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Context Aware Fuzzy Rule Based Vertical Handoff Decision Strategies for Heterogeneous Wireless Networks

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***ABSTRACT** : The 4th generation wireless communication systems aim to provide users with the convenience of seamless continuous connection to access various wireless technologies and to have the connection with the best network which provides the best Quality of service. To achieve this goal it is necessary to have a good decision making algorithm which decides the best network for a specific application under which vertical handoff should be performed. This paper proposes a QoS aware fuzzy rule based vertical handoff mechanism Using fuzzy logic quantitative decision algorithm (FQDA) is used as an handoff decision criteria to choose which network to handover among different available access networks. 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 development of wireless communication technology, the service of wireless communication networks is upgrading extremely fast. Presently, there are many kinds of wireless networks available to fulfil different needs and requirements of mobile users. When a mobile user is switch from one network to another network or one base station to another BS, 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 switching 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 switched 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. A combination of some of the criteria can be considered for making a decision in handoff [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 fuzzy logic quantitative decision algorithm (FQDA) is used as an handoff decision criteria to choose which network to handover among different available access networks.The FQDA has three steps: fuzzification, quantitave evaluation and quantitative decision. (Sivanandam et al., 2007) ; (Xia et al., 2008)

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 and some assistance from the network, 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 AND RELATED WORK

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 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.

In [6], the authors have proposed a vertical handoff decision (VHD) algorithm that maximizes the overall battery lifetime of the mobile terminal in the same coverage area and also aims at equally distributing the traffic load across the networks. This algorithm when implemented in multiple Vertical Handoff Decision Controllers (VHDC) located in the access networks can provide the VHD function for a region covering one or multiple APs or BSs. In [7], a decision method called ALIVE –HO(adaptive lifetime-based vertical handoff) is proposed which is based on the Received Signal Strength (RSS).This parameter is used to estimate coverage of the wireless network and the best network is selected using vertical handoff algorithms. ALIVE- HO algorithm dynamically adopts to the Mobile Terminals (MT) velocity to decrease the unnecessary number of handoffs and ping pong effect but the probability of handoff increases with the distance from the AP. It is also established that the number of unnecessary handoffs using ALIVE handoff algorithm is less than that of algorithms based on traditional RSS hysteresis. According to the authors, the simplest method to increase RSS is to increase the transmit power, which needs further investigation, since an increase in transmit power might lead to an increase in interference leading to a decrease in QoS.

Both QoS parameters and handoff metrics are required for vertical handoff decision [8]. The handoff metrics and QoS parameters are categorized under different groups (e.g., bandwidth, latency, power, price, security, reliability, availability). Various vertical handoff decision mechanisms have been proposed recently. In [9], the handoff decision mechanism is formulated as an optimization problem. Each candidate network is associated with a cost function. The decision is to select the network which has the lowest cost value. The cost function depends on a number of criteria, including the bandwidth, delay and power requirement. Appropriate weight factor is assigned to each criterion to account for its importance. In [10], an Active Application Oriented (AOO) vertical handoff decision mechanism is proposed. The decision mechanism considers the QoS parameters required for the applications (e.g., minimum and maximum bandwidth requirement for voice service). Each candidate network is associated with a utility function. The chosen network is the one which provides the highest utility value. The utilization function is a weighted sum of various normalized QoS parameters.

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 [11] with a number of parameters. In [12], 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 [13], Chan et al. propose a mobility management in a packet-oriented multi-segment using Mobile IP and fuzzy logic concepts.

Handover is separated into initiation, decision and execution phases. MIP is used in the execution phase, fuzzy logic is applied to the initiation phase, and fuzzy logic and multiple objective decision making concepts are applied during the decision phase to select an optimum network. W. Zhang, in [14], 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 [15], 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 [16], 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) (Sivanandam et al., 2007) has an advantage over traditional fuzzy logic algorithm which there is no need to establish a database to store rule bases. In this paper, we presented a vertical handoff scheme satisfying between user requirement and network conditions and avoiding unnecessary handoffs as well.

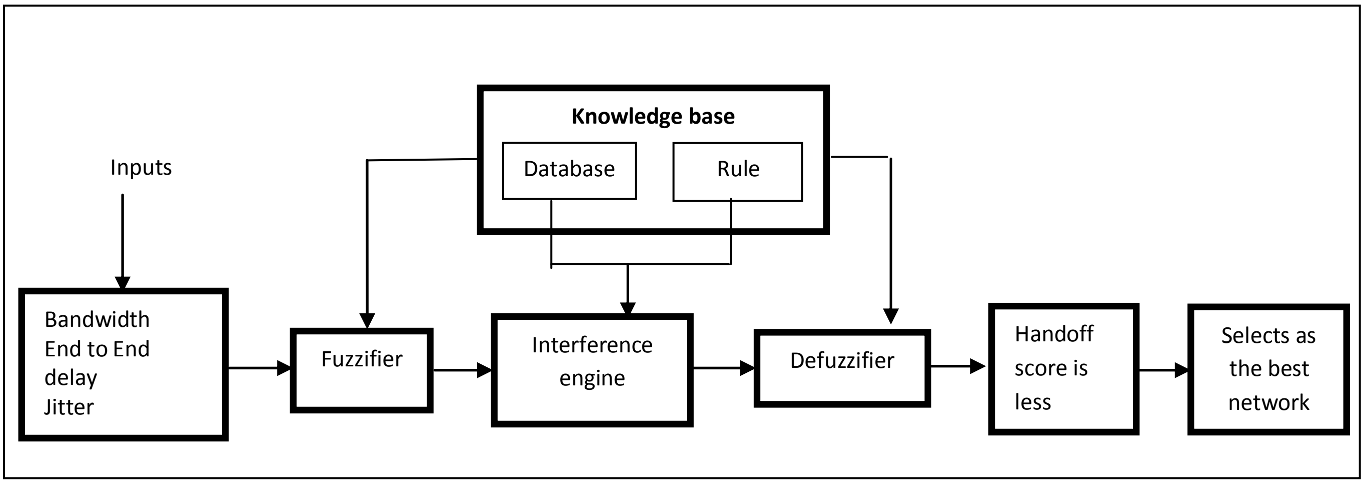
III.QOS AWARE FUZZY RULE BASED VERTICAL HANDOFF DECISION ALGORITHM

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 fuzzy rule based scheme 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.



three different regions: low, medium and high. The output membership function is also assumed to be a triangular function as shown in Fig. 2.

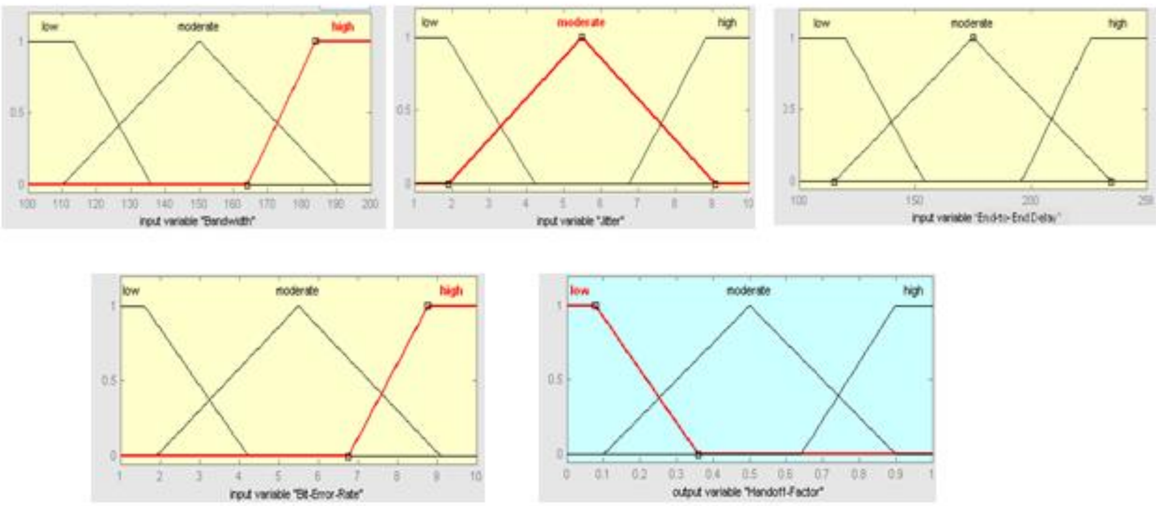


Fig 2: Fuzzy input and output membership functions

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.

Conversational					
Rule No	**Bandwidth**	**E2E Delay**	**Jitter**	**BER**	**Handoff factor**
1	Low	Low	Low	Low	High
25	Low	High	High	Low	Low
50	Moderate	High	Moderate	Moderate	Low
81	High	High	High	High	Low
streaming					
Rule No	**Bandwidth**	**E2E Delay**	**Jitter**	**BER**	**Handoff factor**
1	Low	Low	Low	Low	Low

25	Low	High	High	Low	Low
50	Moderate	High	Moderate	Moderate	High
81	High	High	High	High	Moderate
Interactive					
Rule No	**Bandwidth**	**E2E Delay**	**Jitter**	**BER**	**Handoff factor**
1	Low	Low	Low	Low	Moderate
25	Low	High	High	Low	Low
50	Moderate	High	Moderate	Moderate	Low
81	High	High	High	High	Low
Background					
Rule No	**Bandwidth**	**E2E Delay**	**Jitter**	**BER**	**Handoff factor**
1	Low	Low	Low	Low	Moderate
25	Low	High	High	Low	Moderate
50	Moderate	High	Moderate	Moderate	Moderate
81	High	High	High	High	Moderate

TABLE I RULE BASE FOR EACH TRAFFIC CLASS

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 for all available networks with a set of input parameters by using the fuzzy rule based scheme proposed above, the handoff factor which is less among the networks will be selected as the best one.

IV.SIMULATION AND RESULTS

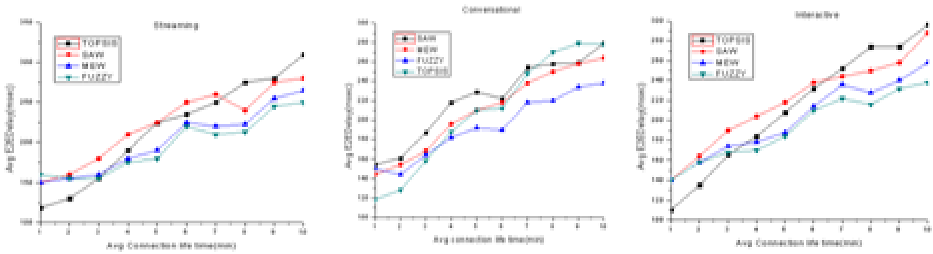
We considered four traffic classes defined by 3GPP [10], which are conversational, streaming, interactive and background. Each traffic class is associated with different QoS parameters. The QoS parameters considered are available bandwidth, end-to-end delay (E2E delay), bit error rate (BER) and jitter with the corresponding importance weight for each traffic class computed using the Analytical Hierarchical Processing (AHP), are shown in TABLE II.

Traffic Class	Bandwidth	E2E Delay	Jitter	BER
Conversational	0.04999	0.45003	0.45003	0.04999
Streaming	0.03738	0.11381	0.42442	0.42442
Interactive	0.63594	0.16052	0.04305	0.16052
Background	0.66933	0.05547	0.05547	0.21977

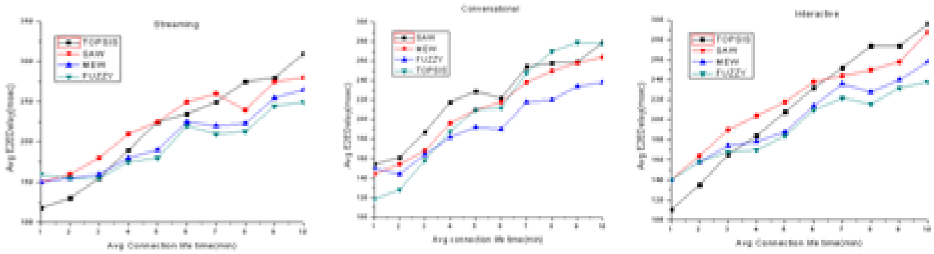
TABLE II. IMPORTANCE WEIGHTS OF EACH QOS PARAMETERS FOR DIFFERENT TRAFFIC CLASSES

The simulation is carried out using Matlab and results are plotted in Fig 3. Results obtained using the proposed technique show better performance for E2EDelay, availability of the network. The Average available bandwidth is also obtained for Streaming and background classes. The available bandwidth performance is moderate while satisfying the E2EDelay and availability requirements. Rules can be more properly tuned to get even better performance in available bandwidth. 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.

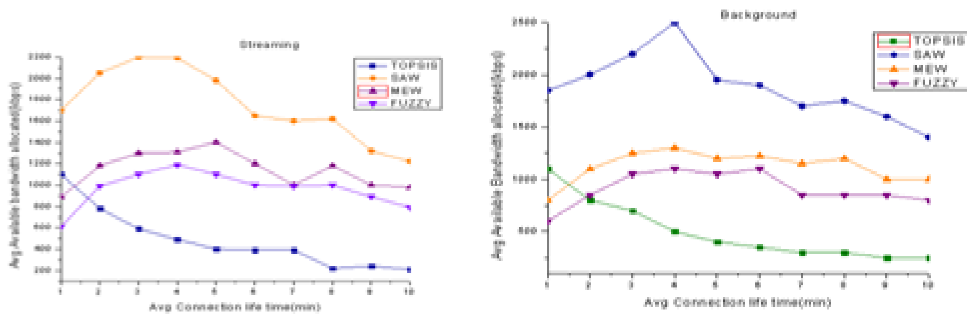
(a)



(a)



(b)



(c)

Fig 3 : (a) Avg E2Edelay (b) availability (c) Avg. Available Bandwidth

V. CONCLUSION

In this paper, we considered two sets of networks for simulation. The paper proposes QoS aware fuzzy rule based algorithm with multi-criteria of bandwidth, delay, jitter and bit error rate by considering different traffic classes. Simulation results show that fuzzy rule based approach gives better delay, availability, with moderate performance of available bandwidth. Hence, QoS aware fuzzy rule based algorithm gives better QoS performance for delay sensitive applications like conversational, interactive and live streaming applications. Our future work will consider minimal fuzzy rule set based vertical handoff algorithms for heterogeneous wireless networks.

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