Access Point Selection for Fair Load Balancing in Wireless LAN

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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 and bandwidth. The traffic load of WLANs is often unevenly distributed among the Access Points (APs) which results in unfair bandwidth allocation among Mobile Users (MUs). In this paper, the proposed algorithm has been presented as an efficient solution to determine the Mobile User (MU)-Access Point (AP) associations for better bandwidth allocation of MUs and better throughput. Load balancing procedure has been proposed 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 and second is whenever the existing MU is going to be relieved. The experimental results of the proposed algorithm indicate that the proposed algorithm achieves performance improvements in throughput and bandwidth allocation compared with previous algorithms.

Key words: Load balancing algorithm, AP throughput, AP association, mobile user association

INTRODUCTION

In recent years, WLAN technology has emerged as the predominant alternative for wireless broadband data access in local and global environments, enabling individuals to connect to the network from almost everywhere. The WLAN environment consists of APs and MUs and each MU selects an available AP in order to connect to the network without any centralized control. The IEEE 802.11 standard currently merely provides a mechanism for association and disassociation. There is no information about access point load is provided; as a result, the only viable policy for access point selection is to pick the access point with the best signal-noise ratio. An analysis of the signal-noise ratios in the two seminar halls reveals that while the access point coverage is equal, for most locations the original access point has a slightly better signal-noise ratio. The result is that nearly all the mobile users associate with the original access point leaving it overloaded and the new access point nearly idle.

Load balancing in WLANs has been intensely studied. Bejerano et al. (2007) proposed association control algorithm for efficient bandwidth allocation. An efficient decentralized AP selection algorithm is needed in order to avoid over load of MUs and different AP selection algorithms have been proposed (Nicholson et al., 2006). Bejerano et al. (2004) proposed the demand users association, the bandwidth of MUs are not stable. Since the throughput of each MU decreases in proportion to the number of MUs connected to the same AP (Fukuda et al., 2004), the concentration causes the degradation of the entire wireless network (Balachandran et al., 2002). In addition, the values of throughputs are not stable and depend heavily on the position of the MUs in case of the common algorithm. For example Fukuda et al. (2004) proposed an AP selection algorithm which is referred to as the Maximizing Local Throughput (MLT) and the result in shows that MLT achieves better minimum throughput of MUs than the throughput obtained by other AP selection algorithms. Tsai and Lien (2003) proposed to re-associate users when some conditions are violated. As suggested in existing studies in Papanikos and Logothetis (2001), the load imbalance problem can be alleviated by balancing the load among the APs via intelligently selecting the user-AP association. Singh et al. (2008) proposed position based load balancing scheme for mobile users, find the position and placing the user is difficult to implement. Jabri et al. (2008) proposed the protocol for increase the throughput but the architecture of the entire mobile user may not able to support. Optimal association control algorithm has been proposed by Venkatesan and Manoharan (2010). Since, the throughput and bandwidth of each MU decreases in proportion to the number of MUs connected to the same AP, the concentration causes the degradation of the entire WLAN. In this study, load sensitive approach has been proposed to access point selection that is distributed in nature.

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PRELIMINARIES

Communication model: The communication model and throughputs has been discussed in this study. It is assumed that there are \( n \) MUs and \( m \) APs in the WLAN environment and \( MU = \{ m_{u_1}, m_{u_2}, \ldots, m_{u_n} \} \) and \( AP = \{ a_{p_1}, a_{p_2}, \ldots, a_{p_m} \} \) denote two sets of MUs and APs, respectively.

For each pair of MU \( m_{u_i} \) and AP \( a_{p_j} \), a packet error rate \( p_{i,j} \) is defined. The packet error rate \( p_{i,j} \) represents the signal strength between MU \( m_{u_i} \) and AP \( a_{p_j} \), and \( 0 \leq p_{i,j} \leq 1 \). Since the packet error rate is the ratio of the number of test packets that are not successfully delivered to a destination, a high packet error rate indicates low signal strength.

Throughput \( T_{i,j} \) has been calculated by using packet error rate between MU \( m_{u_i} \) and AP \( a_{p_j} \) for the case in which \( m_{u_i} \) is connected with \( a_{p_j} \) according to the IEEE 802.11 MAC mechanism. Let \( N_i \) be the number of MUs that are connected to AP \( a_{p_j} \). Then, the throughput \( T_{i,j} \) is given by the following expression (IEEE Standard 802.11, 1999):

\[
T_{i,j} = \frac{\text{Data}(1-p_{i,j})}{t_i \times N_i}
\]

In the above expression, \( t_i \) and \( \text{Data} \) denote the transmission time and the size of the transmitted packet, respectively. Since \( t_i \) is a constant that depends on the WLAN environment, when all of the packets are of the same size, the \( T_{i,j} \) can be represented as:

\[
T_{i,j} = \alpha \times \frac{1-p_{i,j}}{N_i}
\]

In the above expression, \( \alpha \) is a constant that depends on the wireless LAN environment. This expression implies that the throughput \( T_{i,j} \) is linearly dependent on:

\[
\frac{1-p_{i,j}}{N_i}
\]

The following assumption has been employed in the communication model for the wireless LAN environment.

Each AP can send the three values which are the number of connected MUs, the sum of the throughputs and the maximum packet error rate, to any MU. In other words, each MU knows these values for all of the APs.

EXISTING ALGORITHMS

Two Existing AP selection algorithms have been discussed in this section. The first is a conventional approach used in the current WLAN technology, second is algorithm based on a communication model. The existing algorithms are briefly described in the following.

Received signal strength indicator (RSSI): The Received Signal Strength Indicator (RSSI) is a basic and conventional AP selection algorithm. Each MU associates one of available APs according to signal strength. An outline of the algorithm on each MU \( m_{u_i} \) is given below:

**Step 1:** For each AP \( a_{p_j} \) \((0 \leq j \leq m-1)\), compute \( \text{rss}_{i,j} = \frac{1-p_{i,j}}{N_i} \).

**Step 2:** MU will select AP \( a_{p_{h}} \) such that \( \text{rss}_{i,h} = \max \{ \text{rss}_{i,j} | 0 \leq j \leq m-1 \} \).

If all MUs are uniformly distributed, RSSI is sufficient for obtaining sufficient throughputs and bandwidth. However, RSSI causes degradation of the minimum throughput and bandwidth when several MUs are close to one AP.

Maximizing local throughput (MLT): The Maximizing Local Throughput (MLT) (Fukuda et al., 2005) is an AP selection algorithm based. In this the future throughput has been calculated before going to association in the WLAN environment, the throughput between MU \( m_{u_i} \) and AP \( a_{p_j} \) depends linearly on the value of \( 1-p_{i,j} / N_i \). In the MLT, each MU selects one of the available APs according to the future throughput value. An outline of MLT on each MU \( m_{u_i} \) is given below:

**Step 1:** Receive \( N_i \) from each AP \( a_{p_j} \) \((0 \leq j \leq m-1)\).

**Step 2:** For each AP \( a_{p_j} \) \((0 \leq j \leq m-1)\), set \( N_i = N_i + 1 \) then, calculate the value \( \text{ml}_{i,j} \):

\[
\text{ml}_{i,j} = \frac{1-p_{i,j}}{N_i}
\]

**Step 3:** MU \( m_{u_i} \) will select AP \( a_{p_{h}} \) such that \( \text{ml}_{i,h} = \max \{ \text{ml}_{i,j} | 0 \leq j \leq m-1 \} \).

LOAD BALANCING ALGORITHM

Here, a new algorithm has been proposed, 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, MLT 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, MLT and RSSI is making the association in initial stage but after the
association that MUs is associated with the same AP up to the connection termination this is loading the problem because after some session may be the MUs will be relieved from the APs. This type of 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 APs will handover some of the MUs to lesser loaded AP by Hand Over between Access Points (HOAP).

Here, after exploring the details of proposed algorithm for APs and MUs, stability has been analyzed for the proposed algorithm. By exchanging information among MUs and APs, the proposed scheme can be summarized as shown in Fig. 1.

In 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 keep updating the load by iterative moving average as where time gap $T_{eq}$ is the fixed updating interval of 5 milliseconds and $0 \leq T_{eq} \leq 1$.

The average throughput $T_{eq}$ denotes the average of throughput of the MUs. $T_{eq}$ is defined for an output of AP selection as follows:

$$T_{eq} = \frac{1}{n} \sum_{i=1}^{n} T_i = \frac{\alpha}{n} \sum_{i=1}^{n} \frac{1 - (\Theta_i + \Theta_{eq})}{N_i}$$

(1)

where, $\Theta_i$ is the data loss due to circumstances like objects, moisture etc.

In order to maximize the total throughput of the WLAN environment, an AP selection algorithm is needed that maximizes the average throughput.

The load on an AP $a_p$ denoted by $L_{eq}$ is the maximum of its aggregated loads on both its wireless and infrastructure links produced by all the MUs. Its requires relevant information on each mobile user $u_i$, such as its weight $w_i$, the effective wireless link bit rate $r_{ij}$ for each AP and infrastructure bit rate $R_{ij}$ and bandwidth allotted for link by access point is $x_{ij}$. The $L_{eq}$ is:

$$L_{eq} = \max \left\{ \sum_{i \in E_q} x_{ij} w_i, \sum_{i \in I_q} x_{ij} r_{ij}, \sum_{i \in R_q} x_{ij} R_{ij} \right\}$$

(2)

Therefore, the load of an AP is given in terms of the time it takes to complete the transmission of certain traffic volume from each associated user. This is not surprising, since the load should be inversely proportional to the bandwidth that the AP $a_p$ provides to its users. Furthermore, the bandwidth that AP provides to $u_i$ is:

$$b_{ij} = \frac{x_{ij} w_i}{y_i}$$

(3)

**Fig. 1: Proposed Load Balancing Algorithm for WLANs**
Whenever the new mobile user $mu$ is going to be joined in network then, if the $T_{iq}$ with the selected AP is greater than $T_{mn}$ value and, if the load of the selected AP $L_{iq}$ is lesser than Maximum load of the AP $L_{max}$ then the $mu$ will be associated selected AP otherwise, the next best AP will be selected by AP Selection Algorithm. The step by step procedure of AP selection algorithm is follows:

**Access Point Selection Algorithm (APS Algorithm):**

**Step 1:** Select the possible APs from the new $mu$ from all APs according the $T_{iq}$ value

**Step 2:** Calculate the current load $L_{iq}$ of all the APs by Eq. 2

**Step 3:** Sort the APs in ascending order by $L_{iq}$

**Step 4:** Select the AP from the list as minimum load to maximum

**Step 5:** If the load of the AP is lesser than the threshold value then select this AP to connect otherwise go to step iii

**Step 6:** If all the APs from the list is having maximum load then the MU will be connected with AP which is having the maximum $T_{iq}$ value and bandwidth is calculated by Eq. 3 with that MU

Whenever the existing mobile user $mu$ is going to be relieved from the network then, the load of all the APs may be normalized. Select the from first to last and check whether the load of the AP $L_{iq}$ is lesser than maximum load is allotted for each AP $L_{max}$ then normalize the workload of the AP by Normalization algorithm. The step by step procedure of normalization algorithm is follows:

**Normalization algorithm:**

**Step 1:** Calculate the current load $L_{iq}$ of all the APs

**Step 2:** Sort the APs in descending order by $L_{iq}$

**Step 3:** If any of the AP is over loaded then select the AP from the list as minimum loaded and maximum loaded

**Step 4:** Select the common $mu$ between the selected APs; make the hand over between maximum loaded to minimum loaded by HOAP in Venkatesan and Manoharan (2011)

**Step 5:** Repeat the above steps up to the load in normalized for all APs

If all the APs from the list is having maximum load then the MU will be connected with AP which is having the maximum $T_{iq}$ Value and bandwidth is calculated by Eq. 3 with that MU.

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 $T_{rep}$ configured to be more than $T_{rep}$ seconds, is much longer than the load updating period $T_{iq}$ on the AP.

A balance index $\beta$ Chiu and Jain (1989) is defined as a measure that represents the fairness among MUs. The balance index $\beta$ is defined for an output of AP selection as follows:

$$\beta = \frac{\sum_{i=0}^{n} t_i \delta_i}{\sum_{i=0}^{n} t_i}$$

The balance index becomes 1 when all of the MUs have the same throughput. On the other hand, the balance index approaches $1/n$ when the throughputs of the MUs are largely imbalanced.

**PERFORMANCE EVALUATION**

Here, experimental results have been described for known algorithms and the proposed algorithms. All the algorithms are implemented in C language simulation environments. In the simulation, it is assumed that there are 4 APs and 100 MUs in a 2D plain with 50 m² square area and each AP is located at the middle point of all the sides. It is assumed that all the MUs are randomly located in the plan.

In each simulation, locations are randomly generated for 100 MUs. For each $mu$ location, the each packet error rate $p_{i,j}$ is calculated from the distance between MU $mu_i$ and AP $ap_j$. Then, the simulation has been executed for each MU location using the following steps:

**Step 1:** Select the MUs locations randomly

**Step 2:** Relocate some of the MUs from existing locations to new locations

**Step 3:** Calculate the $p_{i,j}$ for the all MUs locations

**Step 4:** Execute three AP selection algorithms which are RSSI, MLT and Proposed Algorithm, for the STA location in order of the permutation. Repeat the steps (2-4) 100 times

**Step 5:** Repeat the steps (1-4) 1000 times in order to stabilize the results of the algorithms

In Fig. 2, the throughput of each and every MU and these results imply that the throughputs obtained by the RSSI and MLT are unstable and depend heavily on the locations of the STAs. However, it is confirmed that the throughput of proposed method is better than that existing methods.
Fig. 2: Throughput of existing and proposed algorithms

Fig. 3: Average Bandwidth per MU of existing and proposed algorithms

Fig. 4: Average Balance Index of existing and proposed algorithms

In Fig. 4, the average balance indices of proposed algorithm and existing algorithms. The values of the balance indices show that the proposed method achieves satisfactory fairness, while the values of the RSSI and the MLT are low.

CONCLUSION

In this research, load balancing scheme has been explored to guarantee the throughput fairness among the MUs in the WLAN environment. The algorithm is proposed for maximizing the throughput and bandwidth of individual user of among MUs. The experimental results show that the proposed algorithm achieves high throughputs and bandwidth per MU. In the future, AP selection algorithms for heterogeneous WLAN environments may be considered. The heterogeneous WLAN environments consist of Aps and MUs having different standards. In heterogeneous environment, the communication model is different from the model used in the present study and some modifications are needed in order to propose an efficient AP selection algorithm in heterogeneous WLAN.

REFERENCES


