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Performance Enhancement with Fuzzy Logic and Neural Fuzzy Logic Algorithm in Heterogeneous Interconnected Network

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ABSTRACT: To achieve Always Best Connected (ABC) services, the mobile nodes are always connecting to available network which has fast and improved link. A RAT selection technique would consider various parameters like the Received Signal Strengths, Errors Rates, Costs, User Preferences, QoS requirements, etc. Algorithms are also implemented and tested to find the most suitable approach for traffic sharing. Extensions to the MIH standard have been implemented in order to support handovers for global networks. In this paper, fuzzy logic algorithm & Neural Fuzzy Logic algorithm is implemented on heterogeneous network for 50 users. In which UMTS, WLAN & WiMAX networks are used. The simulation of this infrastructure is measure in NeSSI[2] simulator. The performances of each network configuration with increase of traffic have been measured. The attributes for traffic distribution are handover latencies, packet drops and throughput have observed and considered for evaluation of traffic sharing using different scenarios.

KEYWORDS: UMTS, WiMAX, WLAN, Heterogeneous Networks, Media Independent Handover (MIH), Heterogeneous Network Traffic Distribution, Dynamic Load Balancing, Load Balancing, Traffic Sharing, Packet Drop Ratio, Handover Latency, No Traffic Sharing, Baseline Algorithm, Fuzzy Logic Algorithm, Neural Fuzzy Logic Algorithm.

I.INTRODUCTION

A Radio Access Technology (RAT) selection technique is useful for a user when mobile device turns on his/her power and also user moves around between the coverage areas of different wireless networks. This paper includes a Load-aware RAT selection algorithm on mobile node and a network traffic sharing algorithm on the radio access network. The framework supports heterogeneous wireless networks containing UMTS, WLAN and WiMAX networks. Algorithms are also implemented and tested to find the most suitable approach for traffic sharing. New simulation modules were implemented in the simulation framework to support traffic sharing algorithms, and the MIH extensions.

The traffic sharing strategies in this research are novel traffic aware RAT selection techniques which uniformly distribute the network traffic between co-located heterogeneous wireless networks. It utilizes parameters collected using MIH to seamlessly handover mobile users between heterogeneous wireless networks for traffic sharing purpose. The advantage of these algorithms is that it minimizes the call blocking and dropping probabilities, number of packet drop/lost and delays during the handover process and enhances the network utilization by continuously balancing the traffic in co-located networks. The following two algorithms are study in this paper for performing traffic sharing in heterogeneous wireless networks during RAT selection:

1. **Fuzzy Algorithm**: Fuzzy logic based traffic sharing algorithm for the RAT selection in heterogeneous wireless networks. This algorithm utilizes the fuzzy logic controller to obtain the most suitable result by efficiently considering all the parameters.
2. **Neural-fuzzy Algorithm**: The benefits of fuzzy and neural network algorithms are combined together to increase the efficiency of traffic sharing in fuzzy neural based algorithm for heterogeneous wireless networks RAT selection.

For efficient traffic sharing in heterogeneous wireless network, above traffic sharing algorithms are deployed on the MIH based integrated network architecture.

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II. RELATED WORK

The traffic sharing (load balancing) mechanism can be divided into two parts in heterogeneous networks such as traffic sharing algorithm and network architecture. This section describes the traffic sharing algorithm approaches done in particular area.

Shiann-Tsong Sheu et al. [2] has proposed a Dynamic Load Balance traffic sharing Algorithm for homogeneous network targeting WLAN. The approach considers the Received Signal Strength Indicator (RSSI) value to distribute the coverage between different Access Points (APs) which have overlapping coverage areas. This approach uses two values in sharing the traffic which are RSSI between Mobile Station (MS) and AP and the average RSSI value of all the MSs currently connected with AP. The method given in considers both RSSI and the number of MS associated with AP which makes it much effective for traffic sharing. Ioannis Papanikos et al. [3], has studied proposed DLBA for WLAN. The author has extended the signaling need for the implementation of already proposed procedure. They consider resource availability of the AP and frame error rate measurements to take added decision level. P.M.L.Chan et al. [4], has proposed a RAT selection algorithm based on a fuzzy Multiple Attribute Decision Making (MADAM). The algorithm considers parameters such as battery status, latency, user’s preferences, reliability, cost, signal strength and bandwidth. The main aim of the algorithm was to select a suitable RAT for a particular service class. A.Tolli et al. [5], has provides seamless interworking with the help of Common or Joint Radio Resource Management (CRRM/JRRM) to efficiently utilized radio resource and provide guaranteed QoS for all active connections. They used RAT selection algorithm to validate the correctness of available RATs in the heterogeneous wireless networks. They studied, and investigate the effect of tuning the traffic based handover thresholds depending on the traffic of inter-system/inter-layer/inter-frequency cell for real time traffic. Authors conclude that the number of unnecessary handover attempts and failures can be significantly reduced by tuning the load based handover thresholds. J. McNair et al. [6], have presented a tutorial on the design and performance issues of VHD policies is presented along with analysis and comparison of several VHD algorithms. However, the focus of this study was quite narrow and only covered cost function and received signal strength (RSS) based VHD algorithms. A.L.Wilson et al. [7], has proposed a fuzzy logic based RAT selection algorithm. The algorithm considers different input metrics like existing candidate networks, application QoS requirements, user defined criteria, etc. Yilmaz et al. [8], have study five different network selection algorithms based on different input parameters. The algorithms are evaluated and compared in terms of achieved bit rate and results indicate that in some scenarios the simple access selection principle “WLAN if coverage” gives good enough results.

Ormond et al. [9], have propose a consumer surplus based algorithm for access network selection selecting the best available network for transferring non real-time data, with user specified time constraints. The basic assumption is that users‟ willingness to pay depends on the required transfer completion time. The proposed access network selection scheme is evaluated through simulations in NS-2 against an always cheapest network selection strategy. A.H. Zahran et al. [10], have presented a framework to compare the performance of different vertical handover algorithms on system resource utilization and Quality of Service (QoS) perceived by users, but only included the evaluation of two VHD algorithms. W.Song et al [11], has adopted RAT selection algorithm based on service class, where the UMTS and WLAN networks are considered with two traffic classes such as voice and data. The policy adopted for the overlapping coverage area, the UMTS network is given higher priority for voice calls and the data connections can only be admitted on WLAN. Q.Guo et al. [12], has proposed a fuzzy Multiple Objective Decision Making (MODM) approach for selecting a suitable RAT for handover calls in heterogeneous wireless networks. The algorithm considers parameters like data rate, network type, transmission delay, call appearance rate, and coverage of the network for evaluation for decision making. J.Perez-Romero et al. [13], has proposed a new Common Radio Resource Management (CRRM) methodology based RAT selection algorithm based on path loss for the heterogeneous wireless network considering CDMA/TDMA based network. In this algorithm the high path loss based mobile users are connected/allocated to the TDMA based network and the low path loss mobile users to CDMA network. A hysteresis margin is introduced in this proposed algorithm to avoid the Ping-Pong effects of undesired handover between different RATs in heterogeneous wireless networks. K.H.Suleiman et al. [14], has provides mechanism for traffic sharing between heterogeneous wireless networks for better radio resource utilization. In their research they found that when the available resources in HWN have been reached after certain time interval or performing traffic sharing up on certain events such as call arrival, handover or reached at particular calculated decision value. Ted Scully et al. [15], has study a solution for traffic sharing in homogeneous wireless networks, by utilizing genetic algorithm. As the genetic algorithm’s convergence directly proportional to the size of population (mobile nodes and APs) therefore this approach is effective for WLAN networks and not for the heterogeneous wireless environment where population size is comparatively large

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due to large coverage areas. All approaches given in [2,3,15] were designed to enhance the performance for homogeneous network environment particularly for WLAN. M. X. Li et al. [16], presents a multi-hop routing mechanism with fuzzy estimation of links for heterogeneous wireless networks. Mun-Suk Kim et al. [17], has study the traffic sharing approach which targets the PMIPV6 domain using MIH for heterogeneous networks. A comparison has been made between the scenario performing traffic sharing in extended PMIPV6 for handover signalling and the scenario using MIH signalling for traffic sharing. The author finds that use of traffic sharing improves the efficiency whereas, MIH based traffic sharing improves data rate as compared to extended MIPV6 based traffic sharing. SuKyoung Lee et al. [18], have been proposed a general set of algorithms. In this algorithms they considers battery power of mobile users, received signal strength and traffic on available points of attachments in handover process to balance the traffic in co-located networks overlapping their coverage areas. They found that traffic sharing approach is done only at network side without any interaction with the mobile node. Alexandros Kaloxylos et al. [19], have analysed a detailed algorithm for network selection in heterogeneous wireless networks. The algorithm divided into two parts: (a) runs at mobile terminals and (b) runs at network entity such as base station (BS) or Access Point (AP). This algorithm considers battery power, speed, received signal-strength and location of mobile user. The author's do not consider MIH which improved the handover process while moving the mobile nodes between different networks. In [20] a Markov chain based model for load balancing and QoS based CAC has been presented and comparisons have been made between the results of load balancing based CAC and QoS based CAC algorithms. The load balancing approach presented in this research report is more efficient than load based CAC approach presented in [20] as our approach uses MIH to minimize the handover delays when moving the mobile nodes for load balancing purpose and tends to uniformly distribute the load among available heterogeneous wireless networks. K. Mokhtarian et al. [21], has analyze an algorithm which minimize the communication overhead. M.Ali et al. [22, 23, 24] proposed approach in which also adapted semi-centralized architecture but utilized the enhanced MIH [1] which is a standardized and more efficient. The undertaken work is an extension of work done [25] in respect of where in baseline algorithm was implemented. A targeted level of performance was achieved. The enhancement of performance level is targeted in this paper with the use of Fuzzy Logic and Neural Fuzzy Logic algorithm on the earlier proposed but cited framework.

III. SIMULATION ARCHITECTURE & PERFORMANCE EVALUATION RESULTS

A. Simulation topology and scenarios

To analyse the performance of the traffic sharing framework and algorithms, a simulation topology implemented in NeSSI[2]. In Fig. 1, the topology is simulate a real-time situation where a mobile may move among the overlapping coverage areas of different networks such as UMTS, WLAN and WiMAX networks. A group of mobile users in their coverage areas contain a different network at different time. And also group of mobile users have been assumed to travel across different networks. The number of users speed movement and group moving can be configured in the simulation. There are 2 scenarios simulated with different number of mobile users in group such as 50 mobile nodes.

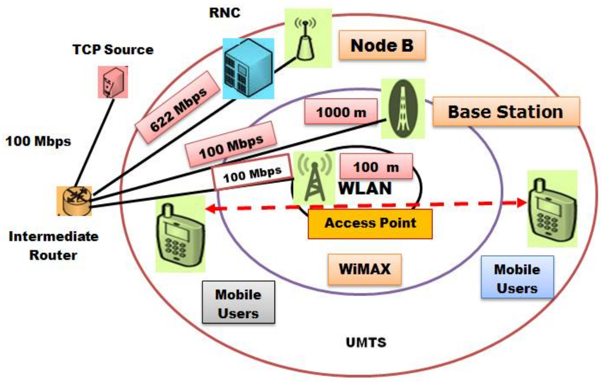

Fig. 1 Heterogeneous Wireless Network Simulation Topology

Table-1 represents the simulation parameters for the different simulation. In simulation a group of mobile users starts from the UMTS coverage area and move together towards common coverage areas of wireless networks such as WiMAX and WLAN.

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TABLE-1 SIMULATION PARAMETERS

Simulation Parameters	Values
UMTS Coverage Radius	1000 meters
WiMAX Coverage Radius	500 meters
WLAN/Wi-Fi Coverage Radius	100 meters
UMTS Data Rate (Second)	384 Kbps
WiMAX Data Rate (Second)	45 Mbps
WLAN/Wi-Fi Data Rate (Second)	11 Mbps
Wired Links Capacity	100 Mbps
Propagation delays wired links	0.0035 ms
Application Type	TCP and CBR
Application Data Rate	5 Kbps
No. of Mobile Nodes	50 users
Mobile nodes (MNs) Speed	25 m/s & 2m/s
Algorithm	1) Fuzzy Logic Traffic Sharing 2) Neural Fuzzy Logic Traffic Sharing

B. Evaluation Methodology

With the help of $NeSSI^2$ simulation framework, different simulation scenarios are described to evaluate the performance of the proposed traffic sharing framework and algorithms. For each of the simulation scenario the set of parameters such as Traffic at each Network, Packet Drop Rate, Average Handover Latencies, Average Throughput of Mobile Nodes & Throughput at different Networks are observed and analyzed. To study the effect of the algorithms across different scenarios, the obtained result are individually analysed and compared. While some of the above parameters like packets drop rate, Average throughput at each mobile node, traffic on each network, total handover latencies observed by each mobile node and total number of handovers performed by each mobile node for the different scenarios can be easily compared, direct comparisons of parameters is not possible in some cases.

C. Results Analysis

This section presents the results obtained for the various scenarios simulated to evaluate the performance of each of the algorithm. The results are presented in the following order:

1. Fuzzy Logic Traffic Sharing Algorithm (50 users)
2. Neural Fuzzy Logic Traffic Sharing Algorithm (50 users)

C.1 Scenario 1 – Fuzzy based algorithm with 50 users

After applying the fuzzy based traffic sharing algorithm on 50 mobile nodes scenario with velocity of 25m/s and 2m/s, following results are obtained.

a) Network traffic

The graphs shown in Fig. 2 & 3 represents the traffic in each network such as UMTS, WiMAX and WLAN at the different position of travel trajectory for the 50 mobile nodes scenarios when no traffic sharing is applied and fuzzy traffic sharing is applied with the mobile nodes moving at 25m/s and 2m/s. It can be seen from these obtained traffic results that without traffic sharing most of the mobile nodes handover to the best available network in terms of cost and network latencies. For example in position 4 in Fig. 2 & 3, we can see that all the users connected to WLAN. This however leaves the other networks under-loaded or underutilized.

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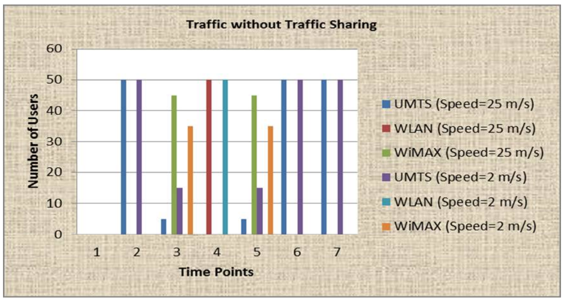

Fig. 2 Traffic Distribution without Traffic Sharing in (Speed=25m/s & Speed=2m/s)

In the scenario where fuzzy traffic sharing is applied, all the networks share the traffic where possible such as in the overlapped coverage areas. For example in the same position 4 in Fig. 3, we can see that the users are distributed across the different networks.

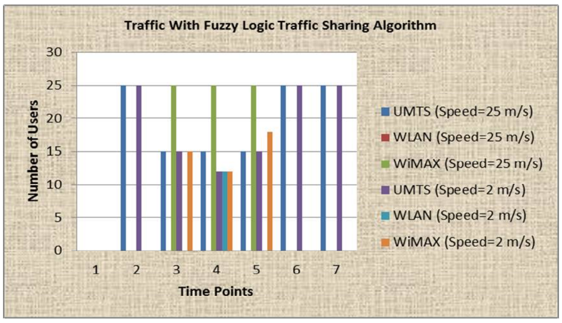

Fig. 3 Traffic Distribution with Fuzzy Traffic Sharing Algorithm (Speed=25m/s & Speed=2m/s)

From the above both graphs, we conclude that the fuzzy based traffic sharing algorithm distributes the traffic efficiently. One unique difference in results obtained by fuzzy is that in 25m/s scenarios the fuzzy algorithm does not move mobile nodes to the WLAN network and the traffic (load) in WLAN remains zero throughout the simulation in 25m/s scenarios. The reason for this is that, the fuzzy traffic sharing algorithm intelligently detects that velocity of mobile node is higher and the coverage area of the network is smaller, therefore, it is not suitable to handover these mobile nodes to the WLAN. Hence the traffic in 25m/s scenarios is divided into UMTS and WiMAX networks. Whereas in scenarios with 2m/s mobile nodes velocity, the mobile nodes could stay in WLAN for a considerable amount of time therefore fuzzy traffic sharing allows the mobile nodes to handover to WLAN.

b) Packet drops

The total packet drop rate in the 50 mobile nodes scenarios with mobile nodes velocity of 25m/s and 2m/s using the fuzzy and no traffic sharing algorithms are shown in Fig. 4. The abbreviations used in these graphs are: NTS stands for “No Traffic Sharing” and FLTS stands for “Fuzzy Logic Traffic Sharing”. The packet drop in fuzzy traffic sharing algorithm is considerably low as compared to the scenarios without traffic sharing.

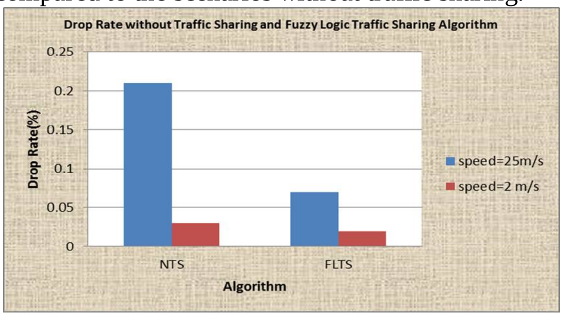

Fig. 4 Total Packet Drop rate in 50 MN with (Speed=25m/s & Speed=2m/s)

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The above graph, Fig. 4 shows that packet drop rate using fuzzy traffic sharing algorithm is 0.034% which is fairly less than that the no traffic sharing scenario which is 0.2%. The cause for higher drops in scenario without traffic sharing is that, this algorithm moves all the mobile nodes to the newly detected better network by means of network latency, data rate and signal strength. This mounts the congestion on the network where all the mobile nodes handover which results into high number of packet drops in scenarios using no traffic sharing. The above graph shows the packets drop rate for the 50 mobile user scenarios using 2m/s mobile node speed. In this case no traffic sharing shows 0.03% packet drop and fuzzy traffic sharing shows 0.0076% packet drop. The scenarios with mobile node velocity of 2m/s shows higher number of dropped packets as compared to the scenarios having 25m/s of mobile nodes velocity. This is because the scenarios with 2m/s mobile nodes velocity produce large traffic while covering the same distance as in case of scenarios with 25m/s.

c) Handover Latency

The graph shown in Fig. 5 represents the mean of the total handover latencies observed by each mobile node using no traffic sharing and using fuzzy logic traffic with 50 mobile nodes and speed velocity is 25m/s and 2m/s..

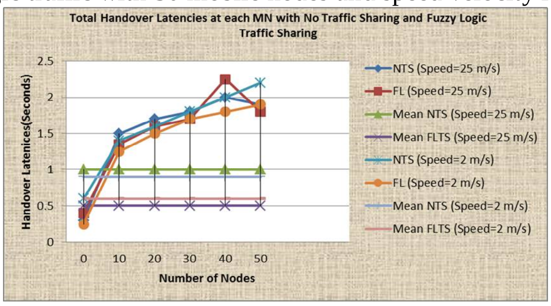

Fig. 5 Handover Latency (Speed=25m/s & Speed=2m/s)

It can be seen from Fig. 5 that the average handover latency for no traffic sharing and with fuzzy logic traffic sharing are at around 1 sec, as in this case most of the mobile nodes handover to the best available network upon entering the common coverage areas. Hence a large number of handovers take place thereby resulting in this large overall delay. The mean values for the fuzzy traffic sharing with at around 0.48 second approximately. This is due to the fewer handovers that take place in these cases. The above chart appeared in Fig. 5 demonstrates the handover latencies when mobile nodes are travelling at speed of 2m/s. It can be seen from this graph that without traffic sharing the handover latencies are highest and the handover latencies for fuzzy is lesser as compared to the no traffic sharing scenario. It is noticed that the handover latencies observed by different mobile nodes in 2m/s scenarios are lower as compared to the handover latencies observed in scenarios with mobile node velocity 25m/s. In case of no traffic sharing the mean value for the handover latencies is nearly 1 second, however in case of 2m/s the same scenario with no traffic sharing showed the mean value of handover latencies observed at each mobile node is approximately 0.5 second. In other scenarios fuzzy traffic sharing the differences is smaller but the delays are lesser and hence better than no traffic sharing.

d) Average throughput at mobile node

Fig. 6 represents the average throughput observed by each mobile node in this scenario where the speed of mobile node is 25 m/s and 2 m/s respectively. The average throughput for all the mobile nodes is shown as horizontal lines.

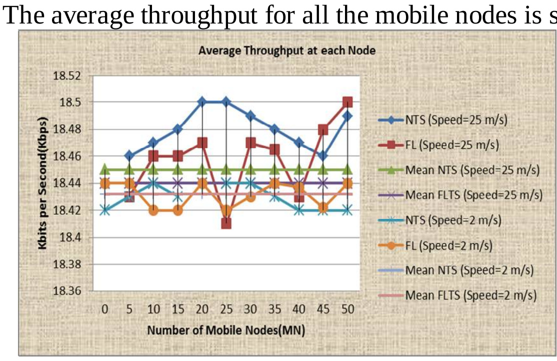

Fig. 6 Average Throughput (Speed=25m/s & Speed=2m/s)

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It can be seen from Fig. 6 that the average throughput is higher in case of no traffic sharing at 18.45 kbps as the mobile nodes select the best available network. On other hand the average throughput for all the mobile nodes in case of fuzzy is almost similar at around 18.44 kbps and only slightly lower than that of no traffic sharing scenario. The reason for this is that traffic sharing tries to maintain the traffic equilibrium between the networks and this practice may result selection of network for some mobile node with high network latencies and lower data rate but only after making sure that the network can fulfill the required QoS of the mobile user. Fig. 6 shows that the average throughput is very close at approximately 18.432 Kbps in all the cases when moving at 2m/s. This shows that the use of traffic sharing does not really affect the throughput of the users. The main reason for closer average values in this scenario is the high total time of simulation due to the slow moving users. The scenario with low speed takes longer to travel the trajectory and therefore generates a large amount of traffic which causes congestion on the networks. This results in a slightly reduced mean values of average throughput of all the mobile nodes for different algorithms.

e) Network Throughput

Fig. 7 and 8 shows the throughput at each network for how the networks are being utilized at different times. Fig. 7 shows the throughput of all the networks when the nodes are moving with the speed of 25m/s without traffic sharing and with fuzzy loaded traffic sharing.

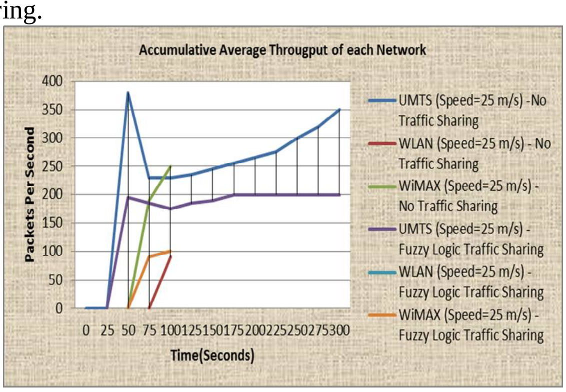

Fig. 7 Network Throughput with No Traffic Sharing &with Fuzzy based Traffic Sharing (Speed=25m/s)

The graph in Fig. 7 shows that all the nodes handover to the UMTS network at time approximately 30 seconds during simulation. At approximately 51 seconds the mobile nodes enter the WiMAX coverage area and leave the WiMAX coverage area at time 90 seconds. The traffic in the WLAN network starts at approximately 66 seconds and ends at approximately 74 seconds. As without traffic sharing the mobile nodes handover to the best available network therefore the average throughput on each network shifts to the newly available better network, whenever the mobile nodes enter the network with low network latencies and high data rates. The graphs represent the number of TCP packets sent/received per unit time across the simulation. Fig. 7 clearly shows that when no traffic sharing is used, at 30 seconds when mobile nodes enter the common coverage area UMTS networks, the traffic shifts to UMTS and the UMTS throughput is approximately 380 packets/second. When the users enter WiMAX, we can see the network throughput for WiMAX increases approximately 180 packets/sec, while the network throughput of UMTS network decreases. This is because there are still some users in the UMTS network. When the users enter WLAN coverage area, we can see from Figure-6.39 that all the user's move into WLAN. However the network throughput is only at around 80 packets/second; due to the high congestion in the network and resulting packet drops. The graph shows the traffic on all networks when the fuzzy traffic sharing algorithm is applied. At time 30 seconds when the mobile nodes enter the common coverage area of UMTS networks the traffic in UMTS network increases as the traffic is now shared UMTS networks. From Fig. 7, we conclude that when traffic sharing is applied the traffic in other networks is lesser (e.g.: UMTS is around 200 packets/second which earlier was around 380 packets/sec). This shows the benefit of traffic sharing algorithm for sharing the traffic between networks to avoid the congestion situation. One major change in this graph is that with fuzzy traffic sharing the WLAN does not get any user as the speed of mobile nodes is 25m/s which are high enough to pass the WLAN coverage area in a very short time. This is detected by the fuzzy algorithm intelligently and therefore it did not allow any mobile node to handover to the WLAN, while passing through WLAN coverage area.

Similarly, Fig. 8 represents the throughput in each network for the 2m/s scenario. Without traffic sharing, at 225 seconds the mobile nodes enter the common coverage area of UMTS and all the mobile nodes handover to the UMTS

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network making the throughput in UMTS to approximately 240 packets per second. At 511 seconds the mobile nodes enter the WiMAX coverage area, therefore the traffic shifts from UMTS to WiMAX making the WiMAX throughput to approximately 70 packets/second and increasing. At 710 second the WLAN network appears in the trajectory of mobile nodes again the traffic shifts from WiMAX to WLAN making the throughput at WLAN approximately 20 packets/second. At 810 seconds the mobile nodes leave WLAN coverage area shifting the traffic back to WiMAX make the throughput on WiMAX approximately 110 packets/second. At 1010 seconds mobile nodes leave the WiMAX coverage area, shifting all the traffic to UMTS network making throughput at UMTS nearly 270 packets/second.

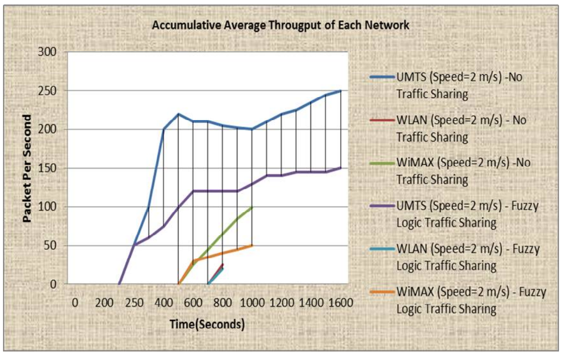

Fig. 8 Network Throughput with No Traffic Sharing & with Fuzzy based Traffic Sharing (Speed=2m/s)

The scenario with mobile nodes velocity 2m/s show the similar behavior as the fuzzy traffic sharing algorithm shares the traffic between co-located networks. However in case of scenario with 2m/s the fuzzy algorithm utilized the WLAN when they pass through the coverage area of WLAN. In case of fuzzy traffic sharing the traffic is shared between co-located networks as shown in Fig. 8. It shows that when traffic is shared between terrestrial networks the average throughput of UMTS and WiMAX network reduces to 150 packets/second and 50 packets/second. This reduction of traffic in each network by sharing the traffic between different available networks minimizes the chances of congestion and hence improves the performance.

C.2 Scenario 2 – Neural-Fuzzy based algorithm with 50 users

The following results were obtained, after applying neural-fuzzy traffic sharing algorithm on 50 mobile nodes with velocity of 25m/s and 2m/s.

a) Network traffic

The network traffic for the 50 mobile nodes scenario is represented in the following set of graphs shown in Fig. 9 and Fig. 10, when no traffic sharing is applied and when neural-fuzzy traffic sharing is applied. Similar to the fuzzy traffic sharing algorithm, the neural-fuzzy traffic sharing algorithm intelligently detects the velocity of the mobile nodes and does not allow the mobile nodes moving with high speed (25m/s) to handover to the WLAN. As the mobile nodes moving with high speed would not stay in the WLAN's coverage area for considerable amount of time. It can be seen from these obtained traffic results that without traffic sharing most of the mobile nodes handover to the best available network in terms of cost and network latencies. For example in position 4 in Fig. 9 and Fig. 10, we can see that all the users connected to WLAN. This however leaves the other networks under-loaded or underutilized.

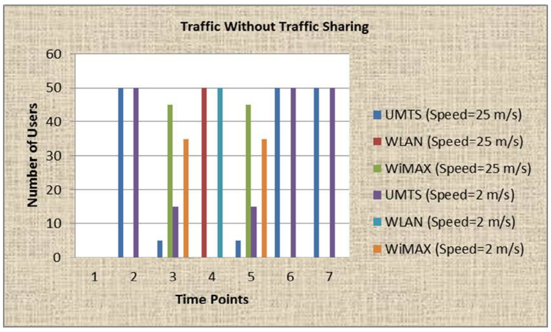

Fig. 9 Traffic Distribution without Traffic Sharing in (Speed=25m/s & Speed=2m/s)

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When Neural Fuzzy Traffic Sharing is applied, all the networks share the traffic where possible such as in the overlapped coverage areas. For example in the same position 4 in Fig. 10, we can see that the users are distributed across the different networks.

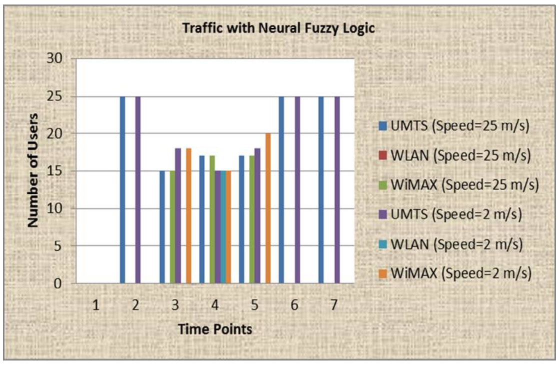

Fig. 10 Traffic Distribution with Nueral -Fuzzy Traffic Sharing in (Speed=25m/s & Speed=2m/s)

b) Packet drops

Fig. 11 represents the packet drop rate in scenario with 50 mobile nodes scenario with mobile nodes velocities 25m/s and 2m/s using no traffic sharing and neural-fuzzy traffic sharing. The abbreviations used in the following graphs are as follows: NTS stands for “No Traffic Sharing” NFTS stands for “Neural-Fuzzy Logic Traffic Sharing”. The packet drops in neural-fuzzy traffic sharing algorithm is considerably low as compared to the scenario without traffic sharing and neural-fuzzy traffic sharing.

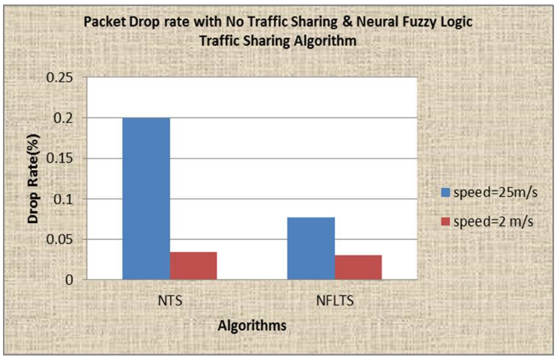

Fig. 11 Total Packet drops in 50 MN with (speed=25m/s & speed=2m/s)

As Fig. 11 shows that packet drop rate using neural-fuzzy traffic sharing algorithm is 0.0342% which is fairly less than that the no traffic sharing scenario which is 0.2%. The cause for higher drop in scenario without traffic sharing is that, this algorithm moves all the mobile nodes to the newly detected better network by means of network latency, data rate and signal strength. This mounts the congestion on the network where all the mobile nodes handover which results into high number of packet drops in scenarios using no traffic sharing. Similarly, the above graphs shows the packets drop rate for the 50 mobile user scenarios using 2m/s mobile node speed. In this case no traffic sharing shows 0.03% packet drop, neural-fuzzy traffic sharing shows 0.00768% packet drop. The scenarios with mobile node velocity of 2m/s shows higher number of dropped packets as compared to the scenarios having 25m/s of mobile nodes velocity. This is because the scenarios with 2m/s mobile nodes velocity produce large traffic while covering the same distance as in case of scenarios with 25m/s.

c) Handover Latency

The graphs shown in Fig. 12 represent the total handover latencies observed by the average mobile nodes in 50 mobile nodes scenarios using no traffic sharing and neural-fuzzy traffic sharing and mobile nodes velocity of 25m/s and 2m/s.

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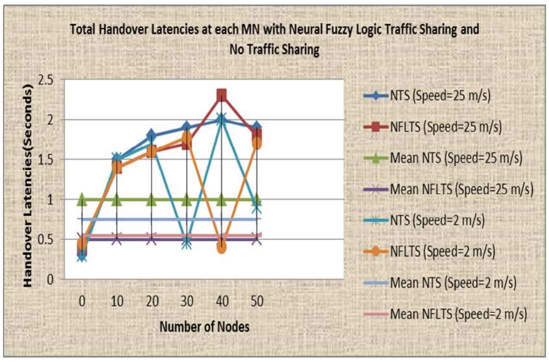

Fig. 12 Handover Latency (speed=25m/s & speed=2m/s)

Above Fig. 12 shows that without traffic sharing the average handover latencies observed by each mobile node is approximately 1 second, whereas the average handover latencies observed with neural-fuzzy 0.465 second respectively. For the scenario with 50 mobile nodes using 2m/s the handover latencies are lower i.e. 0.75 and 0.55 for no traffic sharing and neural-fuzzy algorithms. The above graph shows that the means for the handover latencies observed at each mobile node throughout the simulation is lower in scenarios with low mobile node velocity which is 2m/s. The mean value for the handover latencies in case of neural-fuzzy with cost is lowest as this algorithm minimizes the number of handovers more than neural-fuzzy due to the cost constraint.

d) Average throughput at mobile node

The average throughput of each mobile node in 50 mobile nodes scenarios with 25m/s and 2m/s mobile nodes velocities using no traffic sharing and neural-fuzzy traffic sharing is presented in graphs from Fig. 13.

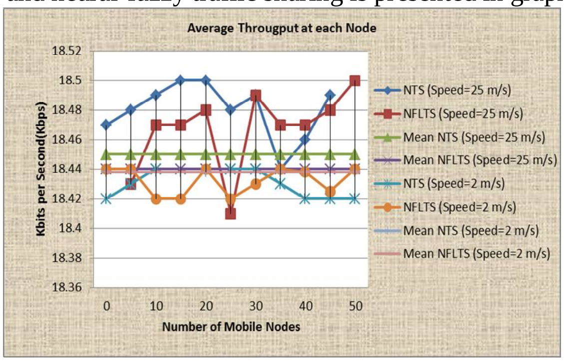

Fig. 13 Average Throughput (Speed=25m/s & Speed=2m/s)

It can be seen from above Fig. 13 that the average throughput is higher in case of no traffic sharing at 18.45 kbps as the mobile nodes select the best available network. On other hand the average throughput for all the mobile nodes in case of neural-fuzzy and neural-fuzzy with cost are almost similar at around 18.44 kbps and only slightly lower than that of no traffic sharing scenario. The reason for this is that traffic sharing tries to maintain the traffic equilibrium between the networks and this practice may result selection of network for some mobile node with high network latencies and lower data rate but only after making sure that the network can fulfill the required QoS of the mobile user. In the above graph shows that the average throughput at each mobile node using no traffic sharing is slightly higher as compare to the scenarios with traffic sharing in case of mobile nodes velocity of 25m/s. Whereas in scenarios with mobile node velocity 2m/s the average throughput of both no traffic sharing and traffic sharing algorithms is approximately same. This concludes that the traffic sharing does not affect the average throughput at each node to a considerable extent and if there is some degradation it is very minute and ignorable.

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e) Network Throughput

Fig. 14 show the throughput of all the networks when the nodes are moving with the speed of 25m/s without traffic sharing and with neural-fuzzy loaded traffic sharing. These graphs show how the networks are being utilized at different times.

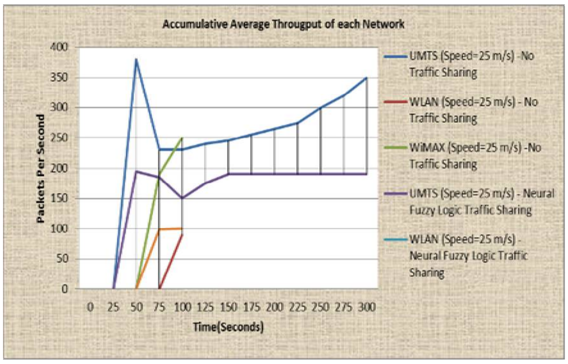

Fig. 14 Network Througput with no trafic sharing & with Neural-Fuzzy based Traffic Sharing (Speed=25m/s)

The graph in above Fig. 14 shows that all the nodes handover to the UMTS at time approximately 30 seconds during simulation. At approximately 51 seconds the mobile nodes enter the WiMAX coverage area and leave the WiMAX coverage area at time 100 seconds. The traffic in the WLAN network starts at approximately 75 seconds and ends at approximately 74 seconds. As without traffic sharing the mobile nodes handover to the best available network therefore the average throughput on each network shifts to the newly available better network, whenever the mobile nodes enter the network with low network latencies and high data rates. The graphs represent the number of TCP packets sent/received per unit time across the simulation. Fig. 14 clearly shows that when no traffic sharing is used, in the beginning at 25 seconds when mobile nodes enter the common coverage area UMTS networks, the traffic shifts to UMTS and the UMTS throughput is approximately, 380 packets/second. When the users enter WiMAX, we can see the network throughput for WiMAX increases to around 180 packets/sec, while the network throughput of UMTS network decreases. This is because there are still some users in the UMTS network. When the users enter WLAN coverage area, all the user's move into WLAN. However the network throughput at WLAN is only at around, 80 packets/second due to the high congestion in the network and resulting packet drops. The above graphs also shows the traffic on all networks when the neural-fuzzy based traffic sharing algorithm is applied. At time 25 seconds when the mobile nodes enter the common coverage area of UMTS networks and the traffic in UMTS network increases (to approximately 200 packet/second) as the traffic is now shared between satellite and UMTS networks. When traffic sharing is applied the traffic in other networks is lesser (e.g.: UMTS is around 200 packets/second which earlier was around 380 packets/second). This shows the benefit of traffic sharing algorithm for sharing the traffic between networks to avoid the congestion situation. One major change in this graph is that with neural-fuzzy traffic sharing the WLAN does not get any user as the speed of mobile nodes is 25m/s which are high enough to pass the WLAN coverage area in a very short time. This is detected by the neural-fuzzy algorithm intelligently and therefore it did not allow any mobile node to handover to the WLAN, while passing through WLAN coverage area.

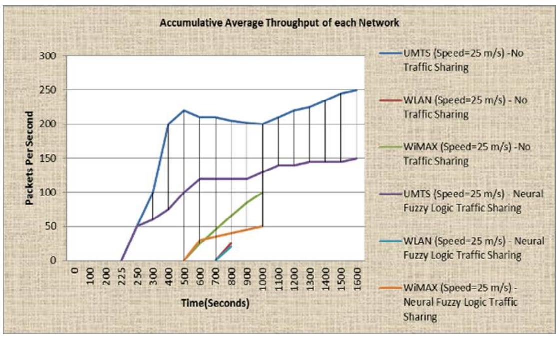

Fig. 15 Network Througput with no traffic sharing & with Neural-Fuzzy Logic Based Traffic Sharing (Speed=2m/s)

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At 710 second the WLAN network appears in the trajectory of mobile nodes again the traffic shifts from WiMAX to WLAN making the throughput at WLAN approximately 20 packets/second. At 810 seconds the mobile nodes leave WLAN coverage area shifting the traffic back to WiMAX make the throughput on WiMAX approximately 110 packets/second. At 1010 seconds mobile nodes leave the WiMAX coverage area, shifting all the traffic to UMTS network making throughput at UMTS nearly 270 packets/second. The scenario with mobile nodes velocity 2m/s show the similar behaviour as the neural-fuzzy traffic sharing algorithm shares the traffic between co-located networks. However in case of scenario with 2m/s the neural-fuzzy algorithm utilized the WLAN when they pass through the coverage area of WLAN. In case of neural-fuzzy traffic sharing the traffic is shared between co-located networks as shown in Fig. 15. It shows that when traffic is shared between satellite and terrestrial networks the average throughput at satellite, UMTS and WiMAX network reduces to 210 packets/second, 155 packets/second and 70 packets/second approximately. This reduction of traffic in each network by sharing the traffic between different available networks minimizes the chances of congestion and hence improves the performance.

IV. PERFORMANCE COMPARISON OF ALGORITHMS

This section presents a detailed comparison of the performance of the three proposed traffic sharing algorithms. The results of all the traffic sharing algorithms are compared with results obtained from no traffic sharing algorithm to prove that proposed traffic sharing algorithms are better than the technique using no traffic sharing for RAT selection and also compared with each other in order to find the most suitable traffic sharing algorithm.

a) Handover latencies comparison

Table-2 represents the mean value of the total handover latencies observed by each mobile node in all different scenarios using baseline, fuzzy and neural-fuzzy traffic sharing algorithms.

Table-2. Comparison of Handover Latencies (Second) using Different Traffic Sharing Algorithms

Comparison Scenario	Mobile Node Velocity	No. of MNs	Algorithm	Handover Latency (Second)
A	25 m/s	50	Baseline	0.5026
			Fuzzy Logic	0.4853
			Neural-Fuzzy Logic	0.4653
B	2 m/s	50	Baseline	0.4912
			Fuzzy Logic	0.5682
			Neural-Fuzzy Logic	0.5583

In comparison scenario A, the neural-fuzzy traffic sharing algorithm has the least handover latency. However this is not true in comparison scenario B where baseline traffic sharing appeared better with least handover latencies. This means that the neural-fuzzy traffic sharing algorithm minimizes the total number of handovers and still manages to balance the traffic between different co-located networks.

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b) Traffic comparison

The traffic in each network with 25m/s in 50 nodes scenario is shown as follows:

Table-3 Comparison of Traffic Sharing Using Different Traffic Sharing Algorithm

50 MNs and 25 m/s			
Algorithm	**UMTS**	**WLAN**	**WiMAX**
Baseline Traffic Sharing	12	15	13
Fuzzy Traffic Sharing	15	-	18
Nueral -Fuzzy Traffic Sharing	17	-	17
50 MNs and 2 m/s			
Baseline Traffic Sharing	12	15	14
Fuzzy Traffic Sharing	12	12	12
Nueral -Fuzzy Traffic Sharing	15	15	15

From the above Table-3, illustrate the traffic distribution between different wireless networks using different traffic sharing algorithm for scenario with 50 mobile nodes and with mobile nodes velocity of 25m/s. It shows that in case of fuzzy and neural-fuzzy the WLAN is not considered in traffic distribution, as the velocities of mobile nodes are high. The fuzzy and neural-fuzzy algorithms show a minor variation in the traffic distribution but for both the cases the traffic between the networks is distributed appropriately.

c) Packet drops comparison

The comparison of packet drop rate for all three proposed traffic sharing algorithms is shown in the Table-4.

Table-4 Comparison of Packet Drop Ratio with Traffic Sharing Algorithm

50 MNs and 25 m/s	
Algorithm	**Drop Rate (%)**
No Traffic Sharing (NTS)	0.03289
Baseline Traffic Sharing (BLTS)	0.02412
Fuzzy Traffic Sharing (FLTS)	0.00768
Nueral -Fuzzy Traffic Sharing (NFLTS)	0.00768
50 MNs and 2 m/s	
No Traffic Sharing (NTS)	0.20587
Baseline Traffic Sharing (BLTS)	0.15453
Fuzzy Traffic Sharing (FLTS)	0.03425
Nueral -Fuzzy Traffic Sharing (NFLTS)	0.03425

The comparison of the different approaches shown in the above table for packet drop rate, shows that fuzzy and neural-fuzzy have lowest drop rates. In 50 mobile nodes scenarios the packet drop rate shows no difference in fuzzy and neural-fuzzy approaches. The reason for this in these particular scenarios is that when the mobile nodes move slowly they remain in the same network for long time (particularly in WiMAX and WLAN where bandwidth is shared between users) and the TCP window for each connection keeps on growing which cause congestion and eventually results in to more packet drops. On other hand when mobile nodes move with high speed they pass on the coverage area of WiMAX and WLAN quickly therefore in these scenarios the packet drop rate is lower. The neural-fuzzy approach has one more advantage that it encompasses lowest handover latencies for average mobile node in all scenarios as shown in Table-2. Therefore the neural-fuzzy traffic sharing algorithm is considered as the most dominant approach overall.

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V. CONCLUSION

The simulation of heterogeneous network contains UMTS, WLAN and WiMAX integrated networks in which algorithms are tested and new modules were implemented to find the most suitable approach for traffic sharing which supports both "RAT selection triggered" and "network triggered" handover approaches. To support handovers for global networks, extensions to the MIH standard have been implemented and also new primitives are introduced in the MIH for forwarding the network information like load to the MIIS in the MIH architecture. The performance evaluation is carried out with and without traffic sharing algorithms. In results all the algorithms i.e. baseline traffic sharing, fuzzy traffic sharing and neural-fuzzy traffic sharing algorithms are analyzed with the help of obtained results. Each of the traffic sharing algorithm is simulated with different number of mobile nodes i.e. 50 mobile nodes and different velocities of mobile nodes i.e. 25m/s and 2m/s. The considered performance parameters such as network traffic, packet drop rate, throughput, average bandwidth observed at mobile node side, average bandwidth utilized on each network and the handover latencies are monitored for each of the scenario and results of different algorithms are also compared at the end to conclude which technique is better under different circumstances. The implemented algorithm results are compared with the earlier published work and the analysis of this comparison reveals that out of the three algorithms: Baseline Traffic Sharing, Fuzzy Logic Traffic Sharing and Neural Fuzzy Logic Traffic Sharing, the Neural Fuzzy Logic Traffic Sharing Algorithm has emerged as the most efficient in performance of the network. It is concluded with the help of results that traffic sharing improves the performance by avoiding the congestion and other problems which are caused by unbalanced utilization of available heterogeneous network.

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