A Study on Dynamic Load Balance for IEEE 802.11b Wireless LAN

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ABSTRACT

We study the problem of load balancing in 802.11-based wireless networks, operating in infrastructure mode. In a large wireless network with multiple collocated Access Points (AP), a load balancing policy is necessary for the distribution of the wireless stations (WS) to the AP's, so as the network performance to be maximized. Already proposed algorithms, which are based only on the received signal strength indicator (RSSI), may cause all the WS to be associated to a single or to a very few number of AP, and result in an overall network performance degradation. In this paper, we propose a load balancing procedure, which acts in two separate levels. First, the AP's are either distributed across the channels (if the number of AP is small) or located in the same channel that is specified by taking into account the channel-location and the received RSSI of the neighbor AP. Second, the WS are distributed across all the available AP based not only on RSSI measurements but also on the number of WS already associated to the AP and other link quality measurements. Besides, in this paper we describe the signaling extension needed for the implementation of the proposed load balancing procedure.

1. INTRODUCTION

In wireless LAN based on the IEEE 802.11 protocol, two different topologies can be configured in order to service different communication needs. These are the Infrastructure Mode and the Ad Hoc Mode [1].

In the Infrastructure Mode, basic network components that we can distinguish are the Wireless Stations (WS), the wire stations and the Access Points (AP) conveying the bridging functions. The WS are associated to an AP and consequently through the AP can communicate with other wire or WS. The WS can be supported by more than one AP in the same region. The operation functions of the AP (Channel, ESSID, WEP, etc) may differ among the AP, although they support the same network. The WS usually have the ability of roaming from one AP to another AP; when the WS are moving stations, the roaming function is a must, for best quality of service. In order for the roaming function to be installed, all AP in the same region need the same key functions as ESSID and WEP, while they can operate in different channels. The maximum number of associated channels per AP is 2007, whereas, it is worth mentioning, there is not any function specifying the AP selected by a WS.

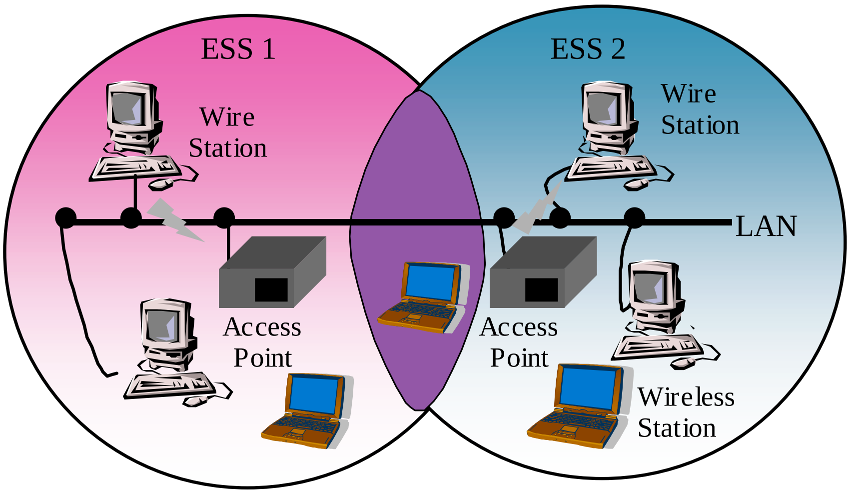


Figure 1: Infrastructure Mode of communication – Wireless LAN.

In the Ad Hoc Mode, the communication protocol gives the ability of peer-to-peer communication among the WS. The mode is suitable for meetings where partners need to exchange data, etc. The usage of the ad-hoc mode seems to be limited to the WS only (it is not possible for a WS to communicate with a wire station through the ad-hoc mode). According to WECA (conformance committee of the IEEE 802.11 products), the ad-hoc mode has a lower priority than the infrastructure mode to be implemented.

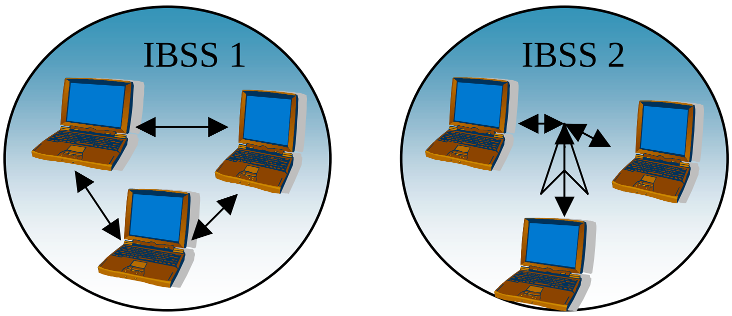


Figure 2: Ad Hoc Mode of communication – Virtual LAN.

In this paper, we concentrate on the infrastructure mode and deal with the problem of load balance between AP [2,3,4]. Due to the fact that there is no function/algorithm which could associate a WS to a specific AP, one AP may support many WS, while some other neighbor AP may support very few stations. In Fig. 3(a), we see that seven WS are associated to AP 1, while only two and three are associated to AP 2 and 3, respectively. This asymmetry causes a high probability of packet loss in AP 1 (and consequently an overall network degradation) in comparison to the AP 2 and 3. This situation could be avoided by balancing the number of associated stations among AP. In Fig. 3(b) we see an equal number of associated stations to each

AP, after applying a proper load balance algorithm (specific function). An improved network performance is anticipated from this symmetry.

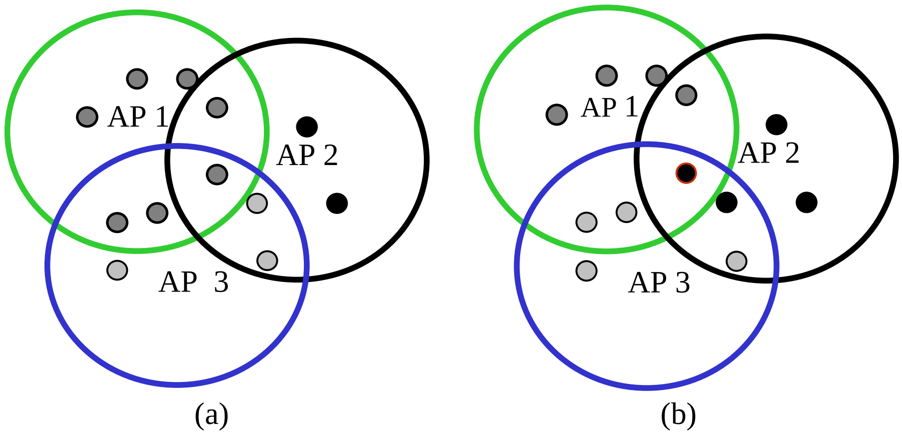


Figure 3: (a) Asymmetry in station assignment.
(b) Symmetry in station assignment.

The applicability of a WS distribution algorithm to the AP whereby a load balance results for each AP, strongly depends on the nature of the wireless LAN and it is not a easy task [5]. The problem becomes even more difficult due to dynamically network topology changes that cannot be avoided when the WS are moving stations. Besides, it is impractical to consider any station rearrangement after a new connection/disconnection. This paper is organized as follows: In Section 2, we present the assignment/association problem of WS to AP. Section 2.1 presents the classical approach. Section 2.2 presents the load balance approach that we propose, and it contains three sub-sections, corresponding to the three levels that the load balance algorithm is structured. In sub-section 2.2.1 we describe the first level of the algorithm, which is called AP Channel Autoselection Level, in sub-section 2.2.2, the second level that is called Station Join Decision Level, and in sub-section 2.2.3 the third level which is the Link Observation Level. Section 2.3 gives the necessary modifications of the communication protocol between WS and AP that facilitate the algorithm implementation. In Section 3, we present the experimental test we have carried out and comment on the improvements that must be done to the algorithm. We conclude in Section 4.

2. ASSOCIATION OF WIRELESS STATION TO AP

2.1 Classical Approach

The procedure for the association of a WS to an AP, as it is currently implemented by most manufacturers is as follows:

A WS 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 WS 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 WS selects that AP with the maximum RSSI, given that the selected AP covers other requirements (usually the ESSID, WEP encryption) as well. The WS 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 neighbor AP remain 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 its already associated WS, in order to associate new WS to an AP.

2.2 Dynamic Load Balance Approach

According to the dynamic load balance approach, a WS joins an AP, dependent on the number of the already associated stations to the AP and the mean RSSI value. We propose a dynamic load balance algorithm, which aims at improving the overall network performance by the least possible functional aggravation of AP and WS. A fair station's distribution among all available APs results, whereas the mean RSSI has a higher value than that of the classical approach and therefore better transmission conditions exist.

The algorithm acts in three different levels:

a) The AP Channel Autoselection Level aims at the best distribution of the AP to the available channels.
b) The Station Join Decision Level determines the manner that the WS selects the AP to associate with it.
c) The Link Observation Level determines when the WS leaves the AP and the roaming function is performed.

As we have found in the literature, similar algorithms dealing with the load balance problem have already been proposed [2,3,4], but their implementation seems to be difficult. As we do (see below), they also make use of the mean value of the RSSI.

Below we describe the three levels of operation of the proposed algorithm and propose the necessary modifications in the communication protocol between WS and AP for the algorithm implementation.

2.2.1 The AP Channel Autoselection Level

More precisely, in the AP channel autoselection level, at the start-up phase of each AP, the AP is informed the existence of other AP in the same region, by using a communication protocol of IEEE, proposed for servicing roaming needs. This is the Inter Access Point Protocol (IAPP), which transfers all necessary information, proving that the AP service the same LAN. At the same time, the AP active scans the channels to find out which AP (having informed from the IAPP) are neighbor. Besides it is informed the operation channels of the neighbor AP. It uses this information in order to start using as operation channel the one where the interference from the neighbor AP will be the lowest possible; this leads to the best quality of communication with the WS. This level of the load balance algorithm is rather an initialization level where the operation conditions of the network are normalized. It is a necessary level, since most network administrators ignore basic aspects of the wireless networks. Till now, there is no AP with AP Channel Autoselection Level, because of the difficulties in the implementation. As far as the initial operation channel is concerned, it is chosen to be 1, or 6, or 11 (for USA, with 1-14 channels), as it is demonstrated in Fig. 4. The equal distance between these channels (1, 6, 11…) gives an a priori minimum interference between neighbor AP.

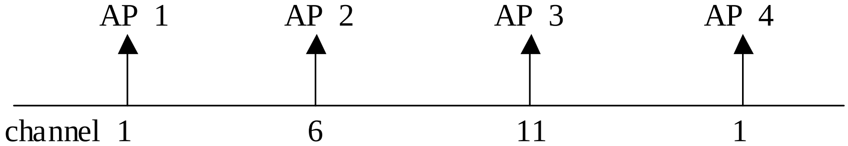
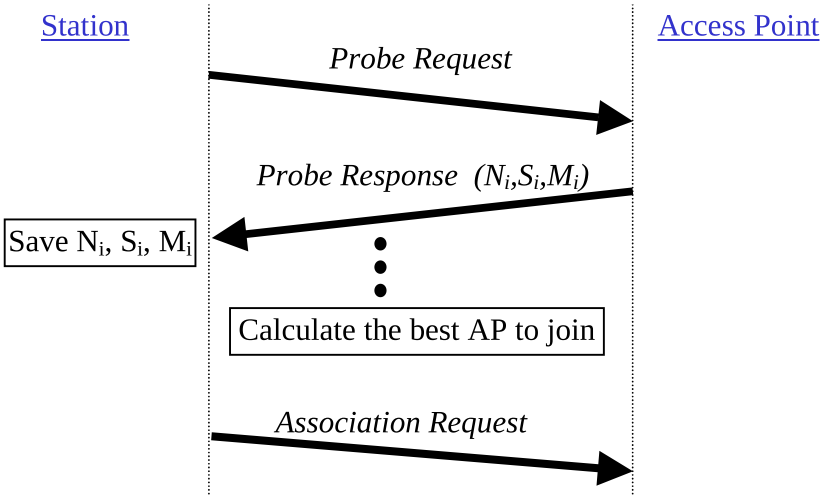


Figure 4: Initial channel autoselection, for a band of 14 channels

2.2.2 The Station Join Decision Level

At the second level of operation, the WS sends a Probe Request to all channels in order to localize the AP. The AP answer with a Probe Response containing additional information than those already defined in the protocol. These are the number of already associated WS to the AP, the RSSI whereby the AP received the Probe Request and the mean RSSI of the links between the AP and all the associated stations including the new WS. The mean RSSI is computed by the mean RSSI for each station; this information is stored in the AP for statistical purposes.



N_i: Number of stations associated to AP i
S_i: RSSI value of the Probe Request in AP i
M_i: Mean RSSI value for the set of stations associated to the AP i

Figure 5: Procedure at the join decision level.

Having finished the scanning procedure, the WS determines the best AP to be associated, relying on the three aforementioned parameters.

The station selects the AP that maximizes the following weighted function, which takes into account the mean RSSI of all WS already associated to AP:

$$W_i = D_i * P_{wi} * P_i$$

where D_i denotes the difference between the RSSI received from AP i, S_i, and the mean RSSI, M_i, of all associated stations to AP i, including the new WS ($D_i = M_i - S_i$)

P_{wi} is a weight proportional function that takes into account not only the differences from the mean value but also the absolute value of the mean value. More precisely,

$$P_{wi} = \begin{cases} 1 + M_i / S_i & if\ D_i \geq 0 \\ 1 - M_i / S_i & if\ D_i \leq 0 \end{cases}$$

P_i is the weight proportional to the number of the already associated WS to an AP i. That is: $P_i = \frac{N_i}{\sum_{j=0}^{n} N_j}$, where n is the total number of the AP in the region.

2.2.3 The Link Observation Level

In the link observation level, the third level, each AP updates the mean RSSI value, M_i, and the number of associated stations, N_i, in each Beacon or Probe Response Frame. The WS probes periodically the AP and updates the RSSI in the side of AP i, S_i, M_i and N_i, or monitors the M_i and the N_i through the Beacon frames.

Each time the WS detects a worst case than that calculated previously (by listening the beacon and probe response packets), increases a Handover Counter and once this counter becomes equal to a predefined threshold, the WS seeks a new AP. The threshold value depends on manufacturing characteristics of both WS and AP (sensitivity, transmission power). It must be determined with accuracy, otherwise it will lead the WS to multiple attempts for seeking another AP; thus, reducing the overall performance of the network.

2.3 Protocol Modifications

New fields must be added in Beacons and Probe responses frames for transmitting additional information needed by the algorithm. As it results from the above description of the algorithm, these are:

- The number of associated stations (Beacon, Probe Response),
- Mean RSSI for the associated stations (Beacon, Probe Response),
- RSSI of the incoming Probe Request (Probe Response),

Besides, the AP must be able to activate active or passive scanning procedures.

Moreover, the algorithm must be supported from both the WS and AP sides.

3. EXPERIMENTAL RESULTS

The above described algorithm was tested in some extend by using the Charriot Test Utility in the premises of ATMEL Hellas, with three AP and 30 WS which transferred data files of 12 MB to and from the Ethernet network. The traffic load conditions were the same for all WS. The results showed a balanced distribution of the number of WS to the AP and an improvement in the overall network performance, especially in the absence of hidden stations. However, in the presence of many hidden stations the results were not satisfactory. Also, the results were not satisfactory in the case of unbalanced traffic to or from the WS.

The hidden stations cause a great aggravation in the network because of the large number of packet collisions when one or more WS cannot listen to other WS that transmit. In order to study the problem of load balance in the presence of hidden station we need the aid of a simulator; because of this ATMEL builds up a simulator for further tests and evaluation.

4. CONCLUSION

The current (first) version of the load balance algorithm performs well under similar traffic conditions among the WS and in the absence of hidden stations. The resultant distribution of WS to AP is absolutely satisfactory, that is, symmetry in the numbers of associated station to AP exists. However, it is absolutely necessary for the algorithm to take into account the hidden stations. Therefore, accurate estimation of the number of hidden stations is necessary. Besides, in order to face the problem of large traffic variations among the WS and the resource availability of the AP, real time measurements for the resource availability and frame error rate have to be added in the decision level of the algorithm.

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