Adaptive tuning of IEEE 802.11e EDCA for medical-grade QoS

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***Abstract*—In this paper, we propose an adaptive tuning algorithm for wireless medical applications to in order to meet medical-grade quality of service (QoS). The conventional IEEE 802.11e protocol is designed to satisfy a certain level of QoS, which is insufficient for medical-grade QoS. In the proposed algorithm, we adaptively tune the AIFS value of the IEEE 802.11e protocol for enhancing the overall network performance while providing the required medical-grade QoS. In our scenario, as representative applications, we consider medical alarms, ECG transmission, and TCP file transfer. We categorize these three applications according to their urgency. Then, we compare the performance of the proposed scheme with the conventional IEEE 802.11e protocol.**

I. INTRODUCTION

In hospitals, various devices are connected to patients with wires, which results in a crisscross of cables that might be a potential hazard for patient safety. In order to resolve this situation and to give more freedom to patients, wireless technologies are being adopted to hospital environments [1]-[3]. However, it is a challenging task to guarantee the required medical-grade quality of service (QoS) of various medical applications. Since medical-grade QoS is directly connected to the patient condition.

In this paper, we consider the problem of how to design a medical-grade wireless LAN. In particular, we consider to adjust the arbitration inter-frame space (AIFS) for improving the network performance. In our simulation study, we compare the performance of the proposed scheme with the conventional IEEE 802.11e and the absolute priority scheme in [6]. Our results show that the proposed scheme can give better TCP performance than the conventional IEEE 802.11e while maintaining the performance of ECG applications.

The IEEE 802.11e EDCA provides QoS for four different types of traffic, i.e., voice, video, best effort, and background traffic by defining access categories (ACs). It gives a shorter AIFS and sets a smaller contention window to higher priority traffic. Thus, high priority traffic has more chance to access the channel than low priority traffic. However, IEEE 802.11e is insufficient for guaranteeing the required medical-grade QoS. The IEEE 802.11e only provides relative priority to each traffic. In order to further enhance the QoS of IEEE 802.11e for medical applications, our scheme adaptively changes the AIFS value while maintaining the priority of traffic.

II. RELATED WORK

In general, there exist a plenty of previous studies on adaptive EDCA for improving IEEE 802.11e, e.g., [4], [5]. In a nutshell, most of the existing schemes adjust the contention window by setting more access categories or adaptively calculating a new contention window for enhancing the performance.

$$\mathrm{AIFS}_i = \begin{cases} \mathrm{AIFS}_0, & \text{if } i = 0, \\ \mathrm{AIFS}_{i-1} + \mathrm{CW}_{i-1}, & \text{otherwise.} \end{cases} \quad (1)$$

More recently, H. Lee et al. [6] design a medical-grade wireless LAN for healthcare facilities. They introduce the concept of absolute priority into medical environment, which sets AIFS as given in (1). For the highest priority traffic, i.e., i = 0, it gives the smallest AIFS. Hence, with the absolute priority scheme in (1), lower priority traffic has to wait its higher priority's AIFS and CW. In this manner, the high priority traffic can always be a winner regardless of the number of the lower priority traffic as long as they compete for the channel at the same time. However, absolute priority is so strict that lower priority traffic may not have enough change for channel access. Even without any high priority traffic, low priority traffic should wait for a large AIFS, which is a waste of the resource.

III. PROPOSED ALGORITHM

Our proposed algorithm changes the value of AIFS with respect to network condition. We use two metrics, i.e., packet delay and ratio of late packets over received packets. The typical QoS requirements for medical applications are summarized in [8]. For example, the maximum latency for alarm signals is 200 ms and hence, we set 100 ms as a threshold for the delay. In our scheme, the rule for setting AIFS is simple. We begin with default values for EDCA parameters as given in Table 1. Then, if the delay is larger than the threshold value or a late packet occurs, we adjust the value of AIFSN as given in (2).

$$\mathrm{AIFS} = \mathrm{SIFS} + (\mathrm{AIFSN} \times \text{Slot time}) \quad (2)$$

TABLE I
DEFAULT VALUES

	AIFSN	CW_{MIN}	CW_{MAX}
AC0 (high)	2	7	15
AC1	2	15	31
AC2	3	31	1023
AC3 (low)	7	31	1023

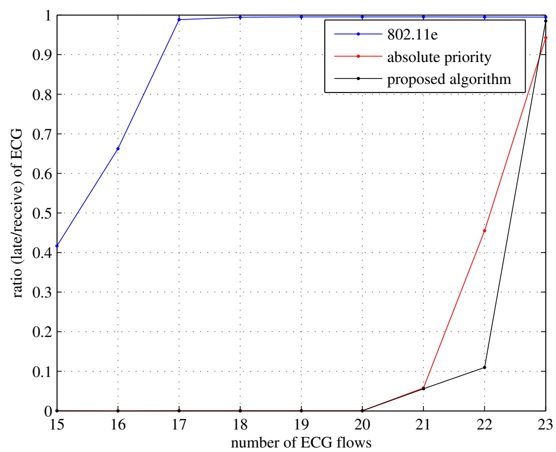

Fig. 1. Ratio of late packets over total received packets in ECG applications.

IV. SIMULATION

In our simulation environment, we consider medical alarms, ECG transmission, and TCP file transfer as representative applications. More specifically, there are three alarm nodes, 20 TCP connections, and we change the number of ECG nodes. We show the ratio of late ECG packets, which violate the delay constraint of 200 ms. In addition, we compare the TCP throughput performance for the conventional IEEE 802.11e, absolute priority [6], and the proposed algorithm.

Fig. 1 shows the ratio of late ECG packets for the conventional IEEE 802.11e, absolute priority, and the proposed algorithm. The IEEE 802.11e protocol shows that the ratio significantly increases with more than 15 ECG nodes, and saturates with 17 ECG nodes. Unlike the conventional IEEE 802.11e, the ratio of absolute priority and the proposed algorithm remains around zero until 20 ECG nodes. However, both of the schemes show a sharp increase and saturation with 23 ECG nodes. We suspect that the capacity of the network is full with 23 ECG nodes, which requires further investigation.

In Fig. 2, we show the TCP performance. It should be noted that absolute priority and the proposed algorithm use larger AIFS values for TCP transmission than IEEE 802.11e. Even though IEEE 802.11e has shorter AIFS, it gives worse TCP performance due to more frequent collisions.

V. CONCLUSION AND FUTURE WORK

We propose an adaptive algorithm for tuning the value of AIFSN according to the network situation. For performance comparison, we consider the conventional IEEE 802.11e protocol, the absolute priority scheme [6], and the proposed scheme. we measure the ratio of late ECG packets as well as TCP throughput. In our future work, we will consider to adjust more parameters for further enhancing the network performance.

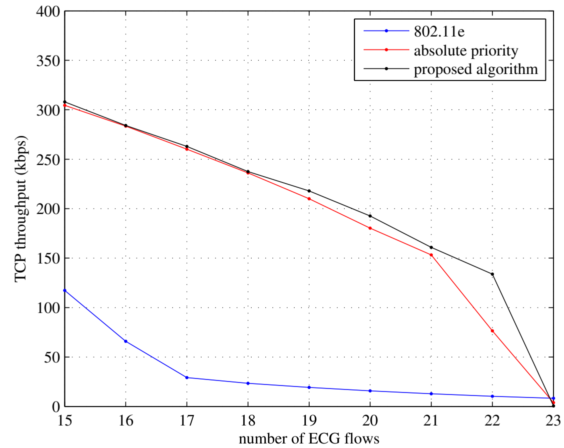

Fig. 2. TCP throughput performance.

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