The Vertical Handoff Algorithm using Fuzzy Decisions in Cellular Phone Networks

Chandrashekhar G. Patil¹ & R.D. Kharadkar²

¹Department of Electronics Engineering, A.G. Awate College of Engineering, Pune, India
²Principal, G.H. Raisoni Institute of Engineering and Technology, Wagholi, Pune, India

Abstract: A new, dynamic, cost effective and efficient Handoff algorithm is the need of the future world of Wireless Communication. The simple Fuzzy decisions can be used to design an effective and efficient Handoff algorithm. Few selected parameters such as Power Level, Cost, and Bandwidth along with the Speed of the Mobile Terminal (MT) are considered here for the design of the Handoff algorithm. The Membership Functions for each of the parameter are determined and corresponding Membership Degrees are evaluated from their concerned Membership Functions. The optimized fuzzification of the parameters is carried out by developing the appropriate weight vector. The simulation results presented elaborates the performance of the algorithm in comparison to the simple RSS and Thresholded RSS algorithm.

Keywords: Handoff, Man Hatton Scenario and Fuzzy Control Theory.

1. INTRODUCTION

In mobile scenario, in spite of the type of the roaming, whether it is intranetworking or inter-networking, a wireless mobile terminal moving from one location to another need to change its point of connection to the wired backbone network. Handoff is a process of transferring a mobile station from one base station or channel to another. [1] The seamless switching of the mobile terminal (MT) to the appropriate network, when it crosses the coverage boundary of two different systems, is much more important in order to offer the guaranteed Quality of Services (QoS). Therefore the implementation of handoff is extremely important in all mobile network applications [2]. Such a cross-system transfer of an ongoing connection is usually referred to as inter-system, or Vertical handoff. The simple Fuzzy control theory concepts are being used in this paper for designing of vertical handover decision algorithm. The four basic metrics such as Power Level, Cost, and Bandwidth along with the Speed of the Mobile Terminal (MT) have been considered as input parameters to the Vertical Handoff Algorithm.

The Manhattan scenario is used for the simulation of this algorithm and it is discussed in detail in Section 2. The determination of the membership functions and their corresponding membership degrees for these 4 input parameters with respect to each BS is evaluated in Section 3. The corresponding optimum weight vector is also determined for all the input parameters. Using the weight vector and the membership degree values the vertical handover decision (VHD) value for each BS are determined. Section 4 deals with the procedure of taking the final vertical handover decision depending upon the VHD values. The comparison of this algorithm with the other traditional algorithms is presented in Section 5 along with the conclusion.

2. THE SIMULATION SCENARIO AND THE INPUT PARAMETERS

The Manhattan scenario is a widely adopted model for performance analysis of wireless cellular communication networks, in which the characteristics of the urban geometry of streets and user mobility are modeled [3, 4]. For the performance analysis of handoff algorithms, a part of a Manhattan type cellular network system with four base stations located in cross sections of the streets can be modeled as shown in Fig. 1. In this scenario, a mobile station moves from the neighborhood of base station BS1 towards another base station BS2 along a direct path.

Figure 1: Microcellular Manhattan Scenario.
2.1. The Statistical Channel Model

The propagation and the received power model used for the simulations characterize path-loss and shadow fading is given by equation 1. [5]

\[ P_r = P_t - L_0 - 20 \log(r) + f(r); r < r_{bp} \]
\[ 20 \log(r_{bp}) + 40 \log(r/r_{bp}) + f(r); r \geq r_{bp} \ldots (1) \]

Where \( P_t \) is the transmitted power, \( L_0 \) is the path loss in the first meter, \( r \) is the distance between the transmitter and receiver, and \( r_{bp} \) is the break-point distance and is defined as

\[ r_{bp} = \frac{(4 \cdot h_{tx} \cdot h_{rx})}{\lambda}; \quad (2) \]

Where \( h_{tx} \) and \( h_{rx} \) are the heights of the transmitter and receiver antennas, respectively, and \( \lambda \) is the wavelength of the carrier frequency. The correlated lognormal shadowing sample \( f(r) \) is obtained by using an exponential autocorrelation function given by equation (3) [6, 7]

\[ \rho(\gamma) = E(f(r) + f(r + \gamma)) = 2 \exp(-\gamma/\gamma_o) \quad (3) \]

where \( \gamma \) is the distance separating two samples, \( \gamma_o \) is a parameter that can be used to specify correlation at a particular distance referred to as the correlation distance, and 's' is the standard deviation of the fading process. The correlated lognormal shadow fading sample \( f(r) \) can now be calculated by

\[ f(r) = \rho^*(f(r - 1)) + \sqrt{1 - \rho^2} N(0, \sigma). \quad (4) \]

Where \( N(0, \sigma) \), represents a normal random variable with zero mean and standard deviation \( \sigma \). In the simulations, a correlation distance of 8.5 m and \( \sigma = 8 \) dB is used [8]. By using equation (1), the received Signal strength from BS1 is shown in Fig. 2.

![Figure 2: The Received Signal Strength from Two Base Stations BS1, BS2, BS3 and BS4.](image)

2.2. The Input Parameters used for the Analysis

The input parameters selected for the analysis can be defined as:

1. **Power (PW):** The power levels received from candidate BSs.
2. **Cost (CT):** The costs of operation networks which the candidate BSs belong to.
3. **Band Width (BW):** The amounts of unused bandwidth of candidate BSs.
4. **Speed (SP):** The Speed of the Mobile Terminal with respect to candidate BSs.

3. THE MEMBERSHIP FUNCTION AND MEMBERSHIP DEGREES FOR THE INPUT PARAMETERS

3.1. The Membership Function of the Power

Without loss of generality, the actual power level that is received from the candidate BS is defined as \( PW(d) \), and \( PW(TH) \) to be the threshold power level, where \( d \) is the distance between the Mobile terminal and the candidate BS. It is assumed that the maximum power level that can be received from a candidate BS be defined as \( PW(MAX) \). A piecewise linear membership function of PW can be calculated by using the normalization factor of \( PW(d) \) and \( PW(MAX) \) as depicted in equation 5.[9,10]

\[ Mue_1 = \begin{cases} 0 & \text{if } PW(d) < PW(TH) \\ \frac{PW(d) - PW(TH)}{PW(MAX) - PW(TH)} & \text{if } PW(TH) \leq PW(d) \leq PW(MAX) \\ 1 & \text{if } PW(d) > PW(MAX) \end{cases} \quad (5) \]

The membership function \( Mue_1(d) \) is plotted as shown in Figure 3

![Figure 3: Membership Function of Power PW.](image)
3.2. The Membership Function of the Cost

In similar fashion let CT (d) be the actual cost of the Operation Network which a candidate BS belongs to and CT (TH) be the Threshold Cost of the Operation Network. When the current cost of the operation of the network exceed the threshold value, then the user will decide that the network is too expensive to accept. The Membership Function for the Cost parameter Mue₂(d) may be evaluated by the equation 6 and plotted as shown in Figure 5. [9,10,11]

\[
Mue_2 = \begin{cases} 
1 - \frac{CT(d)}{CT(TH)} & 0 \leq CT(d) \leq CT(TH) \\
0 & CT(d) > CT(TH) 
\end{cases} \tag{6}
\]

3.3. The Membership Function of the Band Width

For defining the membership function for the Bandwidth, let BW (d) to be the amount of unused bandwidth of a candidate BS, and the BW (max) be the maximum amount of Band width that the candidate BS can provide. The Membership Function for the Band Width parameter Mue₃(d) may be evaluated by the equation 7 and plotted as shown in Figure 5.

\[
Mue_3 = \begin{cases} 
\frac{BW(d)}{BW(max)} & 0 \leq BW(d) \leq BW(max) \\
0 & BW(d) > BW(max) \tag{7}
\end{cases}
\]

3.4. The Membership Function of the Speed of the Mobile Terminal

For defining the membership function for the Speed of the MT, let SP (d) be the Speed of the MT with respect to a candidate BS, and the SP (TH) be the threshold value of the Speed of the MT with respect to a candidate BS. The Membership Function for the Band Width parameter Mue₄(d) may be evaluated by the equation 8 and plotted as shown in Figure 5.

\[
Mue_4 = \begin{cases} 
1 - \frac{SP(d)}{SP(TH)} & 0 \leq SP(d) \leq SP(TH) \\
0 & SP(d) > SP(TH) \tag{8}
\end{cases}
\]

3.5. The Membership Degrees of the Candidate BS

For ‘n’ candidate BSs i.e. BS₁, BS₂, BS₃, BS₄ ... BSₙ the membership degrees of Power, Cost, Band Width and the Speed of the Mobile Terminal for each BS can be determined using the membership functions in Equation(5), Equation(6), Equation(7) and Equation(8). The results are shown in Table 1. For the membership degree Mue in the table, the first subscript indicates the input parameter while the second subscript shows the candidate BS. [9,12]
The Cost of the Operation Network

The standard deviation ‘σ’ of an input parameter value recorded at all the candidate Base Stations. Therefore, the Standard Deviation ‘σ’ for say ‘i’ th input parameter value recorded at all the BS may be given as an equation (10).

\[
\sigma_i = \sqrt{[1/(n-1)] * \sum_{k=1}^{n} [Mue_{ik}(d) - 1/n * \sum_{k=1}^{n} Mue_{ik}(d)]^2} (10)
\]

Accordingly the values of the Standard Deviation σ are calculated for each of the input parameters and can be used to determine the values of the Weight vector W as depicted in the equation (11).[9,12,14]

\[
W = [w_1, w_2, w_3, w_4, \ldots \ldots w_n] (11)
\]

Where the values of \(w_1, w_2, w_3, w_4, \ldots \ldots w_n\) can be calculated by an equation (12).

\[
w_i = (\sigma_i) / \sum_{i=1}^{4} \sigma_i (12)
\]

Where \(i = 4\) since there are only 4 input parameters. In other words the Weight Vector W for 4 input parameters can be defined as in equation (13).

\[
W = [w_1, w_2, w_3, w_4] = [(\sigma_1) / \sum_{i=1}^{4} \sigma_i, (\sigma_2) / \sum_{i=1}^{4} \sigma_i, (\sigma_3) / \sum_{i=1}^{4} \sigma_i, (\sigma_4) / \sum_{i=1}^{4} \sigma_i] (13)
\]

After evaluating the Weight Vector, the Fuzzy vertical Handoff Decision Vector ‘F’ can be determined by using the Weight Vector ‘W’ (equation 11) and the Membership degree values (Table No.1) as shown in equation (14).

\[
F = W * U (14)
\]

Where \(F(d) = [F_1(d), F_2(d), F_3(d), F_4(d)\ldots\ldots F_n(d)]\)

And \(U = [U_1, U_2, U_3, U_4, U_5 \ldots \ldots U_n]\) (15)

Based on the FVHD values final vertical handoff decision can be taken.

4.1. Vertical Handoff Decision Algorithm by using FVHD Vector

From the FVHD vector F, any ‘k’th Base Station \(BS_k\) will be selected for the handoff if and only if it satisfies the following conditions.

1. The FVHD value for this ‘k’th Base Station is maximum as compared to other FVHD values of all other Base Stations.

\[
F_k(d) = \text{Max} \{F_1(d), F_2(d), F_3(d), F_4(d)\ldots\ldots F_n(d)\} \ldots\ldots (17)
\]

2. In order to avoid unnecessary handoff some threshold value for the FVHD vector is decided F (TH). The difference between the FVHD value of the ‘k’th Base Station i.e. \(F_k(d)\) and maximum of all other FVHD values will be compared with the predetermined Threshold value of the FVHD value F (TH). If the difference is larger than the threshold value then and then only the handoff will take place.
in favor of the ‘k’th Base Station BS. Mathematically the condition can be depicted as in equation (18) [9,13]

\[ F_k(d) - \max (F(d)) \geq F(TH) \quad (18) \]

5. SIMULATION RESULTS AND CONCLUSION

For simplicity, the simulation is carried out in a straightforward way, considering only 2 candidate base stations, BS1 and BS2. The route is assumed to be a direct line from BS1 to BS2. In order to present the algorithm in a straightforward way, the membership functions are all assumed to be piecewise linear. However, in actual considerations, the form of membership functions should be modified to achieve better approximation. What’s more, the membership functions for different base stations may not be the same, due to different criteria of different operation networks. The fuzzy control theory based vertical handover decision algorithm presented in this paper provides a generalized vertical handover decision procedure, in which various input parameters are dynamically evaluated and computed to achieve optimized handover. The algorithm can be carried out easily through software method or dedicated fuzzy logic processing modules.

![Figure 7: Occurrence of Vertical Handover Decision using Basic RSS Algorithm](image1)

![Figure 8: Occurrence of Vertical Handover Decision using Basic RSS Algorithm with the Threshold](image2)

![Figure 9: Occurrence of Vertical Handover Decision based on Fuzzy Vertical Handoff Decision (FVHD) Vector Values](image3)

The performance of the FVHD algorithm is compared with the Vertical handoff algorithm using basic Received Signal Strength (RSS) metrics and it is observed that the numbers of unnecessary Handoff decisions have been drastically reduced. Figure 7 shows the occurrence of the Handoff when the basic RSS metrics is used. Similarly Figure 9 shows the occurrence of the Handoff when the threshold RSS metrics is used. The performance of this algorithm is also compared with the new FVHD algorithm which is found to be effectively advantageous. Fig.9 elaborates the performance of the FVHD algorithm using 4 input parameters.

REFERENCES


