Fuzzy Based CRRM for Load Balancing in Heterogeneous Wireless Networks

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Abstract. The ever increasing user QoS demands and emergence of new user applications make job of network operators and manufacturers more challenging for efficiently optimisation and managing radio resources in radio the radio resources pools of different wireless networks. A group of strategies or mechanisms which are collectively responsible for efficient utilisation of radio resources available within the Radio Access Technologies (RAT) are termed as Radio Resource Management (RRM). The traditional RRM strategies are implemented independently in each RAT, as each RRM strategy considers attributes of a particular access technology. Therefore traditional RRM strategies are not suitable for heterogeneous wireless networks. Common Radio Resource Management (CRRM) or joint radio resource management (JRRM) strategies are proposed for coordinating radio resource management between multiple RATs in an improved manner. In this paper a fuzzy algorithm based CRRM strategy is presented to efficiently utilise the available radio resources in heterogeneous wireless networks. The proposed CRRM strategy balances the load in heterogeneous wireless networks and avoids the unwanted congestion situation. The results such as load distribution, packet drop rate and average throughput at mobile nodes are used to demonstrate the benefits of load balancing in heterogeneous wireless networks using proposed strategy.

Keywords: CRRM, Load balancing, radio resource management, heterogeneous wireless networks, load balancing in wireless networks, vertical handovers, satellite-terrestrial wireless networks load balancing.

1 Introduction

In wireless communication networks, the increasing number of mobile subscribers and dynamic change in number of active mobile nodes is a real challenge for the network providers as it incurs in real time load variations in the network. This dynamic change in load on network is due to many reasons like peak hours at hot spots or motorways, special events like football match, exhibition or a festival celebration. The network performance gets significantly degraded at the time when network gets heavily loaded. In the urban areas it is common on most places that multiple networks provide coverage over the same geographically located area. For

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example a busy town market area may possess coverage of WLAN, cellular networks like WiMax and UMTS and coverage of satellite networks. In this context while one of the available networks in particular area gets overloaded, other networks covering the same geographical area may remain lightly loaded. This results in poor utilisation of available wireless resources and poor network performance thereby poor user experience. While network operators considered users' population density and mobility patterns for planning network deployment, each service provider would be required to have large infrastructure in place to cater to the needs of their users in these densely populated areas. Hence the different networks of heterogeneous wireless networks, whose coverage areas overlap experience imbalance of radio resource utilization and performance degradation due to the unbalanced load across the different wireless networks.

This paper presents a novel fuzzy based CRRM strategy which uniformly distributes the network load between co-located heterogeneous wireless networks. It utilizes IEEE 802.21 Media Independent Handover (MIH) [1] to seamlessly handover mobile nodes between heterogeneous wireless networks for load balancing purpose. The advantage of this approach 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 load in co-located networks. The proposed load balancing approach monitors and controls the network load from both side (mobile node and network side), and addresses the most important problem of efficiently utilising radio resources in heterogeneous wireless networks. The rest of the paper is organized as follows; section 2 describes the literature review of CRRM strategies, section 3 briefly describes the proposed load aware RAT selection framework. Simulation topology and results are discussed in section 4, which is followed by the conclusion.

2 CRRM Strategies

In heterogeneous wireless networks the main challenge is the efficient CRRM [2, 3] strategy which can competently manage the resources of different access technologies in heterogeneous wireless networks. The concept of CRRM is based on a two tier RRM model [4, 5] as shown in the Figure 1 below. The lower tier is the local RRM entity which manages and allocates the resources in the local network, whereas the CRRM is the upper tier of the model which is responsible for managing all the resource in multiple networks. The CRRM entity in the two tier architecture controls the RRM entities and can also communicate with other CRRM entities. The users can always be assigned to the most suitable networks using CRRM which improves the performance by efficiently utilising the available resource from different networks. From a network topology point of view, the CRRM functionality can be implemented in various different ways such as CRRM server approach [6, 7], integrated CRRM approach [8], hierarchical CRRM approach [9], CRRM functions in User Terminal (UT) approach [10] and a hybrid approach which can be combination of these approaches. While in the CRRM server approach, a separate CRRM server is added in the core network, in the integrated CRRM approach, the CRRM functionality is added within an existing network entity like the basestation (BS), the Radio Network Controller (RNC) or the Access Point (AP).

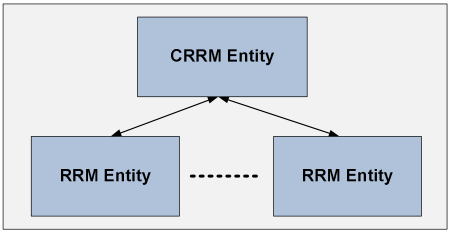

Fig. 1. Two tier model [5]

The CRRM server is a centralised approach due to which it attains high scalability. The integrated CRRM requires minimum infrastructure changes and also reduced the communication delays between the local RRM and CRRM entities. However this approach is distributed and scale well due to the large number of connection between the various local RRM entities. The hierarchical CRRM approach divides the problem into various layers and each layer is managed by a dedicated management entity. This approach adds further complexities due to a number of new entities additions in the architecture infrastructure. The final approach the CRRM functions are present in the end user terminal. This approach allows the mobile node to make decision for suitable RAT selection. In this case, the network needs to provide enough information to the mobile nodes, but this would require extra signalling.

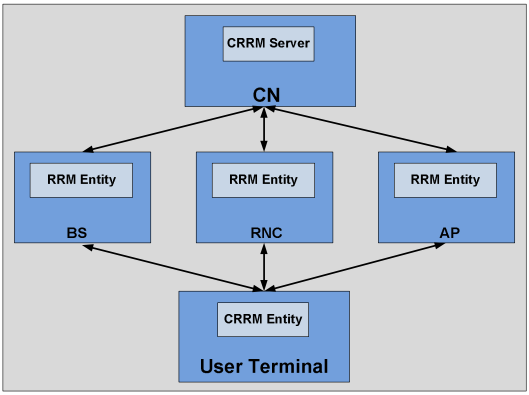

Fig. 2. Proposed CRRM approach

In this paper a hybrid of CRRM server and CRRM functions at the user terminal approach is applied to get advantages of both centralised and distributed approaches. Figure 2 represents the proposed CRRM approach. The CRRM architecture shown in Figure 2 is composed of three layers namely, the Core Network (CN), the access network entities and the UT. For the load balancing purpose each of these layer are equipped with MIH components i.e. CRRM server acts as Media Independent Information Server (MIIS) and similarly the CRRM entity in the mobile node or UT communicate with the RRM entities in the network side using IEEE 802.21 MIH reference model.

3 Load-Aware RAT Selection Framework

3.1 Network Architecture

Figure 3 presents the target network architecture considered in this research. It shows an MIH enabled multi-interface mobile node which can use any of the four available wireless access networks (Satellite, WiMax, WLAN and UMTS) [11] supported by its interfaces. It is assumed that a single operator is controlling all the wireless networks hence all four wireless networks share a common core network. The core network is in turn connected to the Internet. The mobile node can communicate with a correspondent node over the internet, using any available wireless network which it supports. On-going sessions would be handed over to another available network without losing any connectivity if the mobile node moves out of its current network coverage and enters into another network.

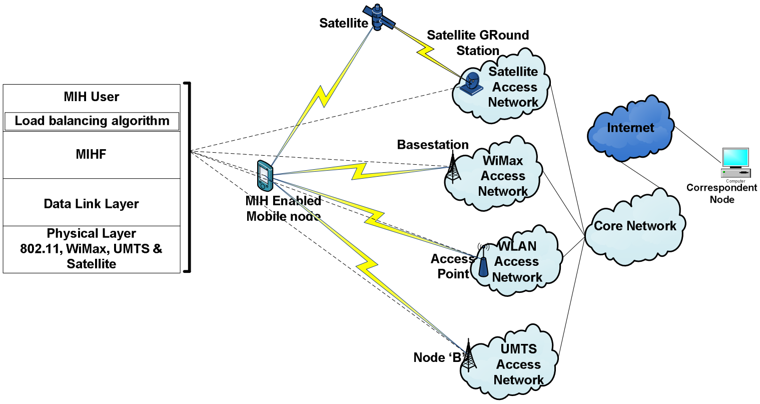

Fig. 3. Load balancing architecture design

The key phenomenon in the MIH reference model is the introduction of Media Independent Handover Function (MIHF) between layer 2 and layer 3 of the OSI layer model. The MIHF receives and transmits the information about the network condition and configurations of the access networks around the mobile node, regardless of the MIHF location such as mobile node or network elements. The information handled by the MIHF originates at different layers of protocol stack in mobile node or in network elements. The MIHF is composed of a set of handover enabling functions which provide service continuity while a MN traverses between heterogeneous wireless access link layer technologies. In the MIH Reference model [1]. The MIH user makes use of the MIHF function to support seamless handovers. Hence as shown in Figure 3, the load balancing module acts as the MIH user. The following sub-sections describe in general the proposed framework of the load balancing algorithms that are running at the mobile node and the network entities.

3.2 Load Balancing Algorithms

The flow chart shown in Figure 4 summarises the load aware RAT selection algorithm which runs at the mobile node. The mobile node side algorithm can also be seen as different phases of a handover process: handover initiation, handover decision and handover execution. In the handover initiation phase, a mobile node detects new network or existing link getting weak. In this phase the process of load aware handover is initiated using MIH event signalling. The second phase is handover decision in which the mobile node compares all the considered parameters from available network and decides the target network for handover. The second phase also comprises of an important component which is the load aware RAT selection algorithm. The last phase is the handover execution in which the mobile node performs the load aware handover and moves all the active connections to the target network.

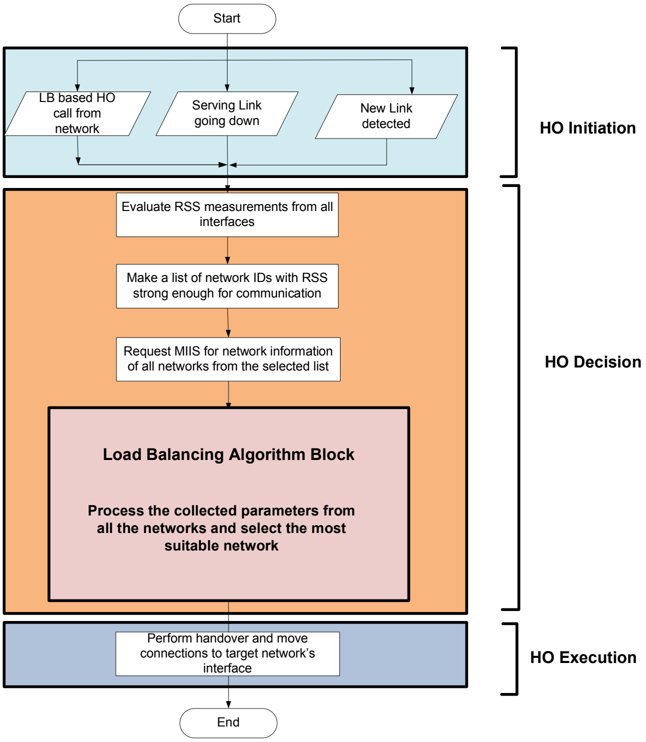

Fig. 4. Load-aware RAT selection algorithm

The mobile node compares the load conditions of the new available networks and the one to which it is currently connected. A list of networks IDs is generated for those networks which are visible to the mobile node such that the received signal strength from those networks is higher than the minimum threshold for basic communication. In the next step load, cost, offered QoS and other network related information of each network in the list is obtained from MIIS. This information is then forwarded to the load balancing algorithm block which applies different algorithms to select the most suitable network. One of the two different algorithms, namely, baseline (least loaded) and Fuzzy algorithm [12, 13] are applied to select the most suitable network. In case of baseline or non-cognitive algorithm the most preferred network from the generated list is the one with lowest load and highest offered data rate, whereas for the fuzzy algorithm all the parameters such as signal strength, load, offered data rate of network, cost of network, coverage area of the network, speed of mobile node, user preferred network and required data rate of mobile node are considered. The Figure 5 shown below represents the fuzzy logic controller used for balancing the load in this paper. All the values obtained from different parameters are first fuzzified and then passed on to the fuzzy inference system. The fuzzy inference system then uses the fuzzy rule base and defuzzification modules to generate the decision factor for each network. At the end the network with highest decision factor is selected as the target network for load balancing based handover.

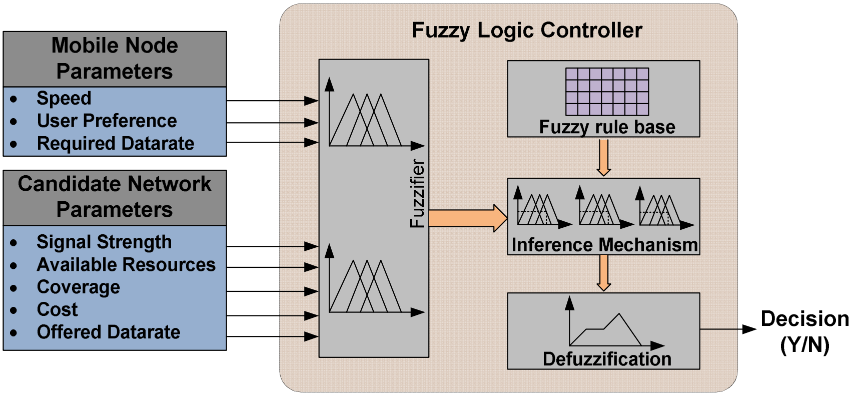

Fig. 5. Fuzzy logic controller for load aware RAT selection

4 Simulation Topology and Results

4.1 Simulation Topology

Figure 6 presents the simulation topology considered in this paper. Purpose for considering particular topology for simulation is to observe the effects of load balancing in most ideal scenarios where mobile nodes can see maximum overlapped coverage areas from different networks. Each mobile node maintains a TCP connection with the TCP source shown in Figure 6 throughout the simulation such that effects of load balancing on active connections can be measured.

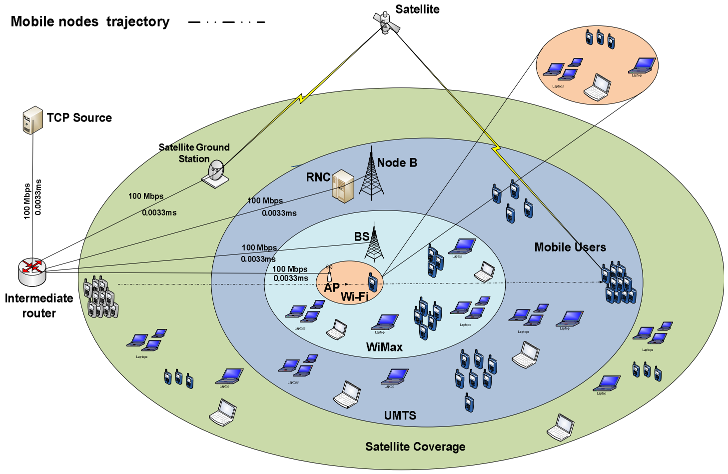

Fig. 6. Network topology for simulation

The scenarios considered in this paper consist of a group of mobile nodes which travel across the coverage areas of all four networks such as Satellite, UMTS, WiMax and Wi-Fi as shown in Figure 6. The Table 1 shown below represents the simulation parameters used in the target simulation scenarios.

Table 1. Simulation parameters

Simulation parameters	**Values**
Satellite coverage radius	4000 meters
UMTS coverage radius	1000 meters
WiMax coverage radius	500 meters
WLAN radius	100 meters
Satellite data rate (per user)	492 kbps
UMTS data rate (per user)	384 kbps
WiMax data rate	45 Mbps
WLAN data rate	11 Mbps
Wired links capacity	100 Mbps
Propagation delays wired links	0.0033 ms
Propagation delay satellite	250ms
Application type	TCP
Application data rate	2 kB/s
Number of mobile nodes	50, 100
Speed of mobile nodes	25m/s

4.2 Results

The simulation scenario discussed in the previous section is simulated using both load balancing and non-load balancing algorithms using the network simulator NS2 [14]. Results of packets drop rate, handover latencies and load distribution at different networks such as satellite, UMTS, WiMax and Wi-Fi networks are described in this section.

a) Handover Latencies Comparison

Table 2 represents the mean value of the total handover latencies observed by each mobile node in different scenarios using baseline and fuzzy load balancing algorithms. In comparison scenario A and B the fuzzy load balancing algorithm has the least handover latency values. This means that the fuzzy load balancing algorithm minimizes the total number of handovers hence results into low handover latencies and still manages to balance the load between different co-located networks.

Table 2. Handover latencies

Scenarios	No. of MNs	Algorithm	HOL (second)
A	50	Baseline	0.502643
		Fuzzy	0.485328
B	100	Baseline	0.684761
		Fuzzy	0.555694

b) Load Distribution Comparison

The load distribution in scenarios with 100 mobile nodes is shown in the following graphs in Figure 7 to Figure 9. Point 1 in these graphs represents the time in simulation where only satellite coverage is available, point 2, 6 & 7 show the time when mobile nodes are under the coverage of UMTS and satellite, point 3 & 6 represent the time when mobile nodes are under common coverage are of satellite, UMTS and WiMax and point 4 represents the time in simulation when mobile nodes are under common coverage areas of all the networks. The load distribution using load balancing algorithm is far better as compared to the no load balancing scenario. The results obtained from baseline load balancing algorithm are slightly different from fuzzy load balancing algorithm as baseline algorithm uses Wi-Fi and fuzzy does not use it. The fuzzy algorithm intelligently detects that mobile nodes are moving with high speed and decides that it is not suitable to handover mobile nodes to Wi-Fi as they would not remain there for long enough. The load distribution in fuzzy algorithm shows very minor variations but in fuzzy this variation controls the total number of handovers and minimizes the total handover latencies. The performance of fuzzy algorithm for load distribution is dominant due to the limited number of handovers.

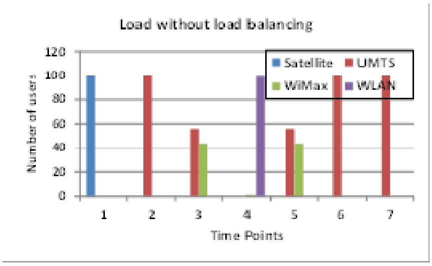

Fig. 7. Load distribution without load balancing using 25m/s

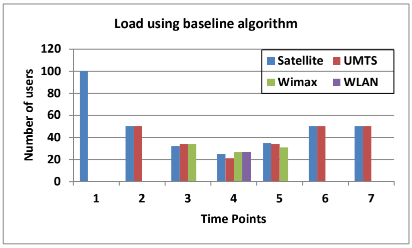

Fig. 8. Load distribution with baseline load balancing using 25m/s

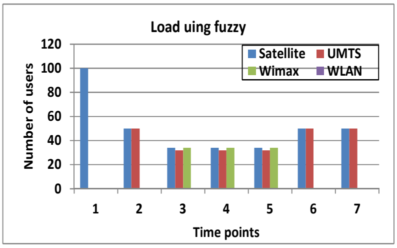

Fig. 9. Load distribution with fuzzy load balancing using 25m/s

c) Packet Drops Comparison

The comparison of packet drop rate for proposed load balancing algorithms is shown in the graphs in Figure 10 and Figure 11.

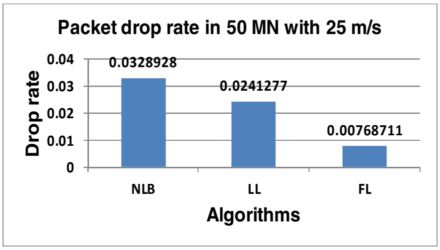

Fig. 10. Packets drop rate with 50 MN

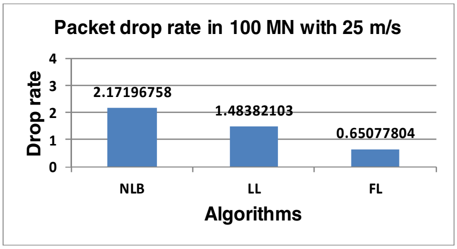

Fig. 11. Packets drop rate with 100 MN

The comparison of the different approaches shown in the graphs below for packet drop rate shows that fuzzy have lowest drop rates. One reason for less number of drops in fuzzy is that it reduces the total number of handovers which results into less packet drops as compared to baseline algorithm. The 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 fuzzy load balancing algorithm is considered as the most dominant approach overall.

5 Conclusion

In this paper a fuzzy based CRRM strategy is presented for balancing the load in heterogeneous wireless networks. The comparison of results generated by simulation scenarios using load balancing algorithms and without load balancing is presented to show the sovereignty of proposed algorithms. Considered attributes for observation are handover latencies, packet drop rate and load distribution on each of the network such as satellite, UMTS, WiMax and Wi-Fi. The results showed that with load balancing all parameters showed improvement in the target heterogeneous wireless network architecture. The baseline and fuzzy load balancing algorithms assured the fair load distribution between the overlapping networks whereas without load balancing different networks show abrupt load variations which decrease the performance with high congestion, high call dropping probability and blocking probability at overloaded network. The benefit of using fuzzy over baseline load balancing algorithm is that it reduces the total number of handovers and hence suffers from low handover latencies and fewer packets drops. The fuzzy algorithm also intelligently detects the speed of mobile nodes and does not allow mobile nodes with high speed to handover to Wi-Fi as they would not remain there for enough time. The Load balancing approach utilizes the available radio resources efficiently. Handover latencies are minimized, as it does not require all the mobile nodes to handover when load balancing algorithms are used. Hence the load aware RAT selection is a better approach as it offers high radio resource utilization with minimum number of handovers and hence low handover delays and ability to maximize the network availability with uniformly distribution of load in co-located networks.

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