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Contention Avoidance with Hop Based Priority in 802.11e Multi-hop Network

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***Abstract*--Wireless multi-hop networks offer lower network bandwidth and longer delay than wireless single-hop networks because of contention. We propose hop based priority (HBP) technique using 802.11e to minimize contention. The HBP technique increases priority in media access control (MAC) by each hop. It makes higher priority at the previous or early sent packet than the next or later sent packet. We validate by modeling and show by simulation that HBP technique can perform 31% better.**

I. INTRODUCTION

Networks have evolved from wired to wireless. Recently, users of wireless LAN (WLAN) like laptop computer, PDA, mobile internet devices are increasing rapidly. WLAN supports scalability, flexibility and ubiquity, and these features make WLAN more popular. Especially, wireless multi-hop network has overcome the limit of WLAN's communication range.

The applications and services of wired and wireless network are not different. Services that need quality of service (QoS) like VoIP, Multimedia Streaming can be served in wireless networks. However, WLAN is hard to guarantee high QoS [1].

To solve this problem, 802.11e [2] is designed. 802.11e has Hybrid Coordination Function (HCF) and Enhanced Distributed Coordination Function (EDCF) to support QoS that could not be supported in previous 802.11.HCF extends Point Coordination Function (PCF) to support immediate sending data. Access Point (AP) based infrastructure mode is used in HCF. EDCF is designed to support priority upon Distributed Coordination Function (DCF). EDCF can be used in both in ad hoc mode and infrastructure mode. In this paper, we will be using EDCF.

In this paper,we propose hop based priority (HBP) technique to minimize contention in WLAN with 802.11e multi-hop network.

II. HOP BASED PRIORITY

Wireless local area networks using 802.11 [3] communicate by shared medium. This characteristic of 802.11 makes that wireless multi-hop network with 802.11must have contention between previous and next hops. This causes delay fluctuation and additional back-off time by collision. These decrease network bandwidth. In HBP technique 802.11e EDCF is used to minimize contention between hops.

A previous packet or an early sent packet contends with a next packet or a later sent packet when packets try to transmit to a destination through a route. The effect that the next packet cannot get the channel by contention with the previous packet is small. If the next packet wins the previous packet and transmit one more hop, it cannot transmit more hops until the previous packet transmits. In other words, winning of the previous packet from the next packet causes the delay to decrease and the bandwidth to increase. So, the previous packet has higher priority than the next packet every time.

We propose HBP technique to avoid contention between the previous and the next packets. In other techniques every packet has fixed priority and the previous packet and the next packet contend each other. In HBP each packet increases priority every hop by hop and minimizes contention between packets. In other words, priority is assigned to each hop and increases priority hop by hop.

III. ANALYSIS AND SIMULATION

A. Analysis

We analyze delay in 802.11 WLAN. The delay in 1 hop transmission is denoted

$$T_{trans} = T_{bas} + T_{cont} + T_{col} \tag{1}$$

The parameter T_{trans} denotes time of 1hop transmission. T_{bas} is basic transmission time. T_{cont} and T_{col} are additional delay caused by the loosening from contention and collision.

T_{bas} is the total sum of DCF interframe space (difs, T_{difs}), random backoff (T_{ran}), transmission data (T_{data}), short interframe space (sifs, T_{sifs}) and transmission acknowledgement (T_{ack}) time. T_{ran} is based on contention windows (CW) size.

$$T_{bas} = T_{difs} + T_{ran} + T_{data} + T_{sifs} + T_{ack} \tag{2}$$

T_{cont} has probability about loosening for contention (P_{loose}).

$$T_{cont} = P_{loose} \times \left(T_{difs} + T_{data} + T_{sifs} + T_{ack}\right) \tag{3}$$

The last parameter is T_{col}. When collision occurs, 802.11 operates random backoff and tries to transmit the data. T_{col} is denoted.

$$T_{col} = \sum_{i=1}^{n\_retry} P_{col\_i} \times \begin{bmatrix} T_{difs} + T_{ran\_i} \\ +P_{loose\_i} \times \left(T_{difs} + T_{data} + T_{sifs} + T_{ack}\right) \end{bmatrix} \tag{4}$$

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P_{col_i} is the probability of collision at i'th try. Like this, T_{ran_i} and P_{loose_i} are random backoff time and the probability of loss at i'th try. n_retry is the number of retry limit, generally 3.

Total delay can be calculated by T_{tran}*(number of hops). In 802.11e with HBP, total delay has to be calculated because priority is changed at every hop. We have calculated total delay about HBP by each 1-hop delay and summarized them.

In 802.11e, there is one more variable, time of arbitration interframe space (aifs) and it can be used in difs. Each variable is different at 802.11, 802.11a, and 802.11b. We use 802.11b to evaluate HBP. Values of variables that we simulate are presented at TABLE I.

TABLE I
TIME OF DIFS, SIFS, SLOT, AIFS AND CW SIZE IN 802.11B AND 802.11E

Variables	802.11b	802.11e			
		Pri 0	Pri 1	Pri 2	Pri 3
difs	50us				
sifs	10us				
Slot time	20us				
aifs	NA	40us	80us	140us	140us
CW_{min}	31	7	10	15	31
CW_{max}	1023	7	31	255	1023

TABLE II denotes 1 hop transmission time, total (4 hops) transmission time, and the estimated bandwidth in 802.11b and 802.11e when data size is 512 byes with 11Mbps link.

TABLEII
TRANSMISSION TIME AND BANDWIDTH OF 802.11B AND 802.11E

Time	802.11b	802.11e			
		hop 1	hop 2	hop 3	hop 4
1 hop Trans. time	1135us	838us	764us	713us	660us
Total Trans. time	4243us	2975us			
Bandwidth	965Kbps	1.377Mbps			

HBP technique using 802.11e has shorter delay and more bandwidth than 802.11b.

B. Simulation

We use NS2 version 2.33 [4] to simulate HBP technique. To support 802.11e, TKN EDCA patch [5] is used. There are 5 nodes on the same line and each node can communicate with neighbor node. The node at one end sends data to the node at the other side with constant bitrates.

Figure 1 shows throughput of 802.11b and 802.11e with HBP from 800Kbps to 1.5Mbps. The lower bitrates result is meaningless because the network is not saturated and very little contention is occurred. The network is saturated about 900Kbps in 802.11b and throughput is steady after 900Kbps. However, 802.11e with HBP is increased until 1400Kbps. Finally, 802.11b's throughput is865Kbps and 802.11e with HBP's throughput is 1138Kbps. It is the reason for smaller bandwidth than our model since our model does not consider necessary operation of MAC like HELLO message, ARP, and etc. MAC operation causes contention of channel and drops throughput.

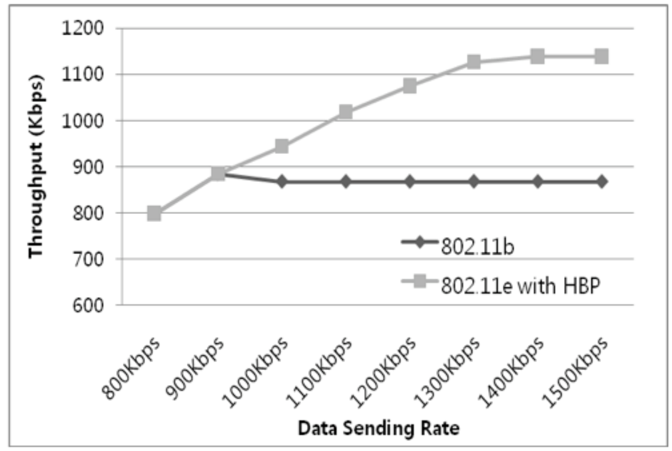

Fig. 1. Throughput of 802.11b and 802.11e with HBP from 800Kbps to 1500Kbps

IV. CONCLUSION AND FUTURE WORKS

We propose HBP technique using 802.11e for wireless multi-hop networks. Analysis and simulation results show that HBP technique using 802.11e can serve31% better performance than 802.11b. Moreover, inter-packet delay is constant in HBP.

HBP technique using 802.11e can be used in wireless multi-hop network, not in ad hoc mesh network. When many routes exist by random, some routes have lower priority than other routes at cross-route node and cannot get the channel. It is hard to solve this problem with 802.11e and it is left to be solved in the future.

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