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NETWORK SELECTION USING MADM METHODS IN HANDOFF PROCESS

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ABSTRACT

In heterogeneous wireless networks, users with multi application terminal have to access different network services. It is necessary for a mobile terminal to have network service provider agreement with all networks. Selecting a suitable network based on different criteria to handle handoff operation seems to be a complex approach. Thus the decision making in heterogeneous network is critical and based on different network criteria and user's information it is uncertain. In this paper, the handoff decision strategy is given by fuzzy MADM (Multiple Attribute Decision Making). The fuzzy logic concept is used because of the imprecise information of the network criteria.

***Keywords*:** Handoff, MADM, Heterogeneous Networks

INTRODUCTION

Mobile devices like laptops, mobile phones have different choice of connectivity and services like cellular, WLAN (Wireless Local area Network) etc. This provides a mobile user great flexibility for network access. So the users have prior responsibility to select a suitable network. However the decision on which network to use becomes much more complicated, because both the number of network and decision criteria increase. The decision criteria involved in network selection are bandwidth, received signal strength, delay time, battery consumption etc. In addition, users with different application will also play a significant role in the decision making that is the users will also give certain preference in the criteria. Thus the complexity problem arises due to mapping of network according to the criteria and application. So an intelligent handoff decision algorithm is very important for heterogeneous network access.

In account of multiple criteria, it is difficult to rank the network according to the user's preference on a single criterion. In such cases, the different criteria are combined. Thus trade – offs are sometimes required. Many different schemes are evolved to solve the handoff decision problem. One of them is call admission control handoff algorithm. However this approach is not suitable for trade – off. Thus fuzzy logic concept is used for trade – off in different criteria. The fuzzy logic is applied in both handoff initiation and handoff decision. But during handoff decision, combination of all such different criteria is involved. Fuzzy logic concept alone doesn't give a solution for this. So arise a fuzzy MADM (Multiple Attribute Decision Making).

The rest of this paper is structured as follows: Section 2 outlines some of the background and related work. Section 3 sketches about the basic Fuzzy Logic concept followed by the

handoff decision strategy as introduced in Section 4. In Section 5, the handoff decision algorithm is identified as fuzzy MADM. Numerical works are explained in section 6. Results and Sensitivity Analysis are presented in Section 7. Finally Section 8 concludes the paper with a brief discussion of future work.

Background and Related Works

The handoff is classified by three subsections. The first is hard handoff and Soft handoff. In Hard handoff, the channel is released first then the new base station channel is accessed. Soft handoff involves the multiple connections of mobile network terminal with neighboring cells. The second is the microcellular handoff and multilayer handoff. The former is due to dividing the areas into smaller cells. And later is the overlaid of number of slow user micro cell on the fast user macro cell. Final Classification is horizontal handoff and vertical handoff. Horizontal handoff will be in homogeneous network and vertical handoff to be in complex heterogeneous network.

The services of wireless communication are upgrading extremely fast. Hence the need of mobile user will goes on increasing. The interconnection problem therefore arises in the coverage boundary of two systems. The connection must be therefore seamlessly switched between two networks. It is referred as intersystem or vertical handoff. The decision of selecting a network is based on fuzzy control theory. Since in heterogeneous network, this selection is given by Fuzzy MADM method.

Basic Fuzzy Logic Concepts

Fuzzy Logic was conceived as a better method for sorting and handling data. It uses an imprecise but very descriptive language to deal with input data. FL offers several unique features that make it a particularly good choice for many applications.

1. It is inherently robust since it does not require precise data information. The output is a smooth control function despite a wide range of input variations.
2. Since the Fuzzy Logic controller processes user-defined rules, it can be modified and tweaked easily to improve or drastically alter system performance.
3. FL is not limited to a few inputs and one or two outputs, it is necessary to measure or compute rate-of-change parameters in order for it to be implemented.
4. Because of the rule-based operation, any reasonable number of inputs can be processed (1-8 or more) and numerous outputs (1-4 or more) generated, although defining the rule base quickly becomes complex if too many inputs and outputs are chosen for a single implementation since rules defining their interrelations must also be defined.
5. FL can control nonlinear systems that would be difficult or impossible to model mathematically.

Steps to perform Fuzzy Logic:

1. Define the control objectives and criteria.
2. Determine the input and output relationships and choose a minimum number of variables for input to the Fuzzy Logic engine.

3. Using the rule-based (IF – THEN rules) that define the desired system output response for given system input conditions. The number and complexity of rules depends on the number of input parameters that are to be processed.
4. Create Fuzzy Logic membership functions that define the meaning (values) of Input / Output terms used in the rules.
5. Test the system, evaluate the results, tune the rules and membership functions, and retest until satisfactory results are obtained.

Handoff Decision Strategy

When a new base station has unoccupied channels, then the handoff should occurred with reduction in the drop of a call (Forced Termination) and time delay (Call Blocking Probability). This handoff can be done either by mobile assisted or by mobile controlled. In former case, mobile makes the measurements while the switching center decides the handoff. In latter case, mobile itself continuously measures and takes the handoff decisions.

The new base station network is selected by using handoff algorithm. It involves three phases: (i) Handoff initiation, (ii) Handoff decision, (iii) Handoff execution. During handoff initiation, the optimal time to initiate handoff is taken place. According to the user's information and segment availability, handoff is initiated. For this, three different QoS parameters are used. They are Bit Error Rate (BER), Received Signal Strength (RSS), and Coverage Area.

The initiation algorithm is based on fuzzy logic concept. The block diagram for handoff initiation is shown in fig. 1. It comprises of three different stages – Fuzzifier, Inference Engine and Defuzzifier. In the first stage, the three QoS parameters are fed to a Fuzzifier where the real time measurements are translated into Fuzzy Sets as linguistic terms like very low, low, medium, high and very high with membership function valid between 0 and 1 as shown in fig. 2.

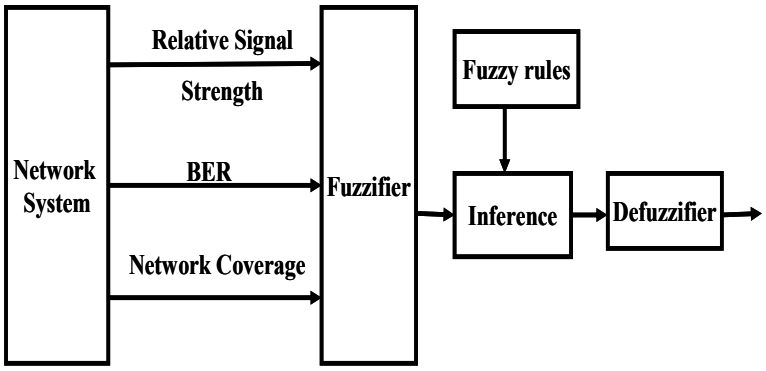


Fig. 1. Block Diagram of Fuzzy Logic Concept in Handoff Initiation algorithm.

The second stage involves in inputting these fuzzy sets into Inference Engine where a set of fuzzy rules like If – Then rules are applied. An example of If – Then rules are as follows:

If (SS is LOW) and (BER is HIGH) and (Coverage Area is LOW) *Then* Handoff.

If (SS is HIGH) and (BER is LOW) and (Coverage Area is HIGH) *Then* No Handoff.

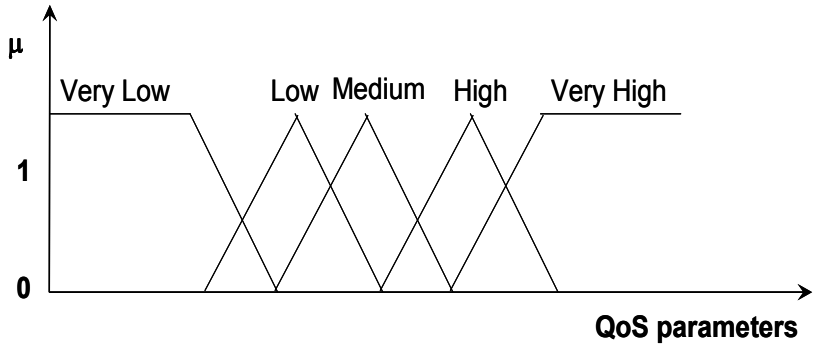


Fig. 2. Example for Membership function

The last stage is Defuzzifier in which the membership values are again converted into real time values by using Centroid method.

$$y = \frac{\sum_{i=1}^{3} \mu_i \bar{y}}{\sum_{i=1}^{3} \mu_i}$$

Where μ_i represent the membership value function for i^{th} criteria y denotes the center of fuzzy region.

In Handoff Decision phase, selection of network depends upon the user's profile, application policy and available network. It has three stages as shown in fig. 3.

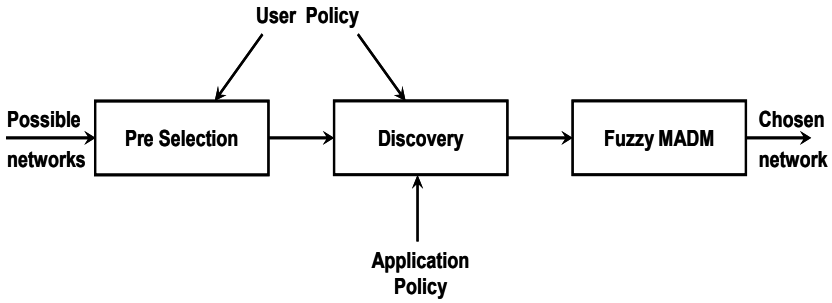


Fig. 3. Block Diagram of Handoff Decision Phase

Pre selection eliminates the unsuitable access network with the help of user policy.

In Handoff Execution phase, by obtaining the Internet Protocol (IP) address of selected network, the operation is executed. The protocols and signaling procedures are established for reliable exchange of handoff data.

Handoff Decision Algorithm Using Fuzzy MADM

The selection of network with respect to the basic criteria is based on Ranking of those criteria. This ranking in deciding the suitable network is determined by using either Multiple Objective Decision Making (MODM) or Multiple Attribute Decision Making (MADM). The

decision making is to choose a "sufficiently good" alternative among a set of alternatives to achieve a goal. In MODM, the alternatives are not pre - determined so selecting the most promising alternative seems to be difficult. But MADM method alternatives are pre - determined and known. So with the imprecise information data, MADM is well suited. Moreover MADM is a qualitative approach. The unique goal for selecting a network using MADM method has two options. 1. Select a criterion presenting the networks with best characteristics.2. Classify the criteria based on role model.

Usually MADM method has two main phases: (1) the rating of each network, by aggregation of the degree of satisfaction for all criteria, per decision network; and (2) the ranking of the network with respect to the global aggregated degree of satisfaction.

For instance, suppose a user is presently connected to GPRS network N_1 and has to make decision on four user networks: N_1, N_2, N_3, N_4 and N_5 where N_2 is a UMTS network, N_3 is a WLAN network, N_4 is a Bluetooth network and N_5 is a Wi - MAX network. Handoff criteria considered here are Receiver Sensitivity, Bandwidth, Delay, Battery Status, Cost, Bit Error Rate, and Data Transfer Rate which are denoted as X_1, X_2, X_3, X_4, X_5, X_6 and X_7 respectively. The decision problem can be concisely expressed in the decision matrix as,

$$D = \begin{array}{c} \\ N_1 \\ N_2 \\ N_3 \\ N_4 \\ N_5 \end{array} \begin{array}{c} \begin{array}{ccccccc} X_1 & X_2 & X_3 & X_4 & X_5 & X_6 & X_7 \end{array} \\ \begin{bmatrix} 85 & 13 & 110 & 0.01 & 10 & 0.001 & 40 \\ 40 & 200 & 190 & 0.05 & 6 & 0.01 & 60 \\ 88 & 1100 & 160 & 0.06 & 2 & 1 & 55 \\ 70 & 220 & 200 & 0.03 & 3 & 0.1 & 55 \\ 80 & 7000 & 120 & 0.01 & 1 & 0.1 & 70 \end{bmatrix} \end{array}$$

Here the decision matrix has 5 rows as networks and 7 columns as QoS parameters. Suppose the user has running applications, voice and file download. The preference on handoff criteria is modeled as weights assigned by the user according to the criteria; for voice are w_v and file download are w_f in such a way that the summation on each criteria to be equal to one.

w_v = [High Medium Low Low High Medium High]

w_f = [Medium High Medium Medium Low Low Medium]

The fuzzy MADM method consists of two steps. The first step is to convert the fuzzy data into a real number. The second step is to use classical MADM methods to determine the ranking order of the candidate networks. Two classical MADM methods are proposed: SAW (Simple Additive Weighting) and TOPSIS (Technique for Order Preference by Similarity to Ideal Solution).

In SAW, the overall average value of a user's network is determined by the weighted sum of all the attribute values. The average value is obtained by adding the normalized criteria value for each network a_{ij} multiplied by its importance weight w_j of that network. Therefore the selected network Y_{SAW} is

$$Y_{SAW} = \arg \max_{i \in M} \sum_{j=1}^{N} w_j a_{ij}$$

where N is the number of parameters, and M denotes the number of networks.

In TOPSIS, the selected network is the one which is the closest to the ideal solution (and the farthest from the worst case solution). The ideal solution is obtained by using the best values for each criterion. Let S_i denote the relative similarity of the user network i to the ideal solution. Therefore the selected network Y_{TOP} is

$$Y_{TOP} = \arg \underset{i \in M}{Max} S_i$$

When a user has several applications running simultaneously and requires handoff, handoff decision may give different results for different applications, because different weights on criteria or even different criteria may be applied.

Numerical Works

The resultant linguistic terms are converted to crisp numbers and the resultant decision matrix is shown below.

$$D = \begin{matrix} N_1 \\ N_2 \\ N_3 \\ N_4 \\ N_5 \end{matrix} \begin{bmatrix} 85 & 13 & 110 & 0.01 & 10 & 0.001 & 40 \\ 40 & 200 & 190 & 0.05 & 6 & 0.01 & 60 \\ 88 & 1100 & 160 & 0.06 & 2 & 1 & 55 \\ 70 & 220 & 200 & 0.03 & 3 & 0.1 & 55 \\ 80 & 7000 & 120 & 0.01 & 1 & 0.1 & 70 \end{bmatrix}$$

The weighting factors for voice w_v and file download w_f are:

$w_v = [0.250 \;\; 0.161 \;\; 0.055 \;\; 0.084 \;\; 0.161 \;\; 0.054 \;\; 0.236]$

$w_f = [0.043 \;\; 0.424 \;\; 0.161 \;\; 0.237 \;\; 0.056 \;\; 0.037 \;\; 0.042]$

Next SAW and TOPSIS method of Fuzzy MADM are applied.

SAW

Larger the criteria value, better the comparable scale.

$R_{ij} = X_{ij} / X_i^{MAX}$; $\quad i = 1$ to 5; $j = 1$ to 7

$R_{ij} = X_i^{MIN} / X_{ij}$; $\quad i = 1$ to 5; $j = 1$ to 7

After scaling, the decision matrix becomes,

$$D' = \begin{bmatrix} 0.471 & 0.002 & 1 & 1 & 0.1 & 1 & 0.571 \\ 1 & 0.029 & 0.579 & 0.2 & 0.167 & 0.1 & 0.857 \\ 0.455 & 0.157 & 0.688 & 0.167 & 0.5 & 0.001 & 0.786 \\ 0.571 & 0.031 & 0.55 & 0.33 & 0.33 & 0.01 & 0.786 \\ 0.5 & 1 & 0.917 & 1 & 1 & 0.01 & 1 \end{bmatrix}$$

By applying the weighting factors of voice and file download,

$A_v = [0.4619 \;\; 0.5378 \;\; 0.4566 \;\; 0.4457 \;\; 0.8169]$

$A_f = [0.4855 \;\; 0.2445 \;\; 0.2970 \;\; 0.2571 \;\; 0.9281]$

TOPSIS

Normalize the decision matrix by,

$$R_{ij} = X_{ij} / \sqrt{\sum_{j=1}^{7} X_{ij}} \quad ; i = 1 \text{ to } 5; j = 1 \text{ to } 7$$

Apply the weight of voice application,

$$V_1 = \begin{bmatrix} 1.323 & 0.130 & 0.379 & 0.0001 & 0.099 & 0 & 0.588 \\ 0.449 & 1.441 & 0.473 & 0.0002 & 0.043 & 0 & 0.636 \\ 0.587 & 4.708 & 0.236 & 0.0001 & 0.009 & 0.001 & 0.346 \\ 0.748 & 1.508 & 0.473 & 0.0001 & 0.021 & 0.0002 & 0.554 \\ 0.235 & 13.178 & 0.078 & 0 & 0.002 & 0.0001 & 0.194 \end{bmatrix}$$

The ideal and negative ideal solutions are:

$A^+ = [0.235 \;\; 13.176 \;\; 0.078 \;\; 0 \;\; 0.002 \;\; 0 \;\; 0.6358]$

$A^- = [1.323 \;\; 0.130 \;\; 0.473 \;\; 0.0002 \;\; 0.1 \;\; 0.0014 \;\; 0.194]$

Separation of each parameter from its ideal and negative ideal solutions are by,

$$S^+ = \sqrt{\sum_{j=1}^{7} (Vij - A_j^+)^2} \quad ; i = 1 \text{ to } 5$$

$$S^- = \sqrt{\sum_{j=1}^{7} (V_{ij} - A_j^-)^2} \quad ; \; i = 1 \text{ to } 5$$

$S^+ = [13.1 \;\; 11.74 \;\; 8.48 \;\; 11.69 \;\; 0.442]$

$S^- = [0.405 \;\; 1.64 \;\; 4.65 \;\; 1.54 \;\; 13.097]$

The relative closeness is obtained by,

$C_v = S^- / (S^- + S^+)$

$C_v = [0.0300 \;\; 0.1224 \;\; 0.3540 \;\; 0.1163 \;\; 0.9674]$

Similarly for file download apply the weight,

$$V_2 = \begin{bmatrix} 0.228 & 0.344 & 1.099 & 0.0001 & 0.035 & 0 & 0.103 \\ 0.077 & 3.811 & 1.369 & 0.0005 & 0.015 & 0 & 0.113 \\ 0.101 & 12.45 & 0.685 & 0.0004 & 0.003 & 0.001 & 0.062 \\ 0.129 & 3.989 & 1.371 & 0.0003 & 0.007 & 0.001 & 0.099 \\ 0.040 & 34.84 & 0.226 & 0 & 0.001 & 0 & 0.035 \end{bmatrix}$$

Similarly the ideal and negative ideal solutions are:

$A^+ = [0.041 \;\; 34.84 \;\; 0.226 \;\; 0 \;\; 0.0007 \;\; 0 \;\; 0.1131]$

$A^- = [0.228 \;\; 0.344 \;\; 1.37 \;\; 0.0005 \;\; 0.347 \;\; 0.001 \;\; 0.035]$

$S^+ = [34.51 \;\; 31.05 \;\; 22.395 \;\; 30.87 \;\; 0.0787]$

$S^- = [0.281 \;\; 3.472 \;\; 12.127 \;\; 3.647 \;\; 34.576]$

$C_f = [0.0081 \;\; 0.1006 \;\; 0.3513 \;\; 0.1056 \;\; 0.9977]$

The relative similarity to ideal solution for voice and file download application are,

$C_v = [0.0300 \;\; 0.1224 \;\; 0.3540 \;\; 0.1163 \;\; 0.9674]$

$C_f = [0.0081 \;\; 0.1006 \;\; 0.3513 \;\; 0.1056 \;\; 0.9977]$

RESULTS AND SENSITIVITY ANALYSIS

Table – 1 shows the Qos parameters like Received Signal Strength, Bit Error Rate and Coverage area data sheets used in Handoff Initiation process. And the simulation result for Handoff Initiation by matlab fuzzy logic toolbox is pictured in Fig. 4. The result can be improved by using many parameters with more number of iterations.

Table 1. Qos Parameter Details

Received Signal Strength Parameters	
Very Low	<= 15 dbm
Low	15 to 20 dbm
Medium	20 to 35 dbm
High	35 to 45 dbm
Very High	>=45 dbm
Bit Error Rate Parameters	
Very High	10^{-2} to 10^{-3}
High	10^{-3} to 10^{-4}
Medium	10^{-4} to 10^{-5}
Low	10^{-5} to 10^{-6}
Very Low	10^{-6} to 10^{-7}
Coverage Area parameters	
Least	<= 10m
Less	10 to 30m
Medium	30 to 50m
Better	50 to 100m
Best	>= 100m

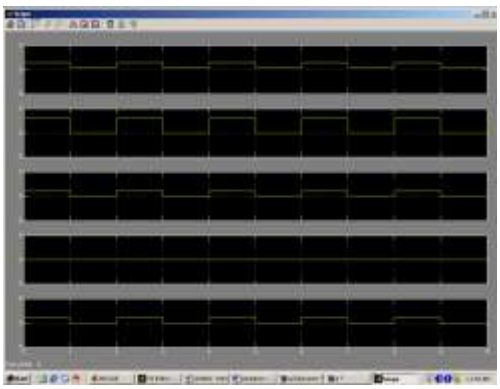


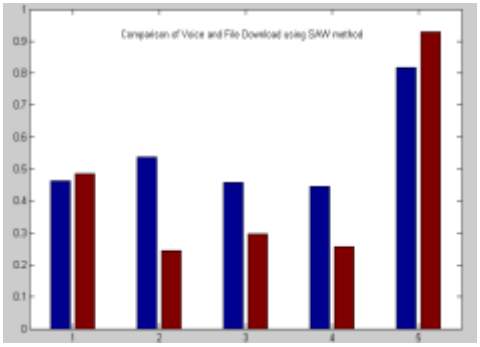
Fig. 4. Simulation result of Handoff Initiation

From the last section, the user preference on ranking order is observed. The ranking result is more sensitive when SAW method is used except in WiMAX network.

The performance of a criterion will definitely influence the decision result and is shown in fig 5. Since the handoff decision is concerned with selecting the best choice, it is worth evaluating the influence of the criteria that contribute to the first rank position.

SAW, Voice	N5, N2, N1, N3, N4
SAW, File Data	N5, N1, N3, N4, N2
TOPSIS, Voice	N5, N3, N2, N4, N1
TOPSIS, File Data	N5, N3, N4, N2, N1

(a)



(b)

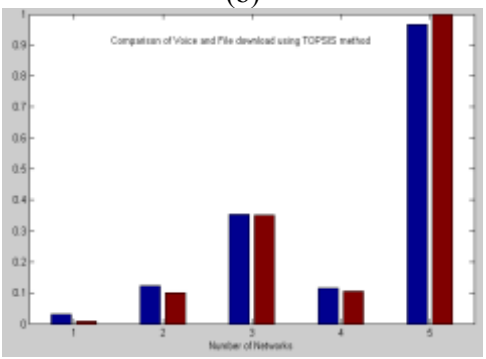


Fig. 5. Simulation result for Comparison of Voice and File download using SAW and TOPSIS method

From the sensitivity analysis, SAW method is more sensitive to the preference on the network and the network performance except in WiMAX network, while the user preference is rather subjective and network 5 to be the best in both voice and file transfer,

CONCLUSION AND FUTURE WORK

It is more complex to make handoff decision in heterogeneous network by considering different criteria. The trade – off of some criteria is required. The approach of fuzzy MADM will solve this problem and deal with imprecise handoff criteria and user's preference. For a systematic analysis, fuzzy MADM methods like SAW, TOPSIS are applied.

The future work of this paper continues with setting the hystersis in Received Signal strength during handoff initiation process and including the Delay parameter in Decision Process.

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