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A New Measurement-Based Admission Control Method for IEEE802.11 Wireless Local Area Networks

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***Abstract*-The upcoming IEEE802.11e standard supports the applications with QoS requirements by using differentiated medium access mechanism for different traffic categories. In order to protect the high priority data flows and improve network performance in a heavy-loaded IEEE802.11e network, a new measurement-based distributed call admission control method is introduced in this paper. The proposed method is based on the measurement of the existing traffic load over IEEE802.11e network. Depending on the amount of the existing traffic load, the admission controller decides whether or not to allow a data unit to have the right to access the wireless medium. The simulation results show that the proposed mechanism works well.**

I. Introduction

IEEE802.11 wireless local area network (WLAN) is a shared-medium communication network that transmits information over wireless links for all 802.11 stations in its transmission range to receive. It is one of the most deployed wireless networks in the world and is high likely to play a major role in the wireless home networks and next-generation wireless communications. IEEE802.11 wireless networks can be configured into two different modes: ad hoc and infrastructure modes. In ad hoc mode, all wireless stations within the communication range can communicate directly with each other, whereas in infrastructure mode, an Access Point (AP) is used to connect all stations to a Distribution System (DS), and each station can communicate with others through the AP.

With the applications over 802.11 WLAN increasing, the customers demand more and more new features and functions. The support of audio, video, real-time voice over IP and other multimedia applications over 802.11 WLAN with Quality of Service (QoS) requirements is the key for 802.11 WLAN to be successful in multimedia home networking and future wireless communications. Accordingly, IEEE 802.11 working group is currently working on a new standard called 802.11e to enhance the original 802.11 MAC (Medium Access Control) sublayer to support QoS [1]. The basic medium access method of original 802.11 MAC is called DCF (Distributed Coordination Function), which is based on CSMA/CA (Carrier Sense Multiple Access/Collision Avoidance) protocol. DCF is best known for its asynchronous best-effort data transfer [2]. In order to support QoS in 802.11 WLAN, the upcoming IEEE802.11e standard adds a new function called HCF (Hybrid Coordination Function). The HCF uses a contention-based channel access method called the enhanced DCF (EDCF) that operates concurrently with a controlled channel access mechanism that is based on a central polling mechanism.

EDCF is the enhanced version of DCF. In EDCF, the QoS support is realized through the introduction of 8 prioritized traffic categories (TCs). EDCF channel access defines the access category (AC) mechanism that provides support for the priorities at the stations. Each station may have up to 4 ACs to support 8 prioritized TCs. One or more TCs are assigned to one AC. A station accesses the medium based on the access category of the frame that is to be transmitted. The prioritized medium access of EDCF is realized by assigning different arbitration inter-frame spaces (AIFS) and contention windows (CW) to different ACs. An AC with higher priority is assigned a smaller AIFS and shorter CW in order to ensure that in most cases, higher-priority ACs will be able to transmit before the lower-priority ones. Since each AC is implemented as a virtual station, the collision rate increases quickly as the number of stations increases. This will significantly degrades the network throughput and increase medium access delay. In order to protecting the existing data flows, 802.11e also includes distributed admission control procedure [1]. In the procedure, AP measures the amount of the time occupied by transmission for each AC during each beacon interval. The AP then computes the transmission budget for each AC by subtracting the occupied time from the transmission limit of this AC. When the transmission budget for an AC is depleted, new node will not be able to gain transmission time, and existing nodes will not be able to increase the transmission time that they are already using during the next beacon period. This admission control algorithm performs well in term of protecting data flows. However, it is complicated for implementation, and it is not applicable in ad hoc mode due to the involvement of AP in this algorithm. This paper presents a new distributed admission control method for 802.11 WLAN. The proposed method is based on the measurement of the existing traffic load over IEEE802.11e network. In the proposed method, each station measures the traffic load on the wireless medium. Depending on the amount of existing traffic load and priority level of the data packet waiting for transmission, the admission controller makes decision on whether or not to allow the data unit to have the right to access the wireless medium. The proposed method applies to both ad hoc and infrastructure network configurations. The details of the proposed method will be described in the following.

II. The Proposed Admission Control Method

The admission control function decides whether a new connection can be granted or not, depending on the status of the network resources and the level of service called for by the new request. The purpose of any admission control is to ensure that admittance of a new data flow into a resource-limited network does not degrade QoS committed by the network to the admitted data flows while optimizing the network resource usage. So, admission control is a key component of QoS–based resource management schemes. Several measurement-based admission control algorithms have been proposed in the literature of high-speed networking [3] [4] [5] [6]. However, few of them focused on IEEE802.11 wireless networks especially 802.11e networks. There are certain issues that have to be addressed for the measurement-based admission control in an 802.11 network. In the proposed scheme, we consider a service set (SS) that includes *N* 802.11e wireless stations. Since the proposed scheme works in both ad hoc and infrastructure modes, the assumed service set could be a basic service set (infrastructure mode) or independent basic service set (ad hoc mode). A SS is a terminology used in IEEE802.11 standard that is equivalent to the cell in cellular communications. If it is a basic service set, the AP will be considered as a wireless station that is identical to the other wireless stations. According to IEEE802.11e standard, each station may have up to 4 ACs represented by AC(i), i= 0, 1, 2, 3. The access priority is increasing with i ascending. That is, AC(3) has the highest medium access priority, while AC(0) possesses the lowest priority. The proposed method requires that each station in the SS to measure the traffic condition (traffic load) on the wireless link. When the traffic load on wireless medium is greater than a threshold, this means that the 802.11 wireless network is experiencing the overload, long medium access delay and possible the degradation of throughput. The station will stop the transmission of the data flows with lower priority to ensure that the high priority dada flows continue to received their requested QoS as much as possible. When the traffic load on wireless medium is smaller than a given threshold, this means that the 802.11 wireless network is insufficiently used. The station will resume the transmission of the stopped data flows to increase the network efficiency. Depends on how the traffic condition is measured and computed, the proposed method can be implemented in the following two ways.

A. Relative Occupied Bandwidth Method

In this method, the proposed admission control mechanism uses a time window to measure the amount of time used for transmission during a fixed sampling period, T. The amount of time used for data transmission is the time when the wireless medium is busy, no matter the transmission is successful or not. As shown in Figure 1, the amount of time when the wireless medium is busy, T_{Busy}, is defined as follows,

$$T_{busy} = \sum_i t_i \qquad (1)$$

Where t_i is the occupied time of the ith transmission. The relative occupied bandwidth, B_{occu}, can be written as

$$B_{occu} = \frac{T_{busy}}{T} \times 100\% \qquad (2)$$

The relative occupied bandwidth indicates at what percentage the wireless medium is being used. Let B_{lo}, B_{up} be the given lower and upper thresholds for B_{occu}. B_{lo}, B_{up} can be empirically obtained from simulations and/or calculations. When $B_{occu} \geq B_{up}$, the network is considered overloaded. When $B_{occu} \leq B_{lo}$, the medium is considered to be under use, more traffic can be admitted without the degradation of QoS performance. When $B_{lo} \leq B_{occu} \leq B_{up}$, the network is considered to be at an optimal state. The admission control mechanism likes to keep the network at this state. The criteria to admit data flows can be summarized below:

1) $B_{occu} \leq B_{lo}$: Admit the inactive AC with highest priority during next *T* period. If no inactive AC available, the station takes no action. If there are 2 or more inactive ACs, the one with highest priority will be admitted.
2) $B_{lo} \leq B_{occu} \leq B_{up}$: No action taken.
3) $B_{occu} \geq B_{up}$: Stop the transmission of lowest active AC during next T period. If no more than 1 active AC available, the station takes no action. If there are 2 or more active ACs, the one with lowest priority will be stopped.

An active AC means the AC that is allowed to be admitted, while an inactive AC represents the AC that is refused to be admitted. Each station computes B_{occu} every *T*, and then compare B_{occu} with B_{lo} and B_{up} to decide which action should be taken during next *T* period according to the above admission criteria. This proposed admission control method will protect high priority ACs, while optimize the network performance.

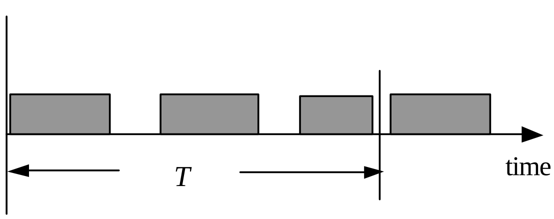

Figure 1. The occupation of wireless medium

This measurement can be easily implemented in 802.11e. Since EDCF uses CSMA/CA medium access protocol, a station has to sense the medium and check NAV (Network Allocation Vector) vector to see if the medium is idle for transmission. It actually doesn't need to add much complexity to compute T_{busy}. Whenever there is transmission on wireless link, NAVs of all stations will be set to indicate the medium is busy. A station can easily compute T_{Busy} by adding a counter to count the time when NAV is set. The commonly used beacon interval of 802.11 wireless networks can be used as the sampling period *T*.

B. Average Collision Ratio Method

In this method, the proposed admission control mechanism uses a time window to measure the average collision ratio during a fixed sampling period, T. The average collision ratio is defined as the number of collisions occurred over the total number of transmissions (include retransmissions). Indeed, the average collision ratio indicates the traffic load over the wireless medium. The average collision ratio, R_c, can be represented as follows,

$$R_c = \frac{N_c}{N_t} \tag{3}$$

Where N_c is the number of collisions occurred, N_t is the total number of transmissions.

Each station in the SS calculates its own R_c. Let R_{lo}, R_{up} be the given lower and upper thresholds for R_c. R_{lo} and R_{up} can be empirically obtained from simulations and/or calculations. When $R_c \geq R_{up}$, the network is considered overloaded. When $R_c \leq R_{lo}$, the network is considered under loaded, more data traffic can be admitted without the degradation of QoS performance. When $R_{lo} \leq R_c \leq R_{up}$, the network is considered to be at an optimal state. The admission control mechanism likes to keep the network at this state. Similar to the relative occupied bandwidth case, the criteria to admit data flows can be summarized below:

1) $R_c \leq R_{lo}$: Admit the highest inactive AC during next T period. If no inactive AC available, the station takes no action. If there are two or more inactive ACs, the one with highest priority will be admitted.
2) $R_{lo} \leq R_c \leq R_{up}$: No action taken.

3) $R_c \geq R_{up}$: Stop the transmission of lowest active AC during next T period. If no more than 1 active AC available, the station takes no action. If there are two or more active ACs, the one with lowest priority will be stopped.

Each station computes R_c every T, and then compare R_c with R_{lo} and R_{up} to decide which action should be taken during next T period according to the above admission criteria.

This measurement can be easily implemented in 802.11e. 802.11e already has the parameter of the number of retransmissions. Even though the total number of retransmissions includes both the retransmissions due to collisions and the ones due to erroneous frames received because of bad channel conditions, we still consider the total number of retransmissions is a good indicator of collision rate especially in the case the frame error rate is very small. In the case of high frame error rate, a more accurate method to estimate the number of collisions is needed. We here use the number of retransmissions to roughly estimate the number of transmission collisions. So, only two counters are needed to count the number of collisions and total of the number of transmissions during the period. The beacon interval of 802.11 wireless networks is also used as the sampling period T.

III. Preliminary Simulation Results

A simulation model for the proposed admission control mechanisms was constructed using OPNET. In the simulation, eight IEEE802.11 wireless stations with EDCF mechanism were configured into ad-hoc mode shown in Figure 2. For simplicity, only ad hoc mode was simulated. However, the proposed algorithms apply to both infrastructure and ad hoc modes. Eight stations remain stationary during the simulations. The simulation uses standard OPNET 802.11b PHY module with maximum data rate up to 11 Mbps to simulate the wireless medium [7]. While, the original 802.11 MAC was modified to support EDCF mechanism of 802.11e. All four traffic classes were fed into the MAC layer from higher layer, which are corresponding to AC(0), AC(1), AC(2) and AC(3) respectively. In the simulation, we assumed that each traffic class has the equal portion of the total data traffic in terms of the average number packets generated per unit time. The packets had the same size of 1024 bytes and remained constant during the simulation. The packets of AC(0), AC(1) and AC(2) were generated according to Poisson Process with a mean interarrival time equal to 0.001 second, while AC(3) packets were generated at a constant rate of 640 Kbps to simulate a voice source. In the simulation, the thresholds for admission criteria were set as $B_{lo} = 0.6$, $B_{up} = 0.8$, $R_{lo} = 0.5$ and $R_{up} = 0.7$.

The simulation results are shown below. Among them, Figure 2 and Figure 3 show the average medium access delays and throughputs for different cases. In Figure 2, As shown, the 802.11e WLAN without admission control has the largest medium delay and lowest average network throughput. While, the network with admission control based on the relative occupied bandwidth has the lowest medium access delay and highest throughput. The results of the network with admission control which is based on average collision ratio are in between. Figure 4 and Figure 5 show the medium access delay for different ACs in three different scenarios. From the figures, we can see that the proposed admission method can improve the medium access delays. The x-axis in the above four figures represent the simulation time in minutes. Compare with the scenario of no admission control, the proposed admission control algorithms improve the network throughput and reduce the medium access delays for high ACs. These results are as expected. The thresholds chosen above greatly affect the simulation results. It is very important that those four thresholds are appropriately chosen.

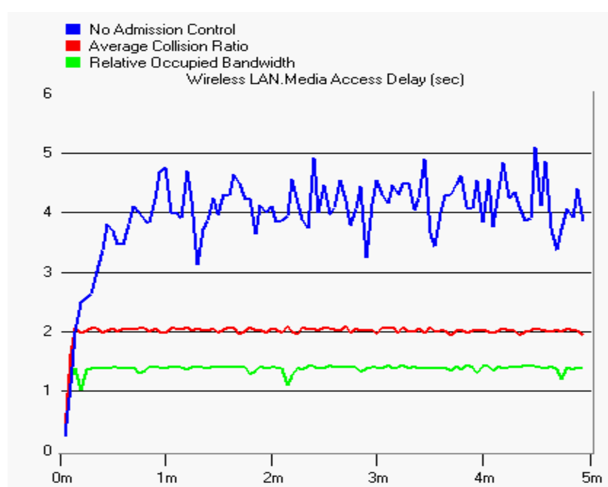

Figure 2: Medium Access Delay

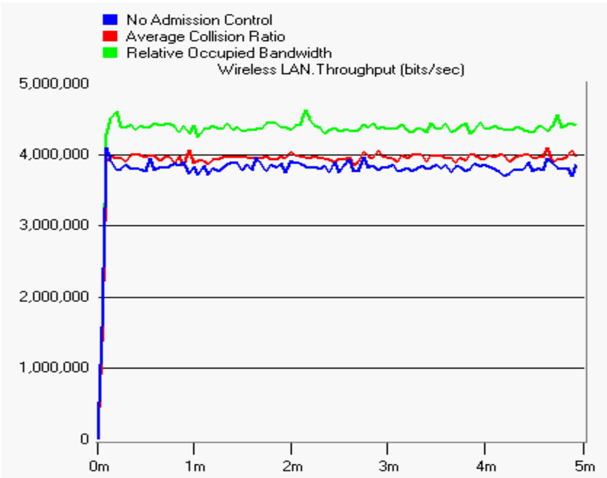

Figure 3: Network Throughput

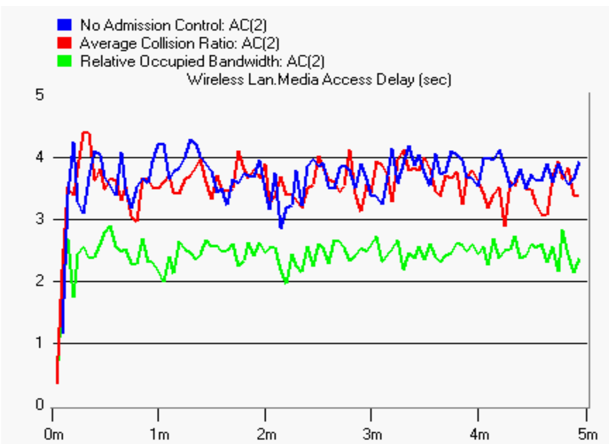

Figure 4: Medium Access Delay of AC (2)

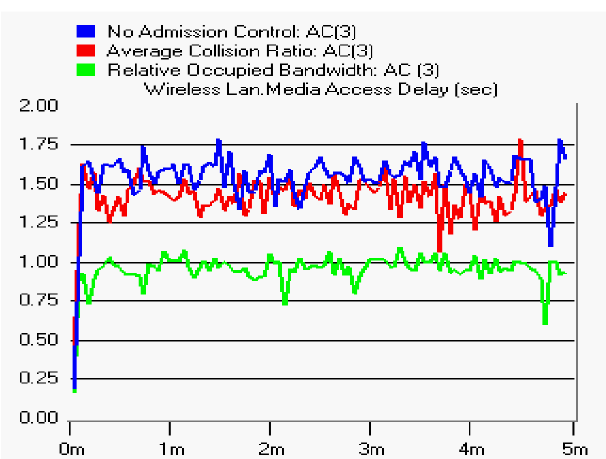

Figure 5: Medium Access Delay of AC (3)

IV. Conclusions

In this paper, a measurement-based admission control mechanism was proposed and described. The simulation results show that the relative occupied bandwidth method performs better than the average collision ratio method. In fact, the proposed mechanism can protect the high priority data flows. The future work could include the refine of the estimation of collision rate and optimization of the thresholds for the admission criteria.

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