. The new normalization criterion is:

$$r_{ij} = \begin{cases} \dfrac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}}, \ for \quad benefit\ parameters \\ 1 - \dfrac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}}, \ for \quad cost \quad parameters \end{cases} \quad (7)$$

### *B. Weighted Product Method – WP*

This approach is similar to SAW but the scaled property values of each alternative are powered by $w_j$ and the overall score is a product of the values made across the attributes. The selected interface is then:

$$A^*_{wp} = \max_i \prod_{j=1}^{m} x_{ij}^{w_j} \quad (8)$$

### *C. Technique for Order Preference by Similarity to Ideal Solution –TOPSIS*

TOPSIS is an algorithm widely used for mobile terminal interface selection using multiple attributes. Here, the chosen network is the one, which have the shortest distance to the ideal solution and the longest to the worst-case solution. TOPSIS requests the following steps to compute the network-ranking list.

Step 1: (7) gives construction the normalized decision matrix, which allows comparison across the attributes.

Step 2: Construct the weighted normalized decision matrix.

Step 3: Determine ideal and negative-ideal solutions.

Step 4: Calculate the separation measure between the networks and the positive and negative ideal networks.

Step 5: Calculate the relative closeness to the ideal solution:

$$C_j = \frac{S^-_j}{S^-_j + S^+_j} \quad (9)$$

Step 6: Rank the preference order. A set of alternatives can now be ranked according to the decreasing order of $C_j$ .

## IV. SIMULATION RESULTS

Here we present the simulation results and performance analysis of the three MADM algorithms: SAW, WP and TOPSIS. The simulations are carried out using MATLAB.

Two simulations are made. In the simulation, we consider a weight vector in two situations: first situation (10) is when the utilization is significantly important compared with other QoS parameters and second situation (11) – when the lost is significantly important parameter.

$$W_1 = [0.225\ 0.225\ 0.325\ 0.225] \quad (10)$$
$$W_2 = [0.200\ 0.220\ 0.250\ 0.330] \quad (11)$$

In the simulation, we consider four attributes associated to five network interfaces (UMTS, 802.11b, 802.11a, 802.11n and 4G). The attributes are packet jitter, packet delay, utilization and packet loss for each network. These attributes represent two main criteria: QoS parameters and user's preferences. The attribute list can be expanded depending on the interface selection objectives.

The Packet Jitter (J): is a measure of the average delay variation within the access system. It can be measured in milliseconds.

The Packet delay (D): measures the average delay variation within the access system. It can be measured in milliseconds.

Utilization (U): is a measure of the current utilization of the access network or the wireless link. It can be expressed in percentage.

The Packet Loss (L): is a measure of the average packet loss rate within the access system over a considerable duration of time. It can be expressed in packet losses per million packets.

TABLE II
THE ATTRIBUTE PARAMETERS

| | J (ms) | D (ms) | U (%) | L (per$10^6$) |
|---|---|---|---|---|
| Net #1 UMTS | 50 | 400 | 10 | 100 |
| Net #2 802.11b | 25 | 200 | 20 | 20 |
| Net #3 802.11a | 15 | 100 | 20 | 15 |
| Net #4 802.11n | 30 | 150 | 40 | 20 |
| Net #5 4G | 20 | 100 | 20 | 15 |

*A. Simulation*

In this section, we calculate the ranking order of the alternatives by using SAW, WP and TOPSIS algorithms. For the first simulation, we calculate with weight vector (10). Table III presents the relative closeness to the ideal solution of TOPSIS and overall score of SAW and WP. The results show the ranking order of the alternatives, which is the same for the three algorithms. The best alternative is with rank #1 (Network 4 in our study).

We measure the difference of ranking values between ranks #1 and #2, #2 and #3, # 3 and #4 and so on of all algorithms. Difference allows distinguishing the ranking order and selecting easily the best alternative. In the Figure 1 is shown the difference of ranking values of all algorithms. As it can see, we only received better results for TOPSIS in dif (r1-r2) and dif (r4 –r5) but for WP we received better results in dif(r2-r3) and dif(r3-r4). In the Figure 2 is shown comparison with the results that we received (dif (r1-r2)my_res …) and the results received in [8] (diff (r1-r2) …). The result for [8] is made from the table III in [8].

*B. Simulation*

For the second simulation, we calculate in the same way but with different weight vector (11).

Table IV presents the relative closeness to the ideal solution of TOPSIS and overall score of SAW and WP. The results show the ranking order of the alternatives, which is the same for the three algorithms

TABLE III
THE RANKING ORDER OF SAW,WP AND TOPSIS

| | SAW | WP | TOPSIS |
|---|---|---|---|
| Net #1 | 0.175 Rank #5 | 0.155 Rank #5 | 0.070 Rank #5 |
| Net #2 | 0.579 Rank #4 | 0.555 Rank #4 | 0.620 Rank #4 |
| Net #3 | 0.669 Rank #2 | 0.629 Rank #2 | 0.684 Rank #2 |
| Net #4 | 0.706 Rank #1 | 0.701 Rank #1 | 0.835 Rank #1 |
| Net #5 | 0.652 Rank #3 | 0.615 Rank #3 | 0.676 Rank #3 |

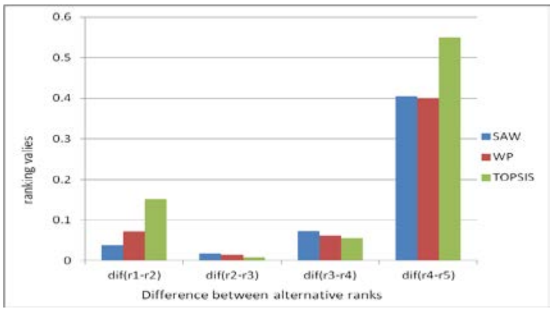


Fig. 1 The difference of ranking values of SAW, WP and TOPSIS

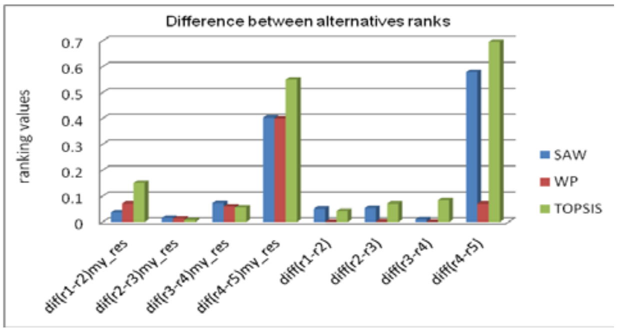


Fig. 2 Comparing the results:
a. on the left on the graphic - our results
b.on the right on the graphic - results in [8]

In the Figure3 is shown the difference of ranking values of all algorithms. As it can see, we again received better results for

TOPSIS in dif (r1-r2) and dif (r4 –r5) compared to [8] and better for WP in dif (r2-r3) and dif (r3-r4).

In the Figure 4 is shown the results that we received compared with the results received in [8] in this case based on other condition for weighting vector (11).

TABLE IV
THE RANKING ORDER OF SAW,WP AND TOPSIS

| | SAW | WP | TOPSIS |
|---|---|---|---|
| Network #1 | 0.160 Rank #5 | 0.135 Rank #5 | 0.143 Rank #5 |
| Network #2 | 0.618 Rank #4 | 0.593 Rank #4 | 0.720 Rank #4 |
| Network #3 | 0.708 Rank #2 | 0.672 Rank #2 | 0.773 Rank #2 |
| Network #4 | 0.718 Rank #1 | 0.712 Rank #1 | 0.858 Rank #1 |
| Network #5 | 0.693 Rank #3 | 0.659 Rank #3 | 0.769 Rank #3 |

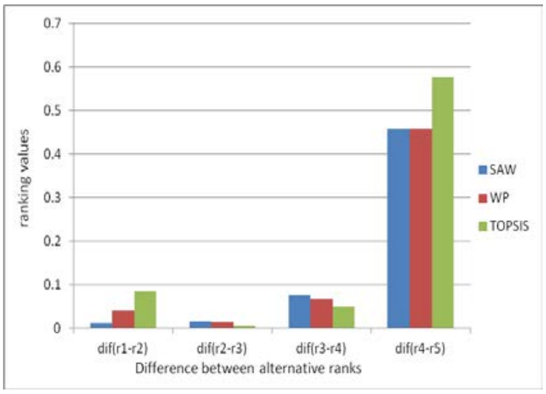


Fig. 3 The difference of ranking values of SAW, WP and TOPSIS

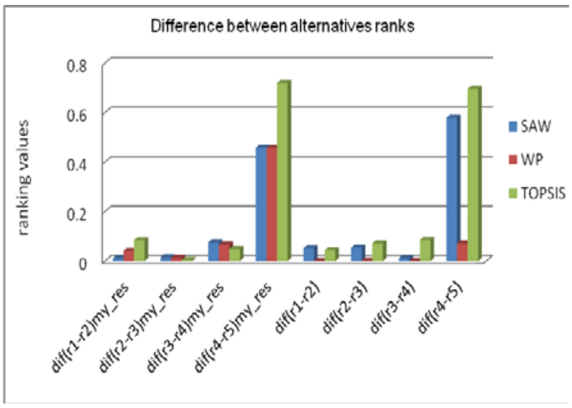


Fig 4. Comparing the results:
a. on the left on the graphic - our results
b.on the right on the graphic - rusults in [8]

## V. CONCLUSION

TOPSIS has the largest difference of ranking values and allows more accuracy in identifying the ranks between the alternatives compared to SAW and WP but in our simulations the best results is only in dif (r1-r2) and dif (r4-r5). In the network with high rank in dif (r2-r3) and dif (r3-r4) WP has larger ranking values compared TOPSIS.

From the tables III and IV we can see that with increase the values of the weight vector for lost and decrease the value of weighting vector for utilization we received better ranking values.

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