A Proposal of TCP Fairness Control Method for Multiple-Host Concurrent Communications in Wireless Local-Area Network

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Abstract—In the IEEE802.11 wireless local-area network (WLAN), the TCP throughput unfairness will appear when multiple hosts concurrently communicate with a single access-point (AP), since the TCP window size, the modulation and coding scheme (MCS), and the packet drop rate become different among them. In this paper, we propose a TCP fairness control method using the transmission delay in WLAN. The target throughput is introduced as the equal throughput, which will be dynamically updated with measured throughputs. Then, the delay is controlled by the PI feedback control such that the measured throughput is equal to the target. The effectiveness is confirmed through experiments using our elastic WLAN system testbed with one AP and up to four hosts, where all the hosts have achieved the similar throughputs based upon the proposal.

I. INTRODUCTION

Currently, the IEEE802.11 WLAN has been deployed around the world as the efficient Internet access network. However, the result of TCP throughput unfairness is frequently detected when multiple hosts concurrently communicate with the same access-point (AP) in WLAN [1]. This phenomenon tends to appear from the differences in the TCP window size, the modulation and coding scheme (MCS), and the packet drop rate between these links. Then, the packet transmissions with faster hosts may dominate the limited shared bandwidth for wireless communications of one AP, which could further reduce the throughputs of slower hosts.

To tackle this problem, the transmission delay was introduced at the AP to a faster host, so that a slower host can use the larger bandwidth for packet transmissions. As a result, the TCP throughput fairness is expected to be achieved by decreasing throughputs of faster hosts and increasing those of slower hosts.

In this paper, we propose a TCP fairness control method using the transmission delay for multiple concurrently communicating hosts in WLAN. The target throughput is adopted as the equal throughput among the hosts, which will be dynamically updated from the measured throughputs during communications. The delay at the AP for each host is dynamically optimized by the PI feedback control, so that the measured throughput will become equivalent to the target one.

The effectiveness of the proposal is verified through experiments using the elastic WLAN system testbed using Raspberry Pi as the software AP [2]. The elastic WLAN system has been examined to reduce the energy consumption and improve the performance by dynamically changing the WLAN configuration depending on traffic demands. The experiment results using one AP and up to four hosts show that all the hosts have achieved the similar throughputs based upon the proposal.

II. PROPOSAL OF TCP FAIRNESS CONTROL METHOD

In this section, we present the TCP fairness control method using the transmission delay.

A. Target Throughput

In the proposal, the target throughput is adopted as the common throughput goal among the hosts. First, the initial value of the target throughput $TH_{tar}$ is given from the throughput estimation model [3]. $N$ does the number of hosts, and $\alpha$ does the constant interference-loss parameter. In this paper, $\alpha = 0.06$ is used.

Then, during the communication, the target throughput is updated by:

$$TH_{tar}(n) = \frac{\sum_{i=1}^{N} TH_i(n)}{N}$$

when either of the three conditions is satisfied: 1) $D_i(n) < D_{min}$, 2) $D_i(n) > D_{max}$, or 3) $|TH_i(n) - TH_{tar}(n)| < \epsilon \times TH_{tar}(n)$ for at least one host. $TH_i(n)$ represents the measured throughput for host $i$ at time-step $n$, $D_i(n)$ does the delay given in (4), $D_{min}$ and $D_{max}$ represent the constant minimum and maximum delay, and $\epsilon$ does the constant saturation parameter, respectively. In this paper, $D_{min} = 0$, $D_{max} = 200$, and $\epsilon = 0.2$ are used.

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B. Transmission Delay Optimization

After starting the communication, the initial delay $D_i(0)$ for host $i$ is calculated by:

$$D_i(0) = \frac{RSS_i}{a} \left( -\frac{RSS_i}{RSS_{\text{min}}} \right)^2 e^{b(RSS_i - RSS_{\text{slow}})}$$

(3)

where $RSS_i$ represents the measured RSS (received signal strength) at the AP from host $i$, $RSS_{\text{slow}}$ does RSS from the slowest host among the $N$ hosts, $RSS_{\text{min}}$ does the constant minimum RSS in WLAN, and $a$, $b$ do the constant parameters. Here, $RSS_{\text{min}} = -88dBm$, $a = 9$, and $b = 0.17$ are used.

Then, the delay is dynamically optimized using the PI feedback control [4] to make the measured throughput equal to the target throughput:

$$D_i(n) = D_i(n-1) + K_P \times (TH_i(n-1) - TH_i(n)) + K_I \times (TH_{\text{tar}}(n) - TH_i(n))$$

(4)

where $K_P$ and $K_I$ represent the P-control and I-control gain, respectively. Here, $K_P = 0.3$ and $K_I = 0.07$ are adopted.

C. Elastic WLAN System Testbed Implementation

The proposed method is implemented in the elastic WLAN system testbed. The testbed adopts the management server to control the whole system through the following periodic procedure with 20sec interval:

1) Measure the throughput between the AP and each host for 20 sec using iperf.
2) Update the delay for each host using (4).
3) Apply the delay at the AP using tc command in Linux for the data transmission to the corresponding host.
4) Update the target throughput using (2), if one described condition is satisfied.

III. Evaluation

In this section, we evaluate the proposal through experiments using the testbed. Figure 1 indicates the experiment testbed that is composed of the server, the AP, and the hosts. It is located in the third floor of Engineering Building #2 at Okayama University shown in Figure 2.

Figures 3 and 4 reveal the measured and target throughput results when three or four hosts concurrently communicate, respectively. When time-step is 0, which is before applying the proposal, the throughput appears to be unfair among the hosts. After applying the proposal, the throughput fairness is achieved at time-step 9 (=180sec) in Figure 3 after updating the target throughput once, and at time-step 10 (=200sec) in Figure 4 after updating the target one twice. Thus, the effectiveness of the proposal is confirmed.

IV. Conclusion

This paper presented the TCP fairness control method using the transmission delay for multiple-host concurrent communications in WLAN. The effectiveness is confirmed through experiments using the elastic WLAN system testbed. Future works will include further experiments in various fields.

REFERENCES