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Application of MADM Algorithms to Network Selection

K.S.S.Anupama[1], Dr.S.Sri Gowri[2], Dr.B.PrabhakaraRao[3], P.Rajesh[4]

Associate Professor, Dept. of EIE, V.R.Siddhartha Engineering College, Vijayawada, Andhra Pradesh, India[1]

Professor and Head, Dept. of ECE, SRK Institute of Technology, Vijayawada, Andhra Pradesh, India[2]

Rector, JNTUK, Kakinada, Andhra Pradesh, India[3]

Assistant Professor, Dept. of EIE, V.R.Siddhartha Engineering College, Vijayawada, Andhra Pradesh, India[4]

Abstract: In heterogeneous wireless networks, vertical handoff plays a crucial role in providing seamless continuity to a multimode terminal user. Network selection is the key element in vertical handoff process. Several strategies have been proposed in literature to address the problem of network selection and multiple attribute decision making (MADM) methods have evolved as one of the most promising solutions. This paper compares the performance of three MADM methods, namely SAW (Simple Additive Weighting), WPM(Weighted Product Method) and PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluations) in network selection. The AHP (Analytic Hierarchy Process) method is used to assign weights to the criteria. Simulation results show that PROMETHEE provides more accurate network selection for conversational, interactive and background traffic classes. However the performance of SAW, WPM and PROMETHEE is found to be similar and inappropriate for streaming traffic class.

Keywords: Network Selection, SA, WPM, PROMETHEE, AHP.

I. INTRODUCTION

The next generation wireless networks (NGWN) is an amalgam of wireless technologies (WLAN, WPAN, WIMA etc.) and cellular networks (GPRS, UMTS, HSDPA, LTE, etc.). Each access technology involved in NGWN, differ in terms of bandwidth, data rate, transmission delay, coverage area range, operational costs and the mobility support capability. The goal of NGWN is to provide seamless service continuity and ubiquitous access for the end users, under the principle "Always Best Connected" (ABC) [1].

A subscriber equipped with a multimode terminal [MT] can utilize the heterogeneous services provided by these networks. For a satisfactory user experience, the MT must be able to seamlessly transfer to the ''best" network among all available networks with no perceivable interruption to an ongoing application. This important process in wireless networks is referred to as handoff or handover. Changing the connections between networks using different technologies is called vertical handoff. In contrast changing connections between networks using same technology is called horizontal handoff.

In the vertical handoff process, network selection is considered as a complex problem. Network selection is the process of identifying the optimal service delivery network when multiple networks are available to the MT in its vicinity. In homogenous networks, network selection decision strategy is based on received signal strength and network coverage. Whereas in heterogeneous wireless environment decision making is relatively complex because it depends on various factors such as cost, bandwidth, signal strength, mobile terminal properties, user preferences and application QOS requirements. When large number of factors are to be taken into consideration, network selection becomes an issue of Multiple Attribute Decision Making [2].

Various Multiple Attribute Decision Making (MADM) [3] methods have been proposed in the literature for network selection decision. MADM deals with evaluation of a set of alternatives using a set of attributes. Some of the most widely used MADM methods in network selection are Simple Additive Weighting (SAW), Multiplicative Exponential Weighting (MEW), Analytic Hierarchy Process (AHP), Grey Relational Analysis (GRA), and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and the Distance to the Ideal Alternative (DIA).

W. Zhang et.al [4] presented the first MADM-based network selection scheme for heterogeneous wireless networks. In this paper handover decision is identified as fuzzy MADM problem. The classical MADM techniques SAW and TOPSIS were used to determine the ranking order of the networks, and the highest-ranking network is selected for handoff.

F.Bari et.al [5] proposed an iterative approach of application of TOPSIS, for improving the results of network selection, by comparing only the more likely candidates in the process.

L.Wang et.al [6] introduced a four-step integrated strategy for MADM based network selection. It addresses the issues of efficient weights, mobility related factors, network load balancing and tradeoff in handing off to a new network.
S.J.Yang et.al [7] proposed two processes for handoff decision: to rate attributes and to select candidate networks. The WRMA (Weighted Rating of Multiple Attributes) is

used to perform the first process of assigning weights to the attributes via five simple steps. TOPSIS is applied for executing the second process of network selecting or ranking.

M.Lahby et.al [8] proposed an enhanced vertical handover decision technique which combines two (MADM) methods, the Analytic Network Process (ANP) and the Enhanced Technique for Order Preference by Similarity to an Ideal Solution (E-TOPSIS). The ANP method is applied to weigh the criteria and the E-TOPSIS method is used to rank the alternatives. This paper compares the performance of SAW,WPM and PROMETHEE MADM methods for network selection in heterogeneous wireless environment during vertical handoff process.

II. MULTIPLE ATTRIBUTE DECISION MAKING METHODS

2.1.SAW

Simple Additive Weighting (SAW) [3] also known as scoring method is one of the best and simplest type of multiple attribute decision making method.

Let A = ($a_1, a_2, ..., a_n$) be a set on alternatives

G= ($g_1, g_2, ...g_n$) be a set of q criteria.

The step wise procedure is given below

Step 1: Construct the decision matrix

$$\begin{matrix} d11 & d12 \ldots\ldots\ldots & d1n \\ d21 & d22 \ldots\ldots\ldots & d2n \\ dn1 & dn2 \ldots\ldots\ldots & dnn \end{matrix}$$

Where d_{ij} is the rating of alternative A_i with respect to criterion G_i.

Step 2: Construct the normalized decision matrix.

For beneficial attribute the normalized value is

$$rij = \frac{dij}{dij^{max}} \quad (1)$$

For non beneficial attribute the normalized value is

$$rij = \frac{dij^{min}}{dij} \quad (2)$$

Step 3: Construct weighted normalized decision matrix

$$vij = Wi \times rij \quad (3)$$

where $\sum_{i=1}^{n} Wi = 1$

Step 4: Calculate the score of each alternative

$$Si = \sum_{j=1}^{m} vij \quad (4)$$

where i=1,2,......,n

Step 5: Select the best alternative

$$BAsaw = max_{i=1}^{n} Si \quad (5)$$

2.2 WPM

Weighted Product Method (WPM)[3] is another scoring method where the weighted product of the criterion is used to select the best alternative. The score computing procedure in terms of Step1 and 2 are identical to SAW approach.

Step 3: Construct weighted normalized decision matrix

$$vij = rij^{wij} \quad (6)$$

Step 4: Calculate the score of each alternative

$$Mi = \Pi_{j=1}^{m} vij \quad (7)$$

Step 5: Select the best alternative

$$BAwpm = max_{i=1}^{n} Mi \quad (8)$$

2.3.PROMETHEE

Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) developed by Brans et. al[9] is a outranking method quite simple in conception and application compared to other MADM methods for multi criteria analysis.

Step 1: Determine deviations based on pair-wise comparisons

$$d_k(a_i, a_j) = g_k(a_i) - g_k(a_j) \quad (9)$$

Where d_k (a_i, a_j) denotes the difference between an alternative a_i and an alternative a_j according to criterion k.

Step 2: Apply preference function

$$P_k(a_i, a_j) = F[\, g_k(a_i) - g_k(a_j)] \quad (10)$$

For each criterion, the preference function translates the difference between the evaluations obtained by two alternatives into a preference degree ranging from zero to one. Six types of preference functions: (1) usual criterion, (2) U-shape criterion, (3) V-shape criterion, (4) level criterion, (5) Linear criterion and (6) Gaussian criterion are available, to cover most of the cases in practical applications.

Step 3: Calculate global preference index

$$\pi(a_i, a_j) = \sum_{k=1}^{q} P_k(a_i, a_j) w_k \quad (11)$$

Where w_k is the weight associated with criterion k .

Step 4: Calculate outranking flows

$$\Phi^{+}(a_i) = \frac{1}{n-1} \sum_{aj \in A} \pi(a_i, a_j) \quad (12)$$

$$\Phi^{-}(a_i) = \frac{1}{n-1} \sum_{aj \in A} \pi(a_j, a_i) \quad (13)$$

Where $\Phi^{+}(a_i)$ and $\Phi^{-}(a_i)$ denote positive outranking flow and negative outranking flow for each alternative, respectively.

Step 5: Calculate net outranking flow

$$\Phi(a_i) = \Phi^{+}(a_i) - \Phi^{-}(a_i) \quad (14)$$

The alternatives are ranked from best to worst based on their net outranking flows and the alternative with highest outranking flow is selected as the best alternative.

2.4.AHP

Analytic Hierarchy Process (AHP) is a structured MADM technique to analyze the complex decision using pairwise comparisons and determine weights of each criterion. The AHP approach [10] for weight assignment is given below.

Step1: Construct a pair-wise comparison matrix using a scale of relative importance.

Step2:Find the relative normalized weight of each criterion

$$W_i = \frac{GM_i}{\sum_{i=1}^{M} GM_i} \quad (15)$$

where GM_i is the geometric mean of the i^{th} row.

Step3: Calculate matrix A3 and A4 such that A3=A1/A2 and A4=A3/A2 where A2= $[W1, W2\ldots\ldots WM]^T$.

Step4: Find out the maximum Eigen value λmax (i.e. the average of matrix A4).

Step5: Calculate the consistency index

$$CI = \frac{\lambda_{max} - M}{M-1} \quad (16)$$

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Step6: Calculate the consistency ratio

$$CR = \frac{CI}{RI} \quad (17)$$

where RI is the random index for the number of criteria used in decision making. CR value should be less than 0.1 for good consistency.

III. SIMULATIONS AND RESULTS

Consider network selection in a heterogeneous wireless environment that comprises a WiMAX network, WiFi network and two UMTS networks (UMTS1, UMTS2**). T**he multimode terminal user is located in an area covered by WiFi access point, WiMAX and UMTS base stations.

When the connection from the current network is becoming weak or if strong signals are being received from the available networks, the multi-mode terminal will make a decision to change its connection to the most suitable network. In this paper, the target network is selected depending on the application QoS requirements of the current traffic class i.e. allowed bandwidth (AB), packet delay (D), packet jitter (J), network utilization (U) and packet loss (L) and also cost per byte (CB) of the available networks. Table I provides a snapshot of criterion values for the four networks at the time of decision on network selection.

TABLE I. NETWORK CRITERION VALUES

	CB(usd)	AB(mbps)	D(ms)	J(ms)	U(%)	L(per 10^6)
UMTS1	50	2	35	6	60	35
UMTS2	50	0.5	70	8.0	25	55
Wifi	4	5	120	12	80	28
Wimax	33	13	90	7	90	40

Four traffic classes [11] namely Background, Conversational, Interactive and Streaming are supported in heterogeneous environment. The four traffic classes have different QoS requirements. For example, Background traffic is highly sensitive to delay but requires low bandwidth so available bandwidth of a network is not an issue. Conversational traffic is very sensitive to delay and jitter. It is a low bandwidth application and can withstand some packet loss.

Interactive traffic is also low bandwidth application but highly loss sensitive. For streaming traffic, available bandwidth, transport cost, and current utilization are important factors. It is less sensitive to delay and jitter. Determining the most suitable weights for different criteria by considering each traffic class is one of the main problems in the network selection.

In this paper the AHP method is used to assign weights to each criterion. Table II provides the weights of each criterion, for all traffic classes, computed by AHP procedure using equations (15) to (17).

TABLE II. WEIGHTS ASSOCIATED WITH THE CRITERIA FOR THE FOUR TRAFFIC CLASSES

Traffic Class	CB	AB	D	J	U	L
Background	0.3204	0.4254	0.0448	0.0141	0.0891	0.1063
Conversational	0.2825	0.2051	0.2751	0.1249	0.0654	0.047
Interactive	0.1098	0.5953	0.1003	0.0144	0.0943	0.086
Streaming	0.0512	0.7911	0.0629	0.0397	0.0356	0.0195

The score values and net outranking flows computed by SAW,WPM and PROMETHEE algorithms, for conversational traffic is shown in Table III.

TABLE III. WEIGHTS ASSOCIATED WITH THE CRITERIA FOR THE FOUR TRAFFIC CLASS

	SAW		WPM		PROMETHEE	
	S_i	Rank	M_i	Rank	Φ (a_i)	Rank
UMT S1	0.5009	3	0.3118	3	1.7794	1
UMT S2	0.3750	4	0.1938	4	-0.6072	3
Wifi	0.5714	1	0.4977	1	-1.0928	4
Wima x	0.5044	2	0.3768	2	-0.0794	2

The ranking of the networks for the four traffic classes is shown in Table IV. Network ranked '1' is selected as best network for handoff.

TABLE IV. NETWORK RANKINGS

	Background			Conversational			Interactive			Streaming		
	P	S	W	P	S	W	P	S	W	P	S	W
UMTS1	2	3	3	1	3	3	1	3	3	1	3	3
UMTS2	4	4	4	3	4	4	4	4	4	4	4	4
Wifi	1	1	1	4	1	1	2	2	2	3	2	2
Wimax	3	2	2	2	2	2	3	1	1	2	1	1

P-PROMETHEE;S-SAW;W-WPM

The rankings of SAW and WPM are identical for all traffic classes, but they differ from PROMETHEE for conversational, interactive and streaming traffic classes. For conversational traffic, delay and jitter are the crucial parameters. Low values of delay and jitter are required to provide good QoS. Among all the available networks UMTS1has low values of delay and jitter. So in this aspect PROMETHEE selection is more accurate, because it selected UMTS1as best network for handoff. SAW and WPM methods selected WiFi network, which is not preferable for conversational traffic. The networks selected for conversational traffic class is depicted in Fig1.

Interactive traffic class is very sensitive to packet loss. Neither PROMETHEE or SAW or WPM selected WiFi network whose packet loss performance is low. However PROMETHEE selected UMTS1 network whose packet loss values are low and near to WiFi network. For streaming traffic, none of the MADM methods selected suitable network for handoff.

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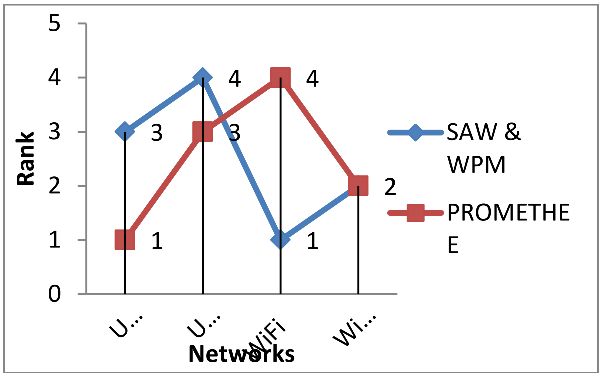

Fig.1 NETWORK RANKING FOR CONVERSATIONAL TRAFFIC

For background class the rankings of SAW,WPM and PROMETHEE are identical and UMTS1 network with low delay values is selected as best network, which is the most appropriate decision under the given operating conditions.

IV. CONCLUSION

Network selection during vertical handoff process, considering multiple criteria is a complex issue. In this paper a comparison is drawn between SAW, WPM, PROMETHEE MADM techniques for selecting an optimal network for handoff. AHP is applied for weighting the criteria. Four traffic classes with different QoS profiles are included to illustrate the method. Simulation results shows that, neither scoring nor outranking method is absolutely suitable for selecting the best network, that satisfies the QoS requirements of all traffic classes. However performance of PROMETHEE is found to be more accurate than SAW and WPM for conversational, interactive and background traffic classes. For further research performance comparison of PROMETHEE with other outranking MADM methods for network selection during vertical handoff will be considered.

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