Novel Validation Approach for Network Selection Algorithm by Applying the Group MADM

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***Abstract*—Variety of vertical handoff algorithms (VHA) based on multi attribute decision making (MADM) methods have been proposed to help the user to select dynamically the best access network in terms of quality of service. However, there is no study that examines the validity of MADM methods which led to inefficient network selection due to inconsistent ranking outcomes.**
To address this issue, this paper proposes a new validation approach based on group MADM methods. This approach takes into account the weighting algorithms and allows to select the most valid ranking algorithm which can be used in specific traffic classes for network selection decision. Simulation results are presented to illustrate the effectiveness of our new validation approach for the network selection algorithm.

***Index Terms*—Heterogeneous Multi-Access, Network Selection, Multi Attribute Decision Making, Group Decision Making.**

I. Introduction

The most important issue in radio access technologies is to maintain a seamless service continuity under the principle “Always Best Connected” (ABC) [1]. The network selection [2] is intended to determine the most suitable network in terms of quality of service (QoS) for mobile users. However, this process is considered as a complex problem and mapped in NP-Hard problem [3]. To address this issue, many existing schemes and algorithms are utilized in the literature to cope with the network selection decision. According to [4], we can categorize the algorithms based network selection into four kinds such as handover based RSS, handover based bandwidth, cost function and combination algorithms. The last category includes handover algorithms that use fuzzy logic, neural networks, genetic algorithms and MADM methods.
Due to nature of network selection problem, MADM methods represent a promising solution which can be applied to network selection problem. We categorize them into two kinds: (a) MADM weighting methods which includes many methods such as analytic hierarchy process (AHP), fuzzy analytic hierarchy process (FAHP), analytic network process (ANP), fuzzy analytic network process (FANP) and (b) MADM ranking methods which includes many methods such as technique for order preference by similarity to ideal solution (TOPSIS), grey relational analysis (GRA), distance to ideal alternative (DIA), multiplicative exponent weighting (MEW), simple additive weighting (SAW), VIKOR and Mahalanobis distance. The third main problem in the network selection is determining the most suitable weights for different criteria for each traffic classes. There are several methods used to weigh the criteria such as AHP, FAHP, ANP, FANP, random weighting and entropy method.
The goal of this paper, is to determine a suitable weighting algorithm which can be combined with the Mahalanobis distance. The remainder of this paper is organized as follows. Section II presents review of related work concerning the network selection algorithms based on MADM approach. Section III describes the group MADM methods problem. Section IV presents our network selection based on validation of group decision. Section V includes the simulations and results. Section VI concludes this paper.

II. Vertical handover based MADM approach

Several network selection algorithms based on MADM methods are utilized to choose the best access network among other available networks. In [5] and [6] the network selection decision is modeled using two MADM methods AHP and SAW. AHP is used to provide a weight for each criterion involved in the network selection. SAW algorithm is applied to provide a ranking of all alternatives. In [7] and [8] the network selection algorithm combines two MADM methods AHP and GRA. The AHP method is used to weigh each criterion and GRA method is applied to rank the alternatives. In [9] and [10] the network selection algorithm is based on AHP and TOPSIS. The AHP method is used to calculate the weights of the criteria and TOPSIS method is applied to determine the ranking of access network.
The authors [11] have proposed a new ranking algorithm based on Mahalanobis distance. This algorithm allows to select the best available access network and to provide the better performance than the classical MADM methods. However, there is no single MADM weighting algorithm which is considered more favorable than other methods to be combined with Mahalanobis distance algorithm. In addition, there is no study that examines the validity of MADM methods that can be used to choose the best access network.
The validity of MADM methods includes two main issues which are the selection of the most valid ranking algorithm and the determination of the most suitable weights for different criteria. To cope with these issues, the authors [12] have proposed a new validation approach based on group MADM methods. The proposed validation approach can select the group ranking outcome of an MADM method which has the

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highest consistency degree with it's corresponding individual ranking outcomes. The weakness of the proposed validation lies in fact that is do not takes into account the weighting algorithms, the approach assumes that all attributes are weighted equally by different decision makers.

In this work, we propose a new validation approach which can take into account different weighting methods. We consider the Mahalanobis distance algorithm to determine the ranking of access network and four MADM methods such as AHP[13], FAHP[14], ANP[15], and FAHP[16] which are applicable to get weights of the criteria.

III. The group MADM methods problem

According to [12], the group MADM problem involves a finite number of alternatives $A = \{A_i,\ for\ i = 1, 2...n\}$, which are to be evaluated by a group of p decision makers $DM = \{DM_k,\ for\ k = 1, 2...p\}$ with respect to a set of m attributes $C = \{C_j,\ for\ j = 1, 2...m\}$. Each decision maker DM_k evaluates the performance rating x^k_{ij} of alternative A_i with respect to attributes C_j in order to construct the decision matrix $X^k = \{x^k_{ij},\ for\ i = 1, 2...n\}$. This evaluation is measurable quantitatively or assessable qualitatively.

In addition, to deal with weakness of the proposed approach in [14], each decision maker DM_k decides the relative importance of the attributes C_j to construct four weight vectors T^k_1, T^k_2, T^k_3, T^k_4 by using four weighting algorithms namely AHP, FAHP, ANP, and FANP respectively. The weight vector W^k combines the four vectors T^k_1, T^k_2, T^k_3 and T^k_4 by using the the arithmetic mean.

The weight vector W^k, given by each decision maker can be calculated by:

$$W^k = [w^k{}_1, w^k{}_2, ...w^k{}_m],\quad where\quad w^k{}_i = \frac{\sum_{j=1}^{4} T^k_j}{4} \tag{1}$$

Finally, the decision matrices X^k and the weight vector W^k are averaged to represent the group decision matrix X and the group weight vector W.

The group decision matrix X is calculated by

$$X = (x_{ij})\ \ where\ \ x_{ij} = \frac{\sum_{k=1}^{p} x^k_{ij}}{p},\ \ i = 1, ..n,\ \ j = 1, .., m \tag{2}$$

The group weight vector W is given by

$$W = [w_1, w_2, ..., w_m] \tag{3}$$

$where\ \ w_j = \frac{\sum_{k=1}^{p} w^k_j}{p},\ \ j = 1, .., m$

IV. Network selection based on validation of group decision

Despite several algorithms based on MADM methods which have been proposed and developed to solve the network selection decision, the validation of the appropriate MADM algorithm which can be applied in the network selection decision remains an open issue. To deal with this issue, we propose a new validation approach which can take into account different weighting methods and allows to select the group ranking outcome of an MADM method which has the highest consistency degree with it's corresponding individual ranking outcome.

Our validation approach combines the four MADM weighting algorithms AHP (W1), FAHP (W2), ANP (W3) and FANP (W4) with the Mahalanobis algorithm will result in four different methods, named as Mahalabis-W1, Mahalabis-W2, Mahalabis-W3 and Mahalabis-W4 respectively. The all methods are used to solve the same general group MADM problem in the context of network selection.

In order to select the most valid ranking outcome which is most acceptable by the all decision markers, we introduce the consistency degree which allows to measure the relationship between V_i and V^k_i.

Let define the vector $V^i = [a_{i1}, a_{i2}, ..., a_{in}]$ which represents the score of one group ranking outcome by using MADM method.

Let define the vector $V^k_i = [b^k{}_{i1}, b^k{}_{i2}, ..., b^k{}_{in}]$ which represents the score of the alternatives A_i of one individual ranking outcomes, where i=1,2...,n and k=1,2....,p.

The Pearson's correlation C^k_i between V^i and V^k_i can be calculated by:

$$C^k_i = \frac{n(\sum_{j=1}^{n} a_{ij} b^k{}_{ij}) - (\sum_{j=1}^{n} a_{ij})(\sum_{j=1}^{n} b^k{}_{ij})}{\sqrt{[n(\sum a_{ij}{}^2) - (\sum a_{ij})^2][n(\sum b^k{}_{ij}{}^2) - (\sum b^k{}_{ij})^2]}} \tag{4}$$

where n is the number of the available networks.

The consistency degree CD_i of the method between the group and individual ranking outcomes is given as follows:

$$CD_i = \frac{\sum_{k=1}^{p} C^k_i}{p} \tag{5}$$

Our new validation approach will select the group ranking outcome of an MADM method which has the greater value CD_i.

V. Simulations and results

In order to deal with the inconsistent ranking outcomes provided by different decision makers by using Mahalanobis distance algorithm, we simulate our new validation approach. This one takes into account the four weighting algorithms AHP (W1), FAHP (W2), ANP (W3) and FANP (W4) and it is applied to select the most valid weighting algorithm which should be used for our Mahalanobis ranking algorithm.

The group decision matrix X was generated from table I and table II according to equation 2. We perform two simulations for two traffic classes namely conversational and interactive. In each simulation the group weight vector W is generated according to traffic's type (see equation 1). We apply the four MADM methods Mahalanobis-W1, Mahalanobis-W2, Mahalanobis-W3 and Mahalanobis-W4 to the group decision matrix X and the group weight vector W, four group ranking outcomes are obtained which are G1, G2, G3 and G4 respectively. The ranking order provided by the four group ranking G1, G2, G3 and G4 are the same because the four MADM methods are based on the same decision matrix X and the group weight vector W.

A. The simulation scenario

In this simulation, the set A represents three candidates networks which are UMTS, WIFI and WIMAX. The set C represents six attributes which are cost per byte (CB), available bandwidth (AB), security (S), packet delay (D), packet jitter (J) and packet loss (L), and the set DM contains three decision makers which are DM_1, DM_2, and DM_3.
The three decision makers assign a different weight to each criterion by using the four weighting algorithms W1, W2, W3, and W4. The measures of every criterion relative to QoS parameters for candidate networks are shown in table I. In the other hand the group decision makers give different performance rating to each available networks respect only to two criteria which are cost per byte and security, these evaluation criteria are given in table II.

TABLE I
THE QOS METRICS FOR THE CANDIDATE NETWORKS

Network	AB ($mbps$)	D (ms)	J (ms)	L ($per10^6$)
UMTS	1.2	35	12	50
WIFI	6	110	15	60
WIMAX	8	100	20	80

TABLE II
THE VALUES OF COST AND SECURITY FOR THE CANDIDATE NETWORKS

	DM_1		DM_2		DM_3	
Network	**CB**(%)	**S**(%)	**CB**(%)	**S**(%)	**CB**(%)	**S**(%)
UMTS	60	70	65	60	70	80
WIFI	12	25	15	30	10	20
WIMAX	70	75	55	50	65	70

B. The simulation 1

In this simulation, the traffic analyzed is conversational traffic. The weight vectors are calculated by each decision maker DM_1, DM_2, and DM_3 by using each weighting algorithm W1, W2, W3 and W4. While the group weight vector W is generated by using the equation 1.
The table III shows the group ranking of the three networks and three individual ranking made by the three decision makers DM_1, DM_2, and DM_3 by using the Mahalanobis-W1 method. While the table IV shows the group ranking and three individual ranking made by the three decision makers using the Mahalanobis-W2 method. Moreover the table V shows the group ranking and three individual ranking made by the three decision makers using the Mahalanobis-W3 method.
Finally the table VI shows the group ranking and three individual ranking made by the three decision makers using the Mahalanobis-W4 method.
By applying the Pearson's correlation coefficients for all group MADM, the consistency degrees of G1, G2, G3 and G4 are given in table VII. We notice that G3 has the highest score, which means that the ANP is most suitable algorithm which should be used to weigh different criteria for conversational traffic.

TABLE III
RANKING COMPARISON BETWEEN THREE DECISION MAKERS USING G1 FOR CONVERSATIONAL TRAFFIC

	G1		$DM_1 - W1$		$DM_2 - W1$		$DM_3 - W1$	
Networks	C_j^*	**Rank**	C_j^*	**Rank**	C_j^*	**Rank**	C_j^*	**Rank**
UMTS	0.0059	1	0.0060	1	0.0066	1	0.0064	1
WIFI	0.0168	3	0.0226	3	0.0203	2	0.0233	2
WIMAX	0.0135	2	0.0192	2	0.0206	3	0.0266	3

TABLE IV
RANKING COMPARISON BETWEEN THREE DECISION MAKERS USING G2 FOR CONVERSATIONAL TRAFFIC

	G2		$DM_1 - W2$		$DM_2 - W2$		$DM_3 - W2$	
Networks	C_j^*	**Rank**	C_j^*	**Rank**	C_j^*	**Rank**	C_j^*	**Rank**
UMTS	0.0059	1	0.0062	1	0.0070	1	0.0065	1
WIFI	0.0168	3	0.0301	3	0.0147	2	0.0188	2
WIMAX	0.0135	2	0.0118	2	0.0151	3	0.0215	3

TABLE V
RANKING COMPARISON BETWEEN THREE DECISION MAKERS USING G3 FOR CONVERSATIONAL TRAFFIC

	G3		$DM_1 - W3$		$DM_2 - W3$		$DM_3 - W3$	
Networks	C_j^*	**Rank**	C_j^*	**Rank**	C_j^*	**Rank**	C_j^*	**Rank**
UMTS	0.0059	1	0.0077	1	0.0083	1	0.0084	1
WIFI	0.0168	3	0.0179	3	0.0155	3	0.0176	3
WIMAX	0.0135	2	0.0137	2	0.0150	2	0.0160	2

TABLE VI
RANKING COMPARISON BETWEEN THREE DECISION MAKERS USING G4 FOR CONVERSATIONAL TRAFFIC

	G4		$DM_1 - W4$		$DM_2 - W4$		$DM_3 - W4$	
Networks	C_j^*	**Rank**	C_j^*	**Rank**	C_j^*	**Rank**	C_j^*	**Rank**
UMTS	0.0059	1	0.0103	2	0.0128	2	0.0173	2
WIFI	0.0168	3	0.0271	3	0.0143	3	0.0198	3
WIMAX	0.0135	2	0.0077	1	0.0091	1	0.0105	1

TABLE VII
PEARSON'S CORRELATION FOR GROUP MADM FOR CONVERSATIONAL TRAFFIC

Group MADM	**G1**	**G2**	**G3**	**G4**
Consistency degree	0.09478	0.9001	0.9850	0.5439

C. The simulation 2

In this simulation, the traffic analyzed is interactive traffic. The weight vectors are calculated by each decision maker DM_1, DM_2, and DM_3 by using each weighting algorithm W1, W2, W3 and W4. While the group weight vector W is generated by using the equation 1.
The table VIII shows the group ranking of the three networks and three individual ranking made by the three decision makers DM_1, DM_2, and DM_3 by using the Mahalanobis-W1 method. While the table IX shows the group ranking and three individual ranking made by the three decision makers using the Mahalanobis-W2 method. Moreover the table X shows the group ranking and three individual ranking made by the three decision makers using the Mahalanobis-W3 method.

Finally the table XI shows the group ranking and three individual ranking made by the three decision makers using the Mahalanobis-W4 method.

TABLE VIII
RANKING COMPARISON BETWEEN THREE DECISION MAKERS USING G1 FOR INTERACTIVE TRAFFIC

	G1		$DM_1 - W1$		$DM_2 - W1$		$DM_3 - W1$	
Networks	C_j^*	**Rank**	C_j^*	**Rank**	C_j^*	**Rank**	C_j^*	**Rank**
UMTS	0.0081	1	0.0078	1	0.0084	1	0.0086	1
WIFI	0.0173	3	0.0267	3	0.0244	2	0.0283	3
WIMAX	0.0125	2	0.0233	2	0.0247	3	0.0276	2

TABLE IX
RANKING COMPARISON BETWEEN THREE DECISION MAKERS USING G2 FOR INTERACTIVE TRAFFIC

	G2		$DM_1 - W2$		$DM_2 - W2$		$DM_3 - W2$	
Networks	C_j^*	**Rank**	C_j^*	**Rank**	C_j^*	**Rank**	C_j^*	**Rank**
UMTS	0.0081	1	0.0070	1	0.0082	1	0.0087	1
WIFI	0.0173	3	0.0305	3	0.0152	3	0.0200	2
WIMAX	0.0125	2	0.0116	2	0.0148	2	0.0213	3

TABLE X
RANKING COMPARISON BETWEEN THREE DECISION MAKERS USING G3 FOR INTERACTIVE TRAFFIC

	G3		$DM_1 - W3$		$DM_2 - W3$		$DM_3 - W3$	
Networks	C_j^*	**Rank**	C_j^*	**Rank**	C_j^*	**Rank**	C_j^*	**Rank**
UMTS	0.0081	1	0.0101	1	0.0107	1	0.0113	1
WIFI	0.0173	3	0.0174	3	0.0149	3	0.0169	3
WIMAX	0.0125	2	0.0106	2	0.0118	2	0.0121	2

TABLE XI
RANKING COMPARISON BETWEEN THREE DECISION MAKERS USING G4 FOR INTERACTIVE TRAFFIC

	G4		$DM_1 - W4$		$DM_2 - W4$		$DM_3 - W4$	
Networks	C_j^*	**Rank**	C_j^*	**Rank**	C_j^*	**Rank**	C_j^*	**Rank**
UMTS	0.0081	1	0.0127	2	0.0093	2	0.0117	2
WIFI	0.0173	3	0.0270	3	0.0101	3	0.0143	3
WIMAX	0.0125	2	0.0068	1	0.0079	1	0.0083	1

By applying the Pearson's correlation coefficients for all group MADM, the consistency degrees of G1, G2, G3 and G4 are given in table XII. We notice that G3 has the highest score, which means that the ANP is most suitable algorithm which should be used to weigh different criteria for interactive traffic.

TABLE XII
PEARSON'S CORRELATION FOR GROUP MADM FOR INTERACTIVE TRAFFIC

Group MADM	**G1**	**G2**	**G3**	**G4**
Consistency degree	0.8809	0.8768	0.9367	0.5144

VI. CONCLUSION

In this work, we have proposed new validation approach which can take into account different weighting methods and allows to select the group ranking outcome of Mahalanobis distance algorithm.

The simulation results show that the ANP algorithm provides higher value of the the consistency degree. We conclude that the ANP allows to assign suitable relative importance of the criteria, for conversational and interactive traffic. For this reason, we should combine the ANP with the Mahalanobis distance in order to select the best access network.

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