Performance Comparison of MADM Algorithms for Network Selection in Heterogeneous Networks

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Abstract:Vertical handover is a need of present era of heterogeneous networks comprising different network technologies. Lot of quality of service (QoS) parameters, user's preferences, network conditions and other parameters participate in selection of appropriate network among available networks. This multi- criteria nature of vertical handover verifiesapplicability of multiple attribute decision making (MADM) algorithms to be used for network selection in heterogeneous networks. In this work, six MADM algorithms SAW, MEW, TOPSIS, GRA, AHP and VIKOR have been implemented. Performance of these algorithms has beenanalyzed for handover latency,number of handovers and optimum network selection. It was concluded that VIKOR algorithm is able to provide compromised solution in the light of these parameters.

Keywords:*QoS, MADM, SAW, MEW,TOPSIS, GRA, AHP, VIKOR*

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1. INTRODUCTION

Next generation mobile networks focus on seamlessly integrating the existing wireless technologies including 2G, 3G, 4G, wireless LAN, and Wireless MAN into all-IP based heterogeneous network. A significant challenge for next generation wireless networks is to coordinate differenttypes of networks using these technologies being used for wireless communications. These different networks ought to be inter-connected in an optimum manner with the ultimate objective to provide the end-user with the requested services and corresponding QoS (Quality of Service) requirements. One of the most challenging problems for coordination is vertical handover (VHO), which is the decision for a mobile node to hand over between different types of networks (e.g. from WLAN to WIMAX networks or WIMAX to WWAN and vice-versa).

Vertical handover is a process of transferring call connected to a network/data session from one channel connected in a cell to the core network of another. However, no single wireless technology is considered to be more favorable than other technologies in terms of QoS requirements including bandwidth, cost, packet delay and jitter etc. For example, 801.11a offers a higher bandwidth with limited coverage, while cellular network ensures a large coverage with lower bandwidth. The most important issue in 4G is to provide ubiquitous access for the end users, under the principle "Always Best Connected" (ABC) [1]. The process of vertical handoff consists of three main phases [2], namely i) system discovery, ii) handover decision and iii) handover execution.

During system discovery, a mobile terminal equipped with multiple interfaces has to determine the networks that can be used and what services are available in each network. During the handover decision phase, the mobile terminal determinesoptimal access network among available networks. During handover execution phase, connections are needed to be re-routed from the current network to the selected network in a seamless manner [3]. Among all these phases, handover decision is critical phase of vertical handover and need consideration of large number of decision criteria such as QoS offered by available networks, user's application preference, present battery level of mobile terminal, network conditions, velocity of mobile terminal etc. Several schemes and decision algorithms such as Cost function based[4], Genetic algorithms[5], Fuzzy logic[6-7], Utility functions[8], Context aware[9] and Multiple attribute decision making (MADM) methods[10-18] have been proposed in literature for optimum network selection in heterogeneous environment. According to multi- criteria nature and requirements of vertical handover, multiple attribute decision making algorithms represent a promising solution to select the most suitable network in terms of quality of service (QoS) for mobile users [19]. In this work, six MADM algorithms have been implemented and analyzed for optimum network selection in heterogeneous network with varying number of decision attributes.

Rest of the paper is organized as follows: Section 2 provides brief introduction of MADM algorithms considered in this work, Section 4 represents simulation setup used, section 4 provides results and section 6 conclude the work with final remarks.

2. MADM ALGORITHMS

Multiple Attribute Decision Making (MADM) algorithms have been proposed in literature to perform network selection during vertical handover .These algorithms are Simple additive weighting (SAW), Techniques for order preference by similarity to ideal solution, Multiplicative exponent weighting (MEW), Analytical hierarchy process (AHP), Grey relational analysis (GRA), Elimination and choice translating priority (ELECTRE) and VIKOR[4-19]. AHP is also used to determine the weights for criterion used in MADM algorithms for the selection of appropriate network among available networks. Every MADM algorithm resulted in ranking list of available networks and selected network is the network having maximum/minimum score in the ranking list. The expression for selection of optimum network in six algorithms considered in this work is as follows:

- SAW algorithm:In SAW algorithm, the expression for selected network is given by
  $select_{SAW} = \arg max \sum_{j \in N} w_j r_{ij}$ for i €M *(1)*
  Here ‘i’ is number of candidate networks, ‘j’ represents number of QoS attributes offered by each network,‘w’ represents priority weight of attribute and ‘r_{ij}’ represents normalized value of every attribute.
- MEW algorithm: Mew is another scoring method in which the expression of selected network is given by
  $$select_{MEW} = \arg max \prod_{j \in N} r_{ij}{}^{w^j} \qquad (2)$$
- TOPSIS algorithm: In TOPSIS, the chosen candidate network is the one which have the shortest distance to the ideal solution and the longest distance to the worst case solution. The selected network is given by:
  $$select_{TOP} = \arg\max c_i \qquad (3)$$
  Here ‘c_i’ is the relative closeness to the ideal solution and is given as:
  $$c_i = \frac{s_i^-}{s_i^+ + s_i^-} \qquad (4)$$
  Here $s_i^+ and s_i^-$ aredistances between the networks and the positive and negative ideal solutions respectively.
- GRA algorithm: GRA algorithm resulted in determination of gray relation coefficient (GRC) which is used to describe the similarity between each candidate network and the best reference network. GRC is given by:
  $$GRC_i = \frac{1}{\sum_{i=1}^{M} |r_{ij} - R_i^*| + 1} \qquad (5)$$
  Here ‘R*’ is ideal solution representing maximum and minimum value of weighted normalized value of attribute for benefit and cost attributes respectively. So selected network is
  $$select_{GRA} = \arg\max GRC_i \qquad (6)$$
- AHP algorithm: According to AHP best alternative (in the maximization case) is indicated by
  $$select_{AHP} = \arg\max \sum_{j=1}^{n} a_{ij} w_j \qquad (7)$$
  Here ‘ a_{ij} ’ is principle eigen vector value of each every attribute.
- VIKOR algorithm: This method is based on the compromise programming of multi-criteria decision making (MCDM). This method focuses on ranking and selecting from a set of alternatives in the presence of conflicting criteria. It introduces the multi-criteria ranking index based on the particular measure of ‘‘closeness’’ to the ‘‘ideal’’. The selected network is given by
  $$select_{VIKOR} = \arg\min Q_i \qquad (8)$$
  Here ‘Q_i’ is
  $$Q_i = v(S_i - S^*)/\,(S^- - S^*) + (1-v)(R_i\_R^*)/(R^- - R^*) \ (9)$$
  where $S^* = Min(S_i)$, $S^- = Max(S_i)$,
  $R^* = Min(R_i)$, $R^- = Max(R_i)$,
  and v is a weighting reference with $0 \leq v \leq 1$.
  $[(S^- - S^*)/(S - S^*)]$ represents the distance rate from the positive ideal solution of the ithnetwork. In other words, the majority agrees to use the rate of the ithnetwork. $[(R^- - R^*)/(R - R^*)]$ represents the distance rate from the negative ideal solution of the ith attribute this means the majority disagree with the rate of the ithnetwork. Thus when the $v$reference is larger (>0.5), the index of Q_i will tend to majority rule. S_i represents the distance rate of the ithnetwork to the positive ideal solution (best combination), R_i represents the distance rate of the ithnetwork to the negative ideal solution (worst combination)

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32 – 37

3. SIMULATION SETUP

In this work, six networks UMTS, WLAN and WIMAX (two of each kind) have been considered to create heterogeneous environment. The attributes associated with these networks varies from 4 to 6 and vary randomly as given in table 1. The attributes are cost per byte, delay, jitter, available bandwidth, security and packet loss.

Table 1: Attributes range for different networks [18]

Attributes → **Network ↓**	Cost per byte (%)	Delay (ms)	Jitter (ms)	Packet Loss (per 10^6)	Available Bandwidth (MHz)	Security (%)
UMTS 1	60	25-50	5-10	20-80	0.1-2	70
UMTS 2	80	25-50	5-10	20-80	0.1-2	90
WLAN 1	10	100-150	10-20	20-80	1-11	50
WLAN 2	5	100-150	10-20	20-80	1-11	50
WIMAX 1	50	60-100	3-10	20-80	1-60	60
WIMAX2	40	60-100	3-10	20-80	1-60	60

The performance of six MADM algorithms SAW, MEW, TOPSIS, AHP, GRA and VIKOR has been analyzed for three scenarios as baseline, voice connection and data connection. In each scenario, different attributes have been assigned different priority weights according to characteristics of that scenario. Baseline scenario represents equal weight distribution among all the attributes (0.25 each for 4 attributes). Similarly, in voice connection, 70% more priority is given to delay and jitter whereas data connection scenario has been designed with 70% more priority to available bandwidth.Handover latency, number of handovers and optimum network selection are the parameters for performance comparison of Six MADM algorithms considered in this work.

4. RESULTS AND DISCUSSION

The simulation results for three scenarios are given as:

i. Scenario 1 (Baseline): As outlined in section 3, in this scenario, every attribute has been assigned equal priority weight. Table 2 provides handover latency in six algorithms for varying number of attributes.

Table 1: Handover latency in conventional MADM methods in baseline scenario

Algorithm/ attributes	***Time elapsed (sec)***		
	4 attributes	5 attributes	6 attributes
SAW	0.0002157	0.0002715	0.000239
TOPSIS	0.0016005	0.0020292	0.00154
MEW	**3.932E-05**	**4.888E-05**	**4.172E-05**
AHP	0.0001063	0.0001339	0.0001176
GRA	0.0001441	0.0001824	0.0001571
VIKOR	0.0004761	0.000605	0.0004976

It can be concluded that MEW offers minimum handover latency among all the algorithms. TOPSIS offered larger handover latency due to its complex decision making process followed by VIKOR algorithm.

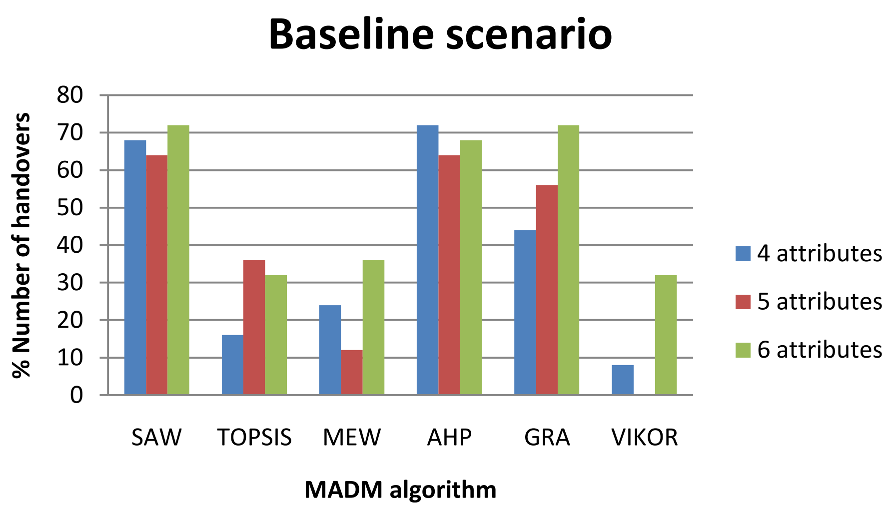

Fig. 1:Number of handovers(%) in 6 MADM algorithms

Fig. 1 shows percentage number of handovers with varying number of attributes. VIKOR algorithm has minimum number of handovers followed by MEW and TOPSIS algorithm. A good handover algorithm should have lower handover latency and minimum number of handovers.Thus a compromise solution should be taken up for network selection in heterogeneous networks.

ii. **Scenario 2 (Voice connection):** Scenario 2 is designed for voice connection which requires highest priority to delay and jitter. Thus 70% importance is given to delay and jitter and remaining attributes have assigned equal importance. For example, in case of 4 attribute performance analysis, weight assignment for cost, delay, jitter and bandwidth are given as 0.15, 0.35, 0.35 and 0.15 respectively. Table 2 provides handover latency in voice connection with varying number of attributes.

Table 2: Handover latency in conventional MADM methods in voice connection

Algorithm/ attributes	Time elapsed (sec)		
	4 attributes	5 attributes	6 attributes
SAW	0.0002026	0.0002114	0.0002424
TOPSIS	0.0014925	0.0015348	0.0017628
MEW	**3.596E-05**	**0.0000394**	**4.248E-05**
AHP	0.0001036	0.0001105	0.000123
GRA	0.0001401	0.0001538	0.0001603
VIKOR	0.0004609	0.0004793	0.000521

As given in Table 2, MEW algorithm offers lowest handover latency among all the algorithms whereas TOPSIS and VIKOR algorithms are still at higher side in terms of handover latency. Fig. 2 shows average percentage number of handovers in all attribute variations. It can be concluded that VIKOR algorithm exhibits lower number of handovers which is an advantage over other algorithms.MEW algorithm, on the other hand exhibits larger number of handovers which are not required. It shows instability of an algorithm in network selection. Large number of handovers increase overall load on network and resulted in increase in energy consumption also. Moreover, network selection is not appropriate in MEW algorithm as handovers occur between WLAN and WIMAX. TOPSIS and VIKOR algorithms perform handover between UMTS and WIMAX. UMTS is ideal network for voice connection thus network selection is more optimum as compared with MEW algorithm.

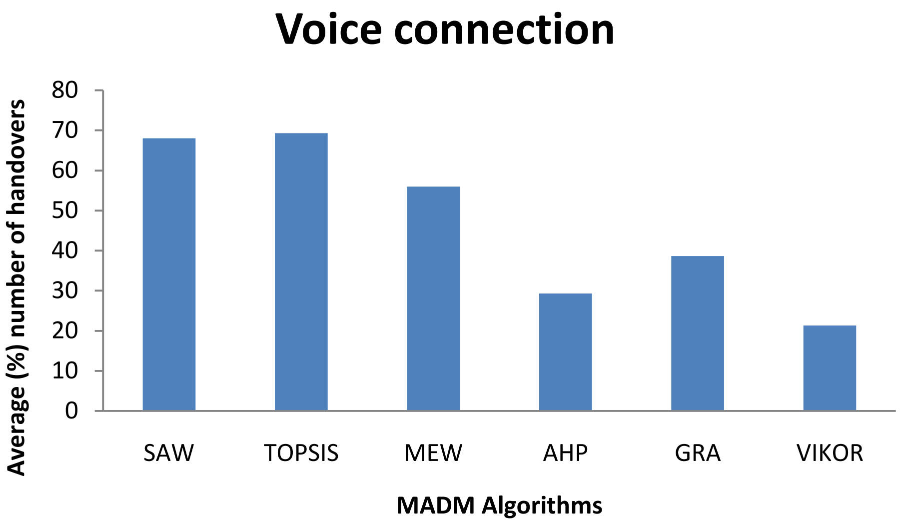

Fig. 2: Average (%) number of handovers comparison in 6 MADM algorithms

iii. **Scenario 3 (Data connection):** Scenario 3 is designed for data connection which requires highest priority to available bandwidth as more bandwidth is required for data applications such as streaming. Thus 70% importance is given to available bandwidth and remaining attributes have assigned equal importance. Table 3 provides handover latency in data connection with varying number of attributes.

Table 3: Handover latency in conventional MADM methods in data connection

Algorithm/ attributes	*Time elapsed (sec)*		
	4 attributes	*5 attributes*	*6 attributes*
SAW	0.0001996	0.0002576	0.0004154
TOPSIS	0.0014777	0.0018996	0.0016437
MEW	**0.0000346**	**0.0000446**	**4.472E-05**
AHP	0.000097	0.0001363	0.0001189
GRA	0.0001349	0.0002032	0.0001587
VIKOR	0.0004527	0.0006216	0.000511

Again, MEW algorithm offers lesser handover latency among all algorithms with varying number of attributes. TOPSIS algorithm is complex algorithm as compared with other algorithms so exhibit larger handover latency in data connection also. VIKOR algorithm is better than TOPSIS algorithm in terms of handover latency as well as number of handovers as shown in Table. 4. In addition, large number of handovers shows selection of less optimum network for handover in MEW algorithm.Thus VIKORalgorithm can be a better option for decision making during vertical handover in heterogeneous networks.

Table 4: Number of handovers (%) comparison in 6 MADM algorithms in data connection

Algorithm/ attributes	*% Number of handovers*		
	4 attributes	*5 attributes*	*6 attributes*
SAW	52	40	52
TOPSIS	16	0	32
MEW	40	44	52
AHP	24	16	32
GRA	56	60	48
VIKOR	0	0	0

5. CONCLUSION

Handover latency and number of handovers are important criteria for selection of any algorithm to be used in decision making phase of vertical handoverin heterogeneous networks. Several algorithms have been suggested in literature but multiple attribute decision making algorithms are able to complement the multi-criteria nature of vertical handover. So,in this work six MADM algorithms have been implemented and analyzed for handover latency and number of handovers. It is concluded that VIKOR algorithm can be a compromise solution due to lesser number of handovers, optimum network selection along with slightly higher handover latency. Lesser number of handovers resulted in decrease in network load as well as saving in energy consumption thus higher handover latency characteristics of VIKOR algorithm can be ignored in the light of other advantages.

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