Performance Evaluation and Comparison of MADM Algorithms for Subjective and Objective Weights in Heterogeneous Networks

Nancy, Silky Baghla

Abstract: **In a fourth generation (4G) wireless environment, the need for an user to be always best connected (ABC) anywhere at any time leads to execute a vertical handoff decision for guaranteeing service continuity and quality of service (QoS). In this paper, Vertical handover decision schemes is compared and Multi Attribute Decision Making (MADM) is used to choose the best network from the available Visitor networks (VTs) for the continuous connection by the mobile terminal. A comparative analysis of these methods including SAW, MEW** and **TOPSIS illustrated with a numerical simulation, showed the impact of the various importance weights assignment in their performance for different traffic classes and applications such as: voice and data connections, in a 4G wireless system.**

Keywords—**4G mobile communication, Algorithms, Decision making.**

I. INTRODUCTION

Future generation wireless networks (FGWN) are expected to support heterogeneous access technologies than homogeneous wireless networks. In FGWN, heterogeneous network is managed by different operators like WiMax, WiFi, UMTS etc. In this heterogeneous wireless network environment, always best connected (ABC)[1] which requires dynamic selection of the best network and access technologies when multiple options are available simultaneously. The typical scenario of Wifi and WiMax as shown in Fig 1 are: WiFi with high bandwidth, low-cost and short coverage and WiMax with high-speed mobile, fixed internet access to the end users, it provides services for data, voice and video.

Handover network has the two types, horizontal handover and vertical handover [2]. A vertical handoff is the process of changing the mobile connection between access points supporting different wireless technologies. Meanwhile, in a horizontal handoff the connection just moves from one base station to another within the same access network. The vertical handoff consists mainly in three phases:

- network discovery,
- handoff decision and
- handoff execution.

Nancy, Silky Baghla is with J.C.D. College of Engineering Sirsa, Haryana, Email: nancy_2589@yahoo.com

In the first step, the mobile terminal (MT) discovers its available neighboring 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 the mobile user, that is, information gathered in the first phase. The last phase is responsible for the establishments and release of the connections according to the vertical handoff decision.

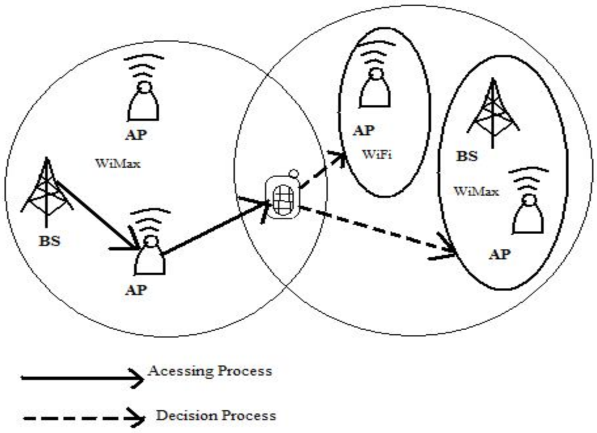


Fig. 1 The scenario of WiFi and WiMax

Various Multiple Attribute Decision Making (MADM) [2] methods have been proposed in the literature for vertical handoff, methods such as SAW (simple additive weighting)[3], TOPSIS (technique for order preference by similarity to ideal solution) [3], MEW (multiplicative exponent weighting)[4] and Artificial Hierarchy process(AHP) [5].

The scope of our work is mainly in handover decision phase, as mentioned in the decision phase; decision makers must choose the best network from available networks. . In this paper, we compare SAW (simple additive weighting), TOPSIS (technique for order preference by similarity to ideal solution) and MEW (multiplicative exponent weighting) MADM algorithms which uses the cost, packet delay, packet jitter and available bandwidth of the participating access networks to make handoff decisions for multi-attribute QoS consideration according to the features of the traffic. According to these attributes, the attribute matrix of alternative networks is established. Appropriate weight factor is assigned to each criterion to account for its importance which is determined by Artificial Hierarchy process (AHP).

Considerable amount of research on develop MADM methods for vertical handoff have been conducted, and it is necessary to evaluate their performance under different scenarios in order to provide the best solution for a particular application. In [4], [9], and [10] brief simulation studies are addressed for this purpose, but only including SAW, MEW, and TOPSIS algorithms.

II. RELATED WORK

At present many of the handoff decision algorithms are proposed in the literature. In (4) a comparison done among SAW, Technique for Order Preference by Similarity to Ideal Solution(TOPSIS), Grey Relational Analysis (GRA) and Multiplicative Exponent Weighting (MEW) for vertical handoff decision. In (3) author discuss that the vertical handoff decision algorithm for heterogeneous wireless network, here the problem is formulated as Markov decision process. In (3) the vertical handoff decision is formulated as fuzzy multiple attribute decision making (MADM).

In (8) 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 consumption. In (7) a vertical handoff decision scheme DVHD uses the MADM method to avoid the processing delay. In (10) the paper is mainly used to decrease the processing delay and to make a trust handoff decision in a heterogeneous wireless environment using T-DVHD. In (11) a novel distributed vertical handoff decision scheme using the SAW method with a distributed manner to avoid the drawbacks. In (14) the paper provides the four steps integrated strategy for MADM based network selection to solve the problem. All these proposal works are mainly focused on the handoff decision and calculate the handoff decision criteria on the mobile terminal side and the discussed scheme are used to reduce the processing delay by the calculation process using MADM in a distributed manner.

In (16) the comparison
n analysis shows the
SAW, MEW, TOPSIS, VIKOR, GRA and WMC with the numerical simulation of vertical handoff in 4G networks.

III. DECISIN MAKERS IN VERTICAL HANDOVER DECISION SCHEMES

Multiple attribute decision making (MADM) refers to making preference decisions (e.g., evaluation, prioritization, and selection) over the available alternatives that are characterized by multiple, usually conflicting, attributes. The structure of the alternative performance matrix Table 1, where xij is the rating of alternative i with respect to criterion j and wj is the weight of criterion j. Since each criterion has a different meaning, it cannot be assumed that they all have equal weights, and as a result, finding the appropriate weight for each criterion is one the main points in MADM. Various methods for finding weights can be found in the literature and most of them can be categorized into two groups:

- **Subjective weights** are determined only according to the preference decision makers.
- **Objective weights** determine weights by solving mathematical models without any consideration of the decision maker's preferences.

Table 1. Matrix format of a MADM problem

	$C1(w1)$	$C2(w2)$	$C3(w3)$
$A1$	$x11$	$x12$	$x13$
$A2$	$x21$	$x22$	$x23$
$A3$	$x31$	$x32$	$x33$

IV.REVIEW OF MADM METHODS

The most known and used MADM algorithms for vertical handoff are Simple Additive Weighting (SAW) [3], Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) [3], and Multiplicative Exponent Weighting (MEW) [4] between others. These algorithms have to evaluate and compare the decision factors for each wireless network, in order to detect and trigger a vertical handover. The factors can be classified as benefical, i.e., the larger, the better, or cost, i.e., the lower, the better. In the following these algorithms are described.

A. Simple Additive Weighting (SAW)

Simple Additive Weighting (SAW) which is also referred as weighted linear combination or scoring methods or weighted sum method is a simple and most often used multi attribute decision technique. The method is based on the weighted average. An evaluation score is calculated for each alternative by multiplying the scaled value given to the alternative of that attribute with the weights of relative importance directly assigned by decision maker followed by summing of the products for all criteria.

For numerical attributes score are calculated by normalized values to match the standardized scale. The SAW is a comparable scale for all elements in the decision matrix, the comparable scale obtained by rij for benefit criteria Eq. (4.1) and worst criteria Eq. (4.2).

$$V_{ij} = \frac{x_{ij}}{x^{\max}{}_j} \tag{4.1}$$

$$V_{ij} = \frac{x^{\min}{}_j}{x_{ij}} \tag{4.2}$$

The SAW method, underlying additive values function and compute as alternatives score Vi = V(Ai) by adding weighting normalized values before eventually ranking alternatives.

$$V_i = \sum_{j=1}^{m} W_j V_{ij} \qquad (4.3)$$

For $V \in R^{n*m}$ with i{1,…..,n},j={1…..m};$V_{ij}, W_j \epsilon (0,1)$
Then the selected network is A^{*}_{SAW} is:

$$A^{*}_{SAW} = max_i \sum_j w_j r_{ij} \qquad (4.4)$$

B. Technique for Order Preference By Similarity To Ideal Solution(TOPSIS)

TOPSIS (15) is a MADM instrument for measuring relative efficiency of alternatives. It determines the preference order on the grounds of the similarity to a positive ideal solution and the worst similarity to a negative solution. The following are the steps of TOPSIS.
Construct the normalized decision matrix. Each element *rij* of the Euclidean normalized decision matrix *R* can be calculated as follows:

$$r_{ij} = \frac{x_{ij}}{\sqrt{(\sum x_{ij}^2)}} \quad \text{for i=1,…,m; j=1,……,n} \qquad (4.5)$$

Next the weighted normalized decision matrix is constructed by

$$V_{ij} = w_j r_{ij} \qquad (4.6)$$

Then positive ideal and negative ideal solutions are determined by Positive Ideal solution.

$$A^{*} = \{v_1^{*}, \dots\dots\dots, v_n^{*}\} \quad \text{where} \qquad (4.7)$$

$$V_j^{*} = \{max_i(V_{ij}) if j \in J; min_i(V_{ij}) if j \in J'$$

Negative ideal solution.

$$A' = \{v_1^{*}, \dots\dots\dots, v_n^{*}\} \quad \text{where} \qquad (4.8)$$

$$V_j' = \{min_i(V_{ij}) if j \in J; max_j(V_{ij}) if j \in J'$$

The distance between each alternative and the positive ideal solution is:

$$S_i^{*} = \sqrt{\left[\sum_j (v_j^{*} - v_{ij})^2\right]} \quad \text{i=1,…., m} \qquad (4.9)$$

The distance between each alternative and the negative ideal solution is:

$$S_i' = \sqrt{\left[\sum_j (v_j' - v_{ij})^2\right]} \quad \text{i=1,…., m} \qquad (4.10)$$

Finally relative closeness to the ideal solution Ci* is calculated as

$$C_i^{*} = \frac{s_i'}{s_i^{*} + s_i'} \quad 0 < C_i^{*} < 1 \qquad (4.11)$$

A set of alternatives can now be preference ranked according to the descending order of c_i^{*} . Then the selected network A^{*}_{TOP} is:

$$A^{*}_{TOP} = max C_i^{*} \qquad (4.12)$$

C. Multiplicative Exponential Weighting(MEW)

MEW[4] another MADM scoring method. The main difference is that instead of addition usually mathematical operation now there is multiplication. As with all MADM methods, WPM is a finite set of decision alternatives described in terms of several decision criteria. The vertical handover decision problem can be expressed as a matrix form and each row i corresponds to the candidate network I and each column j corresponds to the attributes.

$$A^{*}_{MEW} = max_i \prod_j r_{ij}^{w_j} \qquad (4.13)$$

Where xij denotes attribute j of candidate network i, wi denotes the weight of attributed j.

V.PERFORMANCE COMPARISON

In order to evaluate the performance of each MADM algorithm, we consider a network selection situation in a 4G environment integrated by three network types as WLAN, UMTS and WiMAX, and there are two networks of each type.
In this work, four decision criteria have to be evaluated and compared in order to detect and to trigger a vertical handoff. Including available bandwidth (Mbps), packet delay (ms), packet jitter (ms), and cost per byte. The range of values of the parameters or decision criteria is shown in Table II.

For Subjective Weights the values of assigned weights for different services considered in this study are:

case 1, all parameters have the same weight, this is the baseline case;
case 2, delay and packet jitter have 70% of importance and the rest is equally distributed among the other parameters, this case is suitable for voice connections; and
case 3, available and total bandwidth have 70% of importance, this case is suitable for data connections. In each vertical handoff decision point, the attribute values may be the same, increase or decrease within the range shown in Table II.

Table II. Values of the networks parameters.

Criteria Network	Cost per byte	Packet Delay(ms)	Packet Jitter(ms)	Available Bandwidth
UMTS	60	25-50	5-10	0.1-2
WLAN	10	100-150	10-20	1-11

WIMAX	40	60-100	3-10	1-60

For Objective Weights. The four traffic classes have different QoS requirements [14]. To account for this fact, we assigned different weights for the same attribute between different traffic classes. The AHP matrices for the four traffic classes are shown in Table III. The weights determined by using the method are shown in Table IV.

Table III: AHP matrix for each Traffic Class.

Conversational	Cost	Delay	Jitter	Bandwidth
Cost	1	1/9	1/9	1
Delay	9	1	1	9
Jitter	9	1	1	9
Bandwidth	1	1/9	1/9	1
Streaming	Cost	Delay	Jitter	Bandwidth
Cost	1	1/5	1/9	1/9
Delay	5	1	1/5	1/5
Jitter	9	5	1	1
Bandwidth	9	5	1	1
Interactive	Cost	Delay	Jitter	Bandwidth
Cost	1	5	9	5
Delay	1/5	1	5	1
Jitter	1/9	1/5	1	1/5
Bandwidth	1/5	1	5	1
Background	Cost	Delay	Jitter	Bandwidth
Cost	1	9	9	5
Delay	1/9	1	1	1/5
Jitter	1/9	1	1	1/5
Bandwidth	1/5	5	5	1

Table IV: Importance Weights Per Class And Consistency Ratio(CR).

Traffic Class	Cost	Delay	Jitter	Bandwidth	CR
Conversational	0.04998	0.45002	0.45002	0.04998	0.000
Streaming	0.03737	0.11380	0.42441	0.42441	0.049
Interactive	0.63593	0.16051	0.04304	0.16051	0.049
Background	0.66932	0.05546	0.05546	0.21976	0.049

A. Simulation 1

In this simulation, we calculate the ranking order of the alternatives for data application where 70% importance is given to the bandwidth using the SAW, MEW and TOPSIS algorithms. Table V presents the relative closeness to the ideal solution of TOPSIS and overall score of SAW and MEW. The results show that the ranking order of the alternatives is same for both algorithms TOPSIS and SAW. The ranking order of SAW and TOPSIS is **Network #3, Network #6, Network #5, Network #4, Network #2 and Network #1.**

The ranking order of MEW is **Network #3, Network #6, Network #5, Network #4, Network #1 and Network #2.**

Table V.

The Ranking Order of SAW, MEW and TOPSIS.

	SAW	**TOPSIS**	**MEW**
Network # 1 UMTS 1	0.1335 Rank#6	0.665 Rank#6	0.0945 Rank#5
Network #2 UMTS 2	0.3064 Rank#5	0.1858 Rank#5	0.0372 Rank#6
Network #3 WLAN 1	**0.8020 Rank#1**	**0.8206 Rank#1**	**0.7088 Rank#1**
Network #4 WLAN 2	0.3629 Rank#4	0.3116 Rank#4	0.3209 Rank#4
Network #5 WIMAX 1	0.5088 Rank#3	0.5175 Rank#3	0.4416 Rank#3
Network #6 WIMAX 2	0.6358 Rank#2	0.6384 Rank#2	0.5633 Rank#2

The ranking order of MEW is different from the ranking order of SAW and TOPSIS related to **Network #1** and **Network #2** because MEW (equation 4.13) penalizes the alternative having more poor attributes than the other alternatives.

Note that SAW, MEW and TOPSIS algorithms provide the same best alternative (**Network #3**) in this case. Similarly for voice application the best alternative is **Network#2.** For different traffic classes show the similar result according to their weights such as **Network #2** is best alternative for Conversational, Interactive and Background traffic and **Network #3** for Streaming traffic.

B. Simulation 2

In this simulation, we focus on the ranking abnormality problem. We here remove an alternative (e.g. **Network #1**) from the alternative candidate list. Table VI presents the relative closeness to the ideal solution of TOPSIS and the overall score of SAW and MEW.

Table VI.

The Ranking Order of SAW, MEW and TOPSIS.

	SAW	**TOPSIS**	**MEW**
Network # 1 UMTS 1	------	-----	-----
Network #2 UMTS 2	0.3064 Rank#5	0.1993 Rank#5	0.0372 Rank#5
Network #3 WLAN 1	**0.8020 Rank#1**	0.6091 Rank#2	**0.7088 Rank#1**
Network #4 WLAN 2	0.3629 Rank#4	0.3068 Rank#4	0.3209 Rank#4
Network #5 WIMAX 1	0.5088 Rank#3	0.5095 Rank#3	0.4416 Rank#3
Network #6 WIMAX 2	0.6358 Rank#2	**0.8288 Rank#1**	0.5633 Rank#2

In this simulation, the result show that a removal of an alternative causes a change in the ranking order of TOPSIS. The ranking order of SAW, MEW remains the same.

We continue removing an alternative (e.g. **Network #2**) from the alternative candidate list.

The result in Table VII show that the ranking order in SAW and TOPSIS has changed from **Network #6 to Network #3.**

In Table V, all algorithms determine that **Network #3** is the best interface since it has the best QoS attribute values and the cost is not very high. **Network #1** is the worst interface because it has the worst QoS and cost attribute values.

Table VII.

The Ranking Order of SAW, MEW and TOPSIS.

	SAW	**TOPSIS**	**MEW**
Network # 1 UMTS 1	------	-----	-----
Network #2 UMTS 2	------	-----	-----

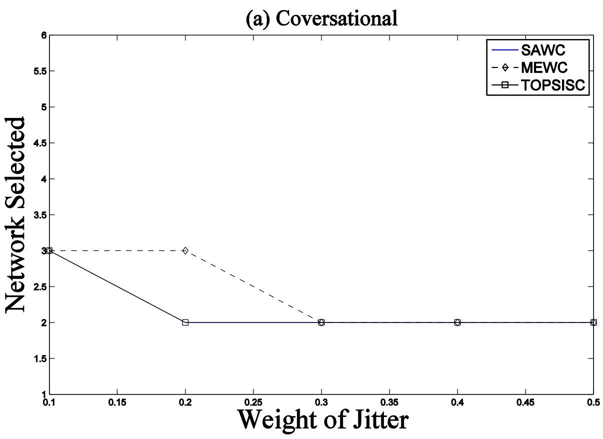
Network #3 WLAN 1	**0.9195 Rank#1**	**0.8505 Rank#1**	**0.878 Rank#1**
Network #4 WLAN 2	0.4464 Rank#4	0.1495 Rank#4	0.3975 Rank#4
Network #5 WIMAX 1	0.5720 Rank#3	0.3528 Rank#3	0.5469 Rank#3
Network #6 WIMAX 2	0.7335 Rank#2	0.5554 Rank#2	0.6977 Rank#2

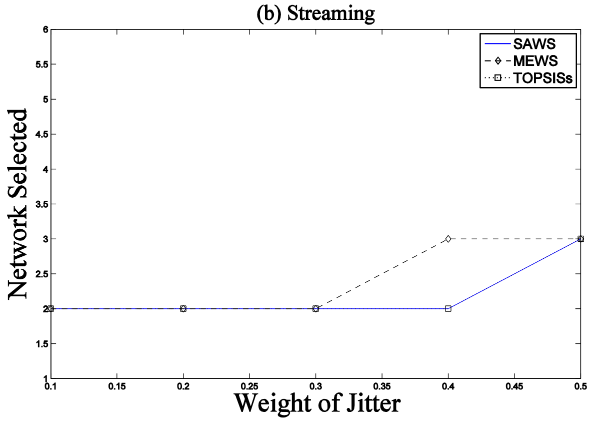
When we remove the worst interface out of the list, this does not influence the ranking order of other interfaces for SAW and MEW. However, the best interface in TOPSIS changes from **Network #3** to **Network #6** in Table VI. When another worst interface (**Network #2)** is removed, the best interface in TOPSIS also changes (Table VII)**.**

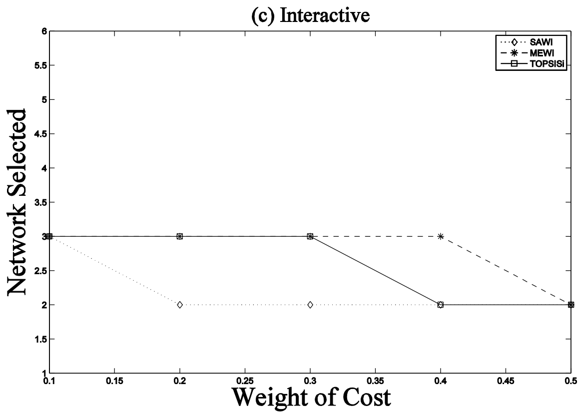
The simulation results highlight the ranking abnormality problem of TOPSIS and show that SAW and MEW provide a more effective behavior in every application and traffic class.

C. Simulation 3

In this simulation, we investigate the sensitivity of the assigned weights to the network selection. For conversational and streaming traffic classes, the weight of the jitter is varied from 0 to 0.5. The weights for other criteria are varied in proportion to the values specified in Table IV. For interactive and background traffic classes, the weights of cost is varied accordingly. Fig. 2(a) and (b) show that when the weight of the jitter increases, eventually all three algorithms select **Network #2**. Fig. 2(c) and 2(d) shows that when the weight of Cost increases, all three algorithms select **Network #2** which has the lowest cost value.







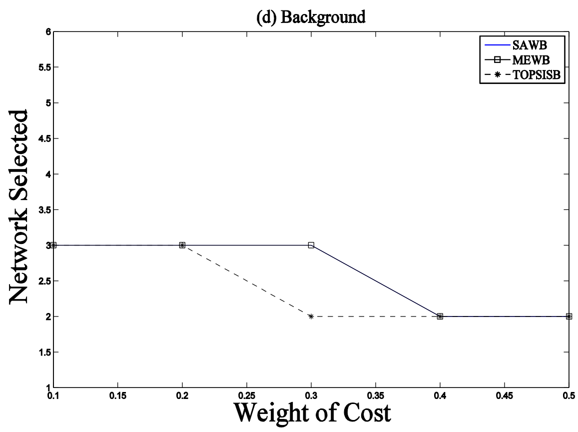


Fig. 2 Sensitivity Analysis

VI. CONCLUSIONS

In this paper, we presented the result for the performance comparison between three vertical handoff decision algorithms, namely, SAW (simple additive weighting), TOPSIS (technique for order preference by similarity to ideal solution) and MEW (multiplicative exponent weighting). Results show that SAW, MEW and TOPSIS provide similar performance to all applications and four traffic classes, with different importance. The simulation result showed that TOPSIS suffered from *Ranking Abnormalities*. Results also showed that all three algorithms depend on the importance weights assigned to parameters.

REFERENCES

[1] M. Kassar, B. Kervella, and G. Pujolle, “An overview of vertical handover decision strategies in heterogeneous wireless networks,” *Computer Communications*, vol. 31, pp. 2607-2620, June 2008.

[2] K. Yoon and C. Hwang, *Multiple Attribute Decision Making: An Introduction.* Sage Publications, 1995.

[3] W. Zhang, “Handover Decision Using Fuzzy MADM in Heterogeneous Networks,” in *Proc. of IEEE Wireless Communications and Networking Conf., WCNC’04,* Atlanta, USA, pp. 653-658.

[4] E. Stevens-Navarro and V. W.S. Wong, “Comparison between Vertical Handoff Decision Algorithms for Heterogeneous Wireless Networks,” in *Proc. of 63rd Conf. on Vehicular Technology, IEEE VTC’06-Spring*, Melbourne, Australia, pp. 947-951.

[5] J. Fu, J. Wu, J. Zhang, L. Ping, and Z. Li, “ Novel AHP and GRA Based Handover Decision Mechanism in Heterogeneous Wireless Networks”, in Proc. CICLing (2), pp. 213-220, 2010.

[6] A.Hasswa, N.Nasser and H.Hassanein, Generic Vertical Handoff Decision Function For Heterogeneous Wireless, Second IFIP International Conference on Wireless and Optical Communications Networks, 2005. WOCN 2005, pp. 239-243..

[7] R.Tawil, G.Pujolle and O.Salazar, A Vertical Handoff Decision Schemes In Heterogeneous Wireless Systems, Vehicular Technology Conference, 2008. VTC Spring 2008. IEEE , Singapore , pp. 2626-2630.

[8] R.Tawil, J.Demerjain, G.Pujolle And O.Salazar, Processing-Delay Reduction During The Vertical Handoff Decision In Heterogeneous Wireless System, : International Conference on Computer Systems and Applications, 2008. AICCSA 2008. IEEE/ACS 2008., pp.381-385.

[9] LIU yu, Ye Min-hue and ZHANG Hui-min, The Handoff Schemes in mobile IP, Vehicular Technology Conference, 2003. VTC 2003- Spring. The 57th IEEE Semiannual , pp. 485-489.

[10] R.Tawil, J.Demerjain and G.Pujolle, A Trusted Handoff Decision Scheme For The Next Generation Wireless Networks, IJCSNS, Vol.8, pp.174-182, June 2008.

[11] R.Tawil, G.Pujolle and O.Salazar, Vertical Handoff Decision Schemes For The Next Generation Wireless Networks, Wireless Communications and Networking Conference, 2008. WCNC.2008, pp. 2789-2792.

[12] R.Tawil, G.Pujolle and J.Demerjain, Distributed Handoff Decision Scheme Using MIH Function For The Fourth Generation Wireless Networks: 3rd International Conference on Information and Communication Technologies: From Theory to Applications, 2008. ICTTA 2008., pp.1-6.

[13] A.Dvir, R.Giladi, I.Kitroser and M.Segal, Efficient Decision Handoff Mechanism For Heterogeneous Networks, IJWMN, 2(2010)

[14] Lusheng Wang and David Binet, MADM- Based Network Selection In Heterogeneous Wireless Networks: A Simulation Study, 1st International Conference on Wireless Communication, Vehicular Technology, Information Theory and Aerospace & Electronic Systems Technology 2009. Wireless VITAE 2009, pp. 559-564.

[15] N.Nasser, A.Hasswa and H.Hassanein, Handoff In Fourth Generation Heterogeneous Networks, Communications Magazine, IEEE , 44(2006), pp. 96-103, doi:10.1109/MCOM.2006.1710420

[16] J.D Martinez- Morales, V.P.rico, E.Steven, Performance comparison between MADM algorithms for vertical handoff in 4G networks, 7th International Conference on Electrical Engineering Computing Science and Automatic Control (CCE), 2010 ,pp. 309-314.

[17] Rajiv Chechi, Dr.Rajesh Khanna, QoS Support in Wi-Fi, WiMAX & UMTS Technologies, International Journal of Electronics & Communication Technology, Issue 3, Sept. 2011, pp. 176-179.