Mobility Management QoS Architecture Based on a Cross-layer Scheme

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Abstract

With fast development of wireless network technologies, a variety of different wireless networks coexist in the future. We are getting more and more focus on convergence of heterogeneous networks. In the environment of heterogeneous wireless networks, traditional mobility management has already become incapable to support mobility in heterogeneous wireless networks. As one of the key function of the future mobility management technology, handoff management which is used to provide session continuity across heterogeneous networks has been one of the most challenging technologies in heterogeneous network environments. Fast and efficient and accurate handoff can give users a different experience of networks, this paper aims to propose a cross layer based mobility management proposal which can meet the needs of the users to ensure that users at anywhere and anytime access to the best network.

Keywords--Mobility Management, QoS, Cross-layer

1. Introduction

In the future, the research background of mobility management technology will expand to ubiquitous and heterogeneous network environment with various wireless access technologies. Mobility management contains two components: location management and handoff management[1]. As one of the key function of the future mobility management technology, handoff management, especially vertical handoff which can ensure session continuity across heterogeneous networks has become one of the most challenging technologies.

Cross-layer design allows communication to take place even between nonadjacent layers through additional entities introduced into the system architecture. Cross-layer design approaches are being increasingly studied and there are many cross-layer design proposals. Several investigations are seeking ways to integrate cross-layer design solutions into wireless communication standards in order to allocate resources, schedule access to shared resources with higher throughput, and improve QoS for multimedia applications[2].

Based on the cross-layer design solution, this study proposes a mobility management QoS architecture based on a cross-layer scheme to meet the needs of the users and ensure users access to the best network. The rest of this work is organized as follows. Section 2 describes the related works on mobility management, and QoS. Section 3 describes in detail the proposed cross-layer-based mobility management QoS architecture design. Section 3 contains two components: architecture design and selection algorithm. Section 4 presents the simulation environment and analysis of the results. Conclusion is finally drawn in Section 5.

2. Related works

2.1. Mobility management

According to the "NGN mobility management requirements"[3, 4], released by ITU-T, the mobility management of NGN is divided into terminal mobility, network mobility, personal mobility and service mobility. Among them, the terminal mobility is the most important management issue of mobility management, in this study, we discuss the terminal mobility issue in the heterogeneous network. In the next generation network environment, users access to a heterogeneous wireless or wired access network, when

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the user's location change, access network which provide services for mobile terminals would change too.

Mobility management includes two components: location management and handoff control. The main purpose of location management is to track the current location of the mobile terminal. Location management includes two important functions: location update and paging. Location update requires the mobile terminal reports its position to the management system; paging is the process that management system help the other nodes find the location of the mobile terminal[5]. The main purpose of handoff control is, when the mobile terminal across heterogeneous networks, ensuring the continuity of the ongoing session, and minimizing data loss. Handoff control which is the core task of mobility management can be divided into horizontal handoff and vertical handoff. There are various wireless access technologies in the heterogeneous network. Handoff between similar access technologies is called horizontal handoff, such as handoff between different access points (AP) in WLAN. On the other hand, handoff between different types of access technology is known as vertical handoff, such as handoff between WCDMA and Wimax[6-8]. This paper mainly considers vertical handoff in heterogeneous networks. The handoff process usually consists of four steps: handoff trigger, network selection, handoff decision and handoff execution[9,10]. Currently, there is not a complete solution for the vertical handoff. Therefore, one of the main works in this study is propose a solution to enable the terminal handoff easily and effectively between different networks.

2.2. QoS

Quality of Service (QoS)[11]reflects the ability of ensuring information transmission and meeting service requirements by various network parameters. QoS is a measure of satisfaction. The evaluation of QoS may be subjective or objective. Personal likes and dislikes and the evaluation criterion have a greater influence on subjective evaluation, different people may come to different results. Objective evaluation is based on monitored data, therefore, with greater comparability and fairness. QoS parameters of the network including data rate, delay, delay jitter, packet loss rate, and so on[12,13].

3. Mobility management QoS architecture based on a cross-layer scheme

3.1. Architecture design

This study proposes a mobility management proposal based on cross-layer design which can meet the QoS requirements of the users. The system architecture is shown in Figure 1. This architecture includes three basic modules, network monitoring, user requirement and handoff management to ensure that users at anywhere and anytime access to the best network.

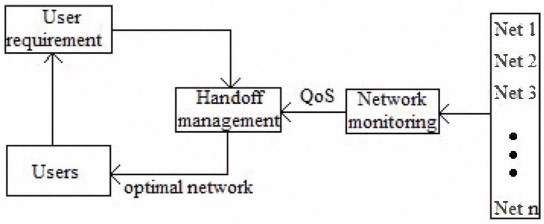

Figure 1. **System architecture**

A. Network monitoring module

Network monitoring module is used for identify and detect the available networks, and also provides a list of alternative networks and QoS parameters to the handoff management module. As shown in Figure 2, the components of the network monitoring module, namely network receiving, network authentication, QoS parameters measurement and resource management module. The network receiving module is used for detect network. Network authentication module is used for verify whether the network has enough signal strength. If it has enough signal strength, adding this network to the list, then, testing the QoS parameters such as packet loss ratio, jitter and throughput of this network. The collected data will be stored in the resource management module for other modules reference.

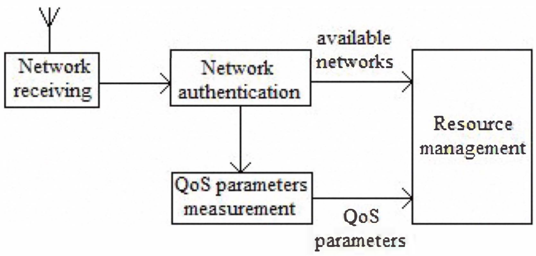

Figure 2. **Network monitoring module**

B. User requirement module

User requirement module is used for determine the user's application type. For different applications, users have different QoS requirements. Applications such as email, instant messaging occupy less bandwidth, allowing the large propagation delay, but the requirements of reliability of transmission is high. VOIP phones and other voice applications have less demand on the reliability of bandwidth and transmission, but have a higher requirement on transmission delay. Online video and other multimedia applications occupy large bandwidth, and do not allow large propagation delay, but have less demand on the reliability.

C. Handoff management module

Handoff management module calculates the parameters which obtained from the other two modules by using specific selection algorithm to select the optimal network which can meet the QoS requirements of the users from alternative networks. Algorithm flow is shown in Figure 3.

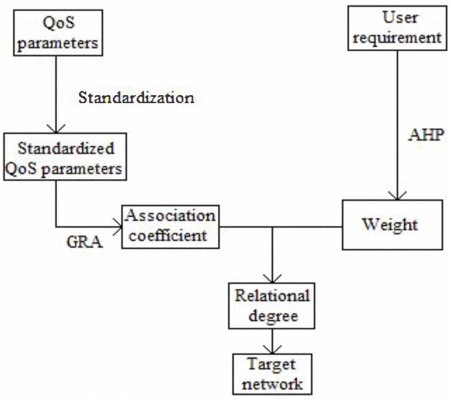

Figure 3. **Algorithm flow**

3.2. Selection algorithm

When the mobile terminal is in the overlapping coverage areas of heterogeneous wireless networks, there are several options of wireless access network (referred as the candidate network). The network selection goal is select the best network as the target network by using a specific selection algorithm. The choice of the target network is usually based on a certain algorithm to sort the candidate network.

Reference [14] proposed a vertical handoff selection algorithm based on received signal strength(RSS). However, the network selection decision criterion only based on RSS is very one-sided. For a particular value of signal strength, the user's application requirements will be influenced by network latency, network load, data transfer rate and other factors. Reference [15] proposed a selection strategy based on analytic hierarchy process(AHP)[16]. This strategy considers the QoS parameters of the network, and fully reflects the difference between different networks. For this algorithm with the shortcomings of subjective arbitrariness on the weights, in this paper, the algorithm was improved by a combination of AHP and Grey Relational Analysis (GRA) [17,18] to balance subjectivity and objectivity of the weights. Specific procedures are as follows.

1) The standardization of QoS parameters

The standardization of QoS parameters can be divided into 3 cases. Assume there are multiple networks referred as $(N_1,\ldots,N_n)$. The actual value of the ith QoS parameter of each network is referred as $(Q_{i1},\ldots,Q_{in})$. For network m, assume the standardized value of the ith QoS parameter is $Q_{im}^{\ *}$.

a. If the parameter is the bigger the better, such as bandwidth, using the formula:

$$Q_{im}^{\ *}=\frac{Q_{im}}{\sum_{k=1}^{n}Q_{ik}} \tag{1}$$

b. If the parameter is the less the better, such as delay, using the formula:

$$Q_{im}^{\ *}=\frac{1}{n-1}\Big(1-\frac{Q_{im}}{\sum_{k=1}^{n}Q_{ik}}\Big) \tag{2}$$

c. For the parameters, such as network security, are described as "good", "poor". They can not be calculated. In this paper, as shown in Table 1, we transformed them into triangular fuzzy numbers.

Table 1. **Conversion table[19]**

Linguistic variable	Triangular fuzzy number
Extremely poor	(0,0.1,0.2)
Poor	(0.1,0.25,0.4)
Ordinary	(0.3,0.5,0.7)
Good	(0.6,0.75,0.9)
Excellent	(0.8,1,1)

Then, for the triangular fuzzy number (a_i,b_i,c_i) , $1\le i\le 5$, transform them into exact values DF_i by using the formula:

$$DF_i=\frac{(c_i-a_i)+(b_i-a_i)}{3}+a_i \tag{3}$$

2) Using AHP method to determine the value of the subjective weight

a. Establish hierarchical structure

In this study, we establish hierarchical structure as shown in Figure 4.

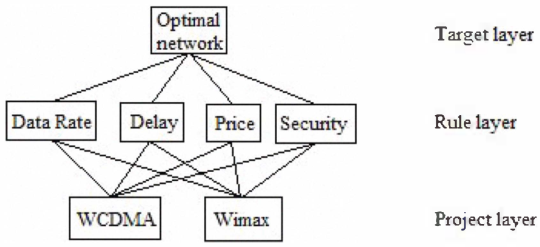

Figure 4. **Herarchical structure**

b. Create the discriminant matrix

The factors of the rule layer are set as $a_1, a_2, a_3, \ldots, a_m$. c_{ij} stand for the results of pairwise comparisons of their relative importance. The value can refer to 1~9 scale proposed by Thomas L. Saaty. All the results will be written in matrix form, namely $A = (c_{ij})_{mm}$. Then, calculate the discriminant matrix to determine eigenvalues and eigenvectors.

c. Consistency check

Using consistency index (CI), random consistency index (RI) and consistency ratio (CR) to make a consistency check. $\lambda_{\max}$ stands for the largest eigenvalue. m stands for the number of factors of rule layer. In this paper, m=4.

$$CI = \frac{\lambda_{\max} - m}{m-1} \qquad (4)$$

Find the corresponding RI from Table 2.

$$CR=CI/RI \qquad (5)$$

If CR ≤ 0.1, indicate that the results meet the consistency check, or need to re-construct discriminant matrix. If the consistency check passed, the eigenvector $U = (u_1, u_2, \ldots, u_m)^T$, corresponding to the largest eigenvalue $\lambda_{\max}$, is the weight vector.

Table 2. **The value of RI[20]**

Order	1	2	3	4	5	6	7
RI	0	0	0.58	0.9	1.12	1.24	1.32
8	9	10	11	12	13	14	15
1.41	1.45	1.49	1.52	1.54	1.56	1.58	1.59

3) Using GRA method to create an association coefficient matrix

a. Create a nondimensional matrix

$Y_0' = (Y_0'(1), Y_0'(2), \ldots Y_0'(m))$ stands for standardized reference sequence. Similarly, $X_1', X_2', \ldots, X_n'$ stand for the standardization sequence of QoS parameters of each network. Create a nondimensional matrix as follows.

$$(Y_0', X_1', \ldots, X_n') = \begin{pmatrix} Y_0'(1)x_1'(1) & \cdots & x_n'(1) \\ \vdots & \ddots & \vdots \\ Y_o'(m)x_1'(m) & \cdots & x_n'(m) \end{pmatrix} \qquad (6)$$

b. Calculate difference sequence

According to the formula:

$$\Delta_{0i}(k) = \left| Y_0'(k) - x_i'(k) \right| \text{ i=1,2,…,n; k=1,2,…,m} \qquad (7)$$

Create a matrix:

$$\begin{pmatrix} \Delta_{01}(1) & \cdots & \Delta_{0n}(1) \\ \vdots & \ddots & \vdots \\ \Delta_{01}(m) & \cdots & \Delta_{0n}(m) \end{pmatrix} \qquad (8)$$

Find out the maximum number $\Delta_{\max}$ and the minimum number $\Delta_{\min}$ of matrix

c. Create an association coefficient matrix

Calculate the association coefficient.

$$\xi_{0i}(k) = \frac{\Delta_{\min} + \rho\Delta_{\max}}{\Delta_{0i}(k) + \rho\Delta_{\max}}, \text{ i=1,2,…,n} \qquad (9)$$

ρ stands for discrimination coefficient. $\rho \in [0,1]$. Generally, $\rho = 0.5$.

Then, create an association coefficient matrix.

$$\begin{pmatrix} \xi_{01}(1) & \cdots & \xi_{0n}(1) \\ \vdots & \ddots & \vdots \\ \xi_{01}(m) & \cdots & \xi_{0n}(m) \end{pmatrix} \qquad (10)$$

4) Calculate the relational degree combine with weight

Combine AHP with GRA, using the following formula to calculate the relational degree.

$$\gamma_{0i} = \sum_{k=1}^{m} \xi_{0i}(k) u(k), \text{ i=1,2,…,n} \qquad (11)$$

The relational degree represents the similar degree between the candidate network and the ideal network. Target network has the highest similarity with the ideal network. Therefore, the network which has the maximum value of relational degree is the target network.

4. Simulation and Analysis

4.1 Simulation scenario

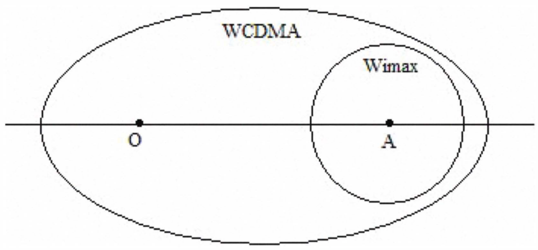

Figure 5. **Simulation scenario**

Simulation scenario is shown in Figure 5. Assuming the mobile terminal (MT) starts from O, along OA, do uniform linear motion. When MT go across the two networks coverage area, according to the specific application requirements, select the better network and handoff.

The initial values of the QoS parameters of the network are shown in Table 3.

Table 3. **The initial values of the QoS parameters**

	Data Rate(R)	Delay(D)	Price(P)	Security(S)
WCDMA	37.5kbps	2.9/ms	0.8RMB/min	Good
Wimax	42.3kbps	1.2/ms	0.5RMB/min	Ordinary

According to formula (1) to (3), standardized QoS parameters are shown in Table 4.

Table 4. **Values of standardized QoS parameters**

	R	D	P	S
WCDMA	0.47	0.29	0.38	0.6
Wimax	0.53	0.71	0.62	0.4

When the mobile terminal moves in this scenario, set the RSS as shown in Figure 6.

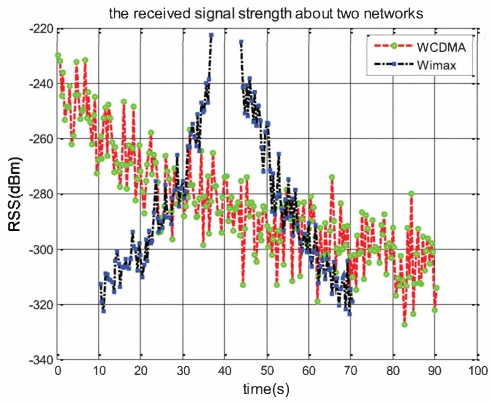

Figure 6. **The RSS in this scenario**

4.2 The simulation and analysis

1) For real-time business

According to the characteristics of real-time business and the user requirement, create the discriminant matrix. Use the values in Table 5.

Table 5. **Values of discriminant matrix**

	R	D	P	S
R	1	1/3	5	3
D	3	1	9	5
P	1/5	1/9	1	1/3
S	1/3	1/5	3	1

According to formula (4) and (5), after calculation, the largest eigenvalue of the matrix satisfy the consistency check, the corresponding eigenvectors is the weight vector. As shown in Table 6.

Table 6. **Values of weight of real-time business**

	R	D	P	S
Weight	0.3951	0.8982	0.0773	0.1765

According to formula (6) to (10), create an association coefficient matrix.

$$\begin{pmatrix} 0.7288 & 0.7818 \\ 0.6056 & 1.000 \\ 0.6615 & 0.8776 \\ 0.8543 & 0.6754 \end{pmatrix}$$

According to formula (11), calculate the value of relational degree of different networks. For WCDMA, the value is 1.0338. For Wimax, the value is 1.3941. Therefore, for real-time business, Wimax is closer to the ideal network and is better to meet user requirements.

According to the handoff selection algorithm based on RSS, simulation of the selection and handoff process of network shown in Figure 7.

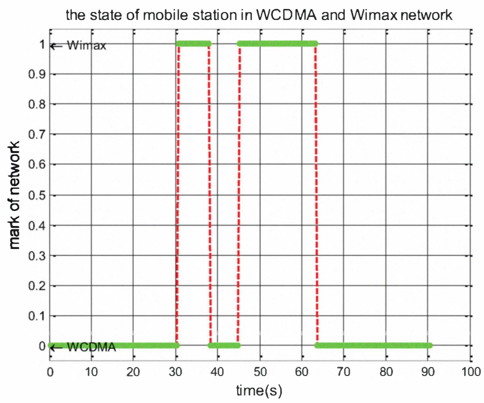

Figure 7. **Handoff process based on RSS**

Under the same environment， according to the selection algorithm proposed in this paper, simulation of the selection and handoff process of network shown in Figure 8.

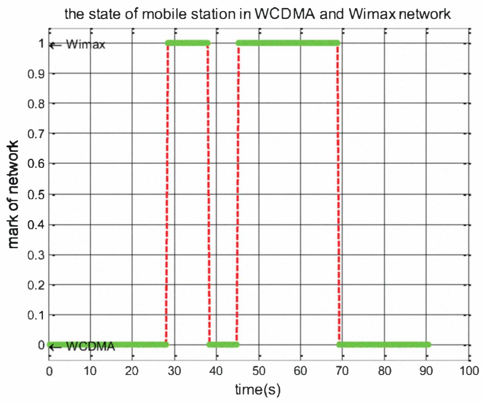

Figure 8. **Handoff process based on the selection algorithm proposed in this paper**

From Figure 7 and Figure 8, we can see that when the MT moved 63s, WCDMA had a bigger value of RSS than Wimax. Therefore, according to RSS based handoff selection algorithm, the mobile terminal performed handoff from Wimax to WCDMA. While, according to the selection algorithm proposed in this paper, for real-time business, the performance of Wimax was still better than WCDMA at that time. So, MT did not perform handoff to meet user requirements as much as possible. When the MT moved 69s, Wimax can not meet the minimum requirement of the RSS, MT switched to WCDMA.

2) For non-real-time business

According to the characteristics of non-real-time business and the user requirements, create the discriminant matrix. Use the values in Table 7.

Table 7. **Values of discriminant matrix**

	R	D	P	S
R	1	9	8	2
D	1/9	1	1/2	1/8
P	1/8	2	1	1/7
S	1/2	8	7	1

According to formula (4) and (5), after calculation, the largest eigenvalue of the matrix satisfy the consistency check, the corresponding eigenvectors is the weight vector. As shown in Table 8.

Table 8. **Values of weight of non-real-time business**

	R	D	P	S
Weight	0.8267	0.0689	0.1037	0.5487

According to formula (6) to (10), create an association coefficient matrix.

$$\begin{pmatrix} 0.7288 & 0.7818 \\ 0.6056 & 1.000 \\ 0.6615 & 0.8776 \\ 0.8543 & 0.6754 \end{pmatrix}$$

According to formula (11), calculate the value of relational degree of different networks. For WCDMA, the value is 1.1816. For Wimax, the value is 1.1768. Therefore, for non-real-time business, WCDMA is closer to the ideal network and is better to meet user requirements.

According to the selection algorithm proposed in this paper, simulation of the selection and handoff process of network shown in Figure 9.

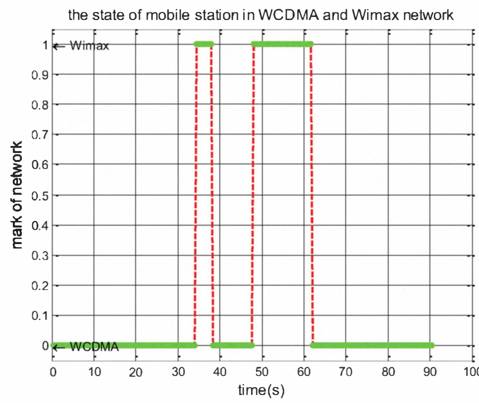

Figure 9. **Handoff process based on the selection algorithm proposed in this paper**

From Figure 7 and Figure 9, we can see that when the MT moved 30s, Wimax had a bigger value of RSS than WCDMA. Therefore, according to RSS based handoff selection algorithm, the mobile terminal performed handoff from WCDMA to Wimax. While, according to the selection algorithm proposed in this paper, for non-real-time business, the performance of WCDMA was still better than Wimax at that time. So, MT did not perform handoff to meet user requirements as much as possible. When the MT moved 35s, WCDMA can not meet the minimum requirement of the RSS, MT switched to Wimax.

5. Conclusion

This work presents a mobility management QoS architecture based on a cross-layer scheme. Mainly describe the architecture design and the selection algorithm. This architecture consist of network monitoring, user requirement and handoff management, thus ensure the users at anywhere and anytime can access to the best network. The proposed selection algorithm can balance subjectivity and objectivity of the weights by a combination of AHP and GRA. Simulation results show that this network selection scheme can choose the best network according to user requirement. As for users, this proposal can improve users' satisfaction on the quality of service, and meet the requirements of users as much as possible.

6. Acknowledgement

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7. References

[1] Mingxin Li, Shanzhi Chen, Yuhong Li, "A Cross-layer Based on Share Database Mobility Management Architecture in Heterogeneous Networks", 2007 IEEE, Jul.2007, pp. 1869-1872.

[2] Jiann-Liang Chen, Ming-Chiao Chen, Shih-Wei Liu, Jyun-Yu Jhuo, "CROSS-LAYER QOS ARCHITECTURE FOR 4G HETEROGENEOUS NETWORK SERVICES", 2009 ICACT 2009, Feb.15-18, 2009, pp. 73-77.

[3] ITU-T Recommendation Q.1706 (2006), Mobility Management Requirements for Next Generation Networks.

[4] ITU-T Draft New Recommendation MMR (working in progress), Mobility Management Requirements for Fixed and Mobile Convergence Networks.

[5] Yu Gao, Study on multi-granular QoS control mechanism and mobility management technology in SUPANET.

[6] Mark Stemm, Randy H. Katz, "Vertical Handoffs in Wireless Overlay Networks", ACM Mobile Networking (MONET), Special Issue on Mobile Networking in the Internet, Vol. 3, 1998, pp. 335-350.

[7] Chakravorty R., Vidales P., Patnapongpibul L., Subramanian K., Pratt I.,Crowcroft J, "On Inter-network Handover Performance using IPv6".

[8] Farhan Siddiqu, Sherali Zeadally, "Mobility management across hybrid wireless Network: Trends and challenges. IEEE Computer Communications, 2005.

[9] J. McNair and F. Zhu, "Vertical Handoffs in Fourth-generation Multi-network Environments", IEEE Wireless Comm., vol.11, no.3, June 2004.

[10] W. Chen, J. Liu, and H. Huang, "An Adaptive Scheme for Vertical Handoff in Wireless Overlay Networks", Proc of ICPADS'04, Newport Beach, CA, July 2004.

[11] J.S. Richters, C.A. Dvorak, "A framework for defining the quality of communications services", IEEE Communications Magazine, 1988, 26(10): 17-23.

[12] Shenker S, Wroclawski J. RFC2216-Network Element Service Specification Template, 1997.

[13]ITU-T Rec. Y.1540-IP Packet Transfer and Availability Performance Parameters. Dec. 2002.

[14] A. Mehbodniya, J. Chitizadeh, "An intelligent vertical handoff algorithm for next generation wireless networks", Second IFIP International Conference on Wireless and Optical Communications Networks(WOCN 2005), March 2005, pp. 244-249.

[15] Bing Xie, The Research on Vertical Handoff Algorithm of the Terminals in IP-based Heterogenous Networks.

[16] T.L.Saaty, "Fundamentals of Decision Making and Priority Theory with the Analytic Hierarchy Process", RWS Publications, U.S.A., 2000.

[17] Lin C T, Hwang S N, Chan C H, Grey number for AHP model: an application of grey relational analysis[C]// Proceedings of the IEEE International Conference on Networking, Sensing & Control, 2004, pp. 226-230.

[18] Liu Sifeng, Guo Tianbang, Dang Yaoguo, et al, "Theory and application of grey system" [M], 2nd ed, Beijing, Science Press, 1999, 55-61.

[19] S.J.Chen, C.L.Hwang, "Fuzzy Multiple Attribute Decision Making Methods and Applications", N.Y., Springer-Verlag, New York, 1992.

[20] T.L.Saaty, "The Analytic Hierarchy Process", [M], New York, McGraw2Hill, 1980.