Load-Aware Radio Access Selection in Future Generation Wireless Networks

Muhammad Ali, Prashant Pillai, and Yim Fun Hu

School of Engineering Design and Technology
University of Bradford, UK
{m.ali28,p.pillai,y.f.hu}@bradford.ac.uk

Abstract. In the telecommunication networks the introduction of Next Generation Wireless Networks (NGWN) has been described as the most significant change in wireless communication. The convergence of different access networks in NGWN allows generalized mobility, consistency and ubiquitous provision of services to mobile users. The general target of NGWN is to transport different types of information like voice, data, and other media like video in packets form like IP. The NGWNs offer significant savings in costs to the operators along with new and interesting services to the consumers. Major challenges in NGWN are efficient resource utilization, maintaining service quality, reliability and the security. This paper proposes a solution for seamless load aware Radio Access Technology (RAT) selection based on interworking of different RATs in NGWN. In this paper novel load balancing algorithms have been proposed which have been simulated on the target network architecture for TCP data services. The IEEE 802.21 Media Independent Handover (MIH) is utilized in load balancing specifically for mobility management, which enable low handover latency by reducing the target network detection time. The proposed method considers the network type, signal strength, data rate and network load as primary decision parameters for RAT selection process and consists of two different algorithms, one located in the mobile terminal and the other at the network side. The network architecture, the proposed load balancing framework and RAT selection algorithms were simulated using NS2. Different attributes like load distribution in the wireless networks and average throughput to evaluate the effects of load balancing in considered scenarios.

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

1 Introduction

Modern mobile devices like cell phones, PDA's, Tablet PCs already support multiple wireless technologies like UMTS, WLAN and Bluetooth and in the very near future would also support satellite and WiMax with multiple interfaces provision. While most of these devices are able to scan the different available networks the user would

P. Pillai, R. Shorey, and E. Ferro (Eds.): PSATS 2012, LNICST 52, pp. 104–112, 2013.

manually select which network he or she may want to use. It is envisaged that in the NGWN these devices may be able to apply some complex Radio Access Technology (RAT) selection techniques to find the most suitable network. Such a RAT selection technique may need to consider various parameters like received signal strengths, errors rates, costs, user preferences, QoS requirements, etc. Such a RAT selection technique would not only play an important part when a user switches on his or her mobile device but also when the user moves around. While most of the current day mobile networks already support seamless handovers, these are restricted to handovers within the same technology, i.e. horizontal handovers. It is envisaged that to efficiently use the network services the future mobile devices shall also support handovers across different radio access technologies. This process of switching mobile devices connectivity from one technology to another type of technology is called vertical handover. The joint call admission control (JCAC) algorithm for next generation heterogeneous wireless networks is envisioned as user-centric. User centricity implies that user's preferences are considered in decision making for RAT selection. However user-centric JCAC algorithms often lead to highly unbalanced networks load, which cause congestion on overloaded network and eventually increase the call blocking and call dropping probabilities. The unbalanced load situation in co-located networks also causes the poor radio resource utilization as some networks remain under loaded and some get over loaded. The load balancing strategies are required to efficiently utilize the available radio resources and avoid the unwanted congestion situations due to overloaded wireless networks.

This paper presents a novel NGWN RAT selection technique which uniformly distributes the network load between co-located heterogeneous wireless networks. It utilizes MIH to seamlessly handover mobile users 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 in NGWN which is efficient resource utilization. The rest of the paper is organized as follows; section 3 describes the literature review of existing and presented load balancing RAT selection techniques, section 4 briefly describes the proposed load aware RAT selection algorithms and target network architecture. Simulation topology and results are discussed in section 5, which is followed by the conclusion.

2 Load Balancing Techniques

Usually more than one wireless networks may provide coverage to any given location in an urban area. For example, when working in an office building, the mobile device of a user may be in the coverage of a UMTS mobile network and a WLAN office network. A user may manually configure to use the UMTs network for voice services and the WLAN access for data services. In such overlapping coverage areas of different wireless networks such as satellite networks and terrestrial networks like WiMax, UMTS and WLAN; a RAT selection technique is required to find the most suitable network based on received signal strengths, errors rates, costs, user preferences, QoS requirements, and most importantly the load of networks.

The load balancing approaches presented in [2] and [3] have considered load balancing in homogenous network targeting WLAN. The approach in [2] considers the received signal strength indicator (RSSI) value to distribute the load between different access points (AP's) which have overlapping coverage areas. This approach uses the two values in balancing the load which are RSSI between mobile station (MS) and AP and the average RSSI value of all the MS's currently connected with AP. The method given in [3] considers both RSSI and the number of MS associated with AP which makes it much effective for load balancing. The technique used in [4] presented a solution for load balancing 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 due to large coverage areas. All approaches given in [2, 3, 4] were designed to enhance the performance for homogeneous network environment particularly WLAN.

In [5] load balancing approach has been presented which targets the proxy mobile ipv6 (PMIPV6) domain using MIH for heterogeneous networks. A comparison has been made between the scenario performing load balancing in extended PMIPV6 for handover signalling and the scenario using MIH signalling for load balancing. It was shown in the results that use of load balancing improves the efficiency whereas, MIH based load balancing improves data rate as compared to extended MIPV6 based load balancing. This disadvantage in this approach is when considering load-aware RAT selection; it is specifically designed for a MIPV6 architecture using Local Mobility Agent (LMA) and a new entity called Mobile Access Gateway (MAG) in the network. In [6] a general set of algorithms have been proposed which considers battery power of mobile users, received signal strength and load on available points of attachments in handover process to balance the load in co-located networks overlapping their coverage areas. In this approach load balancing is done only at network side without any interaction with the mobile node. On the other hand our proposed approach considers both; mobile nodes and network entities such as AP, BS and satellite ground station for load balancing thereby resulting in more efficient load balancing across the neighboring networks.

In [7] a detailed algorithm has been presented for network selection in heterogeneous wireless networks. The algorithm presented in [7] has been divided into two parts, one runs at mobile terminals and other part of algorithm runs at network entity such as basestation (BS) or access point (AP). This approach considers received signal-strength, battery power, speed, and location of mobile user but does not considers MIH which could have improved the handover process while moving the mobile nodes between different networks. In [8] a next generation networks (NGN) based approach has been presented in which hierarchical joint call admission control algorithm is extended to send newly added load reports from hierarchical call admission control (HCAC) entity to vertical call admission control entity (VCAC). The main goals of proposed approach in [8] are simplicity and scalability, however this approach performs balancing of load periodically and therefore may not performs very efficiently with abrupt load changes in different sub networks in the hierarchy. In [9] 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 paper more efficient than load based CAC approach presented in [9] 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.

3 Load-Aware RAT Selection Framework

3.1 Network Architecture

Figure 1 presents the target network architecture which is considered in this paper. It shows an MIH enabled multi interface mobile device which can use any of the three available wireless networks supported by its interfaces.

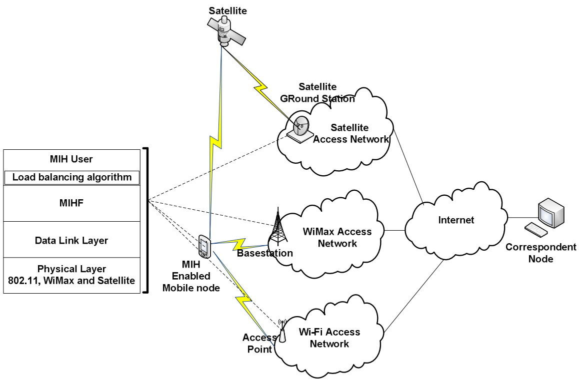

Fig. 1. Target network architecture

The access network of each technology such as Satellite, WiMax and Wi-Fi is connected to internet. There is also a correspondent node located behind the internet as shown in the Figure 1. The mobile node can communicate with the correspondent node over the internet using any available network which is supported by its interfaces. The mobile node handovers to different available networks while moving from coverage area of one network to another and during this mobility it can maintain the communication with correspondent node. The load balancing algorithms are located at the MIH user in MIH reference model as represented by the Figure 1. MIH user is selected for the load balancing process origin as MIH user is the central control point for triggering and handling MIH signalling as described in [1]. In mobile user the load balancing algorithm shown in Figure 2 is adopted and in Satellite Ground Station/BS/AP the load balancing algorithm for the network entity shown in Figure 3 is adopted.

3.2 Load Balancing Algorithms

This section describes the proposed load-aware RAT selection algorithm. The proposed algorithm considers the network type, signal strength, data rate and network load as primary decision parameters for RAT selection process and tries to maintain the load equilibrium on all networks which have common or overlapped coverage areas. It is assumed that all considered networks and mobile nodes support the IEEE 802.21 MIH.

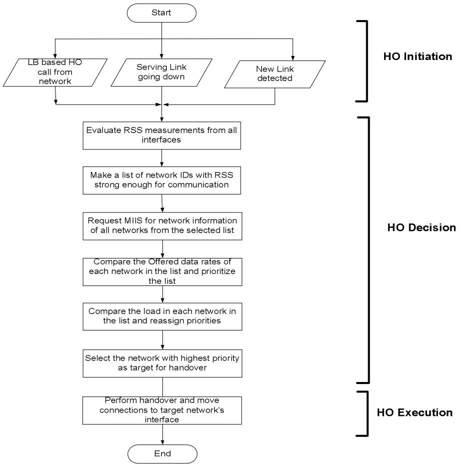

Fig. 2. LB algo. in the mobile device

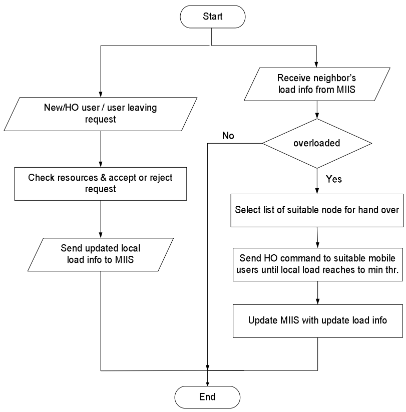

Fig. 3. LB algo. at the Network side

The IEEE 802.21 MIH standard has been brought into use for seamless vertical handover operations of mobile nodes between the co-located wireless networks. The proposed approach has taken advantage of MIH media independent information service (MIIS) specifically for exchange of network load information besides exchanging other network related information like link type, link data rate, link capability, offered security and QoS and cost[1]. The proposed RAT selection framework consists of two load aware algorithms, one running on mobile device and other running on network entity like Satellite Ground Station, WiMax BS or WLAN AP. The flow chart shown in Figure 2 represents the proposed algorithm's which runs at mobile device. At the mobile device, the proposed technique first makes a list of available network IDs which are visible to mobile device such that received signal strength from those networks is higher than the minimum threshold. In next step load value of each network in the list is obtained from MIIS and compared. Then in following step it compares the data rate offered by each network in the list. The most preferred network from the list is the one with lowest load and highest offered data rate. The second algorithm shown in Figure 3 runs in network side. In the network entity like BS or AP the load balancing algorithm continuously keeps on updating the MIIS about its current load status and receives load information of its neighboring networks. This updating process runs on every time when a new connection starts or ends in the network. The most loaded network entity start moving out the suitable mobile users to appropriate networks, if the load variation is gone higher than threshold of 50% free resources margin, such that the percentage of free resources in one network is greater than or equal to the double of available resources percentage at any other network. Load balancing algorithm keeps on migrating out the suitable mobile nodes from over loaded network to the least loaded networks until the load in over loaded network becomes equal to or lesser than the average load in all the neighboring networks of overloaded network. The load balancing is performed by the handover procedures in both mobile and network side. In mobile nodes it is supported by the mobile node initiated handovers and on network entity it is supported by the network initiated handovers of the selected mobile nodes in the network.

4 Simulation Architecture and Results

4.1 Simulation Architecture

Figure 4 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 user maintains a TCP connection with the TCP source shown in Figure 4 throughout the simulation such that effects of handovers on active connections can be measured.

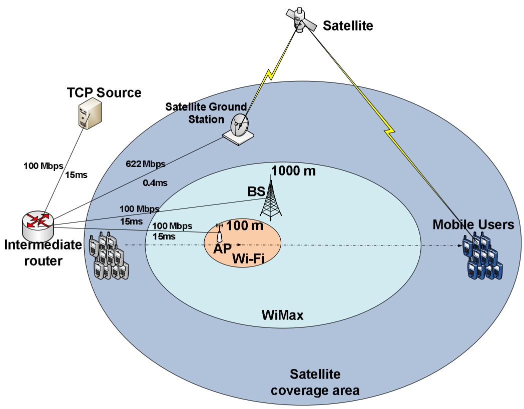

Fig. 4. Network topology for simulation

The scenarios considered in this paper consist of a group of mobile users which travel across the coverage areas of all three networks such as Satellite, Wi-Fi and WiMax as shown in Figure 4. In simulation a group of mobile users starts from the Satellite coverage area and move together towards the WiMax coverage area. At time 20 seconds all mobile users enter in WiMax coverage area and at approximately at 102 seconds they leave WiMax coverage area. The Wi-Fi coverage area is overlapped by WiMax therefore at time 62 seconds group of mobile users enters the Wi-Fi coverage area and at approximately 73 seconds all mobile users leave Wi-Fi coverage. Satellite coverage is available to the mobile users throughout the simulation time from time 0 seconds to 150 seconds. The TCP source shown in the Figure 4 maintains a TCP connection with each mobile node throughout the simulation.

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 [10]. Results of average throughput and load distribution at different networks such as satellite, WiMax and Wi-Fi networks are shown in figures from Figure 5 to Figure 8.

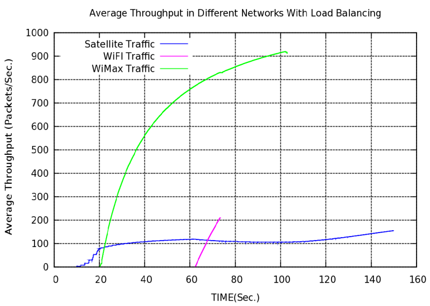

Fig. 5. Avg. Throughput with LB

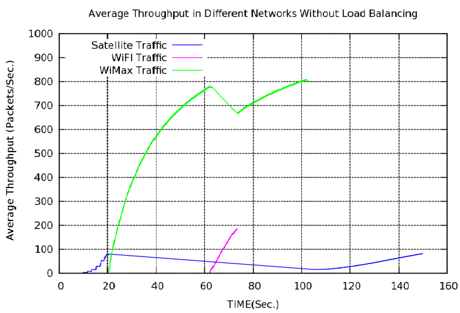

Fig. 6. Avg. throughput without LB

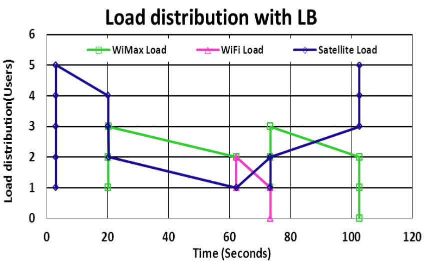

Fig. 7. Load distribution with LB

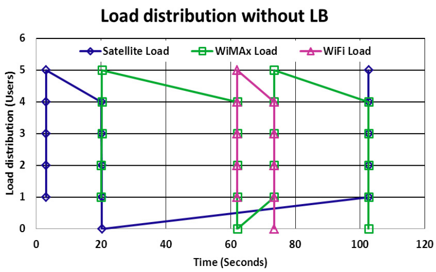

Fig. 8. Load distribution without LB

The Figure 5 is representing the average throughput graph of each network using load balancing algorithm, whereas the average throughput of each network using non-load balancing algorithm is shown in the Figure 6. It can be easily seen from the two graphs shown in Figure 5 and Figure 6 that with load balancing algorithm all the networks showed improved average throughput as compared to the non-load balancing algorithm for RAT selection. The load distributions shown in Figure 7 and Figure 8 represent the load status of each network throughout the simulation time. Figure 7 represents the load status when load balancing algorithm is applied and Figure 8 represents the load status of each network when load balancing algorithm is not applied. These results are showing that in scenario where load balancing algorithm is applied, the overall network load of each network remained lower as compared to the scenario where load balancing algorithm is not applied. As the load balancing algorithm divides the mobile users equally among the network having overlapped coverage areas and non-load balancing algorithm selects the network with highest data rate and highest signalling strength. Balancing the network load enable us to keep the network availability to maximum reducing the call blocking and dropping probabilities and utilizing the available resource efficiently.

5 Conclusion

In this paper a load aware RAT selection algorithm has been presented with the comparison of results generated by simulation scenarios using load balancing algorithm and without load balancing. Considered attributes for observation are load distribution on each of the network and average throughput of each network such as satellite, WiMax and Wi-Fi networks. The results showed that with load balancing both parameters showed improvement in the target heterogeneous wireless network architecture. The average throughput with load balancing is higher for each network as the overall load is divided by load balancing algorithm to avoid the congestion. Load balancing algorithm assures 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. Load balancing approach utilizes the available radio resources efficiently. Handover latencies are minimized, as it does not require all the mobile users to handover when load balancing algorithm is 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, minimized call/connection blocking and dropping probability and ability to maximize the network availability with uniformly distribution of load in co-located networks.

References

1. IEEE Std. 802.21, Media Independent Handover Services (2009)
2. Sheu, S.-T., Wu, C.-C.: Dynamic Load Balance Algorithm (DLBA) for IEEE 802.11 Wireless LAN. Tamkang Journal of Science and Engineering 2 (1999)

3. Papanikos, I., Logothetis, M.: A Study on Dynamic Load Balance for IEEE 802.11b Wireless LAN. In: 8th International Conference on Advances in Communications and Control, COMCON 2001 (June 2001)
4. Scully, T., Brown, K.: Wireless LAN load balancing with genetic algorithms. Knowledge Based Systems (2009)
5. Kim, M.-S., Lee, S.: Load balancing and its performance evaluation for layer 3 and IEEE 802.21 frameworks in PMIPv6-based wireless networks. Wireless Communications and Mobile Computing (2009), doi:10.1002/wcm.832
6. Lee, S., Sriram, K., Kim, K., Kim, Y.H., Golmie, N.: Vertical Handoff Decision Algorithms for Providing Optimized Performance in Heterogeneous Wireless Networks. IEEE Transactions on Vehicular Technology (January 2009)
7. Kaloxylos, A., Modeas, I., Georgiadis, F., Passas, N.: Network Selection Algorithm for Heterogeneous Wireless Networks: from Design to Implementation. Network Protocols and Algorithms (2009) ISSN: 1943-3581
8. Suleiman, K.H., Anthony Chan, H., Dlodlo, M.E.: Load Balancing in the Call Admission Control of Heterogeneous Wireless Networks. In: IWCMC 2006, Vancouver, British Columbia, Canada, July 3-6 (2006)
9. AL Sabbagh, A.: A Markov Chain Model for Load-Balancing Based and Service Based RAT Selection Algorithms in Heterogeneous Networks. World Academy of Science, Engineering and Technology 73 (2011)
10. http://www.isi.edu/nsnam/ns/index.html