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VIKOR MADM Based Optimization Method For Vertical Handover In Heterogeneous Networks

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Abstract: Optimum network selection is one of the major issues for vertical handover in heterogeneous networks so as to provide requisite quality of service (QoS) to the user. In this context, multiple attribute decision making algorithms provide promising solution. Normalization process used can play a vital role for selecting the most appropriate network during handover process. In this work, vector normalized preferred performance based (V-VPP) normalization technique is proposed and applied to multiple attributes decision making (MADM) based VlseKriterijuska Optimizacija I Komoromisno Resenje (VIKOR) algorithm. Performance of the proposed technique is analyzed extensively by varying QoS parameters and weighting methods for different traffic classes in a heterogeneous network. The results obtained are compared with the available MAX, MAX-MIN and Vector normalization. Proposed method is also compared with the popular MADM algorithms. Performance of proposed method is quite optimistic in terms of lesser number of handovers, ranking abnormality, selection of appropriate network though with slight increase in handover latency in comparison to the available normalization methods.

Keywords: QoS, MADM, V-VPP, VIKOR, Vertical Handover, Ranking Abnormality

1. INTRODUCTION

In the era of beyond next generation wireless mobile networks, different cellular technologies and wireless standards such as UMTS, cdma2000, WLAN, LTE and WiMAX shall coexist. Efforts are being made to integrate all these technologies in the form of heterogeneous network rather than developing a new technology. Mobile terminals will be equipped with several interfaces to have ubiquitous and seamless access to these technologies under the principle of “Always Best connected” [1]. Accordingly, different networks need to be integrated in an optimum manner with the ultimate objective to provide end-user with the requisite QoS. To coordinate between different types of technologies effectively and seamlessly, with desired quality of service to the user, is a big challenge. To address the same, vertical handover (VHO) is being suggested by the researchers. It is a process which decides handing over the mobile node to the most appropriate network among different types of available networks [2]. Vertical handover is broadly executed in three phases- (i) System discovery (ii) Handover decision, and (iii) Handover execution. In system discovery phase, a mobile terminal equipped with multiple interfaces has to discover the available networks and services offered by them. The handover decision phase aims at determining the optimal access network among those available. During handover execution, connections with the current network are needed to be rerouted to the selected network in a seamless manner. Handover decision is the most critical phase, as selection of the optimal network includes dealing with large number of quality of service parameters offered by individual networks like available bandwidth, delay, jitter, cost, velocity and security. Traditional decision making algorithms based on received signal strength (RSS) cannot deal with the multi-criterion based network selection, as desired in vertical handover.

Several approaches based on genetic algorithms, fuzzy logic, utility function and multiple attribute decision making (MADM) have been suggested in literature to provide seamless connectivity during vertical handover in heterogeneous networks [3-10]. Vertical handover needs to select a network with largest coverage area for maintaining an on-going call or data session so as to reduce number of handovers. In addition, it should deliver even if the mobile station is moving at a high velocity, which tends to deteriorate the performance of the algorithm by increasing unnecessary handovers. Further, handover latency and optimum network selection are also crucial parameters for the design of an efficient handover technique. Wireless Networks such as UMTS, WLAN and WIMAX were typically developed for specific applications. UMTS networks are basically meant for voice communication and offer lesser amount of delay and jitter within limited bandwidth availability. On the other hand, WLANs provides larger bandwidth to the end user thereby making them more suitable for data connections but suffers from higher delay. WIMAX networks that are developed to provide broadband wireless access to users, offer slightly higher delay than UMTS but provide highest bandwidth as compared to other networks. Going by the nature of user application and requirements, the network selection during vertical handover becomes a multiple attribute decision making problem, for which the available MADM techniques can offer a promising solution. The salient technical parameters of three networks are shown in Table 3.

MADM method utilizes normalization process and weighting method at different stages of decision making. Normalization methods are used for scaling diverse network attributes given in different units of measure in the range from 0 to 1. Weighting methods are used to assign priority weights to various attributes as per the service demanded by user. Normalization methods can be broadly classified into i) performance based normalization methods, and ii) distance based normalization methods. In the former method, performance ratings of all the network attributes is taken into account and do not include user's preference in the normalization process. Max, SUM and Vector methods [12] come under this category. Distance based normalization utilizes the distance between the performance value of the network attribute and appropriate reference point. Max-Min normalization is a distance based normalization method. User's preferences can be incorporated in distance based normalization process to improve the performance of MADM method for optimum network selection.

Among the available weighing methods, Analytic Hierarchy Process (AHP) and Analytic Network process (ANP) are popular weighting methods used for assigning priority weights to different attributes of a network. The hierarchical structure of AHP weighting method assumes independence among all attributes at the same or different hierarchy level, and it does not consider the interdependence among attributes at various levels. ANP has been developed for problems which involves inter-dependence (within same level) as well as outer- dependence (between different levels) among attributes. Fig.1 shows the hierarchical structure of AHP and ANP. Owing to the interdependence of various attributes in vertical handover, ANP weighting method is more suitable for network selection.

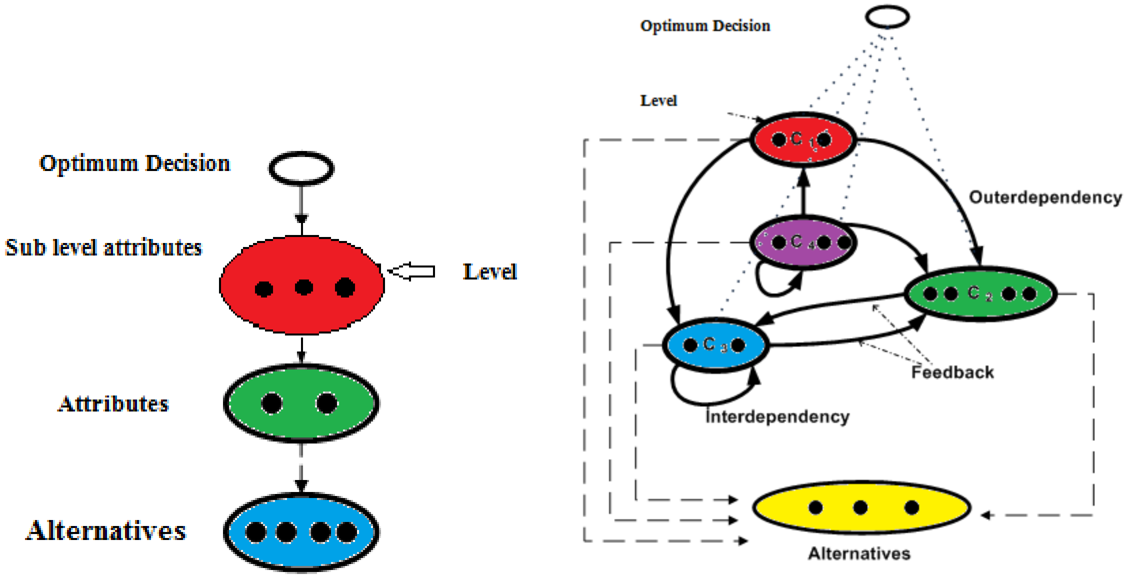

Fig. 1. Structure of AHP and ANP [13]

Based on different normalization techniques, many VHO strategies have been suggested such as SAW, MEW, TOPSIS, GRA and ELECTRE by employing Max, Sum, Vector and Max-Min normalizations. Performance of these algorithms can be evaluated on the basis of number of handovers, latency, optimum network selection and ranking abnormality. Ranking abnormality refers to change in the ranking of selected network if the worst network is removed from the candidate networks. Handover latency refers to the time taken by the decision making algorithm to suggest an alternative network from those available for service continuation. Network selection is considered as optimum if it also takes into account QoS requirements of user along with the received signal strength offered by available networks. Conventional MADM based handover techniques suffer from large number of handovers and ranking abnormality [13]. In this work, to address these issues, we are proposing a Vector normalized preferred performance based normalization (V-VPP) technique that incorporates user's preference with the purpose of selecting most appropriate network, reducing number of handovers and ranking abnormality.

Rest of the paper is organized as follows: Following section presents the work done by various researchers in this area so as to appreciate and appraise their contributions made in this upcoming field, section 3 provide motivation behind the work with section 4 presents procedural details of conventional VIKOR method. Section5 differentiate the process of proposed V-VPP algorithm with respect to conventional VIKOR method. Section 6 describes the simulation set up used and compares the performance analysis with present. Section 7 provides results of simulation and section 8 conclude the work with final remarks.

2. RELATED WORK

Multi criteria nature of vertical handover decision and ability of MADM methods to deal with large number of conflicting criterion reciprocate each other. Traditionally, MADM techniques have been used in the field of manufacturing, construction, financial management, supply chain management, human resource management, and health care [14]. However, in recent times these techniques have been explored for optimum network selection in heterogeneous environment as well. Many MADM methods such as Simple additive weighting (SAW)[6], Multiplicative exponent weighting (MEW)[6], Technique for order preference by similarity to ideal solution (TOPSIS)[6], VIKOR[10,11], Grey relation analysis (GRA)[6], Elimination and choice translating priority (ELECTRE)[7], AHP [8], and ANP [4] have been proposed for ranking of networks participating in the vertical handover process. AHP and ANP methods are typically used for weight assignments of network attributes.

SAW employs MAX normalization method while TOPSIS is based upon vector normalization process. MAX-MIN normalization method is employed by VIKOR and GRA algorithms. Effect of various normalization methods applied with VIKOR algorithm was analyzed in [15]. Improved performance in terms of number of handovers and ranking abnormality was observed with Euclidean distance based vector normalization. Weighting methods also play a significant role to improve the performance of decision making algorithms. Effectiveness of various weighting methods as analyzed in [16] indicates that ANP based weighing method results in reduced ranking abnormality. Similar conclusions were drawn in the work available in [17], where VIKOR method was used as the baseline algorithm with ANP method. A comparative analysis of seven MADM based algorithms for network selection by Martinez et al. In [18], it was indicated that SAW, VIKOR and TOPSIS are more suitable methods for voice application, as these resulted in the selection of UMTS and WIMAX networks which offer lower packet delay and jitter. Similarly, for data connections as well, the SAW, MEW, TOPSIS and VIKOR were able to select the most appropriate network like WLAN and WIMAX, which offer higher bandwidths. However, the work did not consider number of handovers and ranking abnormalities.

MADM methods provides network selection index which is used to rank the available alternatives for the purpose of decision making. Variation in the rank of any alternative with respect to change in the priority weight of an attribute is termed as sensitivity. Sensitivity analysis of an algorithm adjudges the most sensitive network attribute- the least change in the value of which can change the overall ranking of available alternatives [19]. U. Kumaran et al. [20] performed sensitivity analysis of SAW, MEW and TOPSIS and found these to be quite sensitive to the variation in attribute weights.

Traditional MADM methods are applicable for the situations where attributes weights are definite or can be determined by user’s preferences. To deal with other situations, Tao Ding et.al [21] proposed cross-evaluation based MADM method, which results in weight independent ranking of available attributes. The method is further extended for the situations where magnitude of attributes is not defined. An exponential fuzzy numbers based method was proposed by Fu et al. [22] to deal with the situation when both the attribute value and attribute weight are exponential fuzzy numbers. Their scheme calculated expected value, variance and altitude of exponential fuzzy numbers and determined the score function in accordance with user’s preference. The effectiveness of the scheme is verified on the basis of distance between exponential fuzzy numbers and positive negative ideal solution. Chandavarkar et al. [23] suggested a Simplified and Improved Multiple Attributes Alternate Ranking method (SI-MAAR) with improved results.

MADM based methods tends to address the issue of unnecessary handovers and ranking abnormality. However, these two parameters are not sufficient to describe the appropriateness of a network for a particular application or as per the service demanded by user. Moreover, the impact of varying number of network attributes has also not been considered in the available works. The vertical handover decision should be capable of handling large number of QoS parameters and user preferences for optimum network selection. The handover latency also needs consideration for fast switching over. Traditional distance based normalization techniques do not include user’s preference into account. In this work, a new preferred performance based normalization technique is proposed to be used with the baseline VIKOR algorithm by varying normalization techniques for vertical handover in heterogeneous scenario. VIKOR method is used as it provides compromise ranking list for selection of alternatives in the presence of conflicting criteria, thus making it suitable method for network selection in heterogeneous environment. Basically, it is aimed to suggest an algorithm with i) Linear ranking of available networks and iii) Optimum network selection based on preferred performance

3. CONVENTIONAL VIKOR METHOD

A brief overview of VIKOR is given in this section as a ready reference for the work. The VIKOR method is based on distance based normalization process, which does not include user's preference. The step by step procedure for the conventional VIKOR method [24] as used for network selection here is given below:

i. Construction of decision matrix: This step involves construction of a decision matrix, $D = [a_{ij}]_{mxn}$, of attribute values offered by the available networks. Here $i = 1,2,..,m$ represents the candidate networks (alternatives) participating in the decision and $j = 1,2,..,n$ represents network attribute.

$$D=\begin{bmatrix} a_{ij} & \cdots & a_{in} \\ \vdots & \ddots & \vdots \\ a_{mj} & \cdots & a_{mn} \end{bmatrix} \quad (1)$$

ii. Selection of highest and lowest attribute value: The values of various network attributes available in the decision matrix are inspected, among all the alternatives, to get the best and worst values of an attribute for the aggregation process that is next following, as-

$f_j^* = Max\, a_{ij}$ and $f_j^- = Min\, a_{ij}$

iii. Aggregation: Depending upon the type of an attribute, it can be termed as a benefit or cost attribute. For example, since it is desired that the bandwidth of a network should be maximum so it is termed as a benefit attribute, while delay comes under the cost attribute. For benefit attributes, positive and negative ideal solutions indicate the maximum and minimum value of that attribute among the alternative networks, and vice-versa for the cost attributes. Depending upon the type of traffic class or application, every attribute of a network is assigned a weight $(0 < w_j < 1)$ indicative of its priority for that application. The weights of the attributes can be calculated by any of the available weighting schemes such as AHP or ANP, as explained above.

Aggregation process provides a ranking index for every network(S_i). It is aggregation of all attributes and their relative importance. Basically, it is sum of weighted normalizations (Max- Min) of all attributes in a particular network.

$$S_i = \sum_j^n w_j(f_j^* - a_{ij})/(f_j^* - f_j^-), \quad (2)$$

Further, the maximum value of the weighted normalization of all attributes in a network is taken as another boundary measure to find distance rate from non acceptable solution and is termed as R_i.

$$R_i = Max_j\,[w_j\,(f_j^* - a_{ij})/\,(f_j^* - f_j^-)], \quad (3)$$

Thus, S_i represents a measure of group utility where as R_i represents individual regret for an alternative.

iv. Determination of network selection index Q_i : For each alternative, network selection index is calculated as

$$Q_i = v(S_i - S^*)/\,(S^- - S^*) + (1 - v)(R_i - R^*)/(R^- - R^*) \quad (4)$$

where $S^* = Min\, S_i$, $S^- = Max\, S_i$, $R^* = Min\, R_i$, $R^- = Max\, R_i$. The solution obtained by $Min\,(S_i)$ represents measure of maximum group utility and $Min\,(R_i)$ is minimum individual regret among all alternatives. The parameter υ is the weighting reference with $0 \le v \le 1$, and represents the weight of the strategy of criteria used; majority rule with $v > 0.5$, as consensus with $v \approx 0.5$ and as vito with $v < 0.5$. In this work, $v = 0.5$ has been used.

v. Ranking of the alternatives: Sort the available networks in decreasing order of their values in three lists generated as Q_i, S_i and R_i. It will provide three different sets of ranking list. The selected network can be either one or set of networks. The selected network is obtained by $Q = Min\,(Q_i)$ if it satisfies following two conditions:

a) If $Q_i'' - Q_i' \ge DQ$ with $DQ = 1/(|M| - 1)$
Here i'' and i' are alternatives with second smallest and smallest value of Q. This condition is termed as condition of *Acceptable advantage*.

b) If the selected alternative is also the best alternative for S_i and R_i. The condition is termed as *Acceptable stability in decision making.*

If only one of these conditions is satisfied, VIKOR method suggests set of *compromising solutions* given by:

- If condition (a) is not satisfied, the solution will contains all the alternatives $i', i'', \ldots, i^{|M|}$ as long as $Q_{i^{|M|}} - Q_{i'} < DQ$
- If condition (b) is not fulfilled, then the set is compromise of $Q_{i'}$ and $Q_{i''}$.

vi. The selected network A^*_{VIK} is

$$A^*_{VIK} = \arg Min\, Q_i \quad (5)$$

4. PROPOSED VECTOR NORMALIZED PREFERRED PERFORMANCE BASED NORMALIZATION (V-VPP) METHOD

The traditional VIKOR method suffers from the limitation that at any stage of implementation if the two attributes become equal, the method will lead to undefined value of parameters at different steps and the procedure will be stopped at that point. This is due to the fact that while calculating different measures for alternatives, denominator term is using a subtraction term (eq 3). Chia-Ling Chang [25] worked on this drawback of VIKOR method and suggested modifications which can be applied in that particular step where undefined value appears in calculation. But, these modifications do not avoid the undefined terms prior to their occurrence. In this work, the main focus is to modify the process of normalization in aggregation and ranking of network alternatives such as to avoid the subtraction term in the denominator. Moreover, in conventional method, user's preference was not included during normalization process. The proposed method also incorporates user's preferences in the normalization phase as an additional advantage.

The step by step procedure of the proposed V-VPP method is shown in Fig. 1. All the available attributes are normalized in the range of 0 to 1 prior to application to step 3 in conventional VIKOR method. The normalized value of a network attribute in conventional method is replaced by proposed method as-

Step 1: *Get user's preference ap_j for all the attributes considered for decision making*: These values can be greater than, equal to or less than the different attribute values of available alternatives.

Step 2: *Perform preferred performance based vector normalization*: For each alternative, determine preferred performance based vector normalized values for all the attributes as given by

$$\gamma_i = \left|ap_j - a_{ij}\right| / \sqrt{\textstyle\sum_{i=1}^{m} aij^2} \quad (6)$$

Step 3: *Determine Modified aggregation function* Sv_i : The aggregation function given in step 3 of conventional VIKOR method is modified as

$$S_{vi} = \sum_j^n w_j * \gamma_i \quad (7)$$

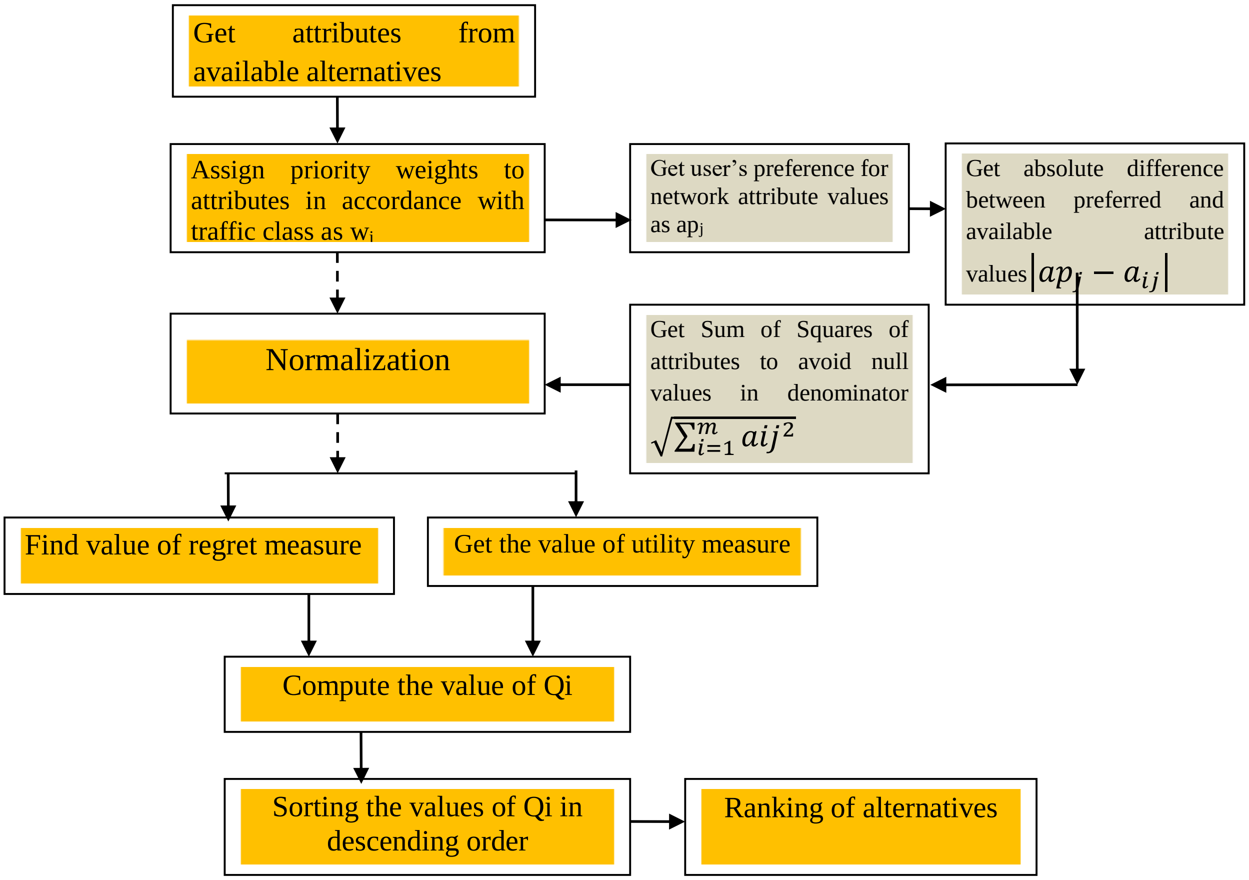

Fig.2: Block diagram of Proposed V-VPP method

Where w_j represents priority weight of individual attribute assigned by user. This aggregating function helps to determine acceptable solution among available alternatives for decision making. The weighted normalized values of all the attributes are given by

$$S_{vt} = w_j * \gamma_i \quad (8)$$

Step 4: *Determine maximum regret attribute value for each alternative*: It is the maximum value of attributes of individual alternative after weighted normalization. Distance based normalization of VIKOR method results in minimization of desired attributes and the attribute having maximum value after normalization is referred to as regret attribute for that alternative. These values as determined from weighted normalized values of all the attributes are given by

$$Rv_i = Max_j [w_j * \gamma_i], \quad (9)$$

Step 5: *Find boundary values for acceptable and non acceptable solution*: Boundary values for acceptable and non acceptable solution are determined from S_{vi} *and* R_{vi} and given by

$$S^* = Min\, S_{vi}, \quad S^- = Max\, S_{vi}, \quad and \;\; R^* = Min\, R_{vi}, \quad R^- = Max\, R_{vi}$$

Step 6: *Assign priority weights to sets of acceptable and non acceptable solutions and aggregate*: The aggregating function or network selection index is similar to the conventional VIKOR method and is given by

$$Q_{vi} = v(Sv_i - S^*)/\,(S^- - S^*) + (1-v)(Rv_i - R^*)/(R^- - R^*) \qquad (10)$$

Here v is strategy weight and is decided by user. It represents the user's approach to reach to the desired solution and can be determined either by consensus ($v \approx 0.5$)or majority $v > 0.5$ or veto ($v < 0.5$). If equal consideration is given to acceptable and non acceptable solutions then the approach is termed as by consensus. The final solution is obtained in a similar manner as that of conventional VIKOR method.

Fig.2 presents the various steps involved in proposed V-VPP method. The method is further explained with the help of a case example by considering four attributes available from three wireless networks UMTS, WLAN and WIMAX. Table 1 provides attribute values of delay, jitter, bandwidth and cost available from these three networks as constituents of decision matrix. Values of these attributes are taken from [18]. w_j represents priority weights assigned to different attributes in accordance with user's preference for conversational traffic [26], as considered in this example. For conversational traffic, delay and jitter are of prime importance so UMTS will be the appropriate network due to lesser values of these attributes.

Table 1: Constituents of decision matrix containing attribute values of different alternative

Alternatives/ Attributes	Delay(ms)	Jitter(ms)	Bandwidth(MHz)	Cost (%)
UMTS	30	12	1	0.6
WLAN	80	15	11	0.1
WIMAX	50	10	54	0.5

Priority weights for different attributes in conversational traffic class are taken as

$$w_j = [0.3162 \;\; 0.3456 \;\; 0.1265 \;\; 0.2107]$$

Preferred values of different attributes as provided by the user are:

$$ap_j = [40 \;\; 11 \;\; 3 \;\; 0.3]$$

Preferred performance based vector normalized matrix is given by:

$$\gamma_j^* = \begin{matrix} \\ UMTS \\ WLAN \\ WIMAX \end{matrix} \begin{bmatrix} Delay & Jitter & B.W & Cost \\ 0.1010 & 0.0462 & 0.0363 & 0.3810 \\ 0.4041 & 0.1847 & 0.1451 & 0.2540 \\ 0.1010 & 0.0462 & 0.9253 & 0.2540 \end{bmatrix}$$

Weighted normalized matrix of all attributes is calculated as:

$$S_{vti} = \begin{bmatrix} 0.0319 & 0.0160 & 0.0046 & 0.0803 \\ 0.1278 & 0.0638 & 0.0184 & 0.0535 \\ 0.0319 & 0.0160 & 0.1170 & 0.0535 \end{bmatrix}$$

$$\text{Aggregation matrix } S_{vi} = \begin{bmatrix} 0.1328 \\ 0.2635 \\ 0.2185 \end{bmatrix}$$

Regret attribute matrix of 3 alternatives is determined as

$$R_{vi} = Max\, S_{vti} = \begin{bmatrix} 0.0803 \\ 0.1278 \\ 0.1170 \end{bmatrix}$$

Network selection Index for each alternative is given by

$$Q_i = \begin{matrix} UMTS \\ WLAN \\ WIMAX \end{matrix} \begin{bmatrix} 0 \\ 1 \\ 0.7149 \end{bmatrix}$$

It shows that for given set of preferred values UMTS is the most suitable network among the available alternatives. Table 2 provides ranking lists of the proposed V-VPP method along with popular TOPSIS method for comparison. As UMTS is selected by three ranking lists of V-VPP method, it is compromised solution among available alternatives. Moreover UMTS is ideal network for conversational traffic thus network selection is optimum in this regard also. TOPSIS method selects WIMAX as suitable network followed by UMTS and WLAN as indicated in Table 2. As this method does not include user's preference for attribute values, network selection is solely dependent upon priority weights assigned by user.

Table 2: Ranking lists generated by V-VPP and TOPSIS

Alternatives	Ranking List			
	V-VPP			TOPSIS
	Si	Ri	Qi	C
UMTS	**0.1328**	**0.0803**	**0**	0.4759
WLAN	0.2635	0.1278	1	0.3996
WIMAX	0.2185	0.1170	0.7149	**0.5857**

Inclusion of user's preference in V-VPP during normalization results in different ranking list of available alternatives. Thus to justify the effectiveness of proposed method, Euclidean distance between and Preferred set of attribute values and alternative selected by two methods is calculated and is given by

$$EU_{V-VPP} = 10.251 \; and \; EU_{TOPSIS} = 51.98$$

It can be concluded that network selection by V-VPP method is closed to user's preference for the given attributes. Moreover, difference between selection indexes of top ranked networks in V-VPP is greater than TOPSIS (0.7149 in case of V-VPP and 0.1098 in case of TOPSIS). So, it will be easier to select the suitable alternative among available ones with the help of proposed method.

From the case study presented above, it is observed that proposed V-VPP method offers following advantages over conventional TOPSIS and VIKOR methods:

- Avoids undefined values at any step occurred by '0' in difference term in denominator
- Includes user's preference at early stage of decision making i.e. normalization
- Maintains adequate gap between two top ranked alternatives/ networks so that clear decision can be taken by user.
- Benefit attributes can be given majority in the decision by varying the value of strategy weight v.

Provision of compromised ranking if two alternatives have equal values for selection index.

5. SIMULATION SET-UP AND PERFORMANCE PARAMETERS

For performance analysis, three networks WLAN, WiMAX and UMTS are considered here to simulate heterogeneous environment with different attributes such as cost, delay, jitter, packet loss, security, throughput, velocity, RSS, and Traffic load. The values of these attributes vary randomly in the range given in Table 3. The various traffic classes considered are conversational, streaming, interactive and background. AHP and ANP methods have been used for the assignment of priority weights to the attributes. Further, 600 vertical handover points for all simulation scenarios are considered to evaluate the performance of proposed method. These simulation scenarios have been implemented with MATLAB platform.

Table 3: Attributes range for different networks [18, 27]

Criteria Network	RSS (dB)	Delay (ms)	Jitter (ms)	Packet Loss (per 10^6)	Throughput (Mbps)	Mobility	Bandwidth (MHz)	Load handling capability	Security (%)	Cost (%)
UMTS	-150 to -90	25-50	5-10	20-80	0.1-3	High	0.1-3	High	70	60
WLAN	-110 to -55	100-150	10-20	20-80	50-150	Low	1-11	Low	50	10
WIMAX	-160 to -100	60-100	3-10	20-80	20-100	Medium	1-60	Medium	60	40

Various attributes considered are as follows:

- Received signal strength (RSS): This attribute represents the signal strength received from the available networks. Signal strength received from various networks considered in this work lies in the range from -160 to -55 dB.
- Delay: It is measure of approximate delay provided by the access network. As given in Table 3, WLAN offers higher delay as compared to others.
- Jitter: Jitter is a measure of the average delay variations within the access network.
- Packet loss: This attribute is a measure of the average packet loss rate within the access network over a considerable duration of time. It can be measured in (number of packets lost per million packets).
- Mobility: This attribute is considered to incorporate mobility characteristics of available networks. Mobility refers to service continuation of mobile terminal with present point of attachment even at high velocity. UMTS network offers highest mobility to mobile terminals due to larger area covered by concerned base station. Small coverage area of access point leads to low mobility characteristics of WLAN. WiMAX offers medium mobility to mobile terminals.
- Bandwidth: It provides the specified bandwidth offered by available access networks and is expressed in MHz WIMAX offers higher bandwidth as compared with other WLAN and UMTS.
- Throughput: It refers to actual rate of packet transmission offered by available networks and is expressed in Mbps.
- Cost: This attribute is a measure of the operator's transport cost for a particular access network. It is expressed as percentage cost per byte. In this work, cost of accessing UMTS is considered as 60% per byte as compared with other two networks.
- Security: Security attribute represents security level of link layer of available network and expressed as percentage security.
- Load handling capability: It represents load handling capability of concerned network. Performance of WLAN deteriorates with increase in traffic load in the network where as load handling capacity of UMTS is greater among networks considered in this work.

The performance evaluation scenarios are summarized in Table 4.

Table 4: Simulation Scenarios

Traffic classes	• Conversational • Streaming • Interactive • Background
No. of attributes	• 4 (Cost, Delay, Jitter and Packet loss

	• 6 (Cost, Delay, Jitter, Bandwidth, Security and Packet Loss) • 9 (RSS, Cost, Delay, Jitter, Throughput, Velocity, Security, Packet loss and Traffic load)
Weighting methods	• Analytic Hierarchy process (AHP) • Analytic Network Process (ANP)

Metrics considered for performance evaluation and comparison are:

- Number of handovers: It indicates number of times an algorithm changes the present point of attachment in heterogeneous environment. Lesser number of handovers is desirable as excessive handovers result in undue network overheads.
- Ranking abnormality: It is the change in the ranking of available alternatives if worst alternative is removed from the list. Conventional MADM methods suffer from increased ranking abnormality reflecting inconsistent algorithm performance.
- Optimum network selection: Network selection is considered to be optimum if it satisfies the quality of service requirements of user.
- Handover latency: It is the time taken by an algorithm to decide next point of attachment or service continuation. Handover decision must be taken prior to decrease in relative signal strength received from new point of attachment.

6. PERFORMANCE ANALYSIS AND COMPARISON

The proposed V-VPP algorithm as outlined in section 5 was implemented using MATLAB platform along with three other relevant algorithms based on different normalizations on VIKOR namely V-MAX (Max normalization based VIKOR method), V-VEC (Vector normalization based VIKOR method) and V-PRN (Performance rating normalization based VIKOR method). The performance of these algorithms is analyzed over 600 vertical handover points in all scenarios. Each handover point represents combination of all network attributes offering random value in the range given in Table 3. Further, comparative performance analysis of V-VPP with four conventional MADM methods viz. SAW, MEW, TOPSIS and GRA is also presented, for additional 100 handover points, to strengthen the analysis and adjudge its effectiveness for network selection in heterogeneous environment.

6.1. Number of handovers:

The performance comparison of proposed V-VPP algorithm in terms of handovers with V-MAX, V-VEC and V-PRN is shown in Table 5. These results are tabulated over the two (AHP and ANP) weighting methods, for four traffic classes, and with 4, 6, and 9 number of network attributes, which were varied randomly in the range given in Table 3. Fig. 3 shows average number of handovers taken over all the four traffic classes for the four vertical handover techniques.

- *ANP weighting method:* It is observed that in conversational traffic no handover occurred in V-VPP, V-PRN and V-VEC techniques when lesser number of network attributes are considered, whereas, with increasing network attributes (equal to 9) V-MAX offered better results followed by V-VPP, V-PRN and V-VEC techniques. In streaming traffic class as well, the proposed V-VPP technique and V-PRN gave optimized performance (zero handover) at lower attributes, while V-VEC did not perform well and resulted in highest number of handovers. The performance of proposed technique is again better (no handover with 4 and 6 attributes) as compared with other techniques in background traffic class. For interactive traffic, V-VEC resulted in minimum number of handovers. However, on an average, over all the traffic classes, the proposed V-VPP technique generated around 40%, 65%, and 48% lesser number of handovers in comparison to V-MAX, V-VEC, and V-PRN algorithms respectively for the ANP weighing method (Fig. 3).

Table 5: Number of handovers in different traffic classes with varying attributes and weighting method

Traffic class	Attributes	Weighing method	Algorithm			
			V-MAX	V-VEC	V-PRN	V-VPP
Conversational	4	ANP	11	0	0	**0**
		AHP	9	0	0	**0**
	6	ANP	2	0	0	**0**
		AHP	6	0	0	**0**
	9	ANP	9	17	15	13
		AHP	7	12	15	12
Streaming	4	ANP	2	10	0	0
		AHP	4	10	0	0
	6	ANP	2	6	0	0
		AHP	2	6	0	0
	9	ANP	2	17	0	0
		AHP	6	6	2	6
Interactive	4	ANP	0	0	10	8
		AHP	8	0	12	2
	6	ANP	10	0	12	0
		AHP	12	0	8	2
	9	ANP	4	12	0	4
		AHP	4	13	2	12
Background	4	ANP	4	8	16	0
		AHP	4	6	2	0
	6	ANP	0	4	1	0
		AHP	2	4	1	0
	9	ANP	2	10	2	4
		AHP	4	12	2	12

- *AHP weighting method*: Similarly the results obtained for AHP based weighting method are tabulated in Table 5. It is seen that the proposed V-VPP vertical handover technique offered least number of handovers in all the traffic classes, for 4 and 6 number of network attributes, except in the interactive traffic class where V-VEC performed marginally better than V-VPP. With 9 attributes, V-MAX performed better for all the traffic classes except in streaming traffic where V-VPP and V-PRN resulted in optimized performance. On an average over all the traffic classes, the V-VPP generated 32%, 33%, and -5% lesser handovers than V-MAX, V-VEC, and V-PRN respectively

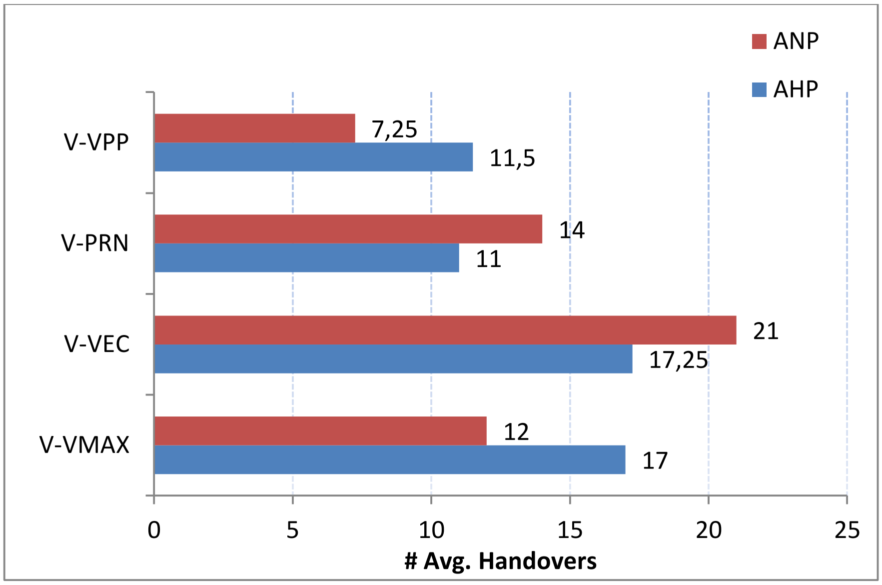

Fig.3: Average number of handovers over all the traffic classes

6.2. Optimum network selection

Optimum network refers to the one that is best suited as per QoS requirements of user. Conversational traffic demands lesser delay and jitter, which can be honored by UMTS or WIMAX networks. In case of streaming traffic, jitter and throughput are given high priority among other network attributes. Thus WLAN and WIMAX networks will be appropriate networks for streaming traffic class. Similarly, interactive traffic can be efficiently supported by lower delay and loss parameters. Since UMTS and WIMAX networks offer lesser amount of delay and thus are able to support this kind of traffic. Higher throughput and lesser delay are the necessities of background traffic, which can be provided by WLAN or WIMAX networks. In this work, a network selection is considered optimum if at any point in heterogeneous environment, attribute values offered by the available network matches with the requirement of particular traffic class. Table 6 provides number of times an optimum network is selected by various handover algorithms in all scenarios for each traffic class (2 weighting methods x3 network attribute classes x 25 handover points per scenario). Fig. 4 shows the percentage optimum network selection for different algorithms for the four traffic classes.

Table 6: Optimum network selection comparison for all attribute and weighing classes

Traffic class	Handover algorithm			
	V-MAX	V-VEC	V-PRN	V-VPP
Conversational	33	143	138	**148**
Streaming	147	118	**150**	147
Interactive	115	**133**	118	125
Background	**145**	112	144	144
Average (%)	73.3	84.3	91.7	**94**

It is seen that proposed V-VPP technique provides largest percentage of optimum network selection among all the vertical handover techniques.

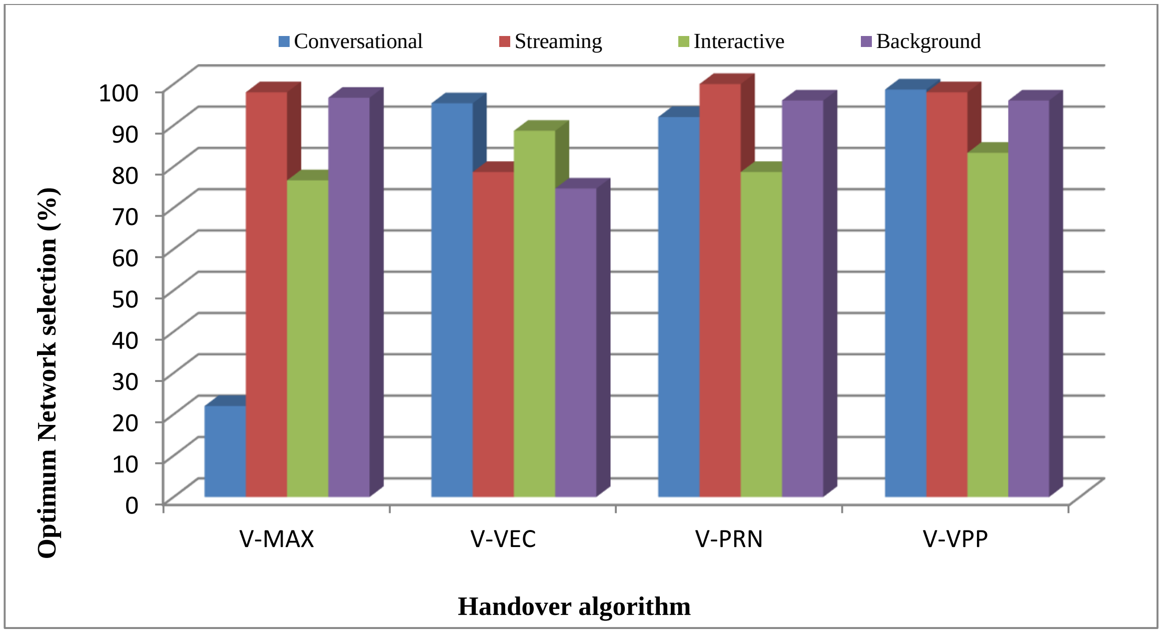

Fig.4: Optimum network selection (%) comparison for different traffic classes

6.3. Ranking abnormality

How much consistent an algorithm is in its performance - it is indicated by the Ranking abnormality. Higher ranking abnormality may result in inappropriate network selection by that algorithm. The performance of all the handover techniques with respect to ranking abnormality is shown in Table 7. It is seen that the proposed V-VPP technique results in minimum ranking abnormality among all, and the goodness over all the four traffic classes is V-VPP>V-PRN>V-VEC>V-MAX. However, it is seen that V-MAX and V-PRN methods resulted in undefined values (16NAN, 36NAN) while making calculations for handover, indicating limitations of these methods. V-VEC and V-VPP methods offer advantage in this regard, however.

Table 7: Ranking abnormality comparison under different traffic classes

Traffic class	V-MAX	V-VEC	V-PRN	V-VPP
Conversational	0	1	16	5
Streaming	56	13	11	1
Interactive	35*	25	7*	10
Background	40	24	12*'	1
TOTAL	**131**	**63**	**46**	**17**
	*16nan		*15nan, *'36nan	

Average ranking abnormality offered by all handover algorithms over the 600 scenarios (4 traffic classes x 25 handover points x 2 weighing methods x 3 sets of attributes (4, 6, and 9 number)) is shown in Fig. 5. The superiority of V-VPP method in terms of considerably reduced ranking abnormality justifies its goodness.

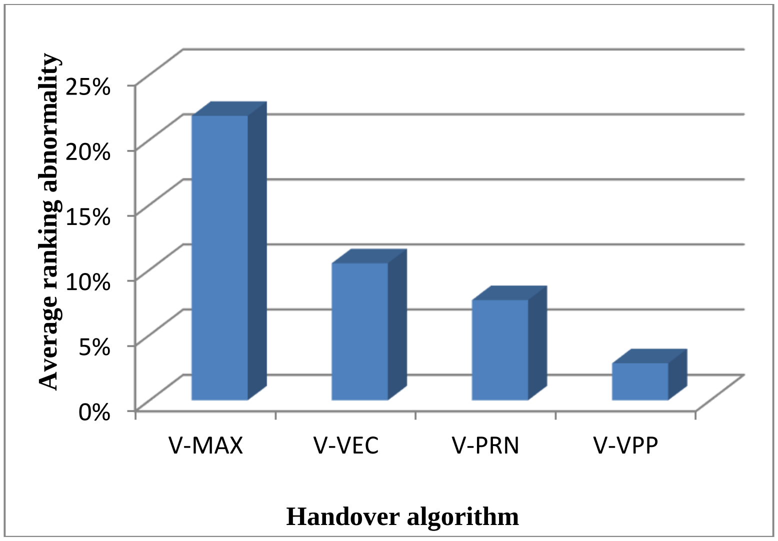

Fig. 5: Average ranking abnormality comparison over 600 scenarios

6.4. Handover latency

It is indicative of the time taken by the decision making algorithm for network selection. The results for handover latency in all the normalization techniques are shown in Fig.6. As the number of network attributes increases, to accommodate the QoS desired by a user, handover latency increases among all the algorithms. However, for the V-VPP algorithm, it is slightly higher than that of V-MAX and V-PRN but much lower than that for V-VEC. For 9 attributes, Handover latency offered by V-VPP is 0.827 and 0.582 times more than that of V-MAX and V-PRN due to two step normalization process.

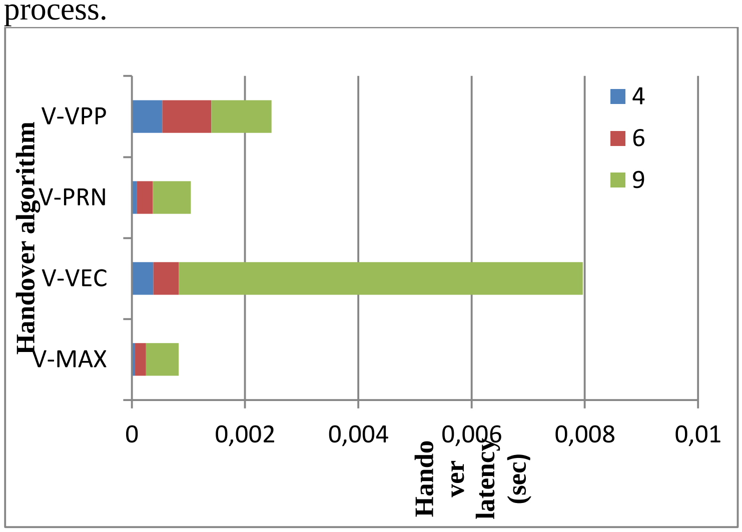

Fig. 6: Handover latency comparison for different number of network attributes

6.5. Performance comparison with conventional MADM methods

The performance comparison of V-VPP algorithm with traditional multiple attribute decision making algorithms SAW, MEW, GRA and TOPSIS is carried out here on the basis of two major performance metrics (i) number of handovers and (ii) Optimum network selection.

6.5.1. Number of handovers

Performance comparison of V-VPP with the well explored TOPSIS algorithm is shown in Table 8 for 9 network attributes with all the four traffic classes at 100 handover points in terms of number of handovers. The proposed method results in lesser number of handovers for all the traffic classes and with both weighing methods. Results are seen to be much better with ANP technique as compared to those with AHP weighting method for all the traffic classes. Accordingly, the comparison is further extended with SAW, MEW, and GRA, other popular MADM methods, with ANP weighting method and results are presented in Fig.7.

Table 8: Performance comparison of V-VPP with TOPSIS method

Number of handovers (%)				
Weighting algorithm	*AHP*		*ANP*	
Traffic class	Handover algorithm			
	V-VPP	TOPSIS	**V-VPP**	TOPSIS
Conversational	**20**	29	**4**	21
Streaming	**16**	38	**0**	34
Interactive	**26**	39	**8**	29
Background	**19**	51	**12**	30
Average	**20.25**	39.25	**6**	28.5

The goodness of the proposed V-VPP technique gets clearly demonstrated as it results in lesser number of handovers for network selection among all these algorithms at almost all traffic classes. Average number of handovers over all traffic classes shown in Fig. 8, also substantiates the observation as the proposed vertical handover technique results in about 78%, 89%, 73%, and 87% lesser number of handovers in comparison to TOPSIS, GRA, MEW, and SAW respectively over all the traffic classes.

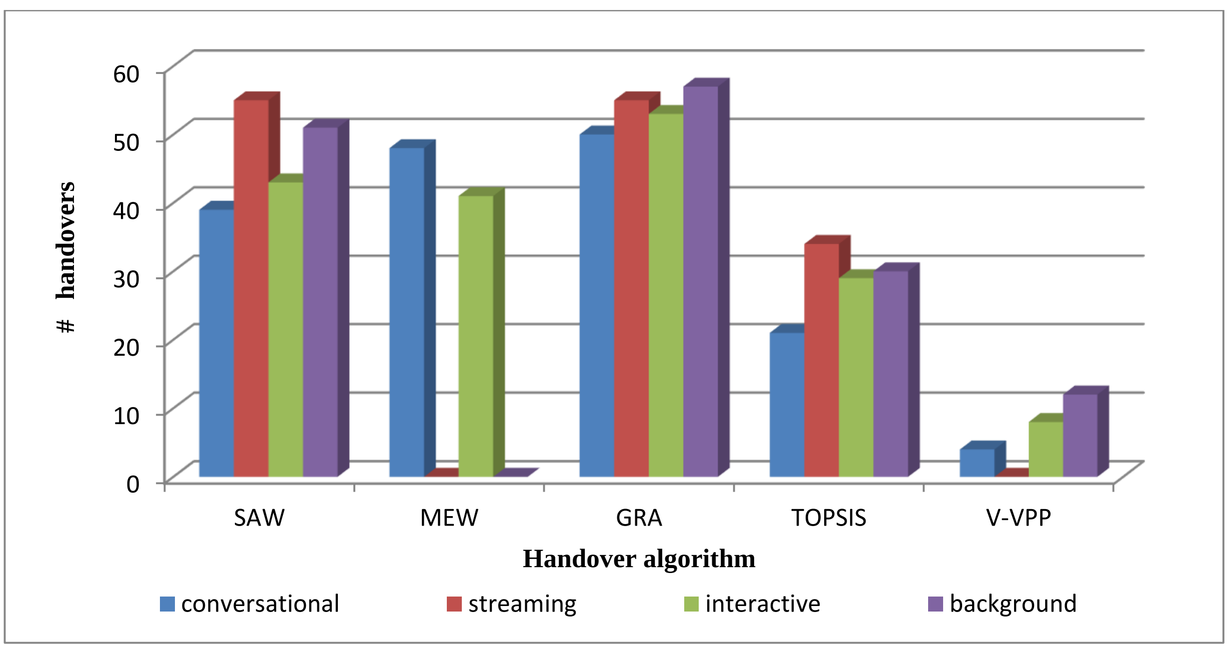

Fig. 7: Performance comparison of proposed V-VPP method with conventional MADM methods

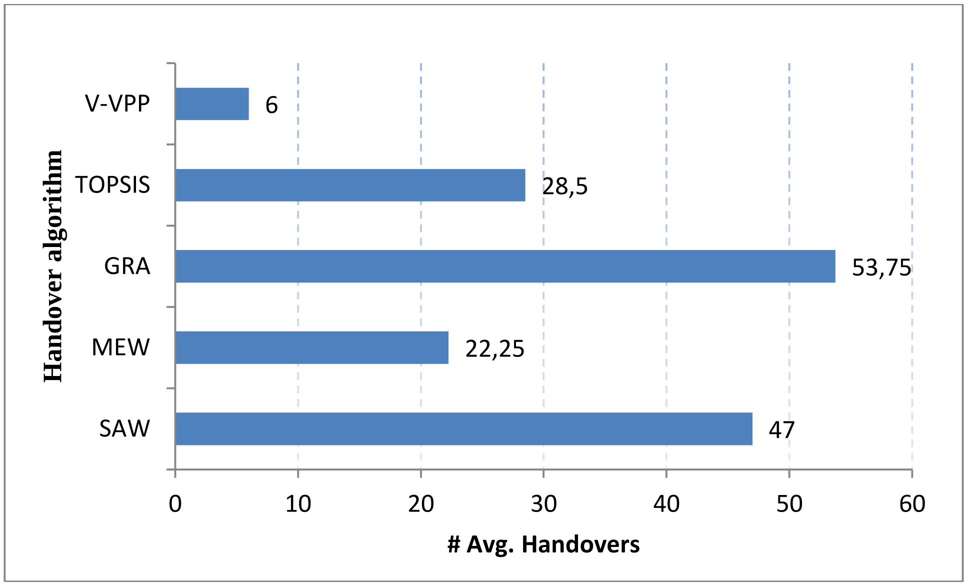

Fig 8: Performance comparison with traditional MADM algorithms for number of handovers

6.5.2. Optimum network selection

In section 6.2, quality of service requirements of different traffic classes were discussed for the purpose of optimum network selection. As outlined in section 4, Euclidean distance is calculated for critical evaluation of proposed method and to justify its effectiveness for network selection. User's preferences can never be exactly matched with quality of service offered by available networks thus a compromise solution is provided by handover algorithm. Euclidean distance will help to determine the effectiveness of handover algorithm for selecting most appropriate network for given set of user's preferences. It is measured between attributes of selected network by any algorithm and predefined set of preferred attributes. A network selection will be considered to be optimum if Euclidean distance between attributes of selected network and predefined set of preferred attributes is minimum. Performance comparison of V-VPP with TOPSIS assuming ANP weighting method with 9 attributes for the conversational traffic class is shown in Table 9 for the optimum network selection parameter. In total 100 handover points are considered for a given set of preferred values of attributes that vary randomly in the range as given in Table 3.

Table 9: Optimum network selection comparison

Selection of preferred values of attributes	Method	# Handovers	Average Euclidean distance	Optimum Network selection (%)
User defined	**V-VPP**	**20**	**120**	**46**
	TOPSIS	36	147.86	17
Best values among available attributes	**V-VPP**	**10**	**80.4**	**57**
	TOPSIS	36	98.4	27

The results are analyzed for i) user defined set of attribute values and ii) considering best values of network attributes from available networks. In user defined approach, set of preferred network attributes remains same for 100 handover points, whereas a new set of preferred values of network attributes is chosen for each handover point for the second option at all the 100 handover points. Thus, number of handovers are determined for 200 vertical handover points (100 in each approach) to compare the performance of both methods.

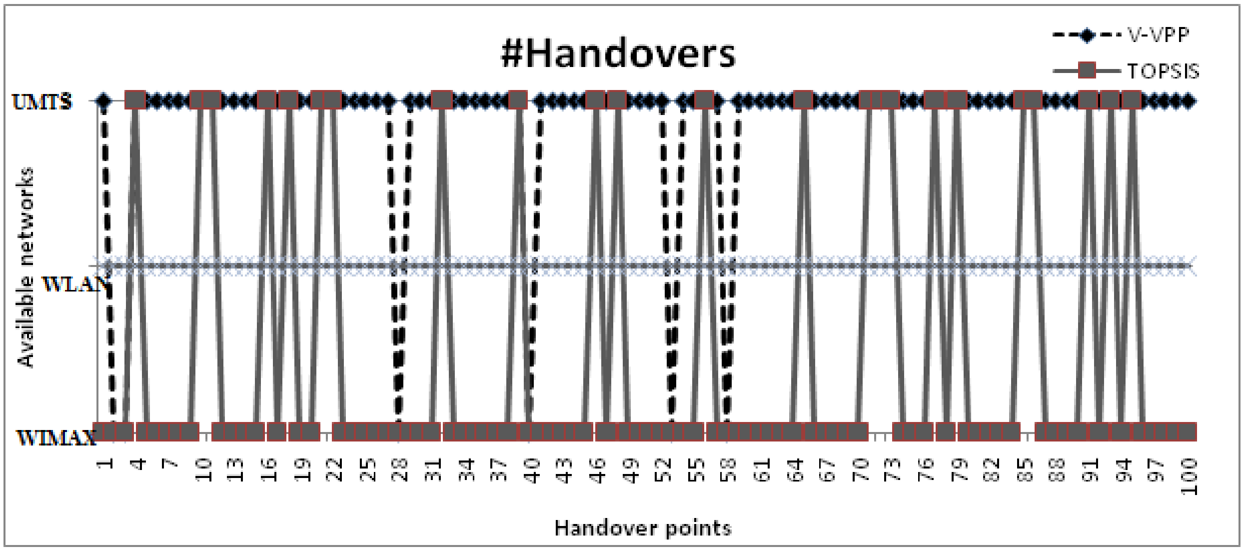

Fig. 9: Network selection in heterogeneous environment using V-VPP and TOPSIS

As outlined in section 6.2, UMTS and WIMAX are the most suitable network selections for conversational traffic. Both V-VPP and TOPSIS methods change their point of attachments between UMTS and WIMAX thereby justifying the requirement of conversational traffic class. In V-VPP, same network (UMTS or WIMAX) is selected most of the time so point of attachment remains same. On the other hand, with TOPSIS network selection switched between UMTS and WIMAX frequently (Table 9 and Fig. 9). As, the number of handovers increases load on the network thus lesser number of handovers provided by V-VPP method is advantageous.

Moreover, to extend the level of performance evaluation of V-VPP and TOPSIS methods, Euclidean distance is calculated between selected network and preferred set of attributes for every handover point. Average Euclidean distances measured at 100 handover points for network selected by both methods is also shown in Table 9 and it can be seen that V-VPP method provides lesser Euclidean distance as compared with TOPSIS. In addition, percentage optimum network selection indicates number of times the Euclidean distance between selected network and user's preferred set of attributes is minimum as compared with other networks. It can be concluded from Table 9 that performance of proposed method is much better than TOPSIS method in percentage optimum network selection as well.

7. CONCLUSION

MADM based vertical handover techniques are being explored by researchers for appropriate network selection for the imminent heterogeneous wireless and mobile network environment. However, the effectiveness of these algorithms is highly dependent upon the underlying weighting and normalization techniques adopted. In this paper, we have proposed a vector normalized preferred performance rating based normalization technique to be used in conjunction with the MADM based VIKOR method for developing a novel vertical handover algorithm named V-VPP. It incorporate user's preference in the normalization process during the aggregation and ranking of alternatives with the purpose of selecting most appropriate network, reducing number of handovers and minimizing ranking abnormality. Performance of the proposed algorithm in comparison to VIKOR based other algorithms using different normalization techniques (V-MAX, V-VEC and V-PRN) distinctively shows an edge over others with widely varying attributes range for all the traffic classes on a heterogeneous network comprising of Wi-MAX, UMTS and WLAN. The simulation results for the V-VPP vertical handover are quite optimistic in terms of lower handovers, reduced ranking abnormality, and optimum network selection though at the cost of slight increase in handover latency. The proposed technique performs well as compared with conventional MADM methods like SAW, MEW, GRA and TOPSIS under the given simulation scenarios. Based on these results, V-VPP seems to be a potential vertical handover technique for usage in the upcoming beyond 3G or fourth generation of wireless mobile communication networks.

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