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QoS Aware Access Point Selection for Pre-load-balancing in Multi-BSSs WLAN

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***Abstract*—This paper presents an AP selection strategy in the office environment covered by WLAN. While most of the selection metrics balances the active load among neighboring BSSs, the quality of voice applications greatly depends on the call blocking probability which is decided by all the potential voice STAs. For this reason, we define a QoS-aware information element that is advertised from APs. On this basis, voice stations are able to select the AP which is associating with less number of voice stations so as to achieve a lower call blocking probability. In order to validate the benefit, we perform simulation using OPNET. As a result, the proposed method effectively balances the load among given BSSs, and greatly increases the number of voice calls that could be admitted into WLAN.**

***Index Terms*—AP selection, load balancing, QoS, VoWLAN, call blocking probability, WLAN**

I. INTRODUCTION

RECENTLY the Wireless Local Area Network (WLAN) has been widely deployed in offices to facilitate the high-speed broadband access. Not only can internet be accessed anywhere inside the working site, but employees are easily reached at a low cost via the Voice over WLAN (VoWLAN). For example, the Passage Duple system, M-zone service, etc. has successfully attracted more and more customers and hence bringing higher revenue [1].

The most popular enterprise WLAN systems are based on the IEEE802.11standard [2]. One Access Point (AP) taking charge of the coordination function, and its associated stations (STAs), constitute the Basic Service Set (BSS) for WLAN. On this basis, multiple overlapping BSSs are typically configured on different channels to provide extensible coverage and enhanced capacity [3], as shown in Fig.1. For a STA accessible from more than one AP, which AP it shall associate with would determine the BSS load, and further impact the WLAN performance. Especially when the contention based medium access policy is adopted by IEEE802.11, AP selection is of great significance by balancing the load to overcome the throughput degradation.

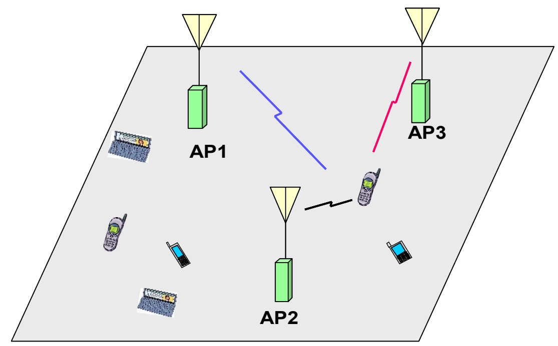

Fig. 1 Access point selection in Multi-BSS WLAN

In this paper we examine the features of enterprise WLAN in a large-scale office environment. In particular the necessity is raised to consider the call blocking probability when performing AP selection for voice applications. Keeping this in mind, we propose a Quality of Service (QoS) differentiated information element (IE). By inserting it into frames advertised from APs, STAs can be balanced via AP selection and hence reduces the probability of being rejected when initiating a call. In the rest of the paper, Section II states the problems that are targeted for the AP selection study. Section III presents the proposed IE that enables the pre-load balancing and explains the procedure on this basis. Furthermore, we perform the simulation in Section IV to evaluate the performance and finally make a conclusion in Section V.

II. PROBLEM STATEMENT

In majority of the WiFi products, AP selection is based on the

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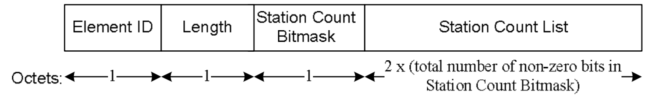
Received Signal Strength (RSS) captured by a STA over each candidate channel. To balance the load, some selection metrics are presented in difference aspects. They could be the load state information in terms of the number of STAs and the aggregate data transmission rate at each AP [4]. They may further be the potential bandwidth estimated based on the delay experienced by beacon frames [5]. Even the direction of movement could be considered to predict the expected load level in case of dynamic scenarios [6]. Given their efforts on pursuing the load fairness among adjacent BSSs, however, none of them have taken into account the QoS of the STAs which result in different weights on their contributions to the BSS load due to their differentiated access priorities. For example, IEEE802.11e [7] enables four access categories (ACs), i.e. voice (VO), video (VI), best effort (BE) and background (BK), and allows different parameters for contending the channel. As voice application is sensitive to the delay, the AC_VO is prioritized by setting shorter contention window and inter-frame space so that the STAs corresponding to other ACs are likely to be preempted. Therefore, while the VoWLAN is exploding together with the large-volume data and video transfer, the higher prioritized AC should be treated with more emphasis when performing AP selection.

IEEE802.11 standardization has launched two task groups, 802.11v, 802.11k, standardizing the management and measurement issues in WLAN. In the draft, some QoS aware IEs have been adopted which are considered as helpful for STAs to select an AP that is likely to accept the future admission control requests. Typical IEs include [8]: 1) BSS Available Admission Capacity, which specifies the remaining amount of medium time available using explicit admission control for corresponding AC traffic. 2) BSS AC Access Delay, a scalar indication of the average access delay at an AP for services for each of the indicated ACs. These IEs show the active load currently ongoing in the BSS, however, they do not reflect the potential part arising from those STAs that are inactive at this moment but may be activated some time later. As the time instant that a STA performs AP selection is not necessarily the instant when a voice call request is initiated, the probability that the call could be admitted is decided by both the active and inactive loads while admission control is enabled.

We take the typical office environment in Japan as example. It is quite common that tens of employees located in one floor are associated with one AP. Given the bursty traffic arrival, the active load may vary unexpectedly in time scale. Considering the call blocking probability for voice applications, the number of voice STAs including active and inactive ones provides a reasonable reference for balancing the load prior to traffic starts. Therefore we present a new IE, AC station count, and propose advertising such information to STAs for pre-load balancing.



(a) AC Station Count element format

Bit (s)	Station Count reported	Description
0	AC_BE	Best Effort
1	AC_BK	Background
2	AC_VI	Video
3	AC_VO	Voice
4~7	Reserved	Others

(b) Station Count Bitmask encoding example

Fig.2 Proposed AC station count information element

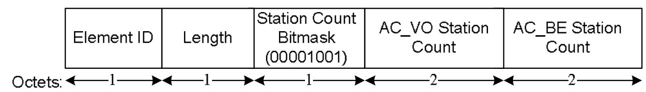


Fig.3 Exampled AC station count information element

III. AC STATION COUNT BASED PRE-LOAD BALANCING

A. *Access Category (AC) Station Count Element*

In consistence with the format adopted by the IEEE802.11 standards, we presented this AC Station Count element in the 802.11v task group, who accepted the proposed element in their draft standard [9]. As shown in Fig. 2 (a), it mainly constitutes two fields to indicate the number of stations corresponding to respective ACs:

1) Station count bitmask, which indicates the ACs that have station count specified in the following Station Count List. Fig.2 (b) shows an exampled encoding for bitmask. The bit set to “0” is to indicate that the Station Count for the corresponding AC is not present in the Station Count List field.

2) Station count list, which comprises a sequence of Station Count fields corresponding respectively to the non-zero bits in the Station Count Bitmask field. The Station Count field specifies the number of stations that are currently associated with this BSS for the corresponding AC.

In this element, the use of bitmask is to provide flexibility for the contents in the proposed element. Considering the overhead, only the STA count corresponding to the highest prioritized AC can be included when it is transmitted at low data rate, e.g. in a beacon frame. We illustrate an example of bitmask setting in Fig.3. By setting Bit#0 and Bit#3 to “1”, the station counts are

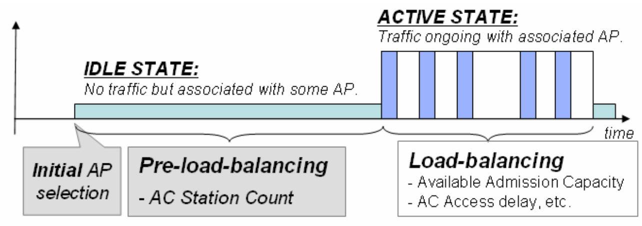


Fig.4 Definition of Pre-load-balancing in WLAN

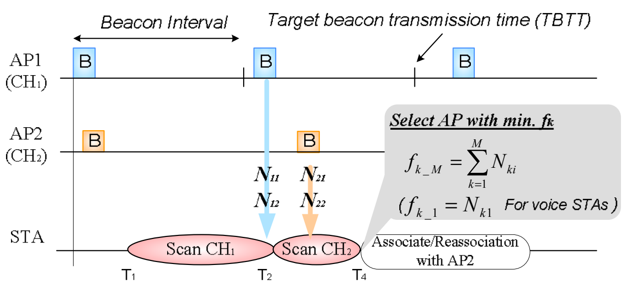


Fig.5 AP selection procedure by using proposed IE

followed corresponding to AC_BE and AC_VO respectively.

B. AC Station Count based AP Selection metric

Given that the higher prioritized AC is likely to preempt the transmission opportunity of other ACs, as stated in Section II, we propose selecting an AP based on the AC for a STA, and the number of STAs with equal or higher priority than itself. Let k indicates the index for non-overlapping channels, i.e. $k = 1,\ldots, K$. The ACs are indexed by $i = 1,\ldots, m$ in decreasing priority order, i.e., the lower priority services are assigned the larger numbers. In case of IEEE802.11e, $m = 4$, corresponding to VO, VI, BE and BK respectively. We use N_{ki} to denote the station counts corresponding to the i^{th} AC over the k^{th} channel, which is extracted from the proposed AC Station Count IE. For a STA corresponding to the M^{th} AC, the selection metric is expressed as:

$$f_{k\_M} = \sum_{i=1}^{M} N_{ki} \qquad (1)$$

By calculating such metric over all the K channels, the AP from which the least value of f_{k_M} is obtained shall be selected for association. Particularly, when $M = 1$, i.e. for a voice STA, $f_{k\_1} = N_{k1}$, which means it shall selects the AP to which the least number of voice STAs are currently associated.

C. Pre-load-balancing via AP selection

On the basis of proposed AC Station Count IE, we propose using the metric f_{k_M} to pre-balance the load. For explicitly Fig.4 illustrates the states a STA is possible to be in WLAN, and the load balancing definition in respective states.

According to IEEE802.11, a STA shall scan, either passively or actively, all available channels and selects an AP to associate with

TABLE I
SIMULATION PARAMETERS SETTING

Parameters	Values
Office area size	200*200 m^2
Number of STAs in office	64
Average call Inter-arrival time period	10 minutes, exponential
Average length per call	3 minutes, exponential
Voice packet size	160 bytes, constant
Packet inter-arrival time period	20 ms, constant
Data transmission rate	11 Mbits/second
EDCA parameters for AC_VO at STAs	AIFS = 2, CWmin = 7
EDCA parameters for AC_VO at APs	AIFS = 1, CWmin = 7
Beacon Interval	100 ms
Max number of admitted STAs by an AP	10
Simulation running time	60 minutes

EDCA: Enhanced Distributed Channel Access

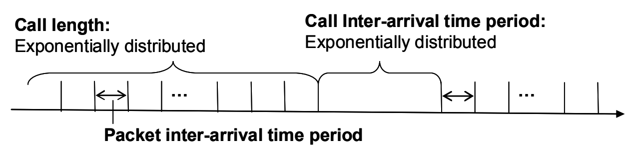


Fig. 6 Traffic model for voice applications

when camping on WLAN, which is said to be "initial AP selection". After that, the STA keeps alternating between IDLE and ACTIVE state until it quits from the system.

Herein, the IDLE state means a STA is associated with an AP but having no traffic ongoing, such as a person who has his/her mobile power-on but no calls at the moment. We name the AP reselection process in this state as "Pre-load-balancing". It aims at providing potentially equalized load to avoid congestion in case of traffic arrival. Specifically the decrease of call blocking probability for voice applications can be expected. Since the pre-load-balancing is a preparation for future transmission, the overall potential load should be referred. We therefore propose selecting the AP based on the proposed IE as expressed in (1). It is noted that such pre-load-balancing does bring some overhead because of power consumption on scanning the channel in IDLE state. Given the semi-static WLAN scenarios, it is suggested to perform pre-load-balancing at a long time interval.

Comparatively the ACTIVE state starts upon traffic initiation. When a STA detects performance degradation or unsatisfied QoS for the ongoing transmission, it may reselect an AP. At this moment, the AP with the least active load level, e.g. the least Admission Available capacity, should be selected. Given these three stages, different AP selection metrics could be adopted independently. We evaluate the proposed metric by applying it to the initial AP selection and/or pre-load-balancing process.

D. AP (re)selection procedure for Pre-load-balancing

With the metric in equation (1), we show the operation flow of the AP selection for pre-load-balancing in Fig. 5. The passive scanning, as defined in IEEE802.11, is illustrated here without loss of generality. We assume that neighboring APs are operation in the non-interfering channels, which is possible by careful channel planning.

As shown in the figure, beacon frames are advertised by AP periodically including some BSS-specific load information. We propose inserting the AC Station count element into the beacon, or the Probe Response frames. As an example, the beacon indicates the number of voice STAs and BE STAs as N_{k1}, N_{k2} respectively (k is the channel index). A STA, upon detection of beacons from an AP, is therefore able to extract such information and calculate the metric based on the AC of the STA itself. Not until all the available channels have been scanned shall the station select the AP which corresponds to the least value of f_{k_M}.

IV. PERFORMANCE EVALUATION

To examine the efficiency of pre-load-balancing we deploy the simulation using the OPNET tool wherein the IEEE802.11e based WLAN module is provided. Three APs are configured respectively on channel #1, #6 and #11 and serve the whole office area at a size of 200 meter square simultaneously. In the scenario, two third of the voice STAs are located around AP2 while the others are randomly distributed. The traffic model for voice application is shown in Fig. 6. Traffic arrival is assumed to follow Poisson distributions, parameterized by the call inter- arrival time period. The length of a call shows the serving time and is taken as exponential distribution. Corresponding to Fig. 4, the STA is supposed to be in ACTIVE state during the length of a call, while the call inter-call arrival time period corresponds to the IDLE state. The proposed pre-load-balancing may occur only within the call inter-arrival time intervals. In summary we list all the simulation parameters in Table I.

We compare the following methods to evaluate the proposal: 1) RSS-based initial AP selection without pre-load-balancing 2) RSS-based initial AP selection with pre-load-balancing 3) Available capacity based initial AP selection without pre-load-balancing, i.e. select the AP corresponding to the least channel occupation at the moment 4) Available capacity based initial AP selection with pre-load-balancing. Given the QoS requirements for voice sessions, admission control is also enabled in the simulation by limiting the number of admitted voice sessions to a pre-defined threshold. We use Add Traffic Stream (ADDTS) request and response frame exchange for this purpose. When a STA is initiating a call, it shall send ADDTS request to the AP asking for admission. Only when the current number of ongoing

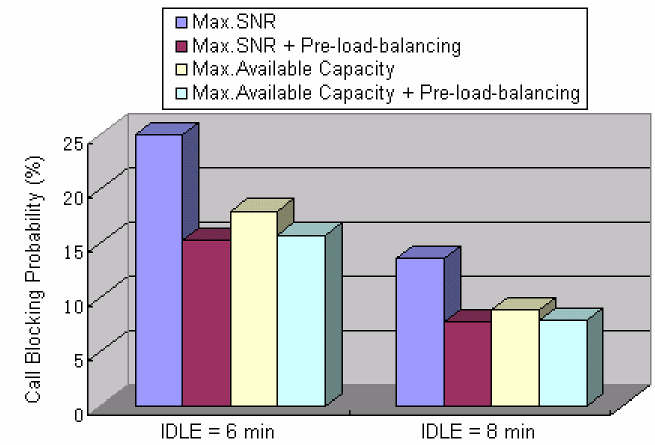


Fig. 7 Performance of call blocking probability

voice sessions does not exceeded the maximum allowed number can the call be admitted by the AP. Otherwise, it will be rejected and results in the a blocked call. Herein the maximum ten voice sessions are allowed from the experience value for 11Mbps WLAN.

Figure 7 shows the performance in terms of the call blocking probability for voice applications when the IDLE period equals to 6 and 8 minutes respectively. When RSS based initial AP selection is adopted, the STAs tend to select the AP from which the strongest signal is detected. As more STAs are located around AP2, the calls initiated within this BSS are more likely to be blocked if the current number of ongoing sessions exceeds ten. As seen from the figure, 25% and 12% of the call attempts are rejected because of admission control. By using the pre-load-balancing, some STAs are redirected to other APs beforehand so that less call attempts are rejected at the moment of call initiation which results in the significant reduction of call blocking probability to 15% and 6% respectively. Moreover we compare the scenarios where pre-load balancing is applied combined with different initial AP selection criteria. It is seen that the performance is almost irrelevant to the AP initial selection policy. The pre-load balancing is able to efficiently correct the load imbalance no matter how the initial access result would be.

In figure 8, we present the throughout performance among respective BSSs for the four compared cases. We find that for the Max.SNR selection method, the BSS2 throughput is almost double of that in the other two BSSs, which results from the 2/3 STAs associated with AP2. While for the Max.SNR combined with pre-load balancing, similar throughputs are achieved for the three BSSs, as some STAs who initially associate with AP2 reselect an AP with less number of associated voice STAs based on the proposed AC STA count IE. Comparatively, when the Max. Available Capacity is adopted for initial AP selection, the load

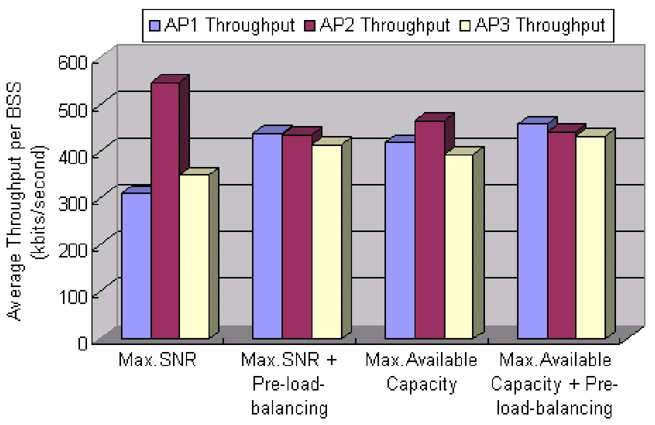


Fig. 8 Throughput performance among three BSSs respectively

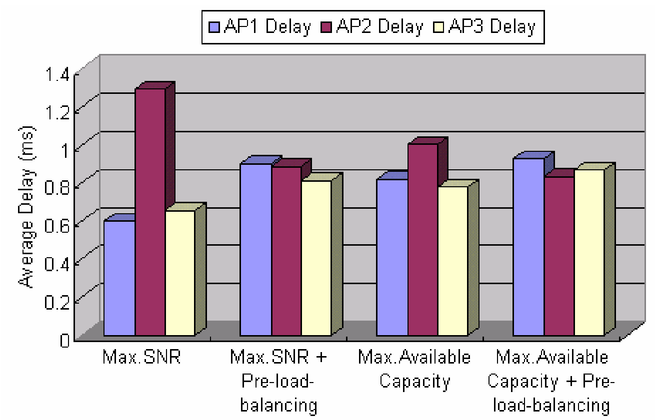


Fig. 9 Delay performance among three BSSs respectively

could be somewhat balanced even without using pre-load balancing as the Available capacity based selection could divert some STAs to BSS1 and BSS3. However, the BSS2 throughput is still 15% higher than that of BSS3. The proposed pre-load balancing further averages the throughput by diminishing such difference efficiently.

In addition to the throughput performance as above, we also illustrate the delay in figure 9, which is defined as the average time a packet experiences from the time instant it is generated at the higher layer to the time instant it is correctly received by the destination or discarded from high-layer queue. As is shown, the delay is also averaged among the three BSSs, which is quite helpful to provide satisfactory quality of service for the delay-sensitive applications.

V. Conclusion

In this paper we presented an efficient AP selection strategy and used it for pre-load-balancing in a multi-BSS WLAN system. Motivated by the burst traffic characteristics, we propose an Access Category Station Count element to specify the number of stations including both active and inactive ones. By inserting such information into advertised frames from APs, the STAs are able to reassociate with the APs that are not the strongest one but with less potential load. Especially for voice applications that require stringent QoS, the potential load greatly affect the call blocking probability a STA is expected to experience. On the other hand, the QoS category for the proposed IE helps differentiate the services in terms of accessing the channel. The proposed AP selection metric therefore emphasize the load that corresponding to the equal or higher priority than the STA itself.

We further evaluate the performance by comparing the cases when the pre-load-balancing is used and not used. The results show that the proposal efficiently balances the load among the BSSs and hence increases the probability that a call could be admitted by the WLAN. Following current stage of study, we shall further simulate the performance given dynamic scenarios with mobile stations, and compare with other AP selection strategies to convince its benefits.

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