A size-based scheduling approach to improve fairness over 802.11 wireless networks

Diego Ferrero
Institut Eurecom, France
ferrero@eurecom.fr

Guillaume Urvoy-Keller
Institut Eurecom, France
urvoy@eurecom.fr

1. MOTIVATION

Fairness over 802.11 wireless networks has been studied by several researchers. Most solutions involve modifications of the MAC protocol, e.g. [4], but only few work has focused on fairness at the TCP level. In [11], the authors study the unfairness between simultaneous TCP uploads and downloads for the case of a multi-hop ad-hoc network connected to the wired Internet. They propose to replace the FIFO scheduling discipline at the MAC layer by a non work-conserving discipline that accounts for the level of contention experienced previously by a node. Their solution addresses the exposed node problem. In [10], a RED-based solution that involves the cooperation of neighboring nodes is proposed to enforce fairness among TCP flows. In [9], the authors focus on the case of an 802.11 hotspot with simultaneous uploads and downloads. They propose to enforce fairness by adjusting the advertised window of TCP connections.

More generally, it has been observed that the size of the advertised window of TCP greatly impacts the performance and consequently the achievable fairness [1]. Experimental studies, e.g. [2, 5], have confirmed the impact of the advertised window on the performance of TCP. In [3], the authors study the optimal advertised window for TCP and a chain topology.

In this work, we propose to replace the FIFO policy by LAS (Least Attained Service - [6], page 172). LAS has been shown to solve most of the fairness issues faced by TCP in a wired environment [8]. With the present work, we aim at investigating the ability of LAS to solve some of the fairness issues encountered in wireless environment using simulations in ns2.

2. LAS OVERVIEW

LAS is a size-based scheduling policy where priority is given to the flow that has received the least amount of service so far. In case of ties, flows share the server in a round-robin manner. A salient feature of LAS is that it has no internal parameter to tune. Upon arrival of a new packet when the queue is full, this packet is assigned a priority and the packet with the lowest priority is discarded. LAS has been proved to interact nicely with TCP by protecting flows in their slow-start phase [7] and to solve classical unfairness situations (UDP vs. TCP or TCP flows with different RTTs) in the Internet [8].

3. AD-HOC SCENARIO

We first compared LAS to FIFO for the case of an ad-hoc network with a chain topology. The chain consists of four nodes spaced by a distance of 150 m such that a node is in the data range of its successor and predecessor only and all nodes are in the same interference range. We consider the case where 3 ftp sessions are initiated from node 1 at one end of the chain to the 3 other nodes. We term them as connection 1, 2 and 3. We consider different maximum advertised window values. Note that since the ftp connections are simultaneously active, the rule obtained in [1] to assign the advertised window in a chain topology cannot be directly applied to our case. Our conclusions for these scenarios are:

(i) When the 3 ftp connections start simultaneously, the value of the advertised window greatly impacts the level of fairness achieved under FIFO/droptail. We investigated window sizes between 10 and 60 kbytes. Under FIFO/droptail, advertised windows larger than 25 kbytes result in clear unfairness as connection 1 receives the larger share of the available bandwidth. On the opposite, under LAS, the 3 connections obtain the same throughput whatever the window size is.

(ii) We further considered the case where the 3 connections do not start simultaneously. In this case, FIFO/droptail is again unfair. LAS enforces fairness among the 3 connections again, but after a transient period. If we consider the case where connection 1 starts at time 0 while the two other connections start later, this transient phase is the period necessary for connections 2 and 3 to send the same amount of packets as connection 1. During this phase, connection 1 is completely locked out. This is due to the fact that ftp connections are long-lived and one newly established connection can fully monopolize the medium in an ad-hoc setting under LAS. We expect that for more realistic traffic patterns consisting of flows of different sizes, this phenomenon will be attenuated.

(iii) The fairness enforced by LAS results in a decrease of the aggregate throughput of the ad-hoc network. However, this is only due to the fact that under LAS, connections 2 and 3 (that send more packets under LAS) require respectively two and three times more accesses to the medium to transmit the same number of packets as connection 1. Overall, the total number of accesses to the air interface is the same under FIFO/droptail and LAS.

4. HOTSPOT SCENARIO

We compare in this section LAS to FIFO/droptail for a hotspot scenario as the one of Figure 1. There are 3 hosts on the wired part and 3 wireless hosts. The link latencies on the wired part are 2, 50 and 150 ms respectively. Links are provisioned such that only the queue of the access point

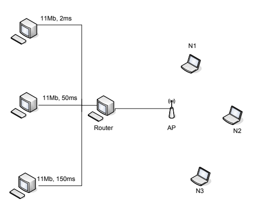

Figure 1: Simulated scenario

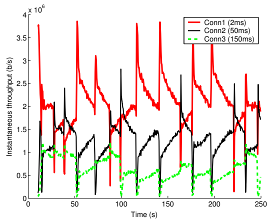

Figure 2: FIFO - Hotspot - Downloads only

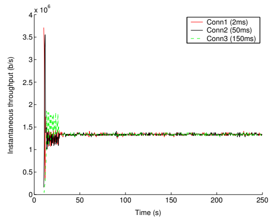

Figure 3: LAS - Hotspot - Downloads only

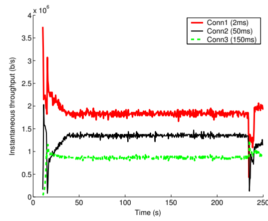

Figure 4: FIFO - Hotspot - 2 downloads and 1 upload

can build up.

We consider two scenarios. In the first scenario, there are 3 ftp servers on the wired network while in the second scenario, there are 2 ftp servers on the wired part and one is on the wireless network. For each scenario, we investigated the impact of the advertised window size (that varies between 10 kbytes and 60 kbytes) and of the buffer size at the access point. Our conclusions for those scenarios are as follows:

(i) For the first scenario (downloads only) and under FIFO/droptail, the connection with the smallest RTT obtains the largest throughput, almost irrespectively of the advertised window value. In contrast, LAS reduces unfairness gradually when the advertised window size is growing. Above 30 kbytes, the 3 connections obtain the same throughput under LAS. This is illustrated by Figures 2 and 3 where we plotted the instantaneous throughput of the 3 connections under FIFO/droptail and LAS for an advertised window of 60 kbytes.

(ii) For the second scenario (2 downloads and 1 upload), FIFO/droptail is unfair as the uploading connection gets the highest throughput (see Figure 4), as already observed in [9]. Again, LAS manages to enforce fairness and the 3 connections obtained the same throughput.

(iii) Fairness under LAS is not obtained at the expense of a decrease of the aggregate throughput as for a given window size, the aggregate throughput under LAS is the same as under FIFO/droptail. In this specific case the number of channel accesses for each delivered packet is exactly one, this explains why the aggregate throughput does not decrease.

(iv) Both FIFO/droptail and LAS are affected by the size of the buffer at the AP. If the buffer is significantly smaller than the sum of the advertised windows, the instantaneous throughputs exhibit high variances under both policies, in line with what has been observed in [9]. When the buffer size increases, variances decrease for both policies though faster for LAS as we observe for instance when comparing Figures 2 and 3 where the buffer size is 120 kbytes.

5. CONCLUSION AND FUTURE WORK

In this work we propose to replace FIFO/droptail by LAS to improve fairness in wireless networks. For the two cases that we studied, namely an ad-hoc chain and a hotspot scenario, LAS manages to enforce fairness, almost irrespectively of the advertised window size. On the contrary, the performance of TCP under FIFO/droptail is very dependent on this parameter. We have further shown that fairness is not obtained at the expense of a decrease of the utilization of the network. The next step for us is to investigate more complex traffic scenarios with flows of different sizes.

6. REFERENCES

[1] K. Chen, Y. Xue, and K. Nahrstedt, “On setting TCP’s congestion window limit in mobile ad hoc networks”, In *ICC ’03*, volume 2, pp. 1080–1084, 2003.

[2] M. Franceschinis, M. Mellia, M. Meo, and M. Munaf, “Measuring TCP over WiFi: A Real Case”, In *1st workshop on Wireless Network Measurements (Winmee)*, Riva Del Garda, Italy, 2005.

[3] Z. Fu, P. Zerfos, H. Luo, S. Lu, L. Zhang, and M. Gerla, “The impact of multihop wireless channel on TCP throughput and loss”, In *INFOCOM 2003*, volume 3, pp. 1744–1753, 2003.

[4] M. Heusse, F. Rousseau, R. Guillier, and A. Duda, “Idle sense: an optimal access method for high throughput and fairness in rate diverse wireless LANs”, In *SIGCOMM ’05*, pp. 121–132, 2005.

[5] V. Kawadia and P. R. Kumar, “Experimental investigations into TCP performance over wireless multihop networks”, In *E-WIND’05*, pp. 29–34, 2005.

[6] L. Kleinrock, *Queuing Systems, Volume II: Computer Applications*, Wiley, New York, 1976.

[7] I. Rai, E. W. Biersack, and G. Urvoy-Keller, “Size-based Scheduling to improve the Performance of Short TCP Flows”, *IEEE Network Magazine*, 2005.

[8] I. A. Rai, Urvoy-Keller, and E. W. Biersack, “LAS Scheduling Approach to Avoid Bandwidth Hogging in Heterogeneous TCP Networks”, In *HSNMC’04*, July 2004.

[9] P. Sinha, S. Pilosof, R. Ramjee, D. Raz, and Y. Shavitt, “Understanding TCP fairness over Wireless LAN”, In *Proceedings Infocom 2003*, April 2003.

[10] K. Xu, M. Gerla, L. Qi, and Y. Shu, “Enhancing TCP fairness in ad hoc wireless networks using neighborhood RED”, In *MobiCom ’03*, pp. 16–28, 2003.

[11] L. Yang, W. K. Seah, and Q. Yin, “Improving fairness among TCP flows crossing wireless ad hoc and wired networks”, In *MobiHoc ’03*, pp. 57–63, 2003.