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Modeling Seamless Vertical Handovers in Heterogeneous Wireless Networks

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Abstract— Vertical handover in heterogeneous wireless networks provides customers with better Quality of Service (QoS) experience. For seamless handover, timely initiation of handover process plays a key role. Various vertical handover management protocols have been proposed and standardized to support mobility across heterogeneous networks. In Media Independent Handover (MIH) based schemes, distributed handover decision is made via certain predefined triggers that consider user context. In this paper, we present a comprehensive review of the modeling techniques used during management of vertical handover. We have also defined a novel architecture, HRPNS: Handoff Resolving and Preferred Network Selection module enabling vertical handover that ensures QoS. The construction of HRPNS module involves integration of fuzzy logic and Markov Decision Process (MDP) for providing precise decision of handover.

Keywords*- Vertical handover ; heterogeneous networks; Quality of Service; MIH; fuzzy logic; Markov decision process*

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I. INTRODUCTION

Advancements towards wireless communication have resulted in a number of different wireless communication systems including the Wireless Local Area Network (WLAN), the Worldwide Interoperability for Microwave Access (WiMAX), and the Universal Mobile Telecommunication System (UMTS), etc. Mobile devices can move freely among different wireless systems using their multiple wireless interfaces. During this traversing procedure, a user switches among different networks to satisfy needs in terms of Quality of Service (QoS). This process is known as handover. Handover process is generally categorized as horizontal, vertical and diagonal handovers. Handover process consists of three main phases[1][2] as stated below:

a] Handover Measurement and Initiation : Mobile Node [MN] or an Access Point [AP] makes the measurements for time varying parameters required in the process of handover.

b] Handover Decision: The decision of whether or not to perform the handover is done by comparing the measured parameter values with predefined values.

c] Handover Execution: In this stage the control of MN is given to newly selected AP or Base Station (BS).

During vertical handover decisions, following context parameters of wireless networks play a key role namely[1][2], Received Signal Strength (RSS),Network Load, Monetary Service Cost, Handover delay/latency, User preferences, Security Control, Throughput , Bit Error Rate (BER) and Signal to Noise Ratio (SNR),etc.

In a typical Heterogeneous Network environment, comprising of Wide Area Network (WAN),Metropolitan Area Network (MAN) and Local Area Network (LAN), the WAN and MAN provides umbrella like coverage under which WLAN Basic Service Sets (BSSs) form small connectivity areas. Because of its long communication ranges, it can be assumed that in such a Heterogeneous Network environment, users always have access to the WAN/MAN connectivity, however access to WLAN ,popularly known as WiFi, is only available at few areas. Users prefer WiFi ,because of its low-cost availability and less power consumption. A MN associates with the WAN/MAN BS only in two situations, either there is no WiFi connectivity, or it does not get desired QoS because of traffic overload at all of the APs in its vicinity. Always choosing WiFi whenever it is available, leads to poor performance of the network. Hence, this paper provides a comprehensive survey of techniques available to decide the next Point of Attachment (PoA). We have also proposed a novel HRPNS: Handoff Resolving and Preferred Network Selection module, which uses fuzzy logic to decide the necessity of handover. Target network i.e. the next PoA is chosen using Markov Decision Process (MDP) based method.

Organization of paper is as follows. Section II gives literature survey of IEEE 802.21 Media Independent Handover standard. Section III gives overview of various algorithms used during vertical handover. Proposed HRPNS model is elaborated in section IV. Simulation results are discussed in section V. Concluding remarks are provided in section VI.

II. LITERATURE SURVEY OF IEEE 802.21

The IEEE 802.21 specification is a standard [3] for vertical handovers among heterogeneous networks. The standard proposes the Media Independent Handover Function (MIHF) to support seamless homogeneous and heterogeneous handovers. MIHF is logically defined as layer between data link layer and the network layer. Usage of MIH enables cross layer vertical handover approach. MIH standard provides information of Layer 2 (L2) to the upper layers. Various link events namely Link UP, Link Down, Link Going Down, Link Detected, Link Event Rollback are generated to achieve this information exchange. MIH also provides facilities for inter-technology candidate network discovery, target network preparation, L2 handover initiation and execution. The MIH framework is shown in Fig. 1. MIHF provides services to higher layers.

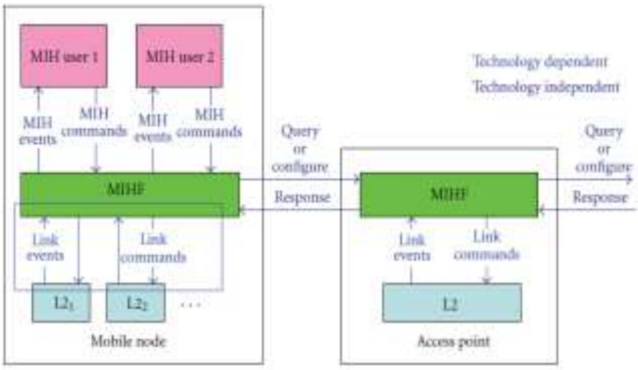

Figure 1. MIH framework [3]

MIH defines three main services through MIH Service Access Points (MIH_SAP) for MIH users [3]. These services are :

MIH Event Service (MIES) - reports both local and remote events to the upper layers.

MIH Command Service (MICS) - sends commands from upper layers to lower layers.

MIH Information Service (MIIS)- provides framework and mechanism for an MIHF entity to discover available neighboring network information.

To get neighborhood information, MN requests for information Elements (IEs) from Information Server (IS).

Link_Going_Down(LGD) trigger [3][4] implies that a broken link is imminent. LGD event is generated when the following condition holds true for received power

$$P_{LGD} = \alpha_c \, P_{RxThreshold} \qquad (1)$$

P_{LGD} = power at which link going down event is generated.

$P_{RxThreshold}$ = minimum power level to receive wireless packets without error

α_c = power level threshold coefficient

P_{LGD} is kept at some higher level than $P_{RxThreshold}$

LGD triggers generated due to sudden fading effects may result into unnecessary handoffs. To avoid this MIH standard provides Link Rollback trigger [3][4]. If a packet with a higher power level is received immediately following a Link Going Down event, then the MAC layer generates a Link Rollback event to cancel the most recently generated Link Going Down event. Link rollback is generated when following conditions hold:

i) $P_{n-2} > P_{n-1}$

ii) $P_{n-1} < \alpha_c \, P_{RxThreshold}$

iii) $P_n > P_{n-1'}$

where, P_n is power received for n^{th} packet.

III. REVIEW OF VERTICAL HANDOVER ALOGORITHMS

Few of the vertical handover methods use predefined Received Signal Strength (RSS) thresholds. If the RSS is less than this predefined threshold value then LGD trigger is generated. However, practically, speed of mobile, wireless channel conditions vary with time. Hence, optimum threshold can be obtained by making dynamic measurements and calculations.

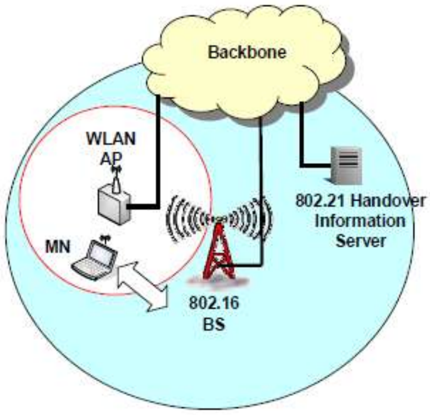

Figure 2. Typical scenario for MIH based handovers [6]

Q. Mussabbir, W. Yao, Z. Niu and X. Fu [5] have proposed an optimized Fast Handover for Mobile IPv6 (FMIPv6) to reduce handover delay in IEEE 802.21 MIH. Handover delay using FMIPv6 is given by (2)

$$D_{Ho\_FMIPv6} = D_{L2} + D_{MN\_nAR} \qquad (2)$$

Where, $D_{MN\text{-}nAR}$ is the delay to send Fast Neighbor Advertisement (FNA) message from the MN to the new Access Router (nAR).

D_{L2} is the delay associated with L2 processes.

Delays associated with movement detection ,New Care-of-Address(nCoA) configuration and Duplicate Address Detection (DAD) are eliminated in FMIPv6.

The Signal to Interference and Noise Ratio (SINR) based vertical handoff is proposed by C.Lin, H.Chen and J.Leu [6].

SINR received by user i, from Base Station BS j is as defined in (3)[6],

$$SINR_{j,i} = \frac{(Gain_{j,i})(PW_{j,i})}{PW_n + \sum_{k\in BS}(Gain_{k,i})(PW_{BSk}) - (Gain_{j,i})(PW_{j,i})} \qquad (3)$$

$SINR_{j,i}$ = SINR received by user i from BSj

PWn = power of n^{th} received packet

$Gain_{j,i}$ = channel gain between user i and BSj

$PW_{j,i}$ = transmitting power of BSj to user i

PW_{BSk} = total transmitting power of BS_k (point of attachment)

Authors of [6] have used distance from cell border, packet loss and throughput to define QoS received. Priority function to determine QoS connection is given by (4)

QoS(t) = F(distance, loss, throughput)

$$QoS_{(t)} = w(d)\frac{P_{th\_Distance}}{M_{-Distance}} + w(l)\frac{P_{th\_loss}}{M_{-loss}} + w(r)\frac{P_{th\_rate}}{M\_rate} \qquad (4)$$

Where,

w(d)+ w(l)+ w(r) = 1

w() = weight for QoS evaluation metric.

Pth_x = required QoS performance metric X

M_x = measured QoS value for metric X

The weights assigned to different QoS criterion are dependent on the nature of application. Typical network scenario is as shown in Fig.2[6]. Multimodal MN will perform handover between WLAN AP and IEEE 802.16 i.e. WiMAX BS using MIH Information Server (IS).

Younghyun Kim, Sangheon Pack ,Chung Gu Kang ,Soonjun Park [7] have proposed an improved vertical handover procedure in which wireless channel conditions are estimated by exploiting spatial and temporal locality at the Information Server. Proposed architecture of Enhanced Information Server (EIS) [7] enables reducing the delays as MN need not perform channel scanning. Every MN measures its location and RSS to available PoAs, and notifies it to the EIS. For a wireless channel model, COST-231 Hata model is chosen by authors [7].Under COST- 231 Hata model [8], the path loss is given by (5)[7],

$$PL(d)_{DB} = 46.3 + 33.9log_{10}(f) - 13.82log_{10}(h_b) - a(h_r) + (44.9 - 6.55log_{10}(h_b))log_{10}(d) + c_m \quad (5)$$

Where, f is the carrier frequency, h_b is the antenna height of a Point of Attachment (PoA), and d is the distance between the PoA and MN. $a(h_r)$ is the MN's antenna height correction factor and, for urban environments, it can be obtained from (6) [8]

$$a(h_r) = 3.20(\log(11.75h_r))^2 - 4.97 \quad (6)$$

The Received Signal Strength (RSS) can be computed using (7)[8]

$$RSS(d)_{dB} = PW_{tdB} - PathLoss(d)_{dB} \quad (7)$$

PW_{tdB} is a transmitting power in dB

Abhijit Sarma, Sandip Chakraborty and Sukumar Nandi [10] have proposed a technique that improves the QoS and Quality of Experience (QoE) of the end users. Proposed scheme [10] minimizes the cost-per-bit and average energy consumption, by balancing traffic load across WiFi APs and WiMAX BS in a WiFi-WiMAX Heterogeneous Network (HetNet) , in the presence of a mix of traffic flows from different service classes. WiMAX BS helps to smooth out the handover related glitches, such as increase in handover latency and occasional transient overload in APs. After reserving bandwidth at AP and BS the proposed scheme performs admission control and handover with class based load balancing.

A fixed percentage of the maximum bandwidth is reserved for traffic class Access Category Voice (AC_VO), Access Category Video (AC_VI) and Access Category Background (AC_BK). A flexibility is given through the upper limit and lower limit of the bandwidth reservation, so that unused bandwidth by one class of traffic can be reused by another classes of traffic, if required. The relationship between bandwidth and traffic flow of various classes is as mentioned in equation (8)[10]

$$\frac{BW\_vi}{Tr\_vi} > \frac{BW\_vo}{Tr\_vo} > \frac{BW\_bk}{Tr\_bk} \quad (8)$$

Tr_vi, Tr_vo, Tr_bk are flows of class Video, Voice and Background.

BW_vi,BW_vo,BW_bk = average bandwidth requirement per flow for class Video, Voice and Background.

Equation (9) illustrates the relationship between total bandwidth and upper and lower bandwidth limits.

$$BW_{max\_vo} + BW_{max\_vi} + BW_{min\_bk} < BW_{tot} \quad (9)$$

BW_{max_vo} , BW_{max_vi} = upper limit of bandwidth for class video, voice

BW_{min_bk} = lower limit of bandwidth for class background

BW_{tot} = total bandwidth

The amount of spare bandwidth at Wi-fi AP is as stated in (10)[10]

$$BW_{sp} = BW_{tot} - (BW_{max\_vo} + BW_{max\_vi} + BW_{min\_bk}) \quad (10)$$

BW_{sp} is required to be greater than zero to keep provision for accommodating a MN performing handover and an occasional traffic burst of some flows. It also provides some head room for the Best Effort class flows.

During admission control at WiFi AP, a MN joining the WiFi AP for the first time with a traffic class is admitted only if the bandwidth occupied by the class does not exceed the lower limit of reserved bandwidth. A new flow of class C having a bandwidth requirement of BWc needs to be admitted. It is admitted only if it satisfies following condition given in (11)[10].

$$BW_c + BW_{occu\_c} \leq BW_{min\_c} \quad (11)$$

Where, BW_{occu_c} is the bandwidth already occupied by class c and BW_{min_c} is the minimum bandwidth reserved for class c.

A MN is admitted in the network by WiFi AP if the total bandwidth occupancy for that class is less than upper limit of reservation. If the lower limit of bandwidth reservation for that class is exceeded then AP initializes load balancing by instructing some of the MNs associated with it to perform a horizontal inter-BSS handover, to another AP in their vicinity or vertical handover to the WiMAX BS.

The total required handover time for a vertical handover is as shown in (12)[11],

$$t_h = t_{L2p\text{-}nbr} + t_{L2n\text{-}scn} + \max\{t_{hp}, t_{hn}\} \quad (12)$$

where,

$t_{L2p\text{-}nbr}$ =message exchange time to obtain the neighboring information

$t_{L2n\text{-}scn}$ =time to scan the candidate POAs.

t_{hp} = handover preparation time for L2 and L3 with the current network Point of Attachment (PoA)

t_{hn} = handover execution time with new network PoA.

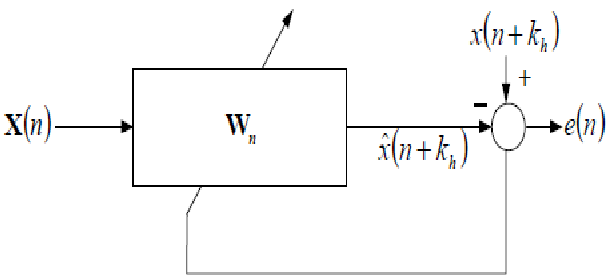

Figure 3. K_h step LMS predictor [11]

In order to generate the LGD event based on the required handover time t_h , an LMS (Least Mean Square) adaptive prediction technique is applied by Sang-Jo Yoo, David handover time (t_h), the triggering point is adaptively adjusted. The signal strength data is noisy and is occasionally inconsistent hence filtering of data is required. The prediction step K_h is determined based on the required handover time. If the K_h ahead predicted power is less than the minimum power level to decode data, the LGD trigger is then generated. Prediction interval K_h can be determined using (13).

$$k_h = \left\lceil \frac{t_h + \Delta_h}{t_s} \right\rceil \tag{13}$$

Δ_h is the handover marginal time to trigger the LGD slightly earlier than the required handover time.

t_s is the filtered sample interval and t_h is required handover time.

The LMS adaptation algorithm monitors the prediction error e(n) and attempts to minimize the mean squared prediction error, E $\{e(n)^2\}$, by adapting prediction weights.

Structure of k_h-step LMS predictor is as shown in Fig.3.[11] W_n is the time varying coefficient vector. Predictor provides estimation of future samples using linear combination of present and past sample values.

Liu Shengmei,Pan su and Mi Zhegkun [12] propose use of Preference Ranking Organization METHod for Enrichment Evaluation (PROMETHEE) algorithm for vertical handoff decision technology. The weight relation of decision elements is determined with Least Square (LS) method.

E. Fallon, L. Murphy, J. Murphy and G. Muntean[13] have proposed FRAME: Fixed Route Adapted Media streaming Enhanced handover algorithm for vehicular systems. Authors have proposed use of neural network along with IEEE 802.21 services. They have utilized knowledge of nature of movement to predict link triggers. FRAME algorithm consists of two components: 1.Route Identification and Management for identifying vehicle routes and 2. Media performance directed learning algorithm for selecting the path intelligently. The complex prediction algorithm putting memory constraints on the device, is a challenge in implementing FRAME.

There are various mathematical modelling techniques that are used for vertical handover. Wang, Lusheng, and Geng-Sheng GS Kuo [14] in their tutorial, have presented a review on these techniques. They have discussed network selection techniques that are based on utility theory, multiple attribute decision making, fuzzy logic, game theory, combinatorial optimization and Markov chain etc. They have also presented various case studies to illustrate these theories.

Multiple Attribute Decision Making (MADM) techniques are explored by many authors as it provides effective mapping with context parameters of wireless environment. MADM algorithms handle multiple conflicting criteria, few are benefit type whereas others are cost type. Various MADM algorithms viz. Simple Additive Weighting (SAW), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), ELimination Et Choix Traduisant la REalit´e (ELECTRE), VIKOR Serbian: VIseKriterijumsa Optimizacija I Kompromisno Resenje, meaning: multi-criteria optimization and compromise solution etc. [15][16]are explored for the purpose of network selection.

Fuzzy logic based techniques[17] have also proved to be beneficial for wireless environment. Fuzzy logic does mapping between linguistic variables and crisp data values. It effectively handles the vagueness and uncertainty associated with wireless environment.

Authors [18][19] have combined fuzzy logic and MADM algorithms for QoS ensured vertical handover.

Markov Decision Process (MDP) [20][21]based scheme is used to solve multi objective dynamic decision making problems. Input data in MDP is not known very precisely as well as perfectly, hence, it is optimum for wireless environment. Proposed system has leveraged features of MDP for selecting best network.

IV. HRPNS MODULE

The architecture of proposed HRPNS module is as shown in Fig.4. It consists of two stages. The first stage, Handoff Resolving (HR) state ,which is responsible for deciding whether there is necessity of handoff. If this module declares that handoff is necessary, then the next stage which is Preferred Network Selection state gets activated.

HR state consists of Fuzzy Logic Controller (FLC). Most commonly used descriptions by humans are linguistic such as low, medium and high, they can be mapped into mathematical value using fuzzy logic. Handoff decision is controlled by various context parameters. The parameters that are considered in the proposed implementation are : RSS, network load, delay, bandwidth and traffic class. The Handoff Resolver FLC takes these parameters as input and based on the rule set defined declares whether handoff is necessary or not. As shown in Fig.4 initially the crisp value inputs are converted into fuzzy numbers using Fuzzifier. Handoff Resolver Coefficient (HRC) is calculated with the help of inference engine rules. Fuzzy value of HRC is converted into crisp value output with the help of defuzzifier. Calculated HRC, triggers the Preferred Network Selection (PNS) block for choosing the best network.

PNS module is designed using MDP rules. To compare between the status of available networks, context parameters information is gathered from IEEE 802.21 based Information Server. This information is applied as an input to MDP algorithm. This block prefers best network after considering the context parameters of neighboring networks as well as the application requirements of the user.

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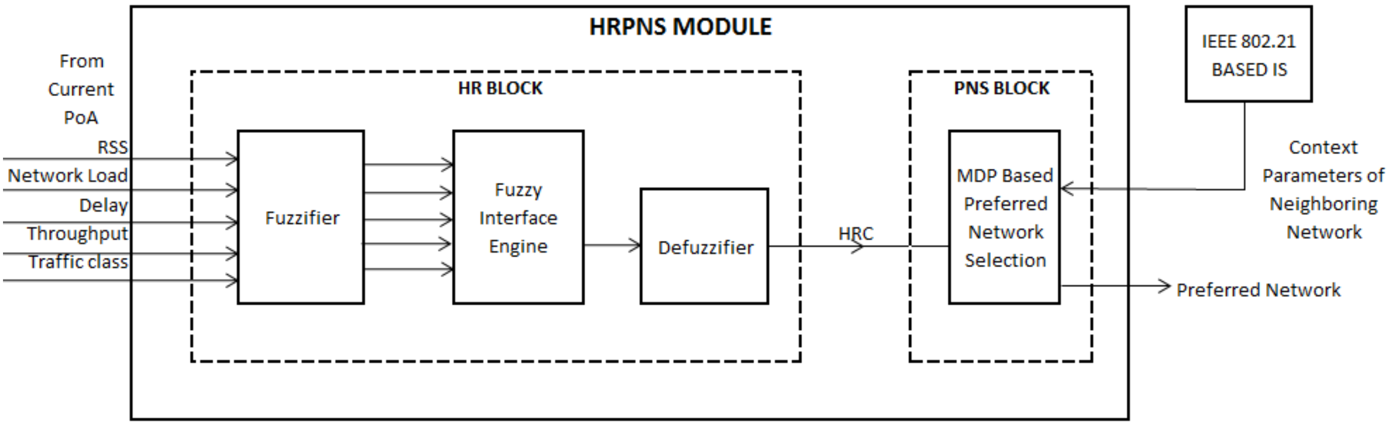

Figure 4. HRPNS module architecture

A. Fuzzy Logic Controller (FLC)

In fuzzy logic based approaches, Universe of Discourse (UoD) are expressed using membership functions. Various membership functions namely, triangular, trapezoidal, Gaussian, sigmoid, etc are available. Triangular membership functions are expressed using Triangular Fuzzy Numbers (TFN). TFNs are represented as $x = (l, m, u)$[17]; parameter $l, u$are lower and upper limits of each attribute and m is the threshold value.

Triangular membership function [17] is given in (14),

$$\text{⍰}(x) = \begin{cases} \frac{x-l}{m-l}, & x \in [l, m] \\ \frac{u-x}{u-m}, & x \in [m, u] \\ 0, & Otherwise \end{cases} \qquad (14)$$

TFN to crisp number conversion can be done using relationship given below in (15) ,

$$a_{ij} = (l_{ij} + 4m_{ij} + u_{ij})/6 \qquad (15)$$

Another popular membership function is trapezoidal membership function, described by (16)[17]

$$\text{⍰}(x) = \begin{cases} 0 & x \le a \\ \frac{x-a}{b-a} & a \le x \le b \\ 1 & b \le x \le c \\ \frac{d-x}{d-c} & c \le x \le d \\ 0 & d \le x \end{cases} \qquad (16)$$

B. Markov Decision Process (MDP):

Markov Decision Process (MDP) , is a discrete time stochastic process, used as a decision making tool. At each time step, the state space S is as defined in equation(17)[20][21]

$$S = \{1,2, \dots, M\} \times B^1 \times D^1 \times B^2 \times D^2 \times \dots \times B^M \times D^M \qquad (17)$$

Where, M is number of available collocated networks.

In MDP, every state is associated with an action, corresponding transition probabilities and rewards. Decision epochs that is decisions of network selection are done at every t s. An instantaneous reward $r(s, s', a)$ is assigned for transition from state s to s' with action a. This system is Markovian since previously visited states do not influence transition of state from one state to other. Sequence of times when mobile terminal takes a decision is given by $T = \{1,2, \dots, N\}$, where N represents connection termination time. The action set is represented by $A = \{1,2, \dots, M\}$ where M denotes total number of coexisting networks. Link reward function assignment is based on QoS required for the particular application given by $f(X_t, Y_t)$, where, random variable X_t, Y_t denotes state and action chosen at decision epoch t respectively.

Interpretation of policy can be a function π, that specifies the action $\pi(s)$ which decision maker has to choose when in state s. Policy π that maximizes expected total reward is selected. Expected total reward $v^\pi(s)$ is represented in (18)

$$v^\pi(s) = E_s^\pi[E_N\{\sum_{t=1}^{N} r(X_t, Y_t)\}] \qquad (18)$$

Where, E_s^π denotes expectation with respect to policy π and initial state s. E_N is expectation with respect to connection termination time random variable N. Assuming N to be geometrically distributed random variable with mean $1/(1-\lambda)$, (18) can be written as follows

$$v^\pi(s) = E_s^\pi\{\sum_{t=1}^{\infty} \lambda^{t-1} r(X_t, Y_t)\} \qquad (19)$$

where, λ is discount factor of the model, and $0 \le \lambda < 1$.

Number of states define number of Bellman equations and number of unknown values. To obtain the optimal policy and optimal value function, these equations are solved simultaneously using Value Iteration Algorithm (VIA). The steps in VIA are as follows[23]:

1. $v^0(s) = 0$ for each state s. Set ε >0 and k = 0.
2. For each state s, compute $v^{k+1}(s)$ using (20)

$$v^{k+1}(s) = \max_{a \in A}\{r(s, a) + \sum_{s' \in S} \lambda P(S'|s, a) v^k(s')\} \qquad (20)$$

3. If $\|v^{k+1} - v^k\| < \varepsilon(1-\lambda)/(2\lambda)$, go to step 4, else k+1 and go to step 2

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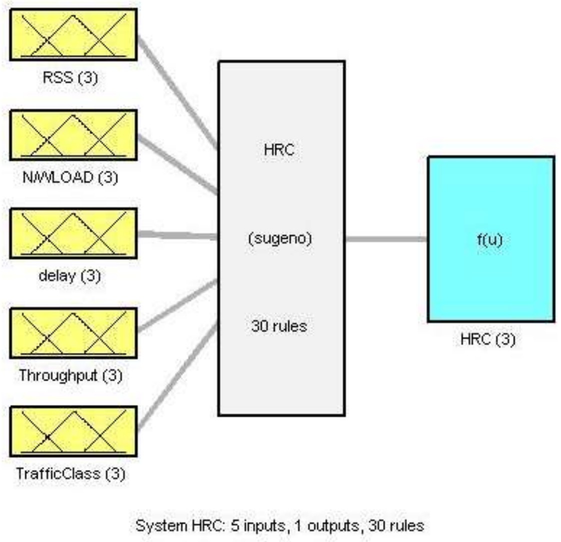

Figure 5. Handoff Resolver FIS

4.For each $s \in S$,compute optimum stationary policy

$$\delta(s) = \arg\max_{a\in A}\{r(s,a) + \sum_{s'\in S} \lambda P(S'|s,a)v^{k+1}(s')\} \quad (21)$$

and Stop.

VIA evaluates stationary optimum policy and expected total reward.

V. SIMULATION RESULTS

The implementation of the proposed HRPNS module is done using MATLAB. Coexistence of Wi-MAX and two WLAN networks is considered for simulation. Typical operating range parameter values for WLAN and Wi_MAX network are as listed in Table I.

The Fuzzy Inference System for Handoff Resolver block is as shown in Fig. 5. As depicted, Sugeno based FIS is used as it provides output membership function which is either linear or constant. The received values of RSS, Network Load, delay and throughput and traffic class are applied as an input .Triangular and trapezoidal membership functions are used as it yields good performance for real time application. The UoD for the membership functions is defined using parameter values of Table I.

As a test case, membership function for RSS of WLAN is illustrated in Fig. 6.

TABLE I. Operating range values for WLAN and WiMAX

Attribute	WLAN	WiMAX
RSS dBm	(-110)- (-55)	(-160)- (-100)
Data rate Mbps	1- 11	1 - 6
Delay ms	100 - 150	60 - 110
Jitter ms	10 -30	3 - 10
PLR (per 10^6 bytes) %	6	4
reliability	0.6	0.8
security	50	60

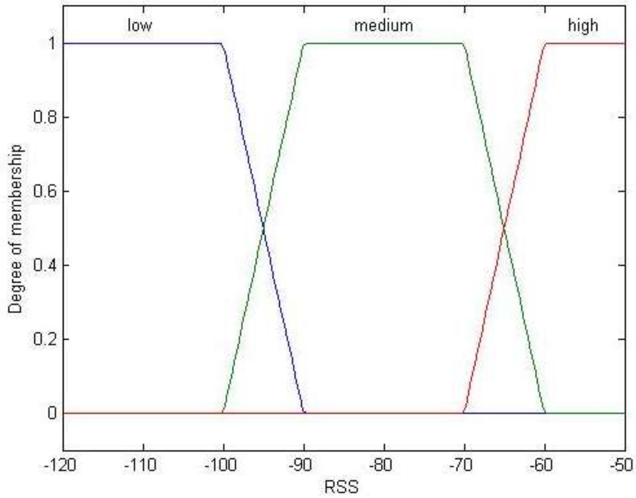

Figure 6. Fuzzy membership function for RSS

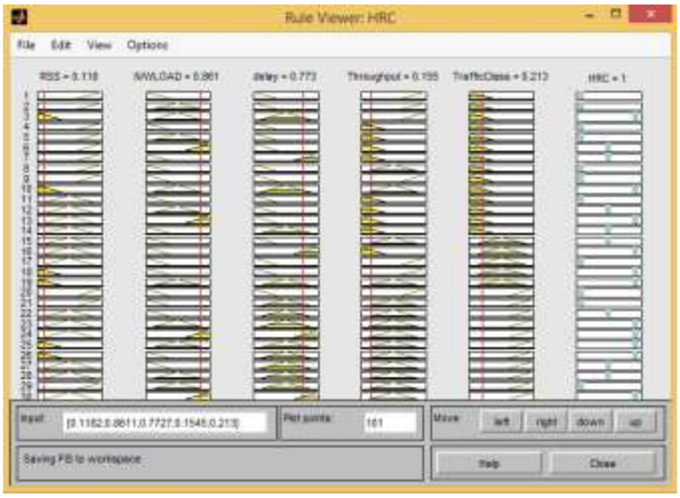

Figure 7. Rule set for Handoff Resolver Coefficient

The rule set for the Handoff Resolver is as depicted in Fig. 7. The defined rules ensure high value of Handoff Resolver Coefficient (HRC), in case of weak RSS, heavy network load, long delays and low throughput. Depending on the traffic class rules define priority amongst delay and throughput.30 rules are defined which determine the necessity of handover based on input parameters.

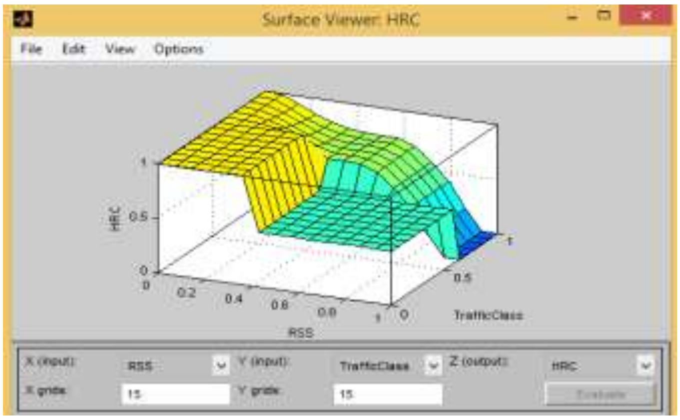

Figure 8. Surface view of HRC for conversational traffic class

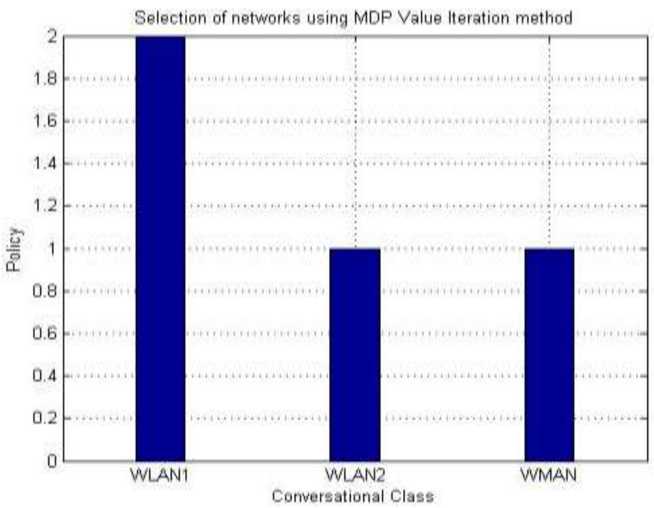

Figure 9. Network selection for traffic class Conversational

Surface view illustrated in Fig. 8 shows a test case scenario with traffic class conversational. As conversational class is delay sensitive, it gives higher value of HRC for longer delays. The HRC value is designed to vary between 0 to 1. The higher values indicate more urgency of handover.

The obtained value of HRC is applied as an input to the Preferred Network Selector block. The candidate network discovery phase is activated if the HRC value is greater than threshold, which is set to 0.45 after experimental trials.

To get the real time value of context parameters, Request message is sent to IEEE 802.21 IS. The reply message from IS consists of context parameter values of neighboring networks.

Markov Decision Process is used to select the best network from available alternatives.

Network numbers 1and 2 are assigned to WLANs and number 3 to WiMAX network while applying MDP algorithm. MDP gives more realistic analysis as here we consider, network switching cost along with the delay and throughput reward function.

PNS block output is depicted in Fig. 9 and 10 for traffic class conversational and interactive respectively. As seen from the results, Traffic class conversational users selects WLAN network whereas Interactive traffic class users prefer WMAN network.

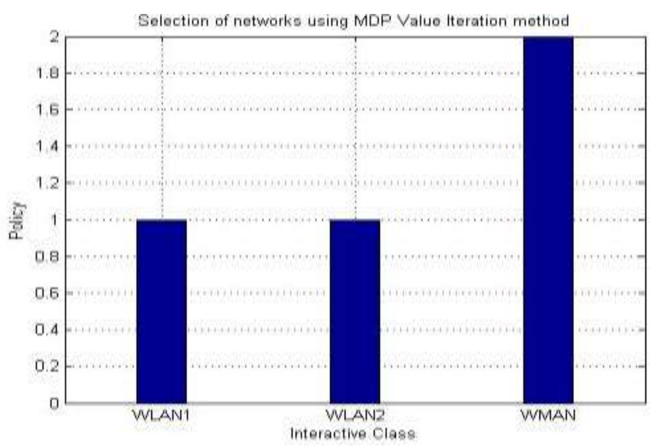

Figure 10. Network selection for traffic class Interactive

VI. CONCLUSION

Review of modeling techniques for vertical handover management in heterogeneous networks is presented in the paper. Mobile users roaming in the heterogeneous wireless network environment will be able to select the available access network that can fulfill their requirements. Prediction algorithm to precisely estimate the required handover time in a situation of degrading RSSI is the key element. IEEE 802.21 MIH based architectures can provide necessary signaling for predictive handover. As illustrated by the simulation results, proposed HRPNS module in association with IEEE 802.21 MIH module, selects best network out of available radio access technologies. Results show that, MDP provides high precision for moderate decision speed and implementation complexity. The proposed selection scheme supports mobility as well as traffic class.

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