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Fuzzy Normalized Handoff Initiation Algorithm For Heterogeneous Networks

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Abstract

Next-generation wireless networks are the promising network to provide Always Best connected network. Mobility management is the primary issue in next generation networks. Mobility management comprises of location and handoff management. When mobile user roams in the next generation networks vertical handoff is the main issue. Vertical handoff decision process can be handled by many researchers in the recent years. Vertical handoff process can split in to three phases such as handoff initiation, handoff decision and handoff execution. Initially vertical handoff initiation and decision are taken with respect to the received signal strength (RSS). Many such algorithm experiences the probability of unnecessary handover and handoff failure. In this paper we proposed fuzzy normalized Handoff initiation algorithm (FUN_HoI) module which considers the combination of different input criteria along with RSS to initiate handoff in time to reduce unnecessary handover and handoff failure probability. The special function of FUN_HoI is to take fuzzy normalization of all input criteria after fed in to the Fuzzy inference system (FIS). An importance of fuzzy normalization is to filter unsuitable candidate networks and thus improves the efficiency of an algorithm. The proposed method is compared with the existing algorithm such as RSS based and Bandwidth based algorithm. The comparative study reveals that the proposed method consumes less delay, reduced handover probability and unnecessary handoff.

Keywords: *Fuzzy normalization, handoff initiation, heterogeneous networks & vertical handoff*

1. Introduction

Heterogeneous networks have different physical and logical networks, different administrative domain and different networking protocols. When a MN switches from one network to other network in Heterogeneous networks, many issues come in to picture as far as vertical handoff is concern. One of the major issues in VHO process is selecting the target network. Many proposals [1, 2] and [3] have been proposed for Vertical handoff decision process using fuzzy multiple criteria. Vertical handoff process sub divided in to three steps such as initiation, decision and execution. A vertical handoff decision algorithm must be able to decide on the need to timely and reliably initiate a handoff, and determine and select the appropriate access network(s) when a user can be reached through several access networks. This paper explores a vertical handoff initiation algorithm (VHO init) which is a pre step to acquire handoff decision for selecting optimum network and the scope for optimization in handoff initiation process is also analyzed. One such optimization based on the fuzzy normalization (FUN_HO_Init) for input metrics in the handoff initiation process is proposed and its results are presented.

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2. Related Work

Research on design and implementation of Vertical Handoff Decision (VHD) algorithms has been carried out by many scholars using various techniques. Based on the handoff decision criteria [4] VHD algorithms are categorized as RSS based algorithms, Bandwidth based algorithms, User Mobility based algorithms and Cost function based algorithms. This can be seen in Figure 1.1.

2.1. Existing VHD Algorithms

There are various ways to classify vertical handoff decision algorithm and have chosen VHD algorithm in to four groups which is shown in figure. These are classified based on the input criteria's. Classification of VHD algorithms are based on the input criteria's such as RSS based, bandwidth based, cost function based and combination based. In this paper we have consider for our comparison and presented some of the representative of RSS and bandwidth based algorithms.

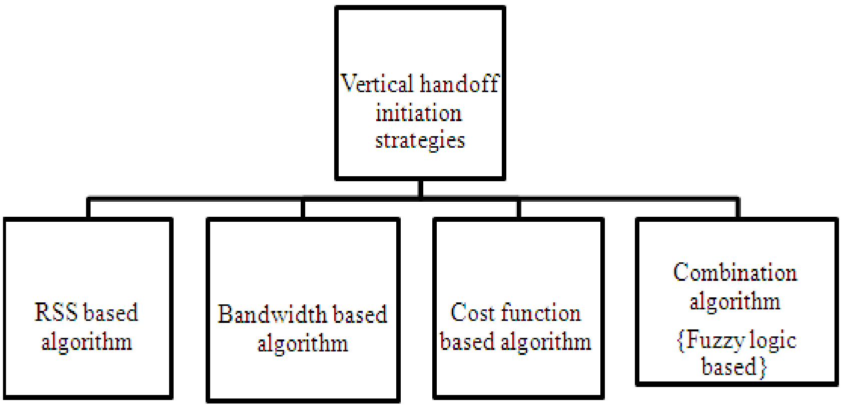

Figure 1.1. Classifications of Vertical Handoff Decision Algorithms

2.1.1. RSS based Algorithms

In this algorithm, RSS is used as the main handover decision criterion in this group. Various strategies have been developed to compare the RSS of the current point of attachment with that of the candidate point of attachment. RSS based horizontal handover decision strategies are classified into the following six subcategories: relative RSS, relative RSS with threshold, relative RSS with hysteresis, and relative RSS with hysteresis and threshold, and prediction techniques. For VHD, relative RSS is not applicable, since the RSS from different types of networks cannot be compared directly due to the disparity of the technologies involved. For example, separate thresholds for each network. Furthermore, other network parameters such as bandwidth are usually combined with RSS in the VHD process. RSS based VHD algorithms compare the RSS of the current point of attachment against the candidate networks to make handover decisions. Enormous studies has been conducted for RSS based VHD algorithm [5, 6]. Among those, we describe below only one representative RSS based VHD algorithms.

An RSS threshold based dynamic heuristic

This algorithm [7] proposed a WLAN to 3G handover decision method based on comparison of the current RSS and a dynamic RSS threshold (S_{dth}) when a mobile terminal is connected to a WLAN access point. S_{dth} in (dm) can be calculated as,

$$S_{dth} = RSS_{min} + 10\beta\log10\left(\frac{d}{d-LBA}\right) + \varepsilon$$

where RSS_{min} (in dBm) is the minimum level of the RSS required for the mobile terminal to communicate with an access point, β is the path loss coefficient, d is the side length of the WLAN cell (in meters, a WLAN cell is assumed to have a hexagonal shape in this study), L_{BA} is the shortest distance between the point at which handover is initiated and WLAN boundary, and ε (in dB) is a zero mean Gaussian random variable with a standard deviation that represents the statistical variation in RSS caused by shadowing. The distance L_{BA} changes with the tolerable handover failure probability *pf* , the velocity of the mobile terminal *v*, and the WLAN to 3G handover delay τ , and calculated as,

$$L_{BA} = \left[\tau^2 v^2 + d^2\left(p_f - 2 + 2\sqrt{1-p_f}\right)\right]^{\frac{1}{2}}.$$

The use of a dynamic RSS threshold helps reducing false handover initiation and keeping the handover failures below a limit. The flow chart of this heuristic is shown in Figure 1.2. However, in this algorithm, the handover failure probability from 3G network to a WLAN cell is considered to be zero since the 3G network coverage is assumed to be available all the time, and thus according to the mechanism, a handover to a WLAN is always desirable whenever the mobile terminal enters the WLAN coverage. This is not efficient when the mobile terminal's travelling time inside a WLAN cell is less than the handover delay, and in such cases a handover may result in wastage of network resources.

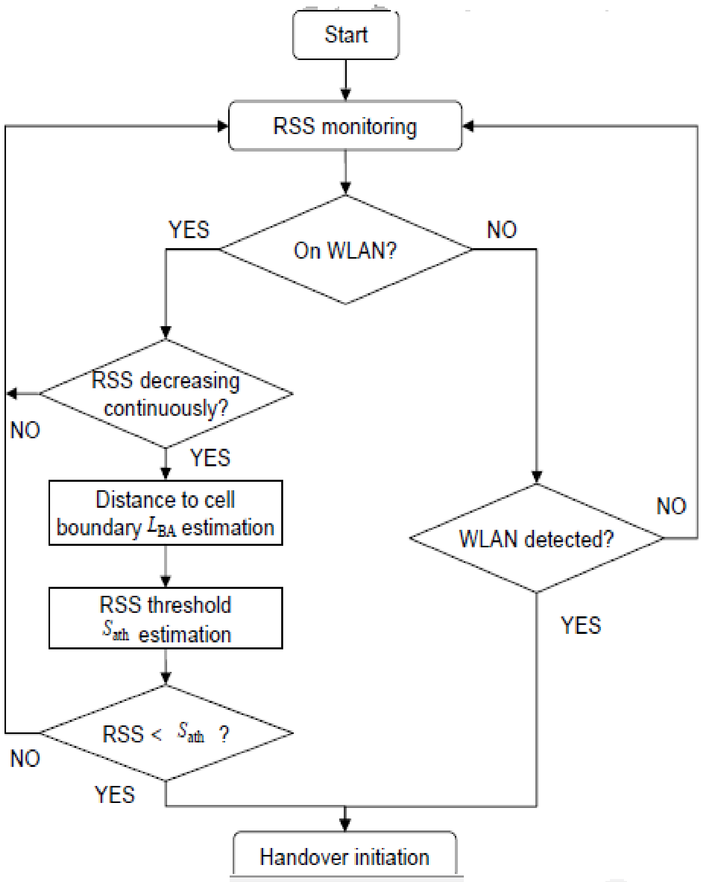

Figure 1.2. RSS based Algorithms

Table 1. Vertical Handoff Initiation Algorithm Comparison

Group	Applicable network technologies	Input parameters	Handoff target selection criteria &complexity	Reliability
RSS based algorithm	Macro to micro cellular network	RSS alone	Candidate network with stable RSS and simple in complexity	Reduced reliability because of fluctuation in RSS
Bandwidth based algorithm	Between any to different networks	Bandwidth combined with RSS	Candidate network with highest bandwidth and simple in complexity	Reduced reliability because of changing in available bandwidth

Vertical lines are optional in tables. Statements that serve as captions for the entire table do not need footnote letters.
[a]Gaussian units are the same as cgs emu for magnetostatics; Mx = maxwell, G = gauss, Oe = oersted; Wb = weber, V = volt, s = second, T = tesla, m = meter, A = ampere, J = joule, kg = kilogram, H = henry.

2.1.2. Bandwidth based Algorithms

Available bandwidth for a mobile terminal is the main criterion. In some algorithms, both bandwidth and RSS information are used in the decision process. Depending on whether RSS or bandwidth is the main criteria considered, an algorithm is classified either as RSS based or bandwidth based. But Bandwidth based VHD algorithms consider available bandwidth for a mobile terminal or traffic demand as the main criterion [8]. In this section, one representative VHD algorithm is discussed in detail.

A Wrong Decision Probability (WDP) Prediction Based Heuristic

A VHD heuristic [9] based on the Wrong Decision Probability (WDP) prediction. The WDP is calculated by combining the probability of unnecessary handovers and the missing handovers. Assume that there are two networks i and j with overlapping coverage, and b_i and b_j are their available bandwidth. An unnecessary handover occurs when the mobile terminal is in network i and decides to handover to j, but b_j is less than b_i after this decision. A missing handover occurs when the mobile terminal decides to stay connected to network i, but b_i is less than b_j after this decision. A handover from network i to network j is initiated if

$$P_r < \rho \times l_0 \text{ or } b_j - b_i \leq L,$$

Where Pr is the unnecessary handover probability, **ρ** is the traffic load of network i, l_0 = 0:001 and L is a bandwidth threshold. The flowchart of this algorithm is shown in Figure 1.3.

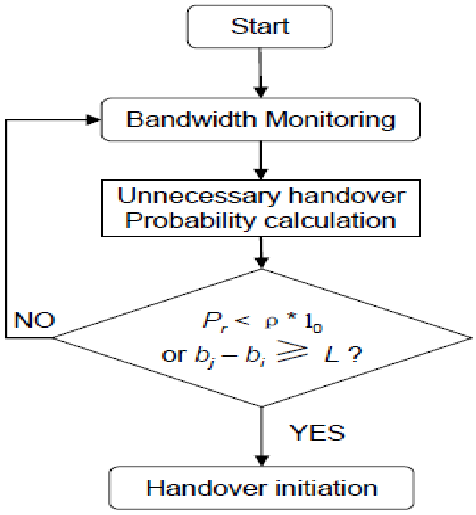

Figure 1.3. Bandwidth based Algorithm

So far we have discussed the representative of both RSS based and bandwidth based VHD algorithms based on the criteria they use for making handover decisions. To provide an overall comparison of these algorithms, we summarize their features on five aspects: networking technologies that they can be applicable, input parameters, handover target selection criteria, complexity and reliability in Table 1. In terms of complexity, RSS based algorithms are usually the simplest, followed by the bandwidth based algorithms. Finally, reliability varies among the algorithms. Fluctuations of RSS decreases the reliability of RSS based VHD algorithms, and the difficulty in measuring available bandwidth reduces the reliability of bandwidth based VHD algorithms.

2.2. Proposed Fuzzy Normalized Vertical Handoff Initiation Algorithm

For an efficient VHO initiation algorithm, we should consider as many as parameters like power consumption, latency *etc*. Thus the combination of different parameter like user preference, RSS, Bandwidth, network coverage are fed in to a fuzzy inference engine for selecting target network. This kind of an algorithm usually referred to as combination algorithm or fuzzy logic based algorithm. Fuzzy logic systems allow human experts' qualitative thinking to be encoded as algorithms to improve the overall efficiency. Examples of applying this approach into VHD can be found in [10]. If there is a comprehensive set of input-desired output patterns available, artificial neural networks can be trained to create handover decision algorithms. It is also possible to create adaptive versions of these algorithms. By using continuous and real-time learning processes, the systems can monitor their performance and modify their own structure to create highly effective handover decision algorithms. Many proposals [11] did not use normalization of fuzzy logic system to normalize the parameters of the heterogeneous wireless network. The algorithm in [12] does not have the preprocessing step and parameter normalization of heterogeneous wireless networks. The importance of normalization of the input parameters like velocity, cost and RSS etc are to filter unsuitable candidate NAPs in the fuzzy normalization procedure. Hence reduce handover decision complexity and increase efficiency. If the complexity reduces, automatically handoff delay also gets reduced. For this we have implemented Handoff initiation with normalized parameters in the initiation process which is a pre step to acquire handoff decision. This unit consists of fuzzy normalization unit, fuzzy inference system, and HoF calculation unit as shown in Figure 2.1.

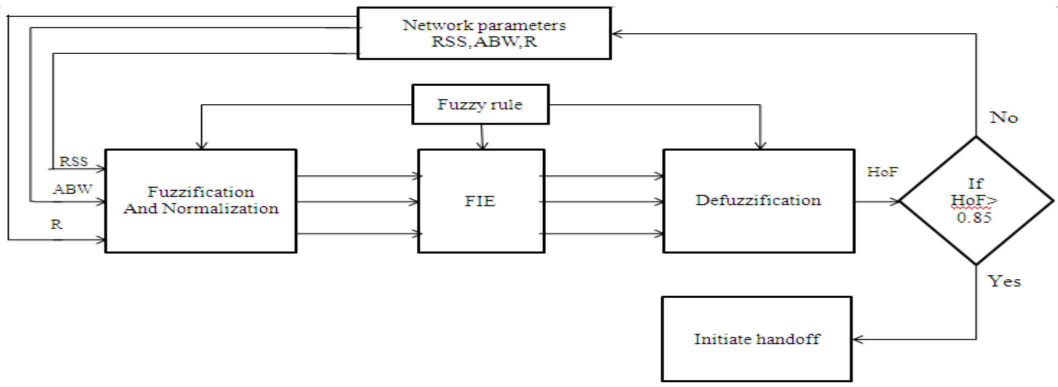

Figure 2.1. Proposed Fuzzy Normalized Handoff Initiation Module

2.2.1. Input Parameter Consideration

The benefit of vertical handoff initiation algorithm is to indicate the need to handoff from current network to the target networks. To improve initiation algorithm efficiency and to reduce handover decision complexity, we need to normalize the input metrics such as RSSI, network coverage, available bandwidth and user preferences. We obtain normalized value with respect to maximum or minimum value of real valued parameters. A suitable normalized function of the parameter *X* is the fuzzy membership function μ_X. In order to develop this function, data from the system are fed into a fuzzifier to be converted into fuzzy sets. The values of the parameters are normalized between 0 and 1. The determination of the membership functions for these input parameters is defined as follows:

Received Signal Strength Indicator (RSSI)

In telecommunication received signal strength indicator (RSSI) is a measurement of the power present in a received radio signal. The membership function for the RSSI is given by,

$$N_{RSS}=\begin{cases} 0, & 0 \le RSSI \le RSSIth \\ \frac{RSSIx - RSSIth}{RSSImax - RSSIth}, & RSSI > RSSIth \end{cases}$$

Where, $RSSI_x$→ actual strength of the signal received from the candidate network base station.
$RSSI_{Th}$→ Threshold signal strength
$RSSI_{max}$→ Maximum RSSI that can be received from the candidate BS.

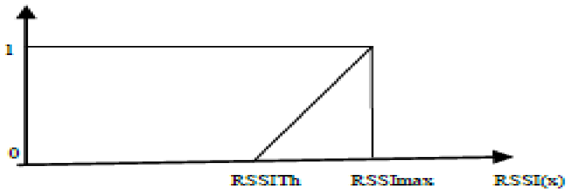

Figure 2.2. Normalization Function for RSSI

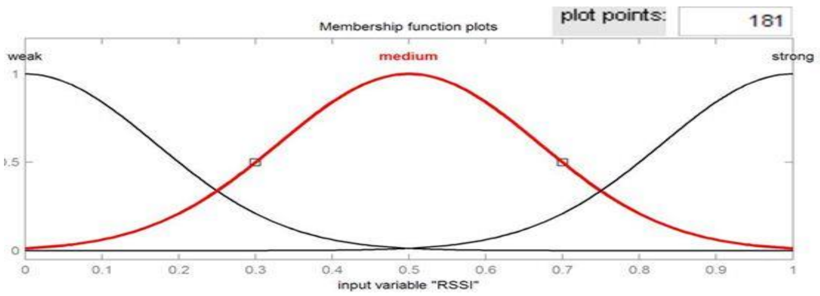

Figure 2.3. Membership Function of RSSI

Bandwidth (BW)

It is the amount of available bandwidth of the candidate network. The membership function of bandwidth is given by,

$$N_{BW} = \begin{cases} 0, & Bx > Bmax \\ \frac{Bx}{Bmax}, & 0 \leq Bx \leq Bmax \end{cases}$$

Where, Bx→ required bandwidth of the MN

Bmax→ maximum bandwidth that can be provided by the BS

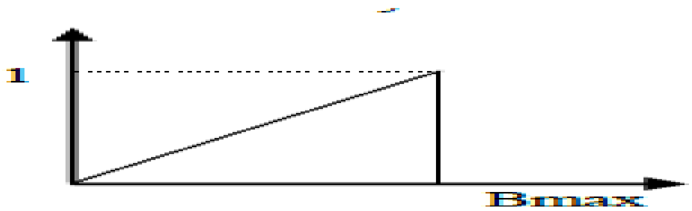

Figure 2.4. Normalization Functions for Bandwidth

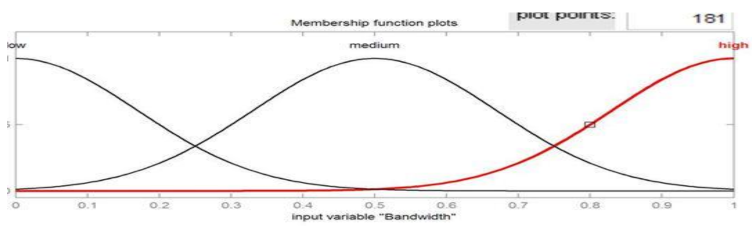

Figure 2.5. Membership Function of Bandwidth

Network Coverage(R)

The network coverage that is supported by the candidate network. Normalization function for the network coverage is defined by,

$$N_R = \begin{cases} 0, & Rx > Rmax \\ \frac{Rx}{Rmax}, & 0 \leq Rx \leq Rmax \end{cases}$$

Where, Rx→network coverage of the preferred network
Rmax→ the maximum range of the preferred networks

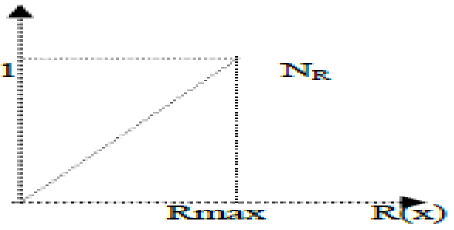

Figure 2.6. Normalization Function for Network Coverage

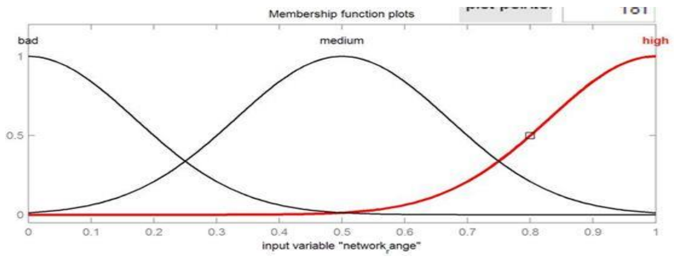

Figure 2.7. Membership Function of Network Range

User preferences
For network preferences,

$$Np = \begin{cases} 0 \;, Px > Pmax \\ \frac{Px}{Pmax}, \; 0 \leq Px \leq Pmax \end{cases}$$

Where, Px→network preferred by the candidate network MN
Pmax→maximum preference that can be given to the BS

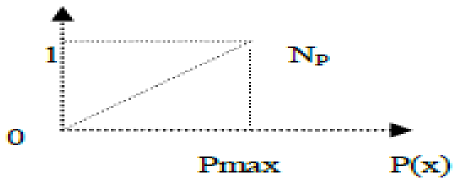

Figure 2.8. Membership Functions for User Preferences

Table 2

Fuzzy Normalized vertical handoff initiation algorithm
1 *Parameter initialization;*
2 *Fuzzification;*
3 *Find fuzzy normalization;*
4 *Computation of HoF*
5 *If HoF>0.85;*

6 Initiate handoff;

Otherwise go to step 1

2.3. Fuzzy Normalized Handoff Initiation Algorithm (FUNHOIA)

The importance of fuzzy normalization in the initiation process is to improve the efficiency of an algorithm and to reduce the handoff initiation process complexity. In this algorithm involves three main components such as environment information, fuzzy normalization and handoff initiation strategy (HoI). Environment information involves the collection of the environmental information that is needed to obtain fuzzy normalization and make a handover initiation. In this part, we collect the system information such as RSSI between the candidate nap, network coverage of candidate NAP, available bandwidth of candidate NAP, and user preferences of the candidate NAP. Then we put non-process information into a fuzzy normalization (FUN). FUN gives RSS, bandwidth, network coverage and user preferences of the different member functions to fulfil parameter normalization and implements a defuzzifier according to fuzzy logic IF-THEN rules. Then it generates the handoff factor to the network access point (NAP) to initiate the handover decision.

2.3.1 Handoff from WMAN to WLAN

Based on the input parameters that the MT collected from candidate network, vertical handoff has been initiated with the following rules,

- If the RSS is weak, bandwidth is medium and the network range is low and the handoff factor found to be very low. Hence no need to initiate.
- If RSS is high, bandwidth is medium and the network range is moderate and the handoff factor found to be high. Hence initiate handoff.
- If RSS is strong, bandwidth is low and the network range is high and the handoff factor found to be very high. Hence initiate handoff.

Table 3. Handoff from WMAN to WLAN

MN under the coverage	RSS	BW	Network Range	Handoff factor (HoF)	Handoff initiation
Public WMAN	0	0.6	0	0.6	NO
Residential WLAN	0.8	0.4	0.48	0.87	YES
Office WLAN	0.7	0.2	0.8	0.89	YES

2.4. Simulation Results

The MT calculates the handoff initiation factor to NAP in the handoff initiation algorithm when the MT detects a new network or the user changes his/her preferences or the current radio link is about to drop. The performance of the fuzzy normalization Vertical handoff initiation algorithm is evaluated using MATLAB toolbox. It has been tested the performance of the initiation algorithm over a varied range of simulation parameters. The importance of handoff initiation algorithm is to calculate handoff factor to decide handoff. Suppose the MT records the values of RSS, Bandwidth, and network range as {0.8 ,0.4, 0.48} and {0.7,0.2,0.8} for residential WLAN and office WLAN respectively. These set of values are fed into the FIS and we obtain the Handoff Factor values 0.874 and 0.89, thus indicating the need to hand off to any of the WLANs for the requested service as shown in the Table 3. The decision on deciding handoff initiation with fuzzy normalization, delay factor is found to be very low as compared with simple fuzzy. We have compared the delay perspective with three different VHO algorithms namely RSS based algorithm, Bandwidth based and simple fuzzy based algorithm with fuzzy normalization algorithm. The comparisons confirms that the reduced delay value as well as handoff failure probability and unnecessary handover with fuzzy normalization as shown in Figure 3.1 to Figure 3.3.

2.4.1. Handover Delay

It is the measure of time consumption to initiate handoff for fuzzy normalized algorithm and the comparison with existing algorithms like RSS based, bandwidth based algorithms confirms that the proposed method is consuming higher delay since it consider many input criteria's. But the proposed fuzzy normalization method is outperforming with simple fuzzy as shown in Figure 3.1. Though it increases the algorithm complexity and improves overall efficiency by fuzzy normalization.

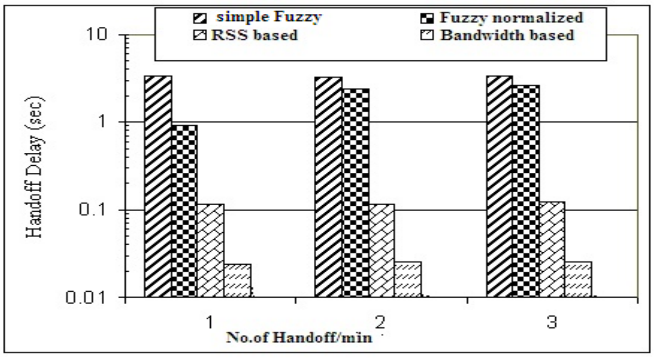

Figure 3.1. Handoff Delay for Fuzzy Normalization Comparison with Existing Initiation Algorithms

2.4.2. Number of Unnecessary Handover

From the Figure 3.2, it can be seen that the unnecessary handover is kept fewer than 500. It has been observed that the unnecessary handover probability is increases sharply with increase the velocity of MT for both RSS based and bandwidth based algorithms. But fuzzy normalized handoff necessity estimation can able to reduce unnecessary handoff up to 80%.

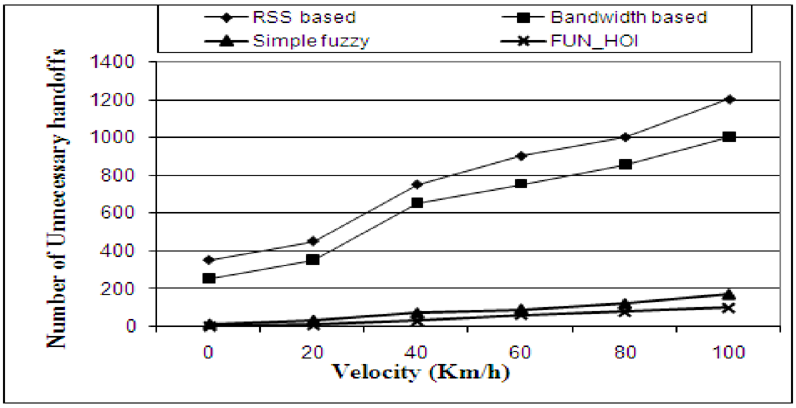

Figure 3.2. Probability of Unnecessary Handover Vs Velocity

2.4.3. Number of Handoff Failure

From the Figure 3.13 it can be seen that the handoff failure probability is kept fewer than 200. It has been observed that the handoff failure probability increases sharply with increase the velocity of MT for both RSS based and bandwidth based algorithms. But fuzzy normalized handoff necessity estimation can able to reduce handoff failure probability up to 80%.

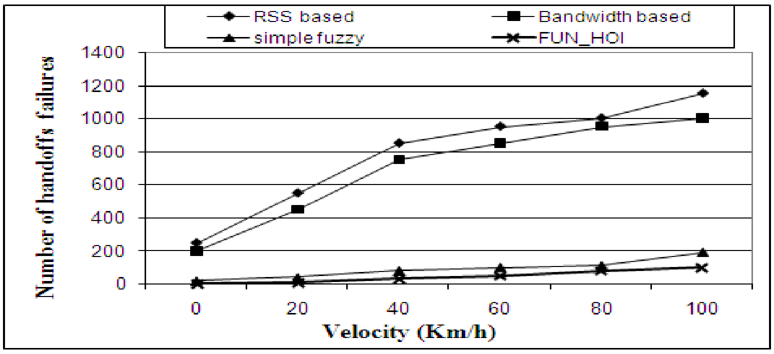

Figure 3.3. Probability of Handoff Failure

3. Conclusion

A thorough experiment of VHO initiation algorithms has been carried out and the scope of performance improvements has been analyzed. The result benefits like handoff failure probability, unnecessary handoff probability and handoff initiation delay with fuzzy normalized HNE algorithm, RSS based algorithm and bandwidth based algorithm of normalized valued input variables. The impact of fuzzy normalization for various input variables like RSS, bandwidth and network coverage has been verified. We have compared the various handoff algorithms with fuzzy normalized algorithm. The comparison confirms less delay for FUNHOI Algorithm than traditional like RSS and Bandwidth based algorithm. The inferences helped in designing base protocol for vertical handoff decision algorithms. The various choices of enhancements like adopting maximum number of input variables to reduce delay as low as possible and an initiation algorithm which uses fuzzy normalization is finalized. Thus, our future work will be an adaptive fuzzy based vertical handoff decision algorithm which uses the FUN-HODs (fuzzy normalized handoff decisions) to select optimum target networks.

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Abstract

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