AHP and Group Decision Making for Access Network Selection in Multi-Homed Mobile Terminals

K. Radhika
Department of Information Technology
CBIT
Hyderabad, India
gavini.radhika@gmail.com

Dr. A. Venugopal Reddy
Department of Computer Science
UCE, Osmania University
Hyderabad, India
avgreddy55@gmail.com

***Abstract*— The evolving fourth generation wireless networks provide heterogeneous wireless access. This feature enables the multi homed mobile devices to seamlessly roam across various wireless access technologies and to connect always to the best available access network that provides the best QOS at a minimum cost. Different applications have different QOS requirements and accordingly their choice of access network selection varies. This Paper presents an Access Network selection mechanism for multi-homed mobile terminals that enable users to dynamically choose the right access network based on a set of QOS parameters, when they are moving from one coverage area to another. It also exploits the use of group- decision making to capture the QOS requirements of audio and video traffic and later these individual assessments are combined into a consensus for multi-media traffic for Voice-over-IP applications.**

Keywords- access network selection; multi-homed mobile terminals; QOS parameters; AHP; group decision making;

I. INTRODUCTION

One of the important features of next generation wireless networks is heterogeneity and hence they are given the name Heterogeneous Wireless Networks. These networks are the integration of different wireless access technologies that complement each other in terms of coverage area, mobility support, QOS parameters and price [1-2]. Each wireless technology is developed by keeping in view of specific application requirements. But due to the evolution in the user applications, no single wireless technology can meet the demands of user application requirements. In this context, instead of developing a new wireless access technology that meets the user application requirements, integration of the existing access technologies that enable the mobile to always connect to the best available access network is a more feasible option [3].

Multi-homing is the ability of a mobile terminal to associate with multiple access networks simultaneously. The advantages of multi-homed mobile terminals include permanent Ubiquitous access, reliability, Load balancing, bandwidth aggregation and interface selection [4-6].

Handoff is defined as the process of transferring an ongoing call or data session from one base station to another without loss or interruption of service. If both the base stations belong to the same access network, the corresponding handoff is termed as horizontal handoff. On the other hand, in vertical handoff the base stations belong to different access networks [7].

Analytic Hierarchy Process (AHP) [8] is a mathematical technique for multiple criteria decision making that gives a numerical score to each decision alternative based on how well each alternative satisfies the criteria provided by the decision maker. By using AHP, complex problems can be reduced to simple pair wise comparisons and are merged to give rationally the best solution. AHP can be exploited to make access network selection decision which decides the target network to which the mobile has to be handed over based on a set of QOS parameters of the available networks.

This paper proposes an access network selection algorithm by extending the traditional AHP Multiple Criteria Decision making technique that suits the QOS requirements of applications. The algorithm considers the criteria that include available bandwidth, end-to-end Delay, Jitter, Packet Loss, Cost and security of the network and Wi -Fi, Wi -Max and CDMA networks as the alternatives. First, we consider the QOS parameters for voice traffic and video traffic and later we apply group decision making technique [9] for obtaining the pair wise comparison matrix for multi-media traffic that has a combination of both voice and Video traffic.

The algorithm assumes that the QOS parameters of the available networks in the vicinity of the mobile station are obtained using the IEEE 802.21 frame work [10-12]. IEEE 802.21, also known as Media Independent Handover is designed to support seamless handover among both homogeneous and heterogeneous wireless networks. It provides 3 types of services namely

- MIES (Media Independent Event Service) which detects dynamic changes in the link characteristics and the lower layers can generate events in the form of triggers to the upper layers.
- MICS (Media Independent Command Service) through which the upper layers can pass control information to the physical and link layers in the selection of an appropriate network by passing some handover commands.
- MIIS (Media Independent Information Service) provides a framework through which a MIHF entity can obtain information about the available networks existing within a geographical area to facilitate handovers.

The rest of the paper is organized as follows: Section II, reviews related research work in the area of access network selection. Section III presents the access network selection algorithm and its description. In Section IV, we present the implementation of the algorithm. The Simulation model is assumed in Section V. Results are presented in section VI. Finally in section VII, we give our conclusions.

II. RELATED RESEARCH

Access network selection is one of the most important issues in fourth Generation wireless systems and has been studied extensively in the literature. In [13], an RSS based algorithm was proposed as an extension to the traditional horizontal handoff algorithm. The performance of this algorithm is limited due to the lack of consideration of other network parameters and user QOS requirements. In [14], an MDP based vertical handoff decision algorithm is proposed. The problem is formulated as a Markov Decision Process, but the model does not consider the location information.

In [15], a vertical handoff algorithm was proposed which computes the handoff cost as a function of available bandwidth and monetary cost. In [16, 17], a periodical fast-Fourier-transform-based method is used to determine the decay of received signal and then reduced the ping-pong effect. This procedure requires a long computation time. A long computation time causes error in the prediction of Received Signal Strength and thereby results in high dropping rate.

In [18], a vertical handoff algorithm between WLAN and Wi-Max was proposed by exploiting the movement pattern of the mobile node. In [19], a network initiated vertical handover technique was proposed that provides QOS continuity in UMTS and 802.16 networks.

In [20], a vertical Handoff Decision Algorithm was proposed that performs handoff decision based on SINR. In [21], a vertical handoff decision algorithm that enables the access network to balance the load among all attachment points was proposed.

Though there were many algorithms proposed in the literature, the proposed algorithm is motivated by two aspects: First one is the necessity to consider the case in which priority is given to certain QOS parameters depending on the type of application. Second one is to consider more than five parameters of the available networks to find an optimal target network [22].

III. PROPOSED ALGORITHM

The algorithm assumes an overlaid architecture as shown in Figure.1 of heterogeneous wireless networks where a set of Wi-Fi networks are under the coverage of a Wi-Max netwok and a set of Wi-Max Networks are under the coverage of a CDMA network.

The algorithm considers vertical handoff decision as a Multiple Criteria decision making problem, which chooses one of the available networks based on a set of specified criteria. It considers Wi-Fi, Wi-Max and CDMA as the available alternatives and a set of QOS parameters as the criteria for access network selection.

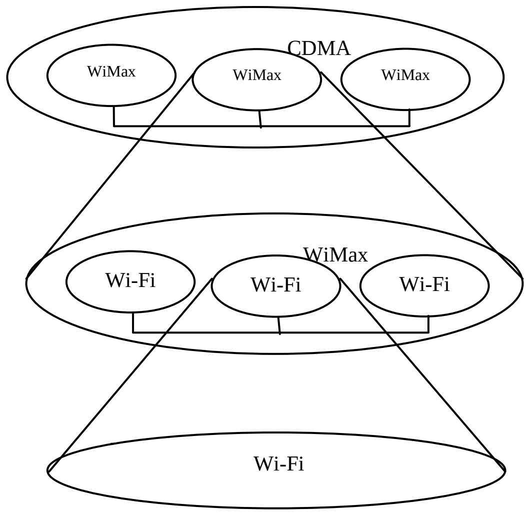

Figure 1. Overlay Architecture

The QOS parameters include Bandwidth (BW), End-to-end delay (D), Jitter (J), Packet Loss (PL), Cost (C) and Security(S). A two level AHP hierarchy of the problem is shown in Figure 2.

Algorithm

Input:

1. Construct a two-level AHP hierarchy by dividing the network selection problem into a hierarchy of decision parameters and a set of available networks as shown in Figure 2.
2. Construct a pair-wise comparison matrix for the QOS parameters considered at level-1 of the hierarchy using the comparison scale given in Figure 3.
3. Construct pair-wise comparison matrices of the available access networks considered at level-2 of the hierarchy for each QOS parameter by using the scoring pattern.

Output:

Composite weights of the available wireless access networks.

Steps:

1. Determine whether the level 1 and level 2 pair-wise comparison matrices satisfy the consistency test. If it does not, reconstruct the pair-wise comparison matrices.
2. Find the weights of the decision parameters.
3. Find the weights of the available networks by considering each parameter.
4. Obtain the composite weights of the available networks.
5. Select the access network that has the highest composite weight as the target network..

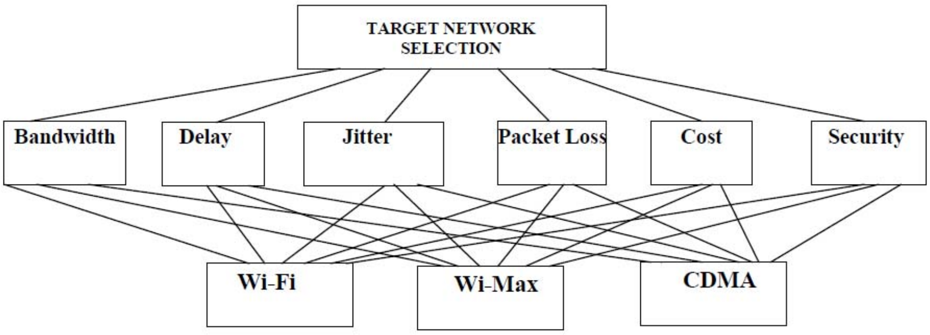

Figure 2. Two-level AHP diagram for network Selection problem

IV. ALGORITHM IMPLEMENTATION

A. *Construction of 2-level AHP hierarchy*

The goal is to select the best available access network and this forms the root node of the hierarchy. In order to make network selection decision, a set of available networks and a set of appropriate decision criteria are to be considered.

The QOS parameters Bandwidth (BW), End-to-end delay (D), Jitter (J), Packet Loss (PL), Cost(C) and Security (S) are considered as the decision Criteria. These are placed at level-1 of the hierarchy.

In this algorithm, we are considering Wi-Fi, Wi -Max and CDMA as the set of available networks as these have a wide variation of network parameters. These are treated as the set of alternatives and are placed at level-2 of the hierarchy.

B. *Construction of Pair-wise Comparison Matrices*

The set of parameters are taken both row-wise and column-wise. Comparisons are made between each pair of parameters and are given values ranging from 1 to 9. The diagonal elements from top-left to bottom-right are assumed to be 1. First the upper triangular matrix is filled based on how much important the row parameter is when compared to the column parameter using the comparison scale shown in Figure 3 and Table 1. Once the upper triangular matrix is filled lower triangular matrix can be obtained by using equation (1).

$$a_{ij} = \frac{1}{a_{ji}} \qquad (1)$$

Construct the pair wise comparison matrix of the decision parameters at level-1 and pair wise comparison matrices of the decision alternatives with respect to each decision parameter. Therefore a 6×6 matrix at level-1 and six 3×3 matrices at level-2 are possible.

C. *Consistency Checking*

The sum of each column of the pair-wise comparison matrix is found and placed in the last row. The resultant matrix is normalized by making the elements of the sum row as 1 and this matrix is termed as Normalized Comparison matrix. Normalized principal eigen vector is obtained by finding average of each row of the normalized comparison matrix.

Next the value of λ_{max} is calculated by using equation (2).

$$\lambda_{max} = \sum_{i=1}^{n} a_i * b_i \qquad (2)$$

'a_i' is the element in the ith row of the Normalized principal Eigen vector. b_i is the element of the sum row in the i^{th} column of the comparison matrix before Normalization.

Consistency index CI is found by using equation (3).

$$CI = \frac{\lambda_{max} - n}{n-1} \qquad (3)$$

' n' is the size of the comparison matrix. For level-1, n=6 and for level-2, n=3.

The Consistency ratio CR is found by using equation (4).

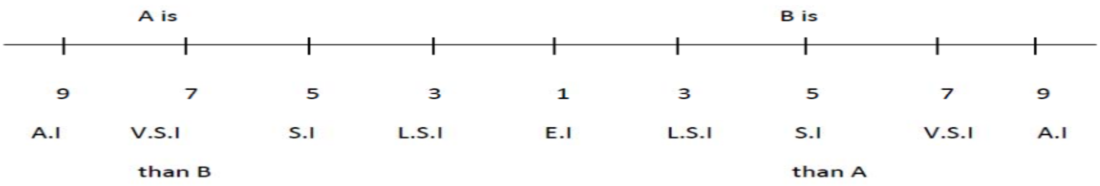

Figure 3. Comparison scale

TABLE. 1 Abbreviations used in the comparison scale

A.I	V.S.I	S.I	L.S.I	E.I
Absolutely Important	Very Strongly Important	Strongly Important	Less Strongly Important	Equally Important

TABLE 2: RI values for comparison matrix of Size n

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

$$CR = \frac{CI}{RI} \qquad (4)$$

Where RI is Random Consistency Index based on the size of the comparison matrix and is shown in Table 2 as given in [6]. The given pair-wise comparison matrix is consistent if CR is less than 0.1.

D. Finding the weight of decision parameter

The weight of each decision parameter is found by using equation (5).

$$W_p = \frac{NPEV_p}{100} \qquad (5)$$

Where W_p is the weight of the parameter ‘p’ and $NPEV_p$ is the element in the Normalized Principal Eigen Vector at level-1 corresponding to the parameter ‘p’.

E. Finding the weight of each available network with respect to each parameter

The weight of each available network with respect to each parameter is found by using equation (6).

$$W_{anp} = \frac{NPEV_{anwp}}{100} \qquad (6)$$

Where W_{anwp} is the weight of the available network with respect to parameter ‘p’.

$NPEV_{anwp}$ is the element corresponding to the access network ‘anw’ in the Normalized Principal Eigen Vector found with respect to parameter p.

F. Finding the Composite weights of the Available Networks

The composite weight of each available network is found by using the equation (7).

$$W_{anw} = \sum_{i=1}^{n} W_p * W_{anp} \qquad (7)$$

$Where\ W_{anw}$ is the composite weight of the access network ‘anw’ and ‘n’ is the number of parameters. Finally the access network that is having the highest composite weight is chosen as the target network.

V. SIMULATION MODEL

Our Simulation model assumes an overlaid network where the coverage area of Wi-Fi is overlapped by Wi-Max network and the coverage area of Wi-Max is overlapped by CDMA network. We assume that the mobile is initially in the CDMA network and moves towards Wi-Max network. Later the mobility of the node is towards the Wi-Fi network. The corresponding simulation model that we assumed in our previous research paper [23] is shown in Figure 4.

VI. RESULTS AND DISCUSSIONS

The algorithm is simulated using Java and the pair-wise comparison matrices are stored in two dimensional arrays. We considered applications that require 3 types of traffic classes namely voice traffic, video traffic and multimedia traffic. As the multi-media traffic involves both voice and video traffic, the QOS parameters are obtained as a geometric mean of QOS parameters of audio and video traffic.

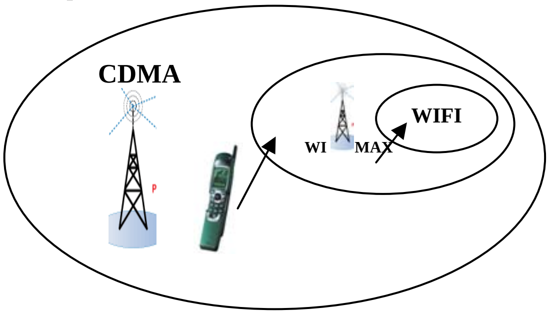

Figure 4. Simulation Model

The pair-wise comparison matrices for these four cases are shown from Table 3 to Table 6.

TABLE 3. Level-1 Pairwise comparison matrix for Voice Traffic

	BW	D	J	PL	C	S
BW	1	1/4	1/4	1/2	1/4	1/3
D	4	1	2	4	2	3
J	4	1/2	1	3	2	2
PL	2	1/4	1/3	1	1/3	1/2
C	4	1/2	1/2	3	1	2
S	3	1/3	1/2	2	1/2	1

TABLE 4. Level-1 Pairwise comparison matrix for Video Traffic

	BW	D	J	PL	C	S
BW	1	2	2	3	4	4
D	1/2	1	2	2	3	4
J	1/2	1/2	1	2	3	4
PL	1/3	1/2	1/2	1	2	3
C	1/4	1/3	1/3	1/2	1	2
S	1/4	1/4	1/4	1/3	1/2	1

TABLE 5. Level-1 Pairwise comparison matrix for Multi-media traffic

	BW	D	J	PL	C	S
BW	1	$\sqrt{2/4}$	$\sqrt{2/4}$	$\sqrt{3/2}$	$\sqrt{4/4}$	$\sqrt{4/3}$
D	$\sqrt{4/2}$	1	$\sqrt{2*2}$	$\sqrt{2*4}$	$\sqrt{3*2}$	$\sqrt{4*3}$
J	$\sqrt{4/2}$	$\sqrt{1/4}$	1	$\sqrt{2*3}$	$\sqrt{3*2}$	$\sqrt{4*2}$
PL	$\sqrt{2/3}$	$\sqrt{1/8}$	$\sqrt{1/6}$	1	$\sqrt{2/3}$	$\sqrt{3/2}$
C	$\sqrt{4/4}$	$\sqrt{1/6}$	$\sqrt{1/6}$	$\sqrt{3/2}$	1	$\sqrt{2*2}$
S	$\sqrt{3/4}$	$\sqrt{1/12}$	$\sqrt{1/8}$	$\sqrt{2/3}$	$\sqrt{1/4}$	1

Next the pair wise comparison matrices of the available access networks at level-2 with respect to each parameter are shown from Table 6. to Table 11.

TABLE 6. Level-2 pairwise comparison matrix based on Bandwidth

	Wi-Fi	Wi-Max	CDMA
Wi-Fi	1	3	7
Wi-Max	1/3	1	5
CDMA	1/7	1/5	1

TABLE 7. Level-2 pairwise comparison matrix based on delay

	Wi-Fi	Wi-Max	CDMA
Wi-Fi	1	1	2
Wi-Max	1	1	1
CDMA	1/2	1	1

TABLE 8. Level-2 pairwise comparison matrix based on Jitter

	Wi-Fi	Wi-Max	CDMA
Wi-Fi	1	1	2
Wi-Max	1	1	2
CDMA	1/2	1/2	1

TABLE 9. Level-2 pairwise comparison matrix based on Packet Loss

	Wi-Fi	Wi-Max	CDMA
Wi-Fi	1	1/2	1/7
Wi-Max	2	1	1/5
CDMA	7	5	1

TABLE 10. Level-2 pairwise comparison matrix based on Cost

	Wi-Fi	Wi-Max	CDMA
Wi-Fi	1	3	7
Wi-Max	1/3	1	4
CDMA	1/7	1/4	1

TABLE 11. Level-2 pairwise comparison matrix based on User Preference

	Wi-Fi	Wi-Max	CDMA
Wi-Fi	1	1/2	1/7
Wi-Max	2	1	1/5
CDMA	7	5	1

The algorithm is implemented for all the above mentioned traffic classes. All the above matrices are checked for consistency and proven to be consistent. The weights of the parameters for all the three different traffic classes are shown in Table 12. The weights of the available access networks for each parameter are shown in Table 13. Composite weights of the available networks when the mobile is under the coverage of Wi-Fi, Wi-Max and CDMA networks are shown in Table 14.

TABLE 12. Weights of the parameters for the three traffic classes

Parameter	Voice	Video	Multi-media
BW	5.24	32.94	14.39
D	32.94	23.24	30.43
J	23.24	18.68	22.89
PL	7.63	12.28	10.45
C	18.68	7.63	13.06
S	12.28	5.24	8.79

TABLE 13. Weights of the Access Networks for each parameter

Access Network	BW	D	J	PL	C	S
Wi-Fi	64.34	41.11	40	9.45	65.55	9.45
Wi-Max	28.28	32.78	40	16.76	26.48	16.76
CDMA	7.38	26.11	20	73.79	7.96	73.79

TABLE 14. Composite weights of the networks for the three traffic classes when mobile is under the coverage of Wi-Fi, Wi-Max and CDMA

Access Network	Composite Weights for voice traffic	Composite Weights for Video traffic	Composite Weights for Multi-media traffic
Wi-Fi	34.13	44.71	41.3
Wi-Max	28.78	30.76	29.88
CDMA	37.09	24.54	28.82

The network that is having the highest composite weight is selected as the target network. When the mobile is under the coverage of all the three networks, CDMA is selected as the target network for voice traffic, Wi-Fi for video traffic and again Wi-Fi for multi-media traffic.

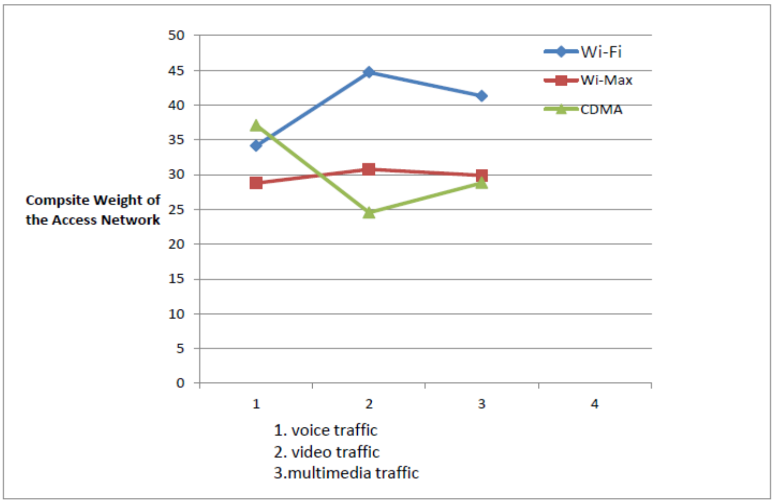

Figure 5. Composite weights of the Access networks for the three traffic classes

VII. CONCLUSIONS

This paper proposes an AHP based network selection mechanism and uses group decision making to arrive at a consensus for multimedia traffic. Since the algorithm is considering the Media Independent framework, it eliminates the delay in scanning for the available networks and thereby reduces handoff latency. As the algorithm is considering the networks whose received signal strength is greater than a threshold value, it eliminates the computation overhead by reducing the number of alternatives whose received signal strength falls below this threshold. Finally Since the algorithm is based on AHP; it gives both qualitative and quantitative evaluation of the alternatives which means that it determines the optimal target network and also evaluates how best the target network is suitable for a specific traffic class.

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AUTHORS PROFILE

K. Radhika is working as an Associate Professor in the department of Information Technology in Chaitanya Bharathi Institute of Technology, Hyderabad. She received B.Tech in Electrical and Electronics Engineering from VRSEC, Vijayawada and M.Tech in Computer Science from JNTU, Hyderabad. She is pursuing PhD in Computer Science from Osmania University under the guidance of Dr. A. Venugopal Reddy. Her research interests include mobile computing, wireless communications and cloud computing. She is a member in IEEE, ISTE, and IETE.

Prof. A.Venugopal Reddy graduated in Electronics & Communication Engineering from JNTU and received M. Tech degree from IIT, Delhi and PhD from IIT Roorkee. His career started in 1980 as Lecturer in JNTU. Later on he joined Osmania University in January 1997. Since then he served the University in various capacities including as head of CSE for 6 years, Dean-Faculty of Informatics for 3 years, Convener-MCA Admissions 1999 to 2001. He was founder Head of Department of Computer Science & Engineering during 1987-1990. He has also served as Director-Infrastructure, Osmania University for a period of 3 years. He has guided many PhDs. To his credit there are more than 30 research publications in various National and International Journals and Conferences. He handled several R&D and Consultancy projects. He has served in various committees constituted by AICTE, APSCHE and other Universities/Institutions in the Country.