Characteristics of QoS-Guaranteed TCP on Real Mobile Terminal in Wireless LAN

Remi Ando
Ochanomizu University
2–1–1, Otsuka, Bunkyo-ku
Tokyo 112–8610, JAPAN
remi@ogl.is.ocha.ac.jp

Tutomu Murase
NEC Corporation
1753, Shimonumabe,Nakahara-ku
Kawasaki,Kanagawa 211-8666, JAPAN
t-murase@ap.jp.nec.com

Masato Oguchi
Ochanomizu University
2–1–1, Otsuka, Bunkyo-ku
Tokyo 112–8610, JAPAN
oguchi@computer.org

***Abstract*—For multimedia communications such as video streaming, a QoS-guaranteed TCP (QoS-TCP) has been proposed and evaluated in characteristics of guarantee performance. For wired networks QoS-TCP can guarantee a target bandwidth against competitive back ground TCP traffic, depending on number of the competitive TCP flows and the target bandwidth. In this paper, the characteristics of QoS-TCP in mobile and fixed wireless networks are investigated through both computer simulations and real terminal experiments in both outdoor and indoor environments. Many wireless related factors such as radio interference and handover could affect the performance as well as buffer size and queueing behavior of access points. The experiment results show that QoS-TCP has a possibility to guarantee a target bandwidth, with depending on both the specified target bandwidth and mobile wireless environments (channel capacity).**

***Keywords*-wireless LAN,Handover,fairness,QoS guarantee**

I. Introduction

In recent years, a demand for multimedia communications including video stream communications or voice (VoIP) communications has been raised extensively. For such multimedia communications, it is important to guarantee a certain level of Quality of Service (QoS). We here aim at securing constant bandwidth as one of QoS criteria.

In IEEE802.11 wireless LAN, QoS control on an uplink, which is a link directed from wireless terminals to an access point (AP), is very difficult because an autonomous distributed control[1] is employed to access the uplink. In order to control uplink traffic for a specific QoS, many previous works including IEEE802.11e (EDCA)[4] have been done. They could well work if we can modify IEEE802.11 MAC protocol or can add dedicated functions in both mobile terminals and APs. In practice, however, it is difficult to modify MAC, because MAC protocols in many implementations are run in LSI chips except some API[2][3]. Even if we can complete to deploy EDCA in any wireless terminals and APs, QoS control of EDCA has still difficulties in a control of a level of QoS differentiation and in a parameter tuning to obtain a specific QoS values.

In order to avoid such difficulties, QoS control by TCP has been introduced. A TCP protocol which is a variant of a traditional TCP(TCP-Reno) and can control QoS by using congestion control mechanisms is here called a QoS-TCP. It is developed for guaranteeing a certain bandwidth for multimedia communications. One of advantages of QoS-TCP is that no modification is needed to guarantee bandwidth in any network devices except TCP behaviors of sending terminals, nor additional any control overhead. The performance evaluation of QoS-TCP [6] reveals that QoS-TCP can guarantee a specific bandwidth, but also can not if competitive back ground traffic increases. The characteristics of QoS-TCP is shown only in a wired network although we need to know how wireless factors and the performance anomalies mentioned above effect on the characteristics.

In addition, we believe we should demonstrate a performance by using real machines, although simulation studies show a good performance. This is because wireless channel capacity varies time by time, and real machines can not be as homogeneous as assumed in usual simulation models.

In this paper, we evaluate characteristics of QoS-TCP in terms of bandwidth guarantee in wireless networks. Experiments by using real machines are performed both in fixed and mobile scenarios in IEEE 802.11g in indoor and outdoor environments.

The rest of this paper is organized as follows. In Section II, Related works are described as well as QoS-TCP technologies and performance anomalies in TCP uplink flows. Evaluation models and preliminary experiment results are explained in Section III. Experiment results as well as simulation results are discussed in Section IV, and the concluding remarks are stated in Section V.

II. Related Works and Technologies

A. Previous Researches

As addressed in the previous section, QoS-TCP has been developed guaranteeing a certain bandwidth for multimedia communications. Results of computer simulations and real terminal experiments have shown that QoS-TCP are effective within a number of competitive background TCP flows in wired networks[6].

Very few results, however, have been reported for QoS-TCP in wireless networks, such as IEEE802.11 LANs(WLANs). In WLAN, performance anomaly in TCP throughput is well known in an assumption of very little radio interference resulting in bit error and packet error [8]. It has been proven in an ideal simulation model that the anomalyaffects on performance of QoS-TCP[7]. In practice, we should consider other factors in wireless networks for QoS-TCP; A total available bandwidth of WLAN varies time by time and place by place, where radio interference varies. Each terminal of real machines has individuality, regardless that it has the same software platform and hardware platform. As well, APs have variety of packet buffer sizes and packet buffer management schemes.

These factors would make the QoS-TCP performance in real different from that in the simulation model. Although measurements of TCP throughput in real mobile terminals have already been done in [10],[11],[12], characteristics of QoS-TCP has not known yet. This paper is devoted for investigating characteristics of QoS-TCP in above-mentioned various situations of WLAN.

B. *QoS Guaranteed TCP*

Several QoS-TCP instances have been introduced [5],[6].They are developed for aiming at quality improvement of streaming communications, and designed to assure a designated bandwidth. Protocols of the QoS-TCP expand the congestion control mechanism of existing TCP, and adopt a retransmission behavior to improve burst packet loss tolerance.

TCP-AV[6] is one of the QoS-TCP instances. TCP-AV modifies slow start threshold according to a target bandwidth that a user specifies, and congestion window behaviors in temporal congestion. Larger slow start threshold in TCP-AV than that in a traditional TCP(TCP-Reno) derives an advantage of obtaining more bandwidth. Congestion window of TCP-AV is aggressively kept large to obtain more bandwidth, and is also carefully controlled to avoid congestion collapse. Thus, TCP-AV eventually gives up guaranteeing the specified bandwidth when competitive background TCP flows are strong enough to cause congestion collapse.

C. *Unfairness Problem of TCP Throughput on Wireless LAN*

A nature of even sending opportunity of MAC frames in each terminal and a fairness problem in TCP throughput seriously give impacts on TCP-AV performance. Even sending opportunity could be a restriction for a terminal of TCP-AV, which tries to take more bandwidth than other terminals[7]. Even sending opportunity also causes the unfairness problem.

The unfairness problem is that TCP throughputs are not evenly divided between terminals. When many TCP uplink flows are multiplexed, it occurs that some terminals have more than fair-share throughputs while other terminals have almost zero throughputs, regardless of even sending opportunity[8][9].

Table I
BUFFER SIZES OF APS

AP	buffer size(packets)
Planex GW-AP54SAG	284.3
BUFFALO WZR-AMPG300NH	256
BUFFALO WHR-HP-AMPG	135.1
NEC PA-WR8500N	90.5
BUFFALO WHR-AM54G54	37.2

A brief explanation of unfairness mechanisms is addressed as follows. Because of asymmetric of link speed of uplink and downlink resulting from CSMA/CA, Buffer of downlink in an AP is likely to be congested A number of discarded TCP-ACK depends on AP buffer size, and increases as the number of terminals increases. The same number of TCP-ACK loss causes different impact on TCP congestion window in different window size. When numbers of TCP-ACKs are lost, and other TCP-ACKs followed by the lost TCP-ACKs are correctly received, congestion window of the TCP can grow up. Such window size increase is likely to happen in TCP flow whose congestion window is large. However, if all the TCP-ACKs within congestion window are lost, congestion window of the TCP decreases. Such window size decrease is likely to happen in TCP flow whose congestion window is small. These feed-forward mechanisms result in that some terminals have more than fair-share throughput while other terminals have almost zero throughputs.

In this paper, an almost zero throughput terminal called an "unlucky terminal". The number of the terminal that becomes fair and unfair changes by buffer size of AP.

III. PRELIMINARY EXPERIMENT TO INVESTIGATE CHARACTERISTICS OF REAL ACCESS POINT

Before evaluating QoS-TCP performance, we made preliminary experiments in order to know our experimental environments. Buffer sizes of APs, and buffer behaviors of APs. They affect much on TCP throughput characteristics.

Although it is better to know buffer sizes and buffer behaviors APs, it is difficult to know those of consumer level APs because venders do not disclose such information. So, we estimated them by preliminary experiments.

1) buffer Size: We estimated the buffer sizes by charging excess traffic to the AP and comparing input packets with output packets of the APs. Results of the buffer size estimation are shown in Table .

We measured five APs. The buffer size shown in the figure is an average of ten trials.

Buffer sizes of the five APs vary between about 30 and 300 packets. As mentioned before, buffer size effects on TCP throughput characteristics, we should carefully choose buffer size in a simulation. We employed BUFFALO WZR-AMPG300NH whose buffer size is 256 packets for our experiments.

2) Buffer Behavior: Buffer behaviors of AP are also investigated by the same methods as the previous section.

Typical, simulations assume that the buffer behavior is FIFO. A packet arrived at the buffer can enter the buffer if the buffer have space to store the packet. We call this behavior ideal FIFO.

In real machine, a buffer behavior is not like ideal FIFO. We observed that a packet arrived at the buffer can not always enter the buffer when the buffer is supposed to have space to store the packet buffer.

Fig.1 shows a behavior of packet output process of a BUFFALO WZR-AMPG300NH AP. X-axis is numbers of output packets from the AP, and Y-axis is sequence number of the output packets recorded at a sending terminal.

The AP is operated in 802.11g and its buffer size is 256 packets. Test packets sent to a terminal through the AP has a sending rate fast enough to cause buffer overflow of the AP. If buffer behavior would be ideal FIFO, the curve would constantly rise after packets fill the buffer up as a curve labeled ”FIFO” in the figure. The curve, labeled ”a real AP”, however, actually steps up in somewhere. The steps mean that a batch of packets, 16, 17 and 12 consecutive packets, entered in the buffer.

Although typical simulations suppose that buffer behaviors of APs are ideal FIFO, this experiment result shows buffer input/output management of APs may not ideal FIFO. The reason why it is not ideal FIFO could come from Operating System or hardware implementations, and detail analysis is for further study.

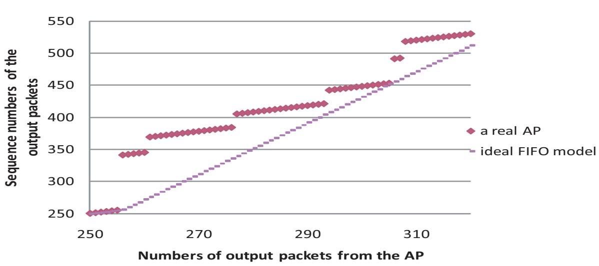

Figure 1. result of buffer behavior

IV. Experimental result

Experiments by real mobile terminals had been done in order to investigate factors of individual differences in wireless equipment and effects of characteristics of wireless channels. In the following subsections, it is addressed that (1)QoS-TCP can guarantee a target bandwidth regardless of individual characteristics of real machines, and (2)QoS-TCP can and can not guarantee a specific bandwidth in moving terminals with good channel condition and bad channel condition, respectively.

A. Fixed Wireless model

1) QoS-TCP throughput for various APs: First, QoS-TCP throughput is examined for various AP buffer sizes. Because throughputs of competitive TCP flows depend on AP buffer size, QoS-TCP performance could depend on the competitive TCP throughput and/or the AP buffer size.

An experiment system consists of sending terminals, wireless modules for the sending terminals, an AP, and a wired receiving terminal. As a wireless module, so-called Ethernet-converter (EC) is used. EC is a kind of MAC Bridge which has both an Ethernet network interface and an wireless network interface. TCP data flows were transmitted from wireless terminals aiming at the receiving terminal. Iperf was used for the data. In the system, wireless terminals and APs are located very close to each other, within approximately 0.3 meters, in order to reduce effects of radio interferences.

First, as a preliminary experiment, Fig.2 shows a result of TCP throughputs of different buffer sizes of different APs. Two TCP uplink flows are multiplexed. The graph shows TCP throughputs depend on buffer sizes of APs.

Next, influences that buffer sizes of APs give to guarantee performance of QoS-TCP are examined. The target that QoS-TCP should guarantee in bandwidth is set to much more than a fair-share value, say 23 Mbps, which is nearly equal to the maximum TCP throughput when IEEE802.11g utilization is 100%[13].

The result of the experiment is shown in Fig.3. QoS-TCP can obtain a certain throughput values regardless of the buffer size although competitive TCP flows increase their throughputs as the buffer size increases.

QoS-TCP reacts moderately against congestion within a state where no congestion collapses occur, even when TCP excessively reacts. Therefore, the more congestion occurs, the more QoS-TCP has an advantage to grab bandwidth.

As a buffer size increases, frequency of performance implications decreases because the buffer can accommodate more TCP-ACK packets.

So, although the curves in the figure show that QoS-TCP can guarantee more than fair-share bandwidth, there are possibility that makes the guarantee performance of QoS-TCP be degraded when the buffer size increases.

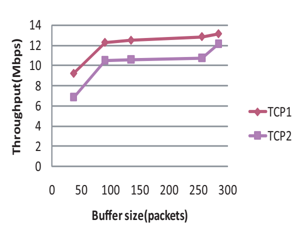

Figure 2. TCP throughput of each buffer size of AP

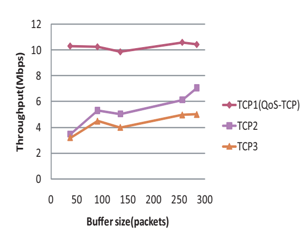

Figure 3. Relation of QoS-TCP and individually of AP

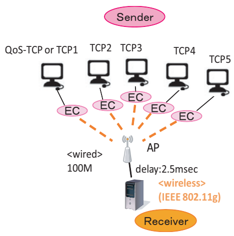

Figure 4. evaluation environment

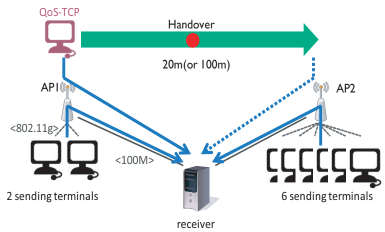

Figure 5. evaluation model

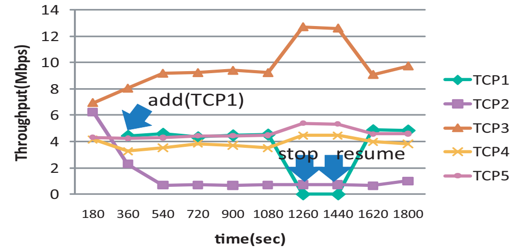

Figure 6. Relation of QoS TCP and difference of individual terminal

2) TCP throughputs in individual terminals: In real, communication characteristics of terminals and wireless modules are not homogeneous but heterogeneous. The heterogeneity could effect on QoS-TCP bandwidth guarantee performance. First, an experiment has been done for evaluation of the fairness characteristics.

In the experiment, a mobile terminal sends an uplink TCP flow to a receiving terminal throughput an AP.

A number of the TCP flows changes as the number makes fairness or unfairness situations.

In the experiment, we confirmed that less than and equal to four terminals and more than four terminals caused fairness and unfairness, respectively.

Four terminals started sending data and shows fairness situations, then at time 360 seconds one terminal was added to cause an unfairness situation in which one terminal was an “ unlucky terminal ”which is denoted as TCP-2. Then one of “ lucky terminals ”, TCP-1 is stopped at time 1260. This was supposed to cause a fairness situation in case of an equivalent simulation model. However, the “ unlucky terminal ”TCP-2 could not obtain any bandwidth and the other “ lucky terminals, ” TCP-3, TCP-4 and TCP-5 shared the all bandwidth. Then, TCP-1 was resumed at time 1440 and recovers its bandwidth against a competition with others. This result shows that “ unlucky terminal ” has something so weaker than others that the terminal can not inherit the bandwidth even in a fairness situation; if such weak terminals join a bandwidth competition late after the competition starts. Note that we can see the similar results at our experiments in the following sections when a terminal is approaching from far away to an AP. So, we conclude that in real models “ unlucky terminals ” exist, and fairness situations are different from those in simulation models.

Fig.4 shows the experimental environment.

B. Mobile Wireless model

Communication link characteristics such as radio interference, capacity fluctuation seriously effects on QoS in mobile wireless communications. Here, QoS for mobile users is investigated.

1) Terminal and AP: In experiments, two APs, AP-1 and AP-2 are used. Several terminals do not move and are connected to the APs, and one mobile terminals moves from AP-1 to AP-2, while the mobile terminal does handover in a middle between the two APs. The handover process required 10 seconds, and in a mean time no connections were established. Both APs have a fixed transmission rate of 54 Mbps, which does not change regardless of levels of radio signal to noise ratio and levels of congestion. Buffer sizes of the APs are approximately 265 packets.

2) Network: The network is consists of nine sending terminals and one receiving terminal. Each sending terminal sends an uplink TCP flow to the receiving terminal. One of the sending terminals is a mobile terminal which moves from AP-1 to AP-2, the rest of the sending terminal do not move but are fixed. Two and six of the sending terminals are connected to AP-1 and AP-2, respectively. The fixed terminals are located close to APs to reduce effects of radio interferences as in the fixed model of the previous section. Through preliminary experiments, it was proven that six terminals do not cause unfairness situation and seven terminals do cause unfairness situation. When the mobile terminal joins AP-2 after handover, AP-2 has an enough number of terminals to cause unfairness.

3) Radio interference: In order to identify the experiment environment, radio interferences are measured in terms of TCP/UDP maximum throughput. One mobile terminal is used to measure its maximum throughput along the moving path. Without competitive terminals, the measured TCP/UDP flow throughputs could be understood as the wireless link capacities in TCP/UDP. Two different environments were chosen for the experiments. One was outdoor and the other was indoor. Distances between two APs are set to 100 m and 20 m in the outdoor and the indoor, respectively. As shown in Fig.7 and Fig.8, the outdoor had much radio interferences and the indoor had little interferences. In the outdoor case, the experiment place was surrounded by many office and resident buildings which sent many signals and so that the interferences were strong enough to reduce the link capacity even somewhere close to the APs. On the other hand, radio interferences seemed to be blocked by walls in the indoor case. So, the emission power of the radio signal adjusts in order to be well attenuated at the point of the handover.

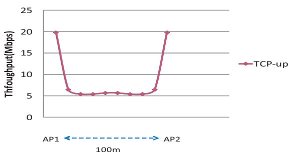

Figure 7. channel capacity measurment:outdoor

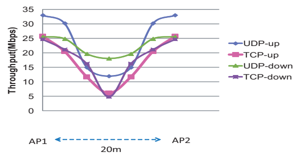

Figure 8. channel capacity measurement:indoor

4) QoS-TCP in outdoor: Figure 9 shows throughputs of a QoS-TCP flow and a TCP flow of the mobile terminal. When TCP is used in the mobile terminal, throughput is always less than or equal the fair-share value. When QoS-TCP is used, although QoS-TCP shows slightly more than fair-share throughput near AP-1, it fails near AP-2 and anywhere else. The radio interference measured in the previous section dominates to decide TCP or QoS-TCP throughput, so that QoS-TCP fails to guarantee a certain bandwidth during the moving.

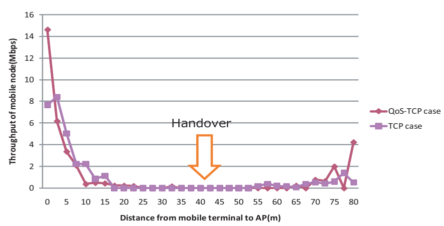

Figure 9. QoS-TCP throughput in outdoor

5) QoS-TCP throughput in indoor: The indoor case could give the mobile terminal more advantages than the outdoor case because the radio interference is not so strong. Figure 10 shows throughput QoS-TCP and TCP in the mobile terminal.

Although TCP in the mobile terminal can not grab bandwidth in the left in the figure after the handover in the middle of two APs, QoS-TCP can. This means that even when QoS-TCP joins a competition with six fixed terminal late after handover, QoS-TCP can become a " lucky terminal ". Moreover, QoS-TCP which joins AP-2 far from AP-2 can get throughput more than fair-share throughput, 30%(about twice of fair-share) in this experiments. The reason why QoS-TCP can get successful to grab some bandwidth is discussed in Section IV.C.

6) computer simulation: Computer simulations are run in order to compare with real terminal experiment and to analyze experiment results since no simulation results have been yet achieved in conventional researches.

Figure11 shows the simulation result. The simulation models and parameters are set to be the same except two parameters. One is that it is difficult to set radio interference parameter to be suit for the real experiments. Instead, no radio interference is assumed and bit error is set to be zero.

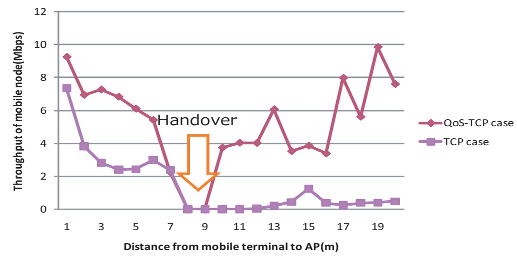

Figure 10. QoS-TCP throughput in indoor

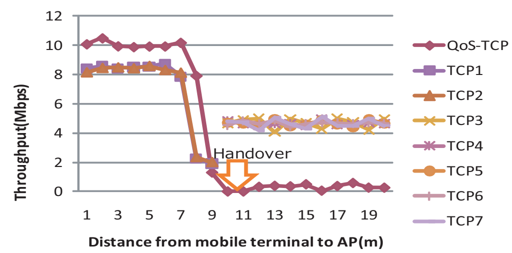

Figure 11. QoS-TCP throughput in computer simulation

The other is that the buffer behaviors of APs are ideal FIFO and all the terminal behaviors are homogeneous.

As shown in the right of the figure, QoS-TCP flows in the mobile terminal can not penetrate existing competitive terminals, and results in almost zero throughputs. Note that our other experiments in the fixed wireless model show that a QoS-TCP flow can obtain more than fair-share throughput against existing TCP flows even if it joins a competition later in the real terminal experiments. A traditional TCP flow, however, can not obtain[13].

This also shows differences between the computer simulation and the real terminal experiments. Generally, we should very carefully perform computer simulations since results could be very different from real experiments. The reason why the results of the computer simulation and the real terminal experiments are different will be discussed in the next section.

C. Analysis of performance evaluation results

In this section, the reason why QoS-TCP can not get enough throughput in the computer simulations and can get more than fair-share throughput in real terminal experiments is discussed. The discussion will reveal the reason why QoS-TCP can grab bandwidth but TCP cannot in the indoor experiments. After careful investigations of congestion window behaviors and packet dump data both in the air and wired links, it is found that burst bit error occurred in the air, and so that many consecutive MAC frame losses occurred. The frame losses forced to retry sending the lost MAC frame. Retry-out and frame deletion, however, occurred in

MAC. This implied TCP data losses. In default, computer simulation used seven as a number of retry-out. Ethernet Converters were found to be set five as the number of retry-out in default. Since we assumed no bit error in the computer simulation, we thought it was extremely rare to cause TCP data losses resulting from consecutive five MAC retries and retry-out. As stated before, TCP ACK packet is likely to be lost due to AP buffer overflow. Therefore, fast retransmission or SACK (selective ACK) does not work well, and for a moment, all the suffered TCP flows go into timeout and reduce their sending rate and congestion window. In this situation, larger slow start threshold in QoS-TCP than that in a traditional TCP (TCP-Reno) derives an advantage of obtaining more bandwidth as explained in the Section II. Therefore, the TCP data losses give QoS-TCP flows more advantages than traditional TCP flows which have no advantages in congestion. In the simulation, QoS-TCP has no advantages against the competitive flows because of no data packet losses, but has advantages in real terminal experiments because of data packet losses. In the real experiment, however, TCP data losses happened with higher probability than we expected. Note that in the experiments and the investigations, APs and terminals were placed enough close (within 0.3 m) to each other, and the experiments were done in two different places. Therefore, we conclude that QoS-TCP is likely to have a possibility to guarantee a target bandwidth, with depending on both the specified target values and mobile wireless environments (channel capacity).

V. Conclusion

QoS-TCP bandwidth guarantee performance is investigated in both fixed and mobile wireless networks both in outdoor and indoor environments. QoS-TCP [6] was proposed, which tries to guarantee a target bandwidth and has a limitation of the guarantee because of avoiding congestion collapse. Through our experiments where real terminals are used, in IEEE802.11 networks, many wireless factors such as unfairness problems between uplink TCP flows, radio interferences and burst bit errors are proved to significantly effect on the QoS-TCP performance. Especially, burst bit errors contribute QoS-TCP in its guarantee performance.

After careful investigations of congestion window behaviors and packet dump data both in the air and wired links, it is found that differences in characteristics of guarantee performance between computer simulations and real terminal experiments simply result from differences of model parameters. However, the parameter differences are not easily foresighted because (1) they are brought from the combination of the unfairness problems and the burst bit errors, (2) the burst errors give advantages not to traditional TCP but to QoS-TCP, and (3) they might be brought from heterogeneity of real individual APs whose buffer sizes vary from 30 to 300 packets and queueing behaviors of the AP are far from ideal FIFO.

The unfairness problem between uplink TCP flows is different from that in computer simulations but it affects little on QoS-TCP performance by itself. Combination of the unfairness problem and burst bit errors gives QoS-TCP advantages against competitive TCP in obtaining throughput even when QoS-TCP later joins the bandwidth competition.

In a real terminal, we conclude that QoS-TCP is likely to have a possibility to guarantee a target bandwidth, with depending on both the specified target bandwidth and mobile wireless environments (channel capacity).

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References

[1] IEEE802.11 MAC, http://standards.ieee.org/getieee802/download/802.11-2007.pdf
[2] Madwifi, http://madwifi-project.org/
[3] GNU Radio, http://gnuradio.org/redmine/wiki/gnuradio
[4] Weili.H, Renle.L , ”A Strategy to Optimize the EDCA in WLAN,” Intelligent Information Technology Application2009, Vol. 1, 2009.
[5] K.Yamanegi, G.Hasegawa, M.Murata, ”Achieving predictable throughput of TCP based on inline network measurement”, IEICE Technical Report, Vol. 106, No. 237, IN2006-50, pp. 7-12, Sep. 2006.
[6] H.Shimonishi, T.Hama, T.Murase, ”TCP Congestion Control Enhancements for Streaming Media,” IEEE Consumer Communications and Networking Conference 2007, pp.303-307, Jan. 2007.
[7] K.Akase, H.Obata, T.Murase, Y.Hirano, K.Ishida, ”Setting Methods of a Slow Start Threshold in TCPs for Guaranteeing Bandwidth over wireless LAN, ”IEICE Transaction on Communications Vol. J93-B, No. 2, pp.153-165, Feb. 2008.
[8] S. Pilosof, R. Ramjee, Y. Shavitt, P. Sinha, ”Understanding TCP fairnessover Wireless LAN,” IEEE INFOCOM 2003, April 2003.
[9] M. Hashimoto, G. Hasegawa and M. Murata, ”Trade-off evaluation between fairness and throughput for TCP congestion control mechanisms in a wireless LAN environment,” Performance Evaluation of Computer and Telecommunication Systems 2010, July 2010.
[10] Methodology for Testing Wireless LAN Performance, http://www.super-g.com/collateral/atheros_benchmark_whitepaper.pdf
[11] K. Tsukamoto, T. Yamaguchi, S. Kashihara, Y. Oie, ”Experimental Evaluation of Decision Criteria for WLAN handover: Signal Strength and Frame Retransmission,” IEICE Transactions on Communications, Vol. E90-B, No. 12, pp. 3579-3590, Dec. 2007.
[12] IEEE 802.11n Outdoor Performance, http://www.lancom.eu/fileadmin/produkte/feature/techpaper/TP-WLAN-Outdoor_Performance-EN.pdf
[13] R.Ando, T.Murase, M.oguchi, ”Experimental Study on Wireless LAN QoS for Bandwidth Guaranteed TCP with Real Terminals and Access Points,” Multimedia, Distributed, Cooperative, and Mobile Symposium, 8E-3, pp.1898-1904, July 2010.