Throughput Enhancement for Uploading TCP Flows in IEEE 802.11 Wireless LANs

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Abstract—**This paper re-analyzes the relationship between MAC contention and TCP congestion control misled in previous efforts. By introducing a prioritized access of an access point, we seek to allow the optimal number of competing stations to contend for media access.**

I. Introduction

The most of Internet applications use Transmission Control Protocol (TCP) as their transport layer protocols; however, TCP shows poor performance in wireless environments. Thus, there have been efforts to improve TCP throughput in IEEE 802.11 wireless LANs. They blindly assume that the number of competing stations at the MAC layer is increasing as there are more stations with TCP flows, which is not true under the congested network condition.

TCP has the congestion control mechanism [1] consisting of two phases: *slow start* and *congestion avoidance*. In the *slow start* phase, the congestion window (*cwnd*) is initialized to one segment[1] when a new TCP connection is established. Each time a TCP ACK is received, the *cwnd* is increased by one segment, hence resulting in an exponential increase in the window size every one round trip time (RTT). After the *cwnd* reaches a slow start threshold (*ssthresh*), the *congestion avoidance* phase starts, where the *cwnd* is incremented by 1/segment for each RTT, hence resulting in an additive increase in the window size. Note that when a TCP flow sends data of its *cwnd* size, it cannot send more data until it receives a TCP ACK from the counterpart. That is, the station waiting for a TCP ACK cannot contend for the channel access at the MAC layer. Therefore, in the congested wireless LANs, only small portion of stations with TCP flows will contend for channel access, while most of the stations will not have any TCP packet to send.

It is normally assumed that each station and an access point will get a fair share of the wireless channel capacity in the long term. After a station transmits TCP packets of *cwnd* size, it cannot attempt to transmit the next TCP packet until it receives a TCP ACK. That is, after the access point transmits a TCP ACK to the station, it will compete with an access point (and other stations, if any) for wireless channel. Our empirical study reveals that the number of competing stations at the MAC layer is mostly around two regardless of the number of stations with uploading TCP flows as shown in Fig. 1. However, the number of competing stations should be increased to achieve an optimal aggregate throughput in IEEE 802.11 wireless LANs.

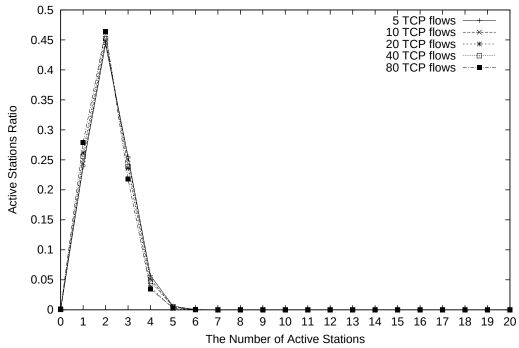

Fig. 1. Active stations ratio versus the number of TCP flows

II. The Algorithm

The central idea behind our proposal is to increase the number of competing stations to achieve a higher aggregate TCP throughput. Suppose that the "optimal" number of competing stations is n, it is well-known that the maximum aggregate throughput of a wireless LAN can be achieved when n stations (including an AP) contend to get the wireless channel access. IEEE 802.11 DCF specifies that a station should perform random backoff for collision avoidance even though there is only a single station. The waste of link bandwidth due to this backoff time can be minimized when a number of stations compete for the wireless channel access. However, frequent packet collisions degrade the aggregate network throughput. Therefore, it is of utmost importance to make the number of competing stations optimal.

In our proposal, the access point can get the wireless channel and transmit TCP packets to $n-1$ stations with the higher priority than stations. To do so, the access point had better win the channel access over the other stations. We propose that the access point intentionally uses the 0-th slot after DIFS, so that it can always win the wireless channel over other stations. Note that there is no station with the backoff time equal to zero; if so, it must have transmitted its packet in the previous transmission. For the access point to transmit multiple TCP packets successively, it can use Transmission Opportunity (TxOP) in the IEEE 802.11e draft or frame aggregation in the IEEE 802.11n draft. After an access point gets the wireless channel as stated above, TxOP enough to transmit $n-1$ TCP

This work was supported in part by the Brain Korea 21 project of Ministry of Education, 2005, Korea.

[1]The segment size is announced by the other end host.

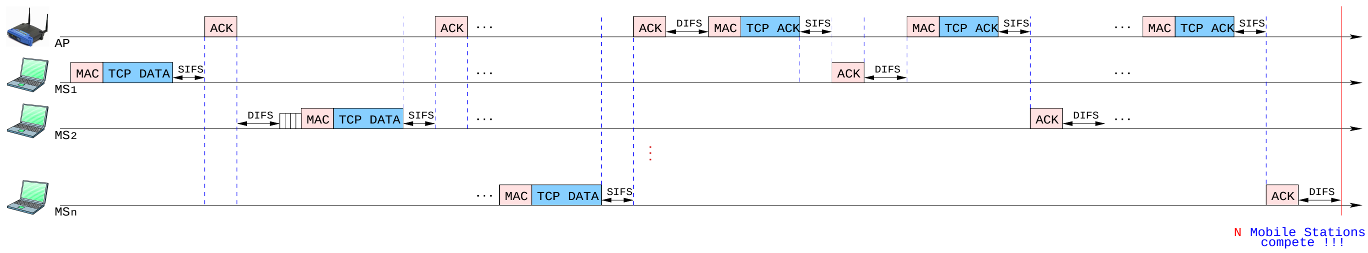

Fig. 2. Basic operation in our proposal

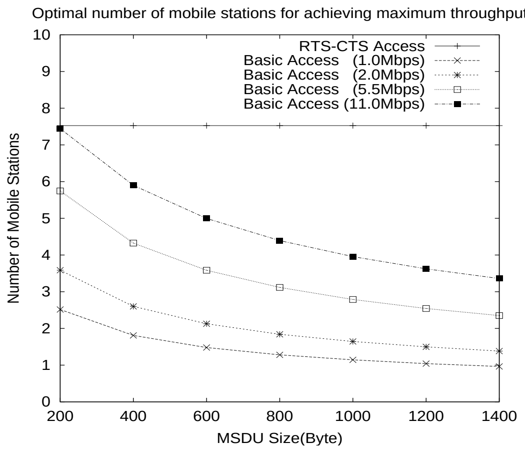

Fig. 3. The optimal number of active stations versus the number of TCP flows

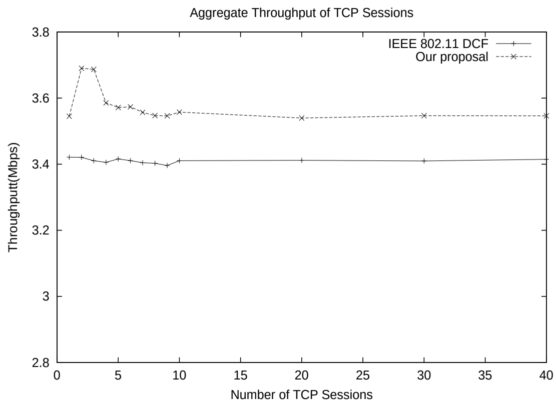

Fig. 4. Aggregate throughput versus the number of TCP flows

packets is given to the access point as Fig. 2. Or it is possible to integrate several MSDU/MPDU frames to a single MPDU and then transmit the aggregated MPDU. Although frame aggregation can avoid additional overhead such as a SIFS and a MAC header for each TCP packets, several TCP flows will undergo performance degradation if the aggregated frame is lost.

III. Performance Evaluation

Fig. 3 plots the optimal number of competing stations to achieve the maximum aggregate throughput. The optimal number is derived from [5] by considering the effect of a packet size, a transmission rate and the RTS/CTS option. For example, if the RTS/CTS option is used, the maximum aggregate throughput is achieved when about 7 stations compete for the channel access. In the other cases, the optimal number of stations depends on a packet size and a transmission rate since the waste time due to a packet collision is also a function of a packet size and a transmission rate. For example, the waste time caused by a packet collision is getting more as the packet size is longer. Hence, the optimal number of stations is decreased to reduce the packet collision probability.

We carry out simulation to compare the aggregate TCP throughput of our proposal with that of IEEE 802.11 DCF as the number of stations with TCP flows increases. In the simulation for IEEE 802.11b, a pair of a wired station and a wireless station generates an uploading TCP flow which has a packet size of 1024 bytes. Fig. 4 shows that the proposed algorithm achieves the higher TCP throughput by making the number of competing stations four, which is optimal when a packet size is 1024 bytes and wireless link has 11 Mbps without RTS/CTS.

IV. Conclusion

Empirical study by simulations reveals that previous efforts on how to model competing TCP flows in IEEE 802.11 wireless LANs are misleading. This paper analyzes the relationship between MAC contention and TCP congestion control. By introducing a prioritized access (0th slot) of an access point, we seek to allow the optimal number of competing stations to contend for media access. We through ns-2 simulations proved that our proposal could achieve a higher aggregate TCP throughput than the original IEEE 802.11 DCF.

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