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Hybrid Association Control Scheme and Load Balancing in Wireless LANs

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***Abstract*—**This paper presents a hybrid association control scheme that can maintain load balancing among access points in the wireless LANs and can satisfy the quality of service requirements of the multimedia traffic applications. The proposed model is mathematically described as a linear programming model. Simulation study and analysis were conducted in order to demonstrate the performance of the proposed hybrid load balancing and association control scheme. Simulation results shows that the proposed scheme outperforms the other schemes in term of the percentage of blocking and the quality of the data transfer rate providing to the multimedia and real-time applications.

***Keywords*—**Association control, Load balancing, Wireless LANs

I. Introduction

WIRELESS Local Area Networks (WLANs) are experiencing tremendous growth and becoming increasingly popular. The use of unlicensed frequency spectrum bandwidth and inexpensive network equipment has facilitated the deployment of WLANs. They are deployed in many places, such as, university campuses, corporate offices, health institutes, and public places like airports, coffee shops, and shopping malls. Furthermore, WLAN cards are integrated into many of today's laptops and handheld computers, and they are optionally available for almost all computers. As WLAN-access devices have become cheaper, smaller and more powerful, the demand for WLAN services has increased, resulting in the phenomenal growth in the number of WLAN users. By the end of 2008, it is projected that there will be more than 700 million WLAN users in the world [1]. There are several kinds of services providing in WLANs, including the multimedia applications (such as Voice-over-IP (VoIP) and video conference) and the best effort services (such as file transfer and email). Such applications require a network to provide a certain level of quality of services to an area with a large number of users demanding variety of traffic sessions. However, the current IEEE 802.11 Distributed Coordination Function (DCF) and the IEEE 802.11e Enhanced Distributed Channel Access (EDCA) still cannot support strict Quality of Service (QoS) for real-time applications such as video and voice [2]. This paper presents a hybrid association control scheme and load balancing technique that can enhance the EDCA protocol to address the QoS problem in WLANs.

Recently research efforts have been carried out to improve QoS in WLANs. Two important research areas in the QoS management of WLANs are the traffic association (admission) control and the load balancing techniques. Most of recent works on the association control schemes make use of the IEEE 802.11e standard which enhances QoS support by providing different priorities to different applications [3]-[5]. Reference [3] and [4] proposed the admission control schemes that used an analytical model estimating average delay for the traffic of different priorities in the unsaturated condition. It was shown that the QoS requirement of the real-time traffic can be satisfied if the incoming traffic is properly limited. Reference [5] proposed an admission control scheme based on the delay analysis in the saturated condition. Although these works can support QoS to some level, the traffic load can be unevenly distributed among APs in the system, resulting in low network efficiency [6].

Other works on the load balancing issue have been investigated in the literature. Reference [7] presented an algorithm to determine the user-AP associations that provide a max-min fair bandwidth allocation. Reference [8] proposed load balancing schemes that use locations of users and APs to dynamically associate/disassociate due to load changes. Reference [9] proposed a distributed approach that considered the throughput to determine the load level at an AP. Although these works can distributed traffic load more evenly, they do not consider the consequences of different QoS requirements for different applications.

In order to address both issues of the QoS management, namely the traffic association (admission) control and the load balancing techniques, we propose a hybrid association control scheme of which the selection policy considers QoS requirements of each application and limit the load on the AP. The main objective of the proposed scheme is to provide high level of QoS to multimedia applications while distributing load evenly among APs in the system.

The rest of the paper is organized as follows. Section II explains existing load balancing and association control schemes and derives mathematical formulation describing operation of the existing schemes. Section II also describes the proposed hybrid load balancing and association control scheme and derives mathematical formulation. Section III

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presents numerical results and discussion. We conclude the paper in section IV and outline some issues for future work.

II. Association Control Schemes and Load Balancing

The existing load balancing techniques and the association control schemes can be classified into two approaches, namely the Maximum Signal strength First (MSF) and the Minimum Load First (MLF) approach. We propose a novel technique, namely the hybrid approach. We first define notations and then present mathematical models describing the operations of the schemes in this section.

TABLE I
NOTATION

Notation	Definition
N_{max}	The maximum number of sessions that can be associated to each AP so that the WLAN can provide appropriate quality of services to the multimedia and best effort sessions
w_i	A weight that is associated with session *i*
s_{ij}	The signal strength that a user requesting session *i* connection receives from AP *j*
s_{th}	The received signal strength threshold
r_{ij}	The data rate that a that a user requesting session *i* connection can communicate with AP *j*
r_{max}	The maximum data rate that a user can communicate with AP
J	A set of access points (APs) in the system
I	A set of all incoming sessions in the system
I_1	A set of multimedia sessions
I_2	A set of best effort sessions
x_{ij}	A binary {0, 1} variable that equals 1 if the session *i* is associated to AP *j*; 0 otherwise

A. Maximum Signal strength First

The Maximum Signal strength First (MSF) is the association control scheme that connects an incoming session with the access point (AP) that provides highest signal strength. As a result, the user will be able to communicate with the AP at the highest data rate available in that environment.

MSF can be mathematically described as a linear programming model that aims to maximize the received signal strength of the connected sessions. The mathematical formulation is written as follows:

$$Maximize \quad \sum_{\substack{j\in J\\ j\neq 0}} \sum_{i\in I} x_{ij} s_{ij} \qquad (1)$$

Subject to

$$\sum_{i\in I} w_i x_{ij} \quad \leq \quad N_{\max} \qquad , \forall j \in J, j\neq 0 \qquad (2)$$

$$x_{ij}\left(s_{ij} - s_{th}\right) \quad \geq \quad 0 \qquad , \forall i \in I, \forall j \in J, j\neq 0 \qquad (3)$$

$$\sum_{j\in J} x_{ij} = 1 \qquad , \forall i \in I \qquad (4)$$

Constraint (2) specifies the capacity limitation at each AP in order to guarantee quality of services to all connected sessions. Since different applications can be generated by users, each requesting session is associated with a weight w_i that depends on the service contract. The weight value of the best effort application, such as a file transfer and email, is set to 1 whereas that of the multimedia application, such as voice or video online, is set to 3.8 [6]. Constraint (2) computes the equivalent number of sessions that can be connected to AP which is limited by N_{max}.

Constraint (3) assesses the signal strength that the user of session *i* receives from AP *j*. It specifies that x_{ij} can be equal to one (i.e., the session *i* can connect to AP *j*) if the received signal strength from AP *j* is greater than the threshold s_{th}. Constraint (4) specifies that each connection can associate to one AP. Note that incoming session that is dropped due to the capacity limitation specified in constraint (2) will be associated to AP *j*=0 (AP for dropped requests).

B. Minimum Load First

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 (2)-(4) in the MSF model.

$$Maximize \quad \sum_{\substack{j\in J\\ j\neq 0}} \sum_{i\in I} x_{ij} \qquad (5)$$

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.

C. Hybrid Approach

We propose a new association control scheme, namely the Hybrid Approach (HA) that considers not only the priority of applications requesting connections but also the load balance among APs in the system. For multimedia applications which mostly are delay sensitive applications, an incoming session will be associated with AP providing the highest signal strength in order to achieve the highest data rate. 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.

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HA can be written as a linear programming model that aims to maximize the sum of functions f_1 and f_2 where f_1 is a normalized function that measures a data rate level of multimedia sessions and f_2 is a normalized function that measures the number of best effort sessions that can be associated with APs in the system. The constraints of the model are the same as the constraint (2)-(4) in the MSF model.

$$Maximize \quad f_1 + f_2 \tag{6}$$

where

$$f_1 = \left(\sum_{\substack{j\in J \\ j\neq 0}} \sum_{i\in I_1} \frac{x_{ij} r_{ij}}{r_{\max}} \right) \Big/ |I_1| \tag{7}$$

and

$$f_2 = \left(\sum_{\substack{j\in J \\ j\neq 0}} \sum_{i\in I_2} x_{ij} \right) \Big/ |I_2| \tag{8}$$

III. Simulation Study and Analysis

We conducted simulation studies in order to demonstrate the performance of the proposed hybrid load balancing and association control scheme. We consider a system of two APs locating in a 2-dimensional space with 75% cell overlapping area as shown in Fig. 1. The physical data rate at which the transceiver operates depends on the level of signal strength received from AP. The signal strength thresholds of -75/-79/-81/-84 dBm are used for data rate of 11/5.5/2/1 Mbps, respectively [10].

We consider wireless users generating both multimedia and best effort traffic in the cells. We assume traffic arrival and service process are Poisson process. For the system offered load of 0.4, mean interarrival time and mean service time of both traffic types are 0.25 and 10, respectively. We run simulation studies for different system offered load varying from 04. to 1.4. For the higher offered load, mean interarrival time is decreased whereas mean service time is kept the same. Furthermore, we assume that locations of wireless users are uniform-randomly distributed in the cell areas.

In the simulation study, we consider that the multimedia traffic profile requires an average throughput of 380Kbps (such as the video conference) and the best effort traffic requires an average throughput of 100Kbps [6]. In order to satisfy the quality of services requirement of those applications, we set N_{max} = 60 (the maximum number of sessions that can be associated to each AP) and set the weight associated with the multimedia and the best effort traffic at 3.8 and 1, respectively [6].

We compare performance of the three schemes (MSF, MLF, and HA) described in the section II in term of the percentage of blocking due to the overload at the AP and the number of multimedia sessions at different physical data transfer rates.

Fig. 2 illustrates the percentage of blocking as a function of the system offered loads. We can see that as the offered load increases, for all control schemes, the percentage of blocking

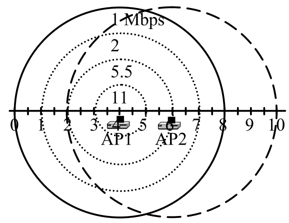

Fig. 1 System model for simulation studies

increases and when the offered load is higher than 0.6, the percentage of blocking using MSF scheme is greater than that from the other two schemes of which the blocking are about the same. We also observe that as the offered load increases the gaps between the percentage of blocking from the MSF scheme and that from the MLF (or HA) scheme becomes larger. The reason is as follows. In the system using the MSF scheme, an incoming session is associated with the AP that provides highest signal strength in the vicinity. As a result, traffic load may not be able to distribute to other APs, causing higher blocking than that in the system using the MLF scheme which tries to associate incoming session with an AP that has least load in the area. The HA scheme allows the multimedia sessions to associate to AP that gives highest signal strength in order to be able to communicate at the highest possibly data rate whereas the best effort sessions are distributed to AP with low load in order to maintain traffic balancing. As we can see from Fig. 2, the HA scheme results in low blocking percentage like that of the MLF scheme. Furthermore, the HA scheme, like the MSF scheme, can provide higher data rate to multimedia sessions than that of the MLF scheme. As we can see in Fig. 3 (the system offered load = 0.4) that MSF and HA yield more than ten multimedia sessions that have data transfer rate at 11 Mbps whereas MLF results in five multimedia sessions at 11 Mbps. As the system offered load increases, HA can provide more number of multimedia sessions at high data rate than that of MSF. As shown in Fig. 4 (the system offered load = 1.0), HA yields 28 multimedia sessions at 11 Mbps whereas MSF yields 26 multimedia sessions at 11 Mbps.

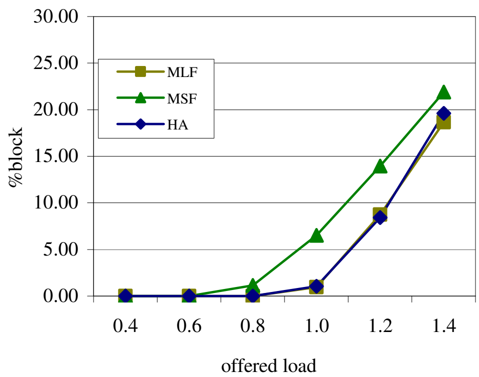

Fig. 2 Percentage of blocking at different system offered loads

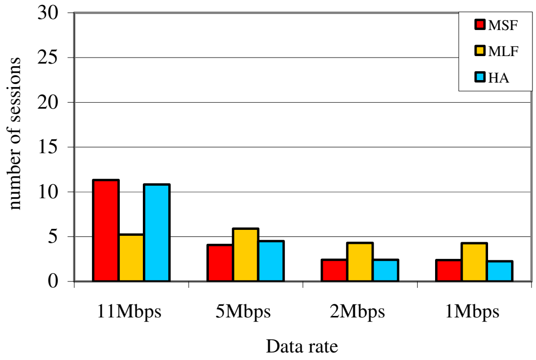

Fig. 3 The number of multimedia sessions at different data rates (system offered load = 0.4)

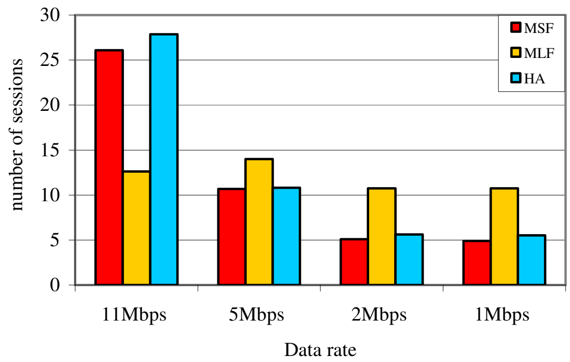

Fig. 4 The number of multimedia sessions at different data rates (system offered load = 1.0)

IV. Conclusion

Although several research works have been carried out to support the multimedia and real-time applications in WLANs, there are opening problems to the traffic admission control and the load balancing issues. In This paper, we enhance the priority differentiation specified in the IEEE 802.11e EDCA by proposing a hybrid association control scheme and load balancing techniques. We first derive mathematical description of the proposed scheme as a linear programming problem. Simulation studies and results show that the proposed scheme can greatly improve the network efficiency in term of the percentage of blocking and the quality of the data transfer rate providing to the multimedia and real-time applications.

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