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Optimal Load Balancing in WLAN using Load Balancing Algorithm

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Abstract

In wireless LAN technology, access point selection at each station is a critical problem in order to obtain satisfactory throughputs.The traffic load of WLANs is often unevenly distributed among the Access Points (APs), which results in unfair bandwidth allocation among Mobile Users. In this paper, we present an efficient solution to determine the MU-AP associations for bandwidth allocation. We propose a load balancing procedure namely Load Balancing Algorithm (LBA), which acts in two separate levels. First that will maintain load of the APs are fair when new MU is going to be joined or existing MU is going to be relieved, and Second if the load is not fair then the AP will make handover between APs by Hand Over between Access Points (HOAP). HOAP is proposed to speed up handover between the APs, meet handover demands of services with different Quality of Service (QoS), and ensure service continuity.

Keywords: Load Balancing algorithm, IEEE 802.11, WLANs, Fair load balancing

Reviewed by* **ICETSET'16 *organizing committee*

1. Introduction

In recent years, IEEE 802.11 wireless LAN technology has spread tremendously, enabling individuals to connect to the Internet from almost everywhere. The wireless LAN environment consists of APs and MUs, and each MU selects an available AP in order to connect to the Internet without any centralized control. For the wireless LAN environment, the spread of technology has made multiple APs available for MUs. Thus, the AP selection for each MU is a critical problem forobtaining satisfactory throughput. A common AP selection algorithm used in current wireless LAN technology is based on the received signal strength, while ignoring its load condition. As users are, typically, not uniformly distributed, some APs tend to suffer from heavy load while adjacent APs may carry only light load or be idle. Such load imbalance among APs is undesirable as it hampers the network from providing fair services to its users. As suggested in existing studies the load imbalance problem can be alleviated by balancing the load among the APs via intelligently selecting the user-AP association, termed association control. In association algorithm, each MU will be connected with one of the available APs with the maximum signal strength with max-min fairness. However, the algorithm based on the signal strength and fairness of the APs may cause a concentration of connections to one of the APs because the bandwidth allocation of the MUs has been done at admission control only. Since the throughput of each MU decreases in proportion to the number of MUs connected to the same AP, the concentration causes the degradation of the entire wireless network. In the present paper, we first propose AP selection algorithm for maximizing the throughput. The AP selection algorithm is proposed for maximizing the average throughput of APs. At each stage of the algorithm, each MU computes the amount of increase in the throughputs for all APs and selects the AP that maximizes the amount of the increase and as well as AP Computes the each MUs bandwidth utilization. The algorithm, which is based on a local search method, is proposed for obtaining near-optimal maximum throughput, and the obtained throughput become base measures for optimal association algorithm. We compare the results of the above three algorithms with those of the common AP selection algorithm using a simulation environment. The experimental results show that the algorithm achieves high throughput in all cases.

The present paper is organized as follows. In Section 2, we give a brief description of the communication model in the wireless LAN environment. In Section 3, we describe the details of the AP selection algorithms. In Section 4, we present the brief explanation of the proposed algorithm. In Section 5, we give a brief explanation about HOAP Algorithm. In Section 6, we present the experimental results of the proposed algorithm. Section 7 concludes the paper.

2. **Review of Literature**

Load balancing in WLANs has been intensely studied. In **[1]-[2],** association algorithm has been proposed for efficient bandwidth allocation with constant bandwidth of each user in integral association and variable bandwidth of each user by fractional association. This association algorithm is applicable at admission stage only. **[3][4]** On operational Wireless LANS (WLANs) have shown that the traffic load is often distributed unevenly among the access points (APs). In WLANs, by default, each user scans all available channels to detect its nearby APs and associate itself with the AP that has the strongest received signal strength indicator (RSSI), while ignoring its load condition. As users are, typically, not uniformly distributed, some APs tend to suffer from heavy load while adjacent APs may carry only light load or be idle. Such load imbalance among APs is undesirable as it hampers the network from providing fair services to its users. As suggested in existing studies **[6]-[7]** the load imbalance problem can be alleviated by balancing the load among the APs via intelligently selecting the user-AP association, termed association control. Association control can be used to achieve different objectives. In **[7]-[9],** different association criteria are proposed. These metrics typically take into account factors such as the number of users currently associated with an AP, the mean RSSI, the RSSI of the new user and the bandwidth a new user can get if it is associated with an AP in **[8].** Various WLAN vendors have incorporated proprietary features in the device drivers' firmware **[10], [11].** In these proprietary solutions, the APs broadcast their load conditions to the users via the Beacon messages and each user chooses the least loaded AP. Propose to associate new users with the AP that can provide a minimal bandwidth required by the user. If there is more than one such AP, the one with the strongest signal is selected. Most of these heuristics only determine the association of newly arrived users. Tsai and Lien **[8]** propose to re associate users when some conditions are violated. Load balancing in cellular networks is usually achieved via dynamic channel allocation (DCA) **[12].** Most existing WLAN systems follow IEEE 802.11 specifications and adopt the MU initiating handover technology defined by IEEE 802.11. In a complex authentication scenario, IAPP-based handover will take longer time for re-authentication during reconnection and FHO's better handover performance will be more prominent **[13].**

3. Existing AP Selection Algorithms

In this section, we provide two exiting algorithms for fair bandwidth allocation and load balancing. Additionally, they describe some useful properties that we need for constructing our algorithmic tools. In the following, the first is a RSS model, where each user is associated with a multiple AP at any given time according the signal strength.

The second is an association control model, also termed a fractional-association that allows each user to be associated with several APs and to get communication services from them simultaneously. Accordingly, a user may receive several differenttraffic flows from different APs, and its bandwidth allocation is the aggregated bandwidth of all of them.

3.1. Received Signal Strength Indicator (RSSI)

A MU scans the available channels of each AP in the region and listens to the Beacon or Probe Response Frames. Dependent on country, one to fourteen different channels per AP exist. The MU stores the RSSI (Received Signal Strength Indicator) of Beacon or Probe Response Frames and other relevant information, as ESSID, encryption (on/off), etc. After finishing the scanning procedure, the MU selects that AP with the maximum RSSI, given that the selected AP covers other requirements (usually the ESSID, WEP encryption) as well. The MU will leave the AP when the RSSI falls under a predefined threshold. This procedure is based on the conviction that the quality of service of the so selected AP is the best. However, this procedure leads to the result that many stations are connected to a few AP, while some other neighbour AP remains idle. This overload of the AP will lead to performance degradation. Therefore, an algorithm is needed that will take into consideration the status of each AP and it's already associated MU, in order to associate new MU to an AP.

3.2. Association Control Algorithm

The Minimum Load First (MLF) aims to distribute connection requests to other APs that provide signal coverage to the user location rather than associating user to merely AP that yields the highest signal strength. As a result, the system can admit more number of requesting sessions. MLF can be mathematically described as a linear programming model that aims to maximize the number of sessions that can be associated with APs in the system. The objective function of the mathematical formulation is written below. The constraints are the same as the constraint (1)-(2) in the MSF model. This association scheme may be able to balance load of the system but the users requesting multimedia session may not be able to communicate at the highest data rate due to the lower signal strength received from the assigned AP. This may cause problem to the delay sensitive applications.

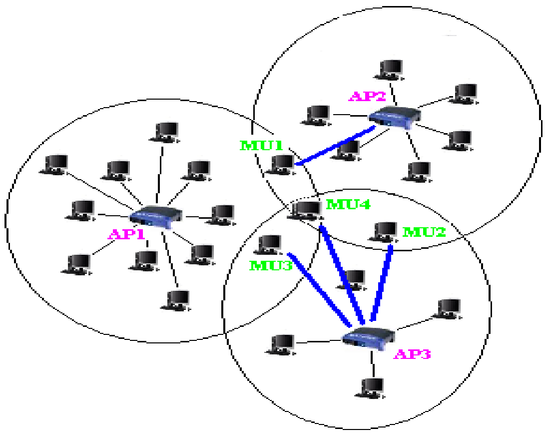

Figure 1: Initial Association of MUs with APs by Association Control Algorithm and Optimal Association Control Algorithm

In Figure 1, we see that initially ten MUs are associated to AP1, while only six and four are associated to AP2 and AP3, respectively. The MU3 is getting strongest signal from AP1 and MU2 is getting from AP3, so those are connected with those APs. But MU1 and MU4 having the problem because of, MU1 is getting the same signal strength from AP1 and AP2, and MU4 getting the same signal strength from all the APs. In this AP3 are having fewer MUS than other APs, so MU3 and MU4 are connected with AP3. And MU1 is connected with AP2.

4. Load Balancing Algorithm (LBA)

We propose a new algorithm, namely the Load Balancing Algorithm (LBA) that considers not only the priority of applications requesting connections but also the load balance among APs in the system. Incoming session will be associated with AP providing the highest data rate with RSSI, MLF and Utilization of bandwidth by each user. For best effort applications which are not delay sensitive, connection requests will be distributed to APs in the vicinity to maintain load balance in the system.

In Association Control Algorithm and RSSI is making the association in initial stage but after theassociation that MUs is associated with the same AP up to the connection termination this is leading the problem because after some session may be the MUs will be relieved from the APs.

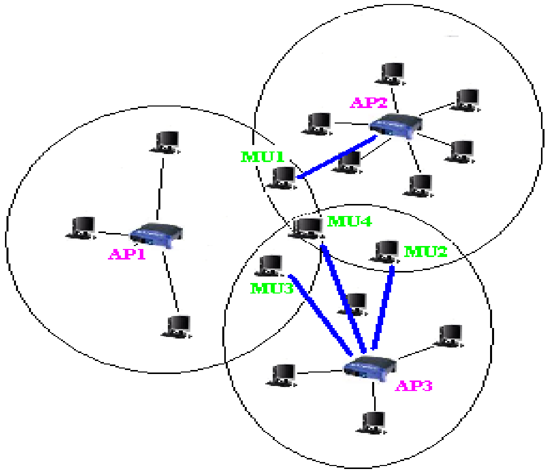

Figure 2: Association of MUs with APs by Association Control Algorithm after some session

In Figure 2, we see that after some session the MUs relieved from AP1. In this case the AP1 is having less utilization than other APs. This association scheme may not be able to balance load of the system but the users requesting frequent session may not be able to communicate at the highest data rate due to the lower data rate received from the assigned APs. This may cause problem to fairness in APs. In this time the AP2 and AP3 will handover some of the MUs to AP1 by HOAP.

In this section, after exploring the details of proposed algorithm for APs and MUs, we also analyze the stability and overhead of the proposed algorithm. By exchanging information among MUs and APs, the proposed scheme can be summarized as shown in Figure 3.

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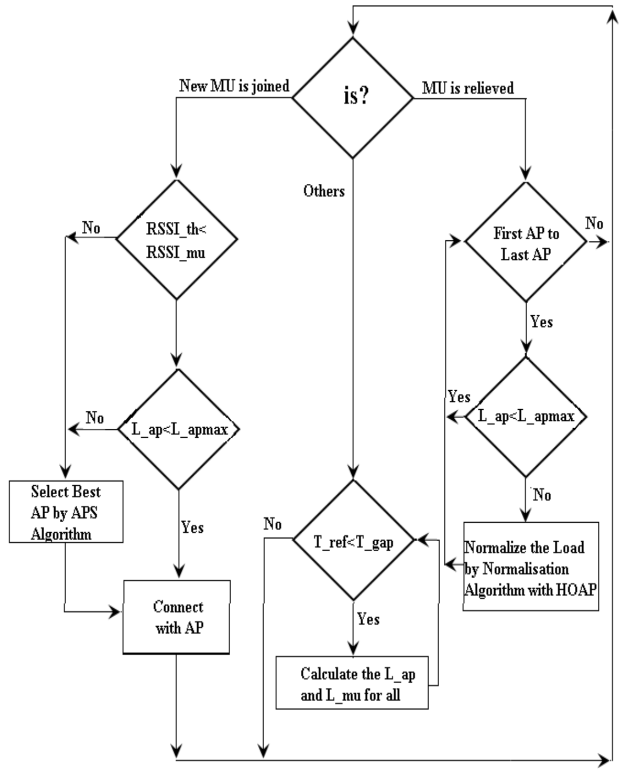

Figure 3: Proposed algorithm for load balancing in WLANs

Where,

RSSI_th -RSSI Threshold Value

RSSI_mu -RSSI value for MU

L_ap -Current load of AP

L_apmax -Maximum Load for AP

L_mumax -Maximum Load for MU

T_ref -Current Time gap

L_mu -Current Load of MU

T_gap -Time gap between normalization

In legacy IEEE 802.11 standard, the management packets from the AP do not contain any field indicating the AP load information. To realize the proposed scheme, it is required to maintain the load of each access point and mobile user. Moreover, due to the dynamic nature of the wireless network and the mobility of MUs, the APs should keepupdating the AP load by iterative moving average as where T_gapis the fixed updating interval and 0≤T_gap≤1 is the weighting parameter to trade-off previously estimated AP load and current value. If the load is going to beyond the threshold then the MU will be associated with other AP by HOAP Mechanism.

The Load of the each MU is calculated by,

$$L\_mu = \sum_{i=1}^{n} ab_i \; (\forall ab_i \in MU) \text{ ----------- } (1)$$

If the current load of the MU is greater than the maximum load of MU then,

If L_mumax<L_mu then

L_mu=L_mumax

The Load of the each AP is calculated by,

$$L\_ap = \sum_{j=1}^{m} L\_mu_j \; (\forall mu_j \in AP) \text{ ------- } (2)$$

Refreshment time is calculated by,

T_ref=T_curr-T_last

After refreshing

T_ref=T_last

Where,

ab -Application Bandwidth

n -No of applications are transferring the data between current MU and AP

m -No of MUs are connected with particular AP

T_curr -Current Time

T_Last -Last normalizing time

Steps for new MU is Joined in Network

Step 1: If the RSSI value for selected AP is greater than RSSI Threshold value, then go to Step2 otherwise step4.

Step 2: If the Load of the selected AP is lesser than Maximum load of the AP, then go to step3 otherwise step4.

Step 3: Connect the MU with selected AP.

Step 4: Select the best AP by AP Selection Algorithm.

Steps for new MU is relieved from Network

Step 1: select the from first to last and check whether the load of the AP is lesser than maximum load is allotted for each AP, then go to step 2 otherwise repeat the step1.

Step 2: Normalize the workload of the AP by Normalization algorithm with HOAP.

This operation is not only necessary to reduce the effect introduced by the joining order of MUs but also required for the MU to be adaptive to the dynamic wireless environment and topology changes. The period T_ref, configured to be more than T_gap seconds, is much longer than the load updating period T_gap on the AP.

Access Point Selection Algorithm (APS Algorithm)

- Select the possible APs for that MU from all APs according the RSSI value.
- Calculate the current load (L_ap) of all the APs by (1).
- Sort the APs in ascending order.
- Select the AP from the list as minimum load to maximum.
- If the load of the AP is lesser than the threshold value then select this AP to connect otherwise go to step iii.
- If all the APs from the list is having maximum load then the MU will be connected with AP which is having the maximum RSSI Value with that MU.

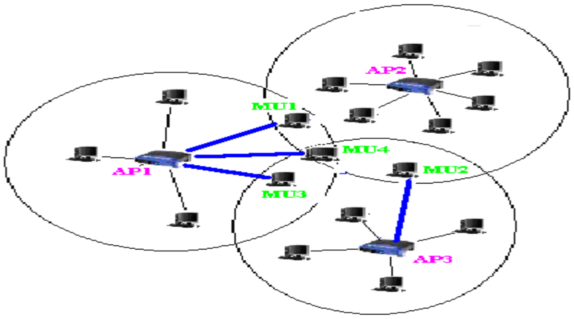

Figure 4: Association of MUs with APs by Proposed Algorithm

In Figure 4, we see that after some session the MUs relieved from AP1, AP2 and AP3 are having balanced workload among these three. In this stage AP1 and AP2 having six mobile users and AP3 having 5 users.

5. Handover between Access Points (HOAP)

In WLAN networks that use the Infrastructure Mode of the IEEE 802.11 standard, each MU is associated with an AP that provides access to the fixed network infrastructure. When the current AP workload is going to beyond the threshold, it is needed to change the AP. This process is called handover. The more WLAN networks are used in telephony and multimedia applications the more important such handovers are becoming. In particular, there is a need to speed up the handover process such that it does not interrupt application level sessions.

Authentication of the mobile stations is an important security requirement in WLAN networks. In particular, due to the lack of a physical connection between the MU and the AP, authentication becomes indispensable for controlling access to the network. However, the authentication mechanisms used in WLAN were not designed to be exceptionally fast, and they are unable to guarantee low handover latencies needed by today's real-time applications.

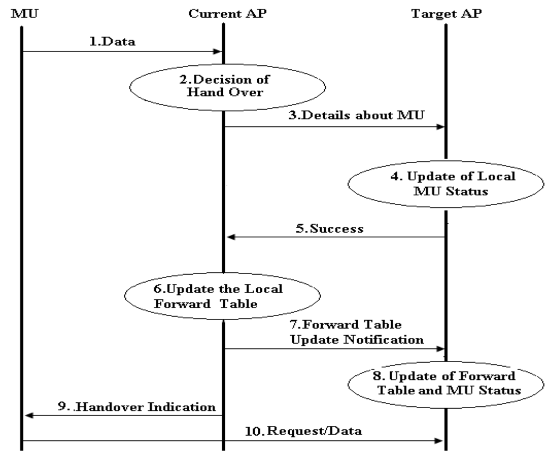

Figure 5: Implementation process an HOAP

Moreover, HOAP shortens the time delay for authentication during handover by pre-authorization and authorization dependency technologies, with which mutual authentication between the AP is fulfilled before handover and the authorization granted by certain an AP can be extended to other reliable APs. Second, the MU initiating handover takes no account of traffic of the target AP, which is more possible to cause frequent handovers among several APs and results in low handover efficiency. The HOAP enables an AP to make handover decision according to its load strategy and distribution of traffic load in the ESS. This greatly improves the handover success rate, and avoids frequent handover. Third, the MU initiating handover has no security guarantee scheme for handover. Though the IAPP supports safe handover based on Remote Authentication Dial In User Service (RADIUS), the handover process with low efficiency is possibly threatened by Denial of Service (DoS) attacks. The HOAP, however, may use the security strategies of wired networks to guarantee mutual authentication and authorization between the AP, and ensure the handover security of the MU by handover control at the AP.

5.1. Step By Step Process Of HOAP In Access Point

HOAP can be fulfilled at the AP with the following process, which is also shown in Figure 5:

(1) The MU establishes a connection and transfers the data with the current AP.

(2) The current AP makes handover decision according the workload of current AP; the AP checks the validity of the target AP.

(3) The current AP sends the information about the MU to the target AP.

(4) The target AP changes the MU into a handover status.

(5) The target AP replies to the current AP with a successful transfer response.

(6) The current AP updates the local Layer 2 forward table, modifies the MU route in DS, and then deletes the local MU information.

(7) The current AP sends update of the Layer 2 forward table in DS.

(8) The target AP renews the local Layer 2 forward table and changes the MU into a status of completed handover.

(9) After receiving the acknowledgement, the current AP gives the MU a handover indication or a permission response to the handover request to inform it to be switched to the target AP.

(10) The MU sends reconnectionrequest to access the target AP

6. Performance Evaluation

In this section, we first introduce the numerical evaluation based on the developed simulation program. The program is able to simulate dynamic and large-scale topology to clearly show the achievable benefits of the proposed scheme. We then provide NS2 **[13]** simulation results for a medium-size topology with suddenly roaming clients. Finally, we also explain our prototype implementation on a tested built with normal computers

In order to evaluate the proposed scheme for large-scale topologies, we have developed a discrete-event simulator based on simply **[13],** which is a Python framework for discrete-event simulation applications. Users can manually place the APs and MUs in the GUI (Graphic User Interface). The generated scenario can also be saved and loaded for future use.

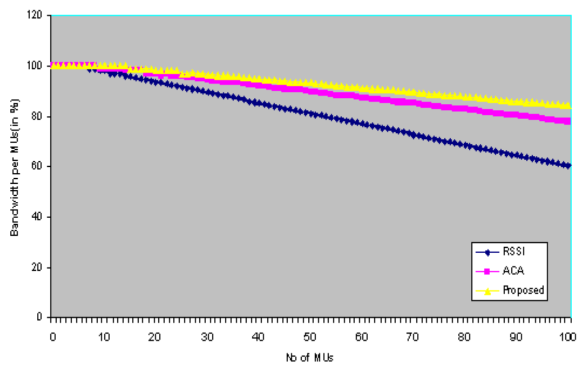

Figure 6: The throughput fair bandwidth allocation Comparison

To accelerate the simulation, the complex behaviour of IEEE 802.11 MACis simplified and the throughput is calculated by the throughput model. We use a set of measured trace files provide by **[15],** which collected the 20 minutes measurement data by capturing the realistic mobility patterns of the MU.

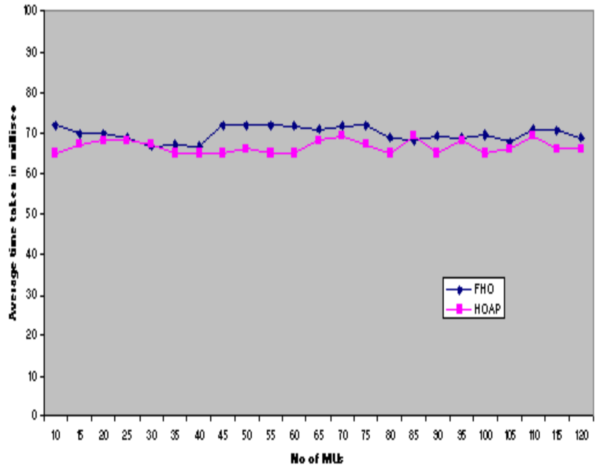

Figure 7: Average of the delays caused by the authentication phase during the handover process when using different existing authentication protocols

According to Figure 6, we can observe that the total throughput achieved by the proposed scheme is generally the same or sometimes higher than that of the default RSSI based and ACA scheme. However, the value of fairness metric has been apparently (between 8%-15%) improved after applying the proposed scheme. On the other hand, we also find that it mostly takes only one probing and reassociation operation for the MUs to reach a steady MUs when they move around in the topology. HOAP performance has been improved up to 20% and it is giving 99% reliable connection for video streaming. Figure 7 shows that the time taken for handover and performance improvement between FHO and HOAP.

7. Conclusion

In this research, we have explored the fair load balancing scheme to guarantee the throughput fairness among the MUs. To achieve this, we have proposed an optimal and self mobilized association scheme for the MUs in the multi-rate WLANs. The proposed scheme balances the AP loads in a distributed manner. With extensive simulations, we can observe that it can significantly improve, or sometimes nearly double, the extent of throughput fairness among the MUs with low overhead. To show the feasibility of the proposed scheme, we have implemented a prototype on normal computers by modifying open source wireless driver software packaged Our research is oriented for practical Wi-Fi products and can be implemented with small additional modification to achieve apparent fairness among the MUs with low overhead. To show the feasibility of the proposed scheme, we have implemented a prototype on normal computers by modifying open source wireless driver software packaged Our research is oriented for practical Wi-Fi products and can be implemented with small additional modification to achieve apparentfairness among the MUs with low overhead. To show the feasibility of the proposed scheme, we have implemented a prototype on normal computers by modifying open source wireless driver software packaged Our research is oriented for practical Wi-Fi products and can be implemented with small additional modification to achieve apparent load balancing in deployed WLANs. The HOAP can be implemented at the AP and has shorter handover time delay than IAPP handover. It is able to ensure excellent service continuity and high reliability and less data loss compare than exiting methods.

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