Fuzzy Rule Based Vertical Handoff Decision Strategies for Heterogeneous Wireless Networks

1Ms. Ashima, 2Mr. Prashant Rana, 3Ms. Neeraj Maan
1M.Tech student, ECE Department, P.M. College of Engineering, Sonepat-131001, India
2Faculty of engineering, ECE Department, P.M. College of Engineering, Sonepat-131001, India
3Faculty of engineering, ECE Department, P.M. College of Engineering, Sonepat-131001, India

Abstract- The 4th generation wireless communication systems goal is to provide continuous connection to users for access various wireless technologies and to have the connection with the best network which provides the best Quality of service. To achieve this goal we need best decision making algorithm which can decide which one is best network for users for specific application under which vertical handoff should be performed. In this paper we are using Fuzzy quantitative decision algorithm FQDA for making multi-attributes decision making process along with QOS aware fuzzy rule based vertical handoff mechanism using fuzzy logic. FQDA is used to decide whether the handoff is required or not. If it require then it will choose best network for the users. The QoS parameters considered are available bandwidth, end-to-end delay, jitter, and bit error rate (BER). Simulation results show that compared to other vertical handoff algorithms, the proposed algorithm gives better performance for different traffic classes.

Keywords - Heterogeneous networks, Vertical handoff, Fuzzy Rule Based algorithm, Traffic Classes, QoS Parameters.

I. Introduction

With the evolution of wireless communication technology, the requirement of wireless communication networks is going to be high. Today, there are many networks available for users according to their need. As we know each mobile user have one frequency band under BTS. As user move from one place to another then it come under another BTS or network which is called “handovering” & the mechanism is called “handover”. There are two types of handover: Horizontal handoff (HHO) and Vertical handoff (VHO). Unlike a horizontal handoff that only occurs within the same network [1] i.e. when the mobile users switch between the networks with the same technology (WiFi to WiFi) this process called HHO, where as a vertical handoff occurs in the heterogeneous wireless network when a mobile user changes its connection between different networks i.e. the mobile users switch in different networks which have different technology (WiMax to WiFi). So in heterogeneous network vertical handoff decision (VHD) is mainly used for seamless service with the best network which provides the best Quality of service. [2]

The traditional horizontal handoff research is emphasized on the received signal strength (RSS) evaluation of the mobile host (MH). However, in the case of vertical handoff, RSS evaluations and comparisons are insufficient for making an optimized vertical handoff decision. A comparison between different vertical handoff algorithms has been presented in [3]. The handoff decision may depend on various parameters including available bandwidth, bit error rate, jitter, average battery lifetime, access cost, transmit power, and end-to-end delay. In this paper a combination of some of the criteria can be considered for making a decision in handoff with one handoff decision algorithm(FAHP)[4]. Vertical handoff is generally categorized into three phases [5] system discovery, vertical handoff decision, and vertical handoff execution. A good decision making algorithm which decides the best network under which vertical handoff should be performed. During handover there is a need to decide and choose the best network. So the Vertical Handoff Decision Making is an important research issue. This paper proposes a QoS aware fuzzy rule based vertical handoff mechanism Using FQDA (fuzzy quantitative decision algorithm) as an handoff decision criteria to choose which network to handover among different available access networks. The FQDA has three steps: fuzzification, quantitate evaluation and quantitative decision.

The various handoff strategies used for executing handoff may in general be classified into: Mobile- Controlled Handoff (MCHO), Network-Controlled Handoff (NCHO), and Mobile-Assisted Handoff (MAHO). In MCHO, the
mobile node continuously monitors the signal of access points and initiates the handoff procedure when some handoff criteria are satisfied. NCHO is a centralized handoff protocol, in which network makes handoff decision based on measurements of the signal quality of mobile station (MS) at a number of base stations (BS). In MAHO, a mobile node measures the signal strength of surrounding base stations and then decides whether or not to initiate the handoff procedures. MCHO has a low complexity in terms of network equipment. However, latency and loss of large number of packets during inter-subnet handoff can be high. Handoff decision in MAHO is made by the network for coordination among mobile nodes and global optimization. However, in heterogeneous wireless access networks only the mobile nodes have the knowledge about the kind of interfaces they are equipped with; so the network dependency on the mobile node is high. Therefore, MCHO with some assistance from the networks is better suited for implementing vertical handoff.

The QoS aware fuzzy rule based handoff mechanism proposed in this paper assumes MCHO, where a mobile will periodically monitor the available networks and using a fuzzy rule based algorithm it determines the best network. This information is then communicated to the current network for executing the handoff. The rest of the paper is organised as follows: the background and related work on vertical handoff decision are in section II, the proposed algorithm is presented in Section III, Section IV contains the simulation results and Section V concludes this paper.

II. Background & Technical Content

In heterogeneous wireless networks, three phases are available for performing a handoff. The MT will have a choice of several networks to which it can connect to. But the outcome of the decision phase of the VHO, which is dependent on several parameters like available bandwidth, battery power status of the mobile terminal, cost, received signal strength, jitter, BER etc will decide on the network to which a connection will be made. RSS has a great role in the horizontal decision process due to its compatibility between the current attachment point and that of the candidate attachment points. But in VHO, the RSS are incomparable due to asymmetrical nature of the heterogeneous networks. However, it can be used to determine the availability as well as the condition of different networks. If more than one candidate network is available, the MT should associate itself with the one having the strongest RSS as it does in HHO. Considerable work has been done in literature to determine the appropriate parameters that can be considered in the decision process for VHO. number of parameters. In [7], Pahlavan et al. present a neural networks-based approach to detect signal decay and making handoff decision. Stevens et. al have selected parameters such as bandwidth, delay, jitter and bit error rate (BER) to conduct their comparisons of some of the prominent decision algorithms in literature, that is, simple additive weighting (SAW), technique for order preference by similarity to ideal solution (TOPSIS), multiplicative exponent weighting (MEW) and the grey relational analysis (GRA). Good performance improvement of SAW and GRA over several vertical handoff decision algorithms has been obtained. The GRA decision algorithm provided a slightly higher bandwidth and lower delay for interactive and background traffic classes while MEW, SAW and TOPSIS provided almost similar performance In [8], Chan et al. propose a mobility management in a packet-oriented multi-segment using Mobile IP and fuzzy logic concepts.

The decision about access network selection in a heterogeneous wireless environment can be solved using specific multiple attribute decision making (MADM) algorithms such as Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Weighted Product Model (WPM), Weighted Sum Model (WSM), Analytic Hierarchy Process (AHP), and Grey Relational Analysis (GRA). An integrated AHP and GRA algorithm for network selection is presented in [6] with a Handover is separated into initiation, decision and execution phases. MIP is used in the execution phase, fuzzy logic is applied to the initiation, and fuzzy logic and multiple objective decision making concepts are applied during the decision phase to select an optimum network. W. Zhang, in [9], proposes that the vertical handoff decision is formulated as a fuzzy multiple attribute decision-making (MADM) problem. Fuzzy logic is used to represent the imprecise information of some attributes of the networks and the preferences of the user. In [10], Pramod Goyal, and S. K. Saxena proposes the Dynamic Decision Model, for performing the vertical handoffs to the “Best” interface at the “best” time moment, successfully and efficiently. They proposed Dynamic Decision Model for VHO which adopts a three phase approach comprising Priority phase, Normal phase and Decision phase. In [11], a Markov decision process (MDP) approach for vertical handoff decision making problem is proposed. This MDP approach takes into account multiple factors such as user preference, network conditions, and device capability. Although there have been various vertical handoff decision algorithms proposed, most of them applied through Fuzzy logic theory based quantitative decision algorithm (FQDA) has an advantage over traditional fuzzy logic algorithm which there is no need to establish a database to store rule bases.
III. QOS Aware Fuzzy Rule Based Vertical Handoff Decision Algorithm

To process vertical handoff-related parameters, we use fuzzy logic, which mimics the human mind and uses approximate modes of reasoning to tolerate vague and imprecise data. Fuzzy logic inference systems express mapping rules in terms of linguistic language. A Mamdani FIS can be used for computing accurately the handoff factor which determines whether a handoff initiation is necessary among the networks.

A fuzzy logic inference system can be implemented in the MT as a Handoff Initiation Engine to provide rules for decision making. We use a Mamdani FIS that is composed of the functional blocks:

- A **fuzzifier** which transforms the crisp inputs into degrees of match with linguistic values;
- A **fuzzy rule base** which contains a number of fuzzy IF-THEN rules;
- A **database** which defines the membership functions of the fuzzy sets used in the fuzzy rules;
- A **fuzzy inference engine** which performs the inference operations on the fuzzy rules;
- A **defuzzifier** which transforms the fuzzy results of the inference into a crisp output.

Suppose that a MT that is connected to a UMTS network detects a new WLAN. It calculates the handoff factor which determines whether the MT should handoff to the WLAN. We use as input parameters bandwidth, end to end delay, jitter and Bit error rate perceived QoS of the target WLAN network. The crisp values of the input parameters are fed into a fuzzifier in a Mamdani FIS, which transforms them into fuzzy sets by determining the degree to which they belong to each of the appropriate fuzzy sets via membership functions (MFs). Next, the fuzzy sets are fed into a fuzzy inference engine where a set of fuzzy IF-THEN rules is applied to obtain fuzzy decision sets. The output fuzzy decision sets are aggregated into a single fuzzy set and passed to the defuzzifier (centroid method) to be converted into a precise quantity, the handoff factor, which determines whether a handoff is necessary. When handoff is required, a mobile calculates the handoff score value for all available networks with a set of input parameters by using the AHP & other techniques proposed above, and selects the best one. The information about the best network is then communicated to the current network to execute the handoff. The block diagram shown in Figure 1 describes the vertical handoff decision algorithm.

![Figure 1: Block diagram of vertical handoff decision algorithm](image1.png)

There are three different sets for each input & output Variable: low, medium and high. The input & output membership function is also assumed to be a same with triangular functions as shown in fig 2.

![Figure 2: Fuzzy input and output membership functions](image2.png)

The universe of discourse for the variable Handoff Factor is defined from 0 to 1, with the maximum membership of the sets “Lower” and “Higher” at 0 and 1, respectively. Since there are four fuzzy input variables and three fuzzy sets for each fuzzy variable,
the maximum possible number of rules in our rule base are $3^4 = 81$. Due to space limitation we show only 4 rules for each traffic class in Table I.

Table I
Rule Base for Each Traffic Class

<table>
<thead>
<tr>
<th>Traffic Class</th>
<th>Rule No</th>
<th>Bandwidth</th>
<th>E2E Delay</th>
<th>Jitter</th>
<th>BER</th>
<th>Handoff factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conversational</td>
<td>1</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>Moderate</td>
<td>High</td>
<td>Moderate</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>81</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td>Streaming</td>
<td>1</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>Moderate</td>
<td>High</td>
<td>Moderate</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>81</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td>Interactive</td>
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<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>Moderate</td>
<td>High</td>
<td>Moderate</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>81</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Moderate</td>
</tr>
<tr>
<td>Background</td>
<td>1</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Moderate</td>
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<tr>
<td></td>
<td>81</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

The crisp handoff factor computed after defuzzification is used to determine when a handoff is required, then initiate handoff; otherwise do nothing. When handoff is required, a mobile calculates the handoff score value/Importance Weight for all input parameters by using the AHP & other techniques proposed above, After that according to that importance weight we will choose best network using TOPSIS.

IV. Simulation and Results

We considered four traffic classes, which are conversational, streaming, interactive and background. traffic class is associated with different QoS parameters. The QoS parameters considered are available bandwidth, end-to-end delay (E2E delay), bit error rate (BER) and jitter with the corresponding importance weight/handoff factor.

For each traffic class importance weight for criteria will be determine by FAHP technique & ranking of network will be determine by TOPSIS Technique.

The simulation is carried out using Matlab and results are plotted in Fig 3. Fuzzy rule based approach based on awareness of QoS requirements of the traffic classes makes clear decision to do the handoff among the networks, which uses the fuzzy membership functions defined in the Fig.2. The fuzzy membership regions helps to make a clear distinction among the parameter values of the network and fuzzy rule base will be used to infer the result of handoff score value.
V Conclusions

The simulation results indicate a better overall performance of the proposed scheme in terms of minimized handoffs, lower probability of handoff blocking and new call blocking, and increased connection time with the selected network that is preferred by the end-user. The VHITS necessity estimation scheme is able to reduce the number of handoffs, and the VHITS target network selection scheme based on TOPSIS outperforms the other schemes implemented and simulated in terms of intelligent and efficient handoff decisions.

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References