Journal of Basic and Applied Engineering Research
Print ISSN: 2350-0077; Online ISSN: 2350-0255; Volume 2, Number 5; January-March, 2015, pp. 365-371

http://www.krishisanskriti.org/jbaer.html

Adaptive Network Selection Scheme Based on Adjacent Pair Priorities and GRA

Adarsh Kumar Pal[1] and N.P. Singh[2]

[1,2]ECE Department NIT Kurukshetra Kurukshetra, India
E--mail: 1adarsh_3132527@nitkkr.ac.in, 2nirajatnitkkr@gmail.com

Abstract—*Integration of heterogeneous technologies such as WLAN, UMTS &WiMAX have the good capability to offer various services at anytime, anywhere as per user requirement with seamless interoperability at affordable price. Enabling network selection mechanism in order to keep mobile user always best connected (ABC) anywhere and anytime is one of the important challenge in such heterogeneous wireless environment. In this paper, multiple criteria based network selection algorithm is proposed in WiMAX-WLAN environment in order to satisfy different service level agreements. The proposed methodology combines the Adjacent Pair Priorities (APP) to determine relative weights of attributes and Grey Relational Analysis (GRA) to rank the available networks. The advantages of using APP technique over other popular weight estimation method like Analytic Hierarchical Process (AHP) is that it can adaptively control the spanning of the weights in response to user preference.*

Keywords: *heterogeneous wireless environment, QoS, adjacent pair priority, grey relational analysis, WiMAX-WLAN environment*

1. INTRODUCTION

The world of communication has been totally revolutionized by the recent development of wireless technologies. Multiple technologies are integrating simultaneously to provide higher Quality of Services (QOS) to the end users. This is the basic aspect of 4G wireless technology in which wireless networks are developed to provide support for multimedia services with different traffic characteristics, different QoS guarantees and to satisfy different types of service level agreements between user and service providers with seamless mobility. In heterogeneous wireless network (HWNs) where multiple wireless technologies are evolved simultaneously, it is important to select the best possible available network among them [1].

To access the services in HWNs mobile terminals (MTs) (e.g. Cellphones and laptops) should be installed with multiple interfaces. To select best possible network at any time anywhere usually termed as Always Best Connected (ABC) [2]. The concept of ABC leads to development of different vertical handoff Decision algorithms. Vertical handoff decision algorithm deals with problem of selection of best possible network among limited number of alternatives from various wireless service providers (WSPs) based on multiple criterion attributes [3].

Various methodologies have been proposed for network selection. Multi-Criteria Decision Making (MCDM) is one of the most promising one receiving a great deal of attention now a days. MCDM algorithms are used to determine ranking of available networks based on multiple criteria that can influence the decision. Paper [4, 5] have introduced four classical MCDM methods: Simple Additive Weighting (SAW), Multiplicative exponent weighting (MEW), Technique for Order Preferences by Similarity to Ideal Solution (TOPSIS) and Grey Relational Analysis (GRA). Paper [6] has proposed network selection scheme using Analytical Hierarchical Process (AHP) and GRA. Paper [7] has proposed an application-oriented cooperative Vertical Handoff Decision Algorithm for multiple interface MTs. A cross layer based adaptive network selection scheme has been proposed in paper [8].

Most of these papers are based on AHP to provide weight values to different attributes. The AHP process is slow and susceptible to inconsistent settings of relative importance of parameters. To avoid limitations of AHP which is one of the popular weight estimation techniques, Adjacent Pair Priorities (APP) [9] weighting method with GRA [10] has been used to make network selection more adaptive and more user controllable in nature. APP is a novel weight estimation technique allowing users to calculate subjective weights of multiple attributes that influence the network selection decision. GRA is the part of Grey System Theory proposed by Deng (1982). GRA method is very useful to deal with problems having poor, incomplete and uncertain information. Combination of APP and GRA provides an optimum solution to network selection problem.

The rest of this paper is organized as follows: In section II, the theory of evaluation of APP weighting technique and GRA algorithm are presented. Section III presents IS based handover structure from WiMAX-WLAN environment.

Evaluation of network selection algorithm based on APP and GRA are presented in section IV. Finally conclusion and future works are discussed in section V.

2. HWN SYSTEM MODEL (WIMAX-WLAN SCENARIO)

In recent years, integration of WiMAX and WLAN onto a common device platform is gaining attention due to the fact that SP can provide high speed internet connectivity any time anywhere in building WLAN or campus-wide WMAN environment. The deployment of World Wide Interoperability Microwave Access (WiMAX) has its relevance as a competitive broadband service alternative to wired DSL and cable. WiMAX and WLAN both are broadband connectivity but they are used for different usage models. WiMAX for high speed WMAN environment and WLAN for high speed local environment. Merging of these two technologies onto a common platform enable users to stay connected as they move [11].

Here it is assumed that user is currently on WiMAX network services. The handover of MT from WiMAX to WLAN depends on a number of factors such as QoS and cost etc. In case of degradation of WiMAX network within building, MT will discover a suitable WLAN network and switch onto it to continue ongoing process keeping WiMAX network in idle mode. Similarly in open environment where WLAN coverage degrades abruptly, MT will switch back to WiMAX quickly. This switching between WiMAX to WLAN facilitated by information server (IS) can be summarized in following steps [12]:

a) Discovery of information server through query or periodicscanning.
b) Authentication of MT with IS.
c) Accessing of all relevant information with IS required for handover.
d) Selection of target WLAN network by MT based on WSP policies.

3. MULTI-CRITERIA NETWORK SELECTION ALGORITHM

In this paper a novel weight estimation technique APP is used for calculating subjective weights of different attributes that influence network selection process. APP technique was introduced by with goal of removing the shortcomings of AHP technique and introducing a more user friendly weight assessment technique. APP technique consists of following steps [9]:

Step1: The QoS attributes are arranged in descending order of priorities. Let user defined priority order for$m$ available attributes is $p_{0,}p_1, \ldots\ldots p_{m-1}$. The priority order defines that the priority of attribute $i, (P_{p_i})$ will be greater than or equal to priority of attribute $j, (P_{p_j})$if $i < j$.

Step2: In this step, the relative priority for each adjacent pair of attributes $(P_{p_i}, P_{p_{i+1}})$ is defined according to above priority order where$i = 0,1,2 \ldots\ldots m-2$. Let relative priority of attribute P_{p_i} against attribute$P_{p_{i+1}}$ can be labeled as$r_{p_{i,}p_{i+1}}$. The user has to select this relative priority from u number of increasing levels with $u = 3$.Without any loss of generality, these levels can be labeled as '=', '>', '>>'.

Step3. Relative priority levels are quantified using an exponential scale. Let $\alpha$is a user defined exponent also known as 'sensitivity factor' that quantifies relative priority levels as:

$$l_q = \alpha^q;\; q = 0,1, \ldots . u-1 \tag{1}$$

Step 4. The non-normalized weight of attribute P_i that is labeled as w_i^* can be calculated as:

$$w_{p_{m-1}}^* = 1\; w_{p_i}^* = r_{p_i,p_{i+1}} * w_{p_{i+1}}: k = m-2,0 \tag{2}$$

Step5. Finally, the normalized weight of attributeP_i, labeled as w_i where $i = 0,1, \ldots\ldots m-1$can be calculated as:

$$w_i = w_i^* / \sum_{k=0}^{m-1} w_k^* \tag{3}$$

2. Advantage of using APP over AHP:

The conventional AHP has some draw back because of its composite ranking approaches. The pairwise comparison process is slow and susceptible to inconsistent importance setting. The Adjacent Pair Priority (APP) technique can avoid all the above mentioned shortcomings of AHP by allowing user to set relative priority for only adjacent pair of attributes in descending order of priority. After setting relative importance for each of the adjacent pairs, APP quantifies relative priority level using an exponential mapping with a user defined exponent. Moreover this technique is far more adaptive than AHP because it can adaptively control the width of spanning of estimated weights by proper selection of user defined parameters u and α (spanning width increases when either u or α is increased with higher sensitivity) and provides user the ultimate flexibility to control the weight distribution.

3. Grey Relational Analysis (GRA):

GRA was originally introduced to analyze the relational grade for several discrete sequences and choose the best alternative among them. The GST is one of the popular methods used to study uncertainty according to the degree of information (DOI). GST uses DOI as measuring parameter of uncertainty. If DOI is '1' (fully known information), the system is referred as white system; if the DOI is '0' (unknown information), the system is referred as black system. In case of DOI value lies between 0 and 1 ($0 < DOI < 1$) means the system is having partial information, it is termed as grey system [13].

GRA is part of grey system theory which provides an optimum solution to problems having complicated interrelationship among multiple attributes and variables. Because GRA is based on uncertainty problems having discrete data sequence, one of the sequences is defined as reference sequence that represents the ideal solution. All the other sequence will be compared with this ideal solution in terms of relative closeness. To find out relative closeness of particular sequence with respect to ideal one, Grey Relational Coefficient (GRC) is calculated for each of the sequence. Higher value of GRC for a particular sequence is benefitted because it shows that the sequence is more close to ideal one which makes the sequence more selective over others [14]. In network selection problem GRA is used as an optimum method for ranking of available networks based on their GRC values. The GRA method can be implemented in network selection problem in the following steps:

a) Classification of attributes that influence network selection decision. Classification is based on two assesment either "larger the better" or "smaller the better".
b) Defining of upper and lower values of attributes which depends on application classes.
c) Normalization of attributes.
d) Calculation of grey relational coefficients (GRC) for each of alternative network.
e) Ranking of available networks based on their GRC values.

The five basic steps of GRA can be elaborated by usingmathematical description. Here we can take example of m possible networks ($N_1, N_2, \ldots\ldots N_m$) to be compared. Each of the networks has k possible attributes. For each of the attribute, the upper bound is represented as:

$$U_j = \max\{N_1(j), N_2(j), N_3(j), \ldots .\, N_m(j)\} \tag{4}$$

Similarly lower bound (L_j)is represented as:

$$L_j = \min\{N_1(j), N_2(j), N_3(j), \ldots\ldots N_m(j)\} \tag{5}$$

Where$j = 1,2,3, \ldots .\, k$. Now we know there are two types of attributes we have 'smaller the better attribute' and 'larger the better attribute'.

'Smaller the better attribute' normalized value of$N_i(j)$ can be calculated as:

$$N_i^*(j) = {(U_j - N_i(j))}\Big/{(U_j - L_j)} \tag{6}$$

'Larger the better attribute' normalized value of $N_i(j)$ can be calculated as:

$$N_i^*(j) = {(N_i(j) - L_j)}\Big/{(U_j - L_j)} \tag{7}$$

Each of the networks can be represented as a row matrix where the elements of the matrix are nothing but normalized value of k different attributes.

$$N = [N^*(1), N^*(2), \ldots\ldots N^*(k)] \tag{8}$$

The ideal network is often described as the network having best values for each of the attributes. In this paper the ideal network is defined as the network which has all its attributes normalized weight values equal to '1' that is $N_i(j) = 1$ for all $j = 1,2,3, \ldots .\, k$ given as:

$$N = [1\ 1 \ldots .\, .1] \tag{9}$$

If we have $'m'$ networks with $'k'$ no. of attributes are defined for each one the row matrix in eq. (13) can be extended to $m \times k$ matrix. The matrix contains all theattributes values which influence the network selection procedure. The matrix can be represented as follows:

$$N_{m\times k} = \begin{bmatrix} N_1(1) & N_1(2) \ldots . & N_1(k) \\ N_2(1) & N_2(2) \ldots . & N_2(k) \\ N_m(1) & N_m(2) \ldots . & N_m(k) \end{bmatrix} \tag{10}$$

Finally we have to calculate GRC values for each of the alternative networks ($1 < i < m$) that is given by:

$$GRC_i = 1\Big/\left[\left(\sum_{j=1}^{k} w_j .\left|N_i^*(j) - 1\right|\right) + 1\right] \tag{11}$$

The network with largest value of GRC will be selected as the most desirable one.

4. EVALUATION OF NETWORK SELECTION ALGORITHM

In this paper, APP and GRA method is applied for optimal network selection in WiMAX-WLAN environment. We have assumed a HWN environment which consist of a WiMAX and a number of WLAN networks (WLAN1, WLAN2, and WLAN3). Our assumption is based on the fact that WiMAX network ensures user's mobility in larger area with satisfied accessibility while WLAN network provides accessibility with heavy network traffic. WiMAX supports five different class of services named as Multiplayer Interactive Gaming (MIG), VoIP and video conference (VoIP & VC), Streaming Media (SM), Web Browsing and Instant Messaging (WB & IM), Media Content Download (MCD) whose approximate values for WiMAX has been depicted in Table 1 whereas each WLAN networks ensures user's accessibility in some fixed class of services based on different User Types. We have three types of users (Type1, Type2, and Type3) for which degree of QoS satisfaction and Price are different.

Table 1: WiMAX SERVICE CLASSES

No.	Service Class	B (bps)	D (ms)	J	QoS Classes
1	MIG	Low (55 K)	Low <25	---	UGS &rtPS
2	VoIP/ VC	Low (32-64K)	Low <165	Low <60	UGS &ertPS
3	SM	Low to High (5K-2M)	---	Low <160	rtPS
4	MCD	Moderate (10K-2M	---	---	nrtPS& BE
5	WB&IM	High >2M	---	---	nrtPS& BE

Here we are interested in case where user either does not receive good quality of signal strength or WSP does not have resources to continue ongoing services. To improve the performance of ongoing services and to provide uninterrupted services to its users WSP has to route some of its users to existing WLAN networks. The selection of appropriate WLAN network depends on a number of QoS attributes and price of available WLAN networks. Here we have taken three different QoS attributes Bandwidth (B), Delay (D) and Jitter (J) that influences optimal network selection. Service cost /price (P) is another important attribute from user's point of view which affects selection of appropriate network. All the QoS attributes and price values are given for each WLAN networks available for each type of different users as depicted from Table 2, Table 3and Table 4 respectively according to the service related agreement defined between WSP and subscribers. The QoS attributes and price values for each user type are given at the time of decision making of selection of most appropriate WLAN network.

Table 2: AVAILABLE NETWORKS FOR TYPE 1 USER

N/W WLAN	B (bps)	D (ms)	J (ms)	P (Rs)	Service Type
1	25K	15	160	0.025	MIG
2	50K	30	10	0.021	
3	10K	480	50	0.012	
1	0.22M	140	200	0.210	SM
2	0.5M	15	50	0.268	
3	10M	1100	50	0.295	
1	60K	37	110	0.020	VoIP /VC
2	64K	38	150	0.017	
3	50K	35	75	0.035	

Table 3: AVAILABLE NETWORKSFOR TYPE 2 USER

N/W WLAN	B (bps)	D (ms)	J (ms)	C (Rs)	Service Type
1	64K	35	140	0.015	VoIP/Vc
2	60K	37	110	0.020	
3	32K	35	74	0.350	
1	2M	100	20	0.550	MCD
2	1M	120	30	0.393	
3	0.5M	200	35	0.450	
1	1M	16	150	0.075	SM
2	0.5M	250	350	0.090	
3	0.5M	100	50	0.085	
1	10M	25	16	0.031	WB&IM
2	2M	50	25	0.025	
3	5M	100	50	0.021	

TABLE 4: AVAILABLE NETWORKS FOR TYPE 3 USER

N/W WLAN	B (bps)	D (ms)	J (ms)	C (Rs)	Service Type
1	2M	200	40	0.045	MCD
2	1M	120	50	0.038	
1	50K	150	150	0.050	VoIP/VC
2	10K	100	20	0.075	
3	48K	30	150	0.085	
2	0.5M	100	30	0.025	WB&IM
3	1M	250	15	0.055	

Weight Estimation of QoS Attributes and Price for different type of QoS application:
Based on user preferences (either 'Quality First' or 'Money First'), we have assumed three different types of user here. Type1 users are 'Quality First Users', Type2 and Type3 users are 'Money First Users' based on service level agreements defined between user and WSP. Table 4 shows the non-normalized and normalized weights for QoS requirement and price for each type of different user. At the same time normalized weights of QoS and price are graphically shown by Fig. 1.

TABLE 5: QoS AND PRICE WEIGHTS FOR DIFFERENT SERVICE TYPES

User Type	Non-normalized weight		Normalized weight	
	w^*_{QoS}	w^*_p	w_{QoS}	w_P
Type1	8	1	0.889	0.112
Type2	1	5	0.167	0.834
Type3	1	3	0.250	0.750

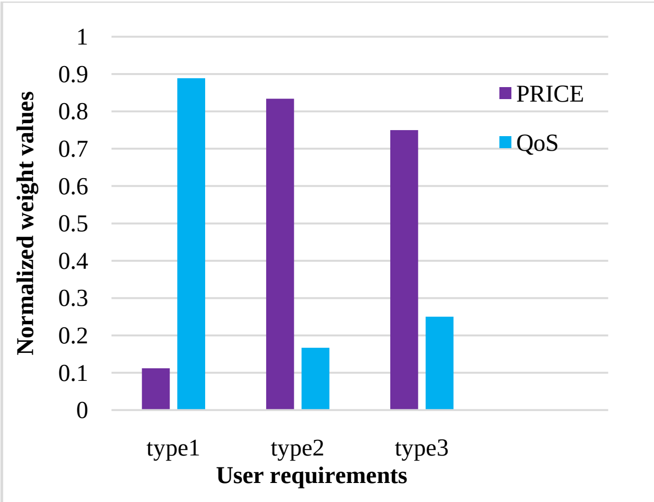

Fig. 1: Normalized weights of QoS and Price for each user type

To calculate weight values of QoS attributes for each of supported application type in each of available WLAN environment, we have used APP method. Table 6 shows calculation of weight values of each of the QoS attributes using APP method based on proper selection of priority order and sensitivity factor (α) in each of service class. Normalized weights are graphically shown by Fig. 2. After getting normalized weight values of QoS attributes {Bandwidth (B), Delay (D) and Jitter (J)} and Price (P), we have to calculate effective normalized weight values of these parameters based on intensity of importance based on 'Quality first 'and 'Price First'. It is depicted from Table 5, the intensity of importance for 'QoS' and 'Price' are different for different User Type.Here, QoS is more important for Type1 user than that of Price whereas Price is more important for Type2 and Type3 user as compared to QoS. TABLE 7 shows the effective weight values of bandwidth, delay, jitter and price for each User Type in different service class. Graphical representation has been shown by Fig. 3, Fig. 4and Fig. 5.

TABLE 6: CALCULATION OF WEIGHT VALUES OF ALL QoS ATTRIBUTES

Service Type	Order of Priority	α	Relative Pair Priority	Non-normalized weights	Normalized weights
MIG		3	$r_{B,D} = 3^0$ $r_{D,J} = 3^1$	$w_B^* = 3$ $w_D^* = 3$ $w_J^* = 1$	$w_B = 0.4285$
					$w_D = 0.4285$
					$w_J = 0.1428$
VoIP/VC	$D = J > B$	5	$r_{D,J} = 5^0$ $r_{J,B} = 5^1$	$w_D^* = 5$ $w_J^* = 5$ $w_B^* = 1$	$w_D = 0.4545$
					$w_J = 0.4545$
					$w_B = 0.0909$
SM	$B > J > D$	3	$r_{B,J} = 3^1$ $r_{J,D} = 3^1$	$w_B^* = 9$ $w_J^* = 3$ $w_D^* = 1$	$w_B = 0.6923$
					$w_J = 0.2307$
					$w_D = 0.0769$
WB & IM	$B > D = J$	3	$r_{B,D} = 3^1$ $r_{D,J} = 3^0$	$w_B^* = 3$ $w_D^* = 1$ $w_J^* = 1$	$w_B = 0.600$
					$w_D = 0.200$
					$w_J = 0.200$
MCD	$B > D > J$	2	$r_{B,D} = 2^1$ $r_{D,J} = 2^1$	$w_B^* = 4$ $w_D^* = 2$ $w_J^* = 1$	$w_B = 0.5714$
					$w_D = 0.2857$
					$w_J = 0.1428$

For optimal network selection GRA has been used. Based on GRC values of all of available WLAN networks foreach type under his supported class of services, WLAN network with highest GRC value is being selected. Table 8 presents GRC values for each user type in each of WLAN environment. Highest values of GRCs are presented from bold numbers. Graphically, it is shown by Fig. 6, Fig. 7 and Fig. 8. Finally Table 9 shows best possible available networks for each user type in each of different service classes.

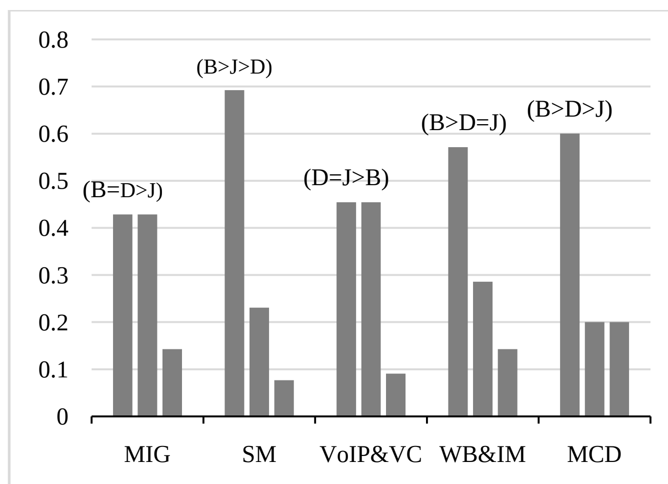

Fig. 2: Weight values of all QoS attributes in each service class

5. CONCLUSION AND FUTURE WORK

In this paper, optimal network selection scheme has been presented in heterogeneous wireless environment by using combination of APP and GRA methods. APP takes advantageof adjacent pair priority comparison which will provide wider spanning of weights of QoS attributes so that user can control priorities of attributes more effectively. It allows users not to bind with inconsistent settings of relative priorities among different QoS attributes. Moreover GRA provides an optimal way of ranking of available networks based on their GRC values. It is one of the optimal network ranking methods which can handle large no. of attributes and provides precise solution

Table 7: EFFECTIVE VALUES OF WEIGHTS

User Types	Service Type	B (bps)	D (ms)	J (ms)	P (Rs)
Type1	MIG	0.3809	0.3809	0.1269	0.112
	SM	0.0554	0.0683	0.2050	0.112
	VoIP/VC	0.0808	0.4040	0.4040	0.112
Type2	VoIP/VC	0.0159	0.0759	0.0759	0.834
	MCD	0.0954	0.0477	0.0238	0.834
	SM	0.1156	0.0128	0.0385	0.834
	WB&IM	0.1002	0.0334	0.0334	0.834
Type3	MCD	0.1429	0.0714	0.0357	0.75
	VoIP/VC	0.0227	0.1136	0.1136	0.75
	WB& IM	0.1500	0.0500	0.0500	0.75

TABLE 8: GRC VALUES FOR EACH SERVICE TYPE IN EACH WLAN NETWORK BASED ON DIFFERENT USER TYPE

User Type	Service Type	WLAN1	WLAN2	WLAN3
Type1	MIG	0.6770	0.9175	0.5569
	SM	0.7884	0.8578	0.8735
	VoIP /VC	0.6534	0.5530	0.8383
Type2	VoIP /VC	0.9294	0.8836	0.5405
	MCD	0.5452	0.9182	0.6802
	SM	0.9629	0.4998	0.8854
	WB&IM	0.5452	0.8854	0.8993
Type3	MCD	0.5490	0.8484	---
	VoIP /VC	0.8148	0.6154	0.5326
	WB&IM	0.8334	---	0.5556

TABLE 9: OPTIMAL NETWORK SELECTED BY EACH USER TYPE

User Type	Service Type	Selected Network
Type1	MIG	WLAN2
	SM	WLAN3
	VoIP/VC	WLAN3
Type2	VoIP/VC	WLAN1
	MCD	WLAN2
	SM	WLAN1
	WB&IM	WLAN3
Type3	MCD	WLAN2
	VoIP/VC	WLAN1
	WB&IM	WLAN1

to the decision problem. In future work, one possible idea is to integratesome more QoS attributes like bit error rate (BER), battery power, network load and security issues in network selection model. We can analyze their importance in network selection decision issues and what complexity they will bring in algorithm evaluation.

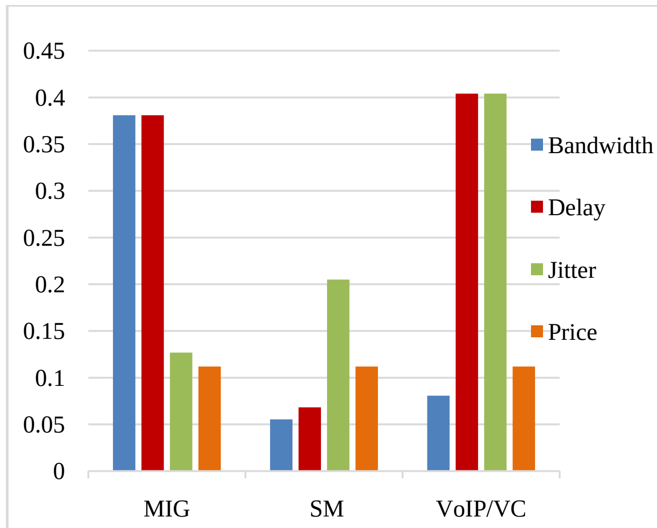

Fig. 3: Effective weight values of Type1 user

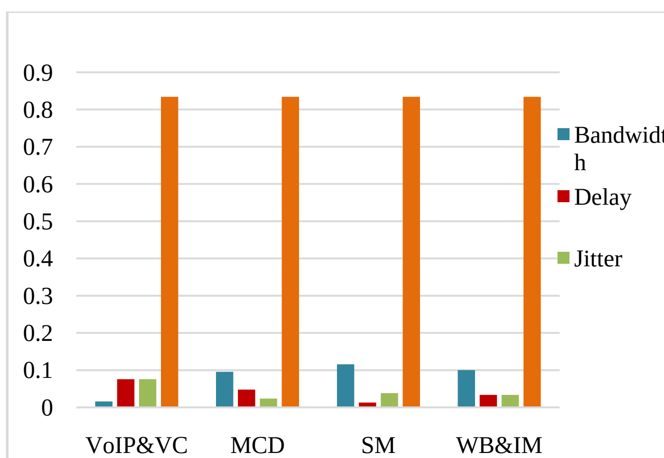

Fig. 4: Effective weight values of Type2 user

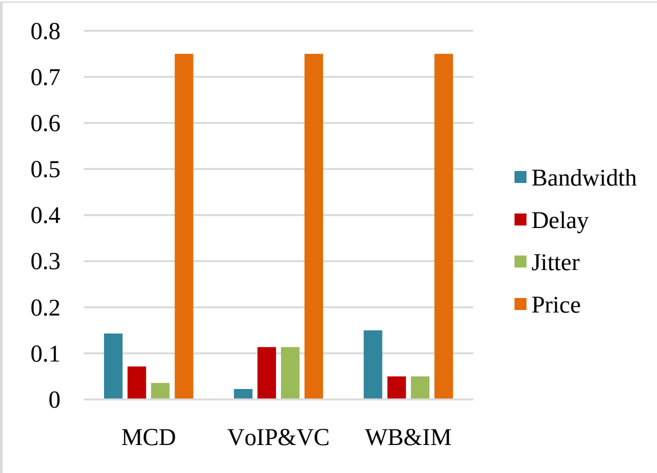

Fig. 5: Effective weight values of Type3 user

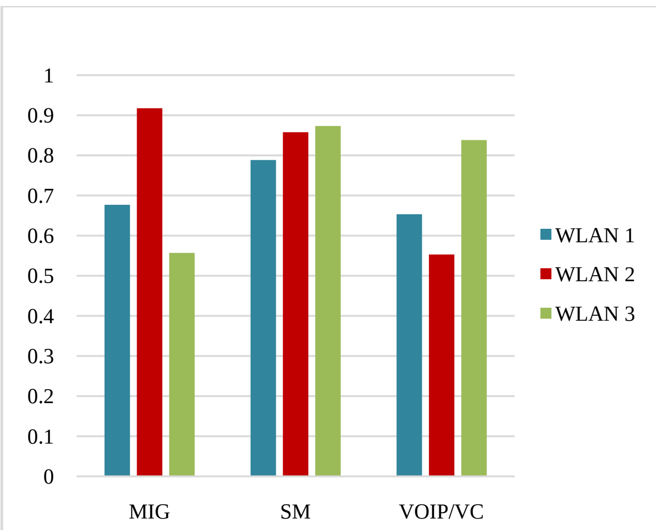

Fig. 6: GRC values for Type1 user in each supported service class

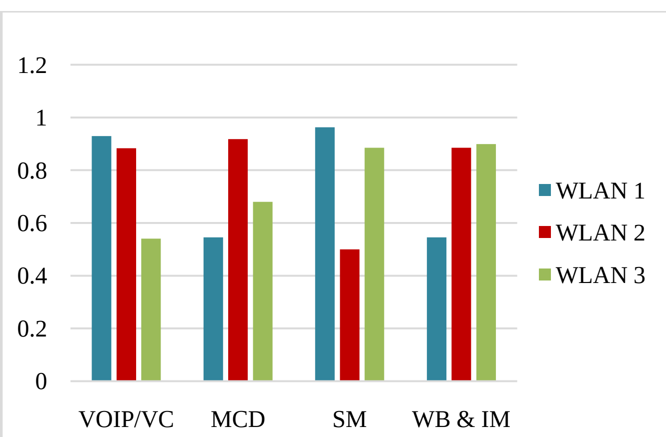

Fig. 7: GRC values for Type2 user in each supported service class

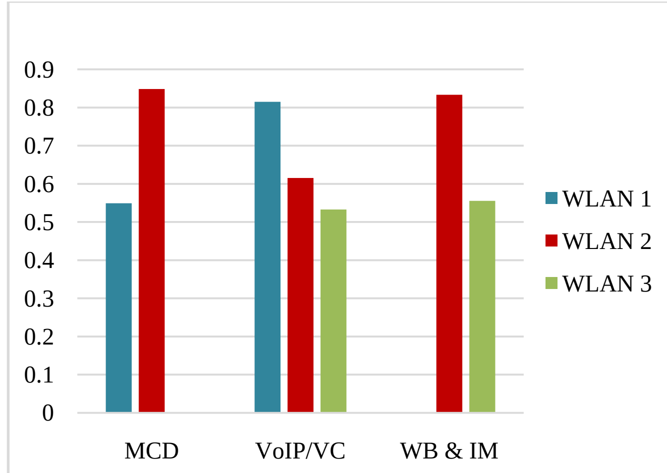

Fig. 8: GRC values for Type3 user in each supported service class

REFERENCES

[1] D. E. Charilas, and A. D. Panagopoulous,"Multi-access Radio NetworkEnvironments," inIEEE Veh. Technol. Mag., vol. 5, no. 4, pp. 40-49,2010.

[2] E. Gustafsson and A. Jonsson, "Always best connected," IEEE WirelessCommunication., vol. 10, no. 1, pp. 49–55, Feb. 2003.

[3] N. P. Singh,Brahmjit Singh, "Vertical handoff decision in 4G wireless networks using multiattribute decision making approach", New York: Springer Wireless Netw, 20, pp.1203-1211, November 2014.

[4] C. L. Hwang and K. Yoon, Multiple attribute decision making methodsand applications,Springer-Verlag, 1981.

[5] J. Mcnair and F. Zhu, "Vertical handoffs in fourth-generation multi network environments, "IEEE Wireless Communication., vol. 11, no. 3, pp. 8–15, June 2004.

[6] J. Fu, J. Wu, J. Zhang, L. Ping, and Z. Li, " Novel AHP and GRA BasedHandover Decision Mechanism in Heterogeneous Wireless Networks", inProc. CICLing (2), pp.213-220, 2010.

[7] S. Yan, C. Shanzhi, L. Yuhong, Y. Lei, and D. Decail, "An Application-Oriented Cooperative Vertical Handoff Decision Method for Multi-interface Mobile Terminals", in Proc. ITST, June 2007.

[8] B. Chang andJ.Chen, "Cross-Layer-Based Adaptive Vertical Handoff with Predictive RSS in Heterogeneous Wireless Networks", "IEEE Transaction of Vehicular Technology, vol.57, no.6, pp. 3679-3692, Nov. 2008.

[9] Shusmita A. Sharna and ManzurMurshed, "Adaptive Weight Factor Estimation from User Preferences for Vertical Handoff Decision Algorithms" IEEE WCNC- network, pp. 1143-1148, 2011.

[10] Wei, G., "Grey relational analysis model for dynamic hybrid multiple attribute decision making, Elsevier, Journal of Knowledge-Based Systems. 24, pp. 672–679, 2011.

[11] So-In, C., Jain R. and Tamimi A.-K." scheduling in IEEE 802.16e mobile WiMAX networks: Key issues and survey" IEEE Journal on Selected Area Networks, JSAC, 27(2), pp.156–169, 2009.

[12] WiMAX forum network architecture: Architecture, details protocols and procedures; Wi-Fi—WiMAX interworking WMF-T37-010-R016v01, WiMAX forum approved, 2010.

[13] Huszak, A.,andImre, S."Eliminating rank reversal phenomenon in GRA based network selectionmethod", IEEE ICC, 2010.