Understanding TCP fairness over Wireless LAN

INFOCOM 2003

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2003/5/23

Outline

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Introduction

- More and more hot spots such as airports, hotels and cafes are providing wireless access to Internet
- Because most of today's Internet applications use TCP and with the increasing popularity of WLAN, TCP fairness over WLAN ensures the access to the network to be equitable

Problem overview

- Unfairness between upstream and downstream TCP flows in 802.11 networks
- Test environment
  - A commercial 802.11b network consisting of one BS and three mobile nodes
  - One mobile TCP sender and one mobile TCP receiver

Problem overview (cont'd)

MTU	# of up flows	# of down flows	UDP flow	R_u / R_d	SD
1500	1	1	–	1.44	0.22
1500	2	2	–	1.58	0.23
1500	3	3	–	1.76	0.34
1500	4	4	–	1.80	0.27
1500	2	2	500/2ms	1.79	0.35
1500	2	2	1000/2ms	2.15	0.55
500	1	1	–	1.77	0.39
500	2	2	–	1.83	0.38
500	3	3	–	1.87	0.41
500	1	1	450/1ms	3.05	0.83
500	2	2	450/1ms	7.9	4.57

MTU: maximum transmission unit

R_u: average TCP uplink throughput

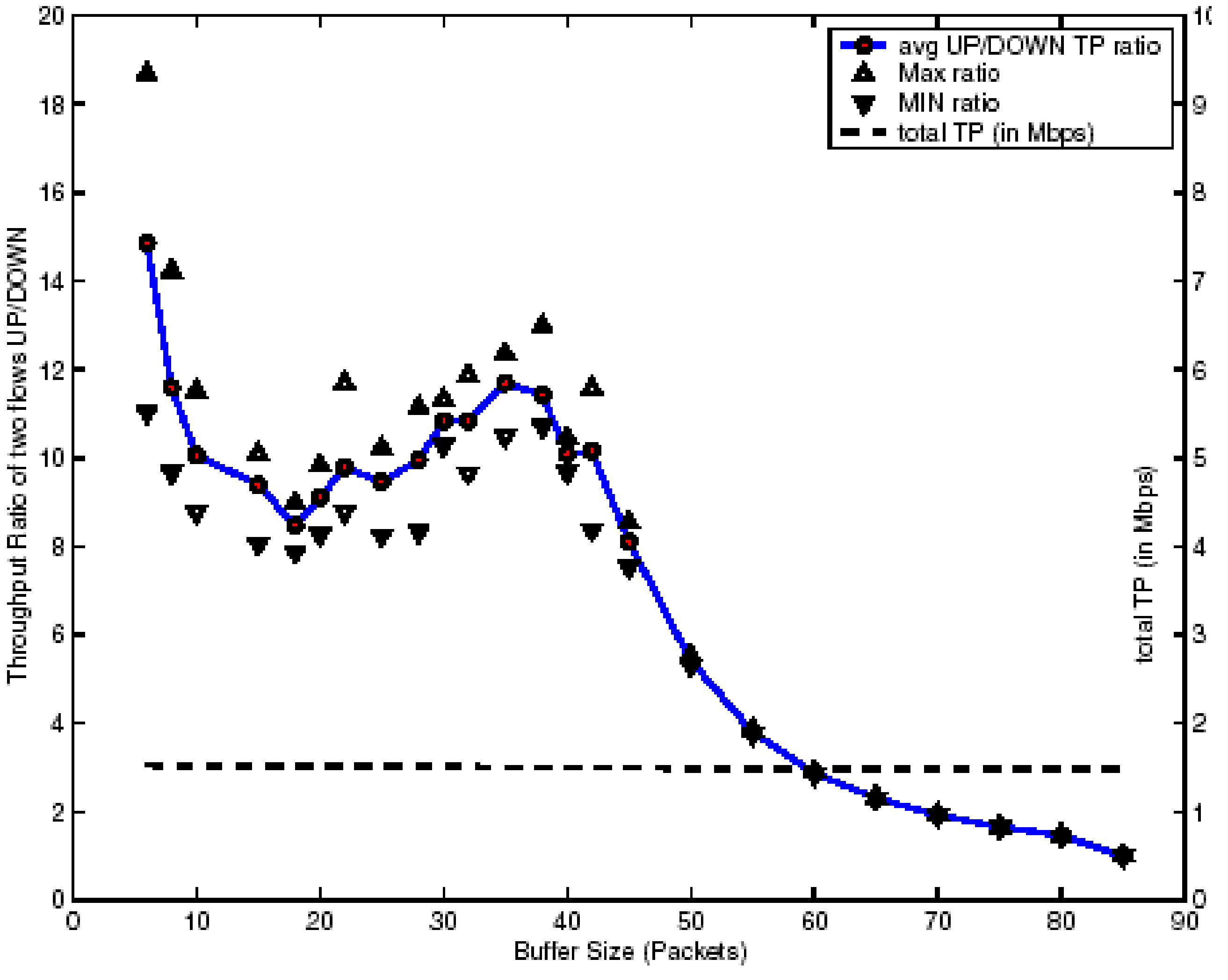
R_d: average TCP downlink throughput

SD: standard deviation

Simulation study

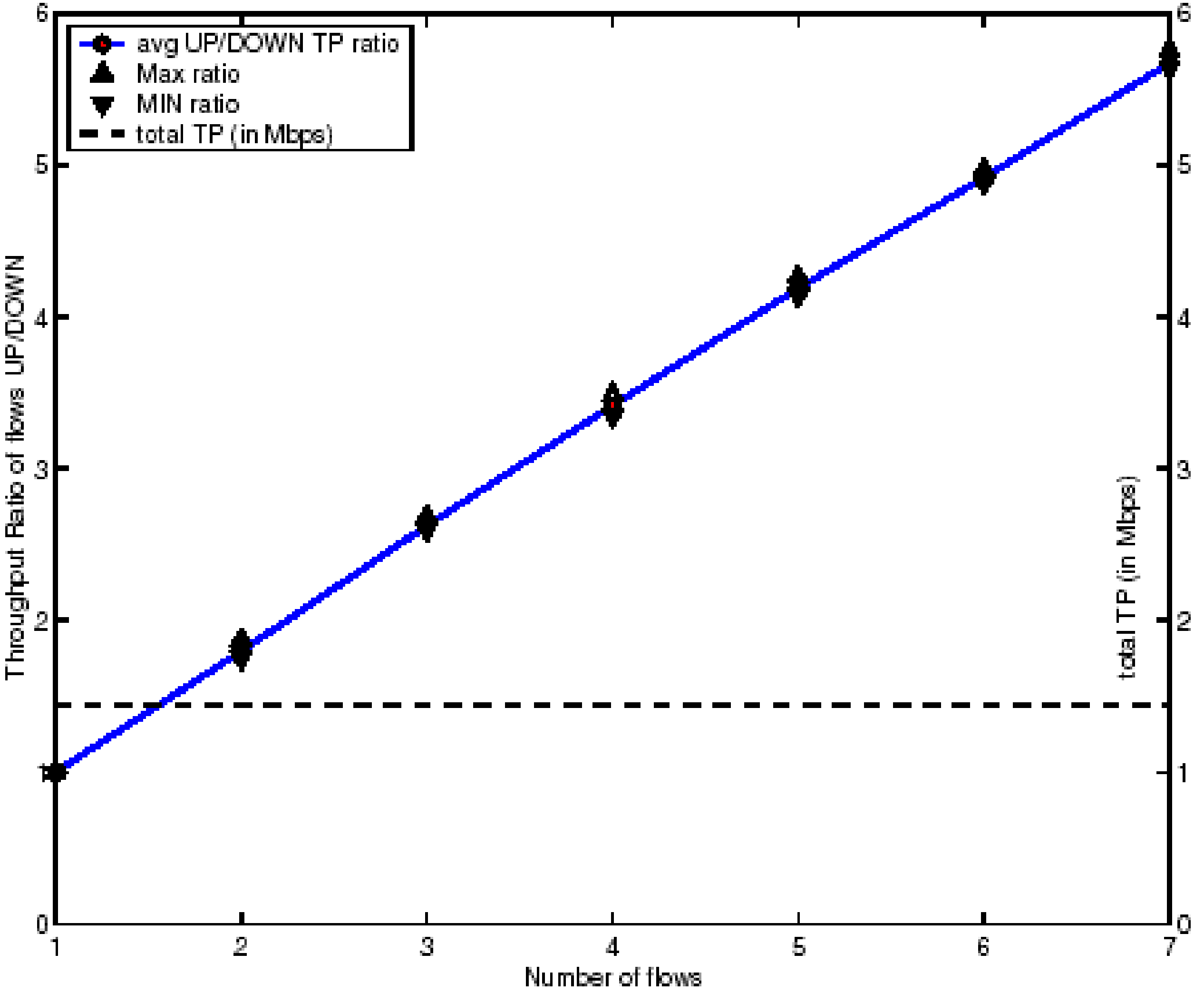
- To isolate the impact of factors like wireless link interference and implementation details of the 802.11 MAC layer, a NS2 simulation is carried out

Simulation Study (cont'd)



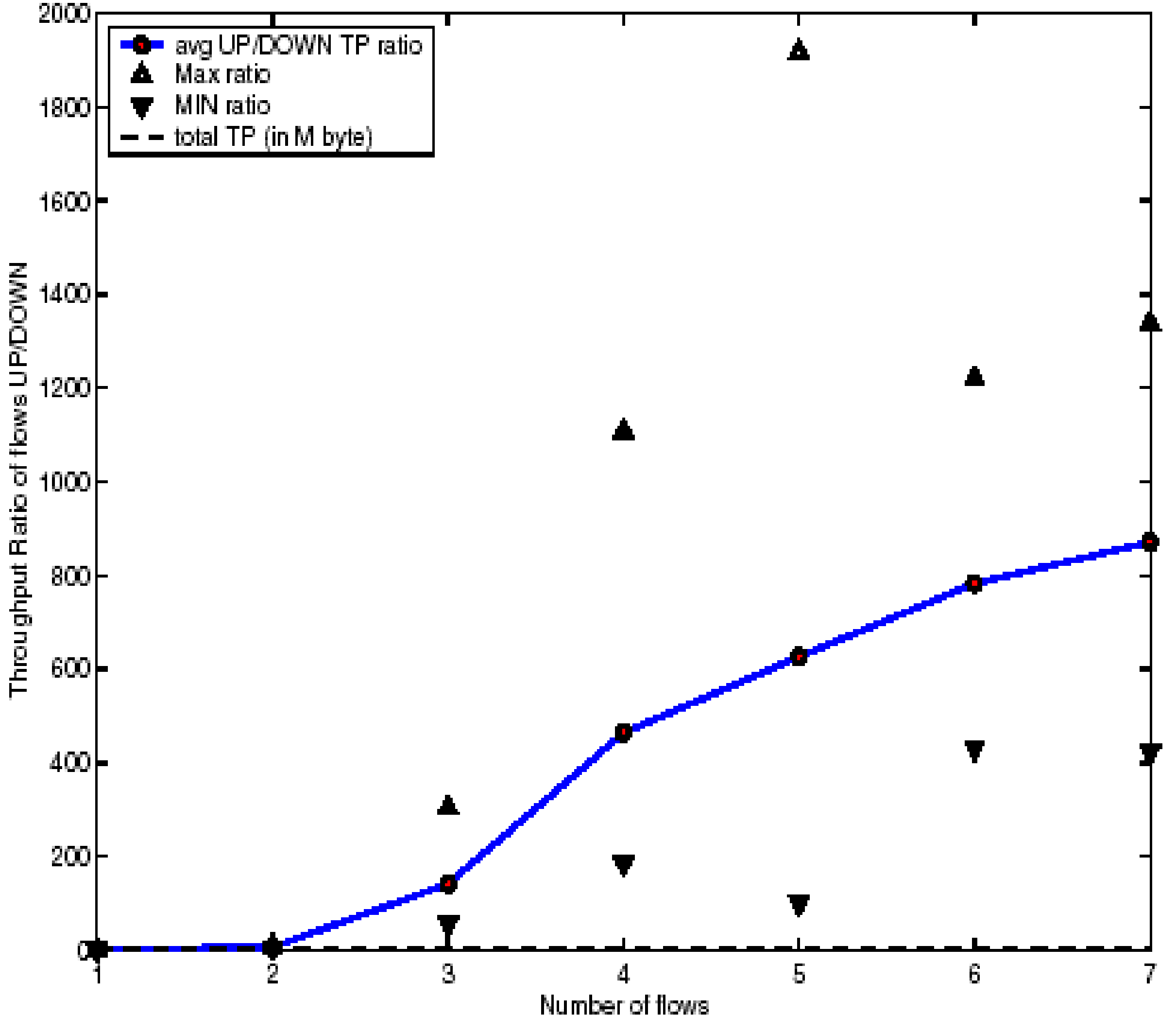
One upstream and one downstream flow

Simulation Study (cont'd)



One upstream and multiple downstream flows

Simulation Study (cont'd)



Equal number of upstream and downstream flow

TCP access model

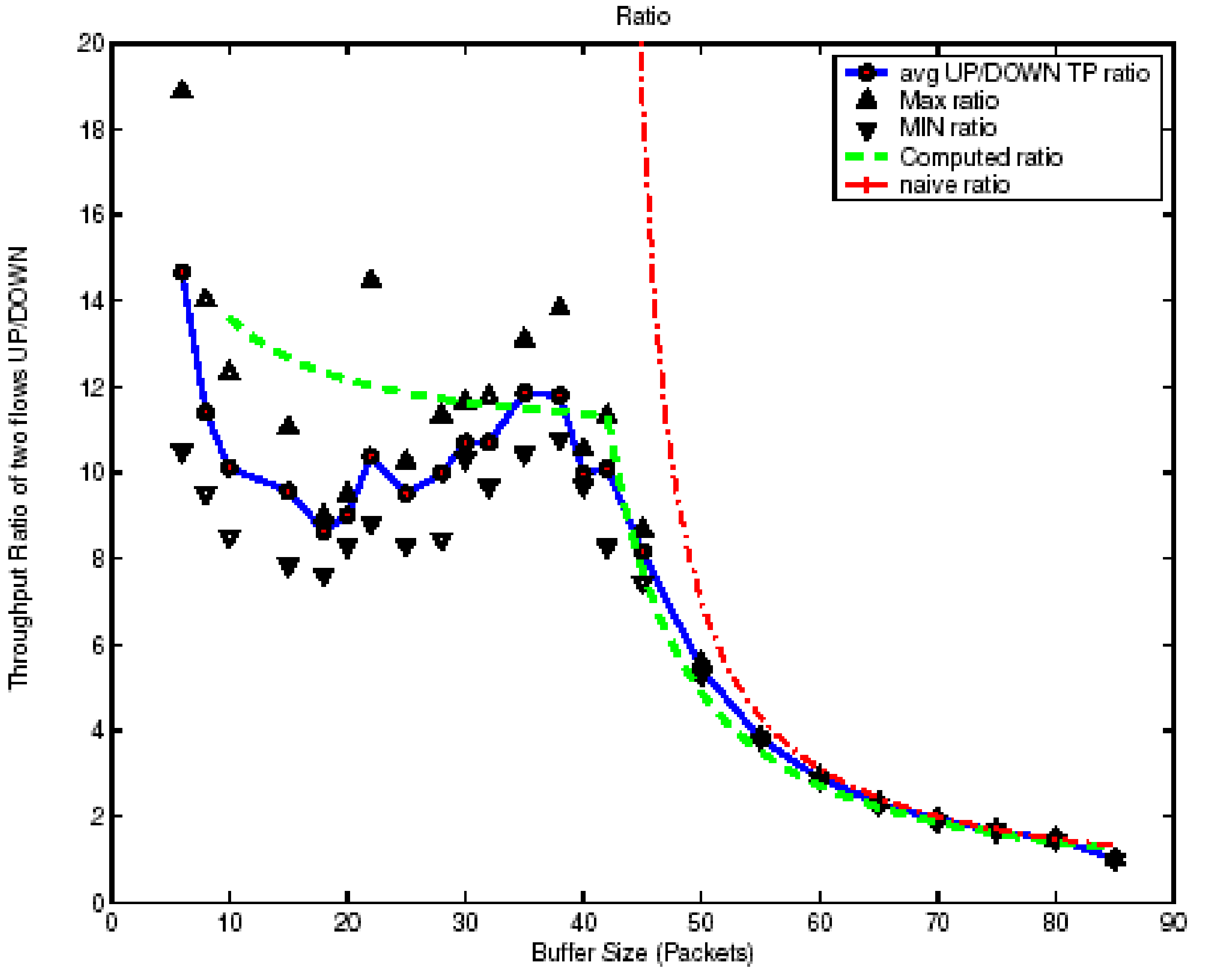
- For one upstream and one downstream, the ratio $\overline{R}$ between them is:

$$\bar{R} = \frac{-1}{3B} + \frac{4 \cdot 2^{\frac{2}{3}}\, w^2}{\left(81\, B^2\, w^4 + 81\, B^3\, w^4 - 4\, w^6 + X\right)^{\frac{1}{3}}\, 12B} + \frac{2 \cdot 2^{\frac{1}{3}} \left(81\, B^2\, w^4 + 81\, B^3\, w^4 - 4\, w^6 + X\right)^{\frac{1}{3}}}{12Bw^2}$$

B: buffer size at the BS

w: TCP receiver window size

TCP access model (cont'd)



One upstream and one downstream flow

TCP access model (cont'd)

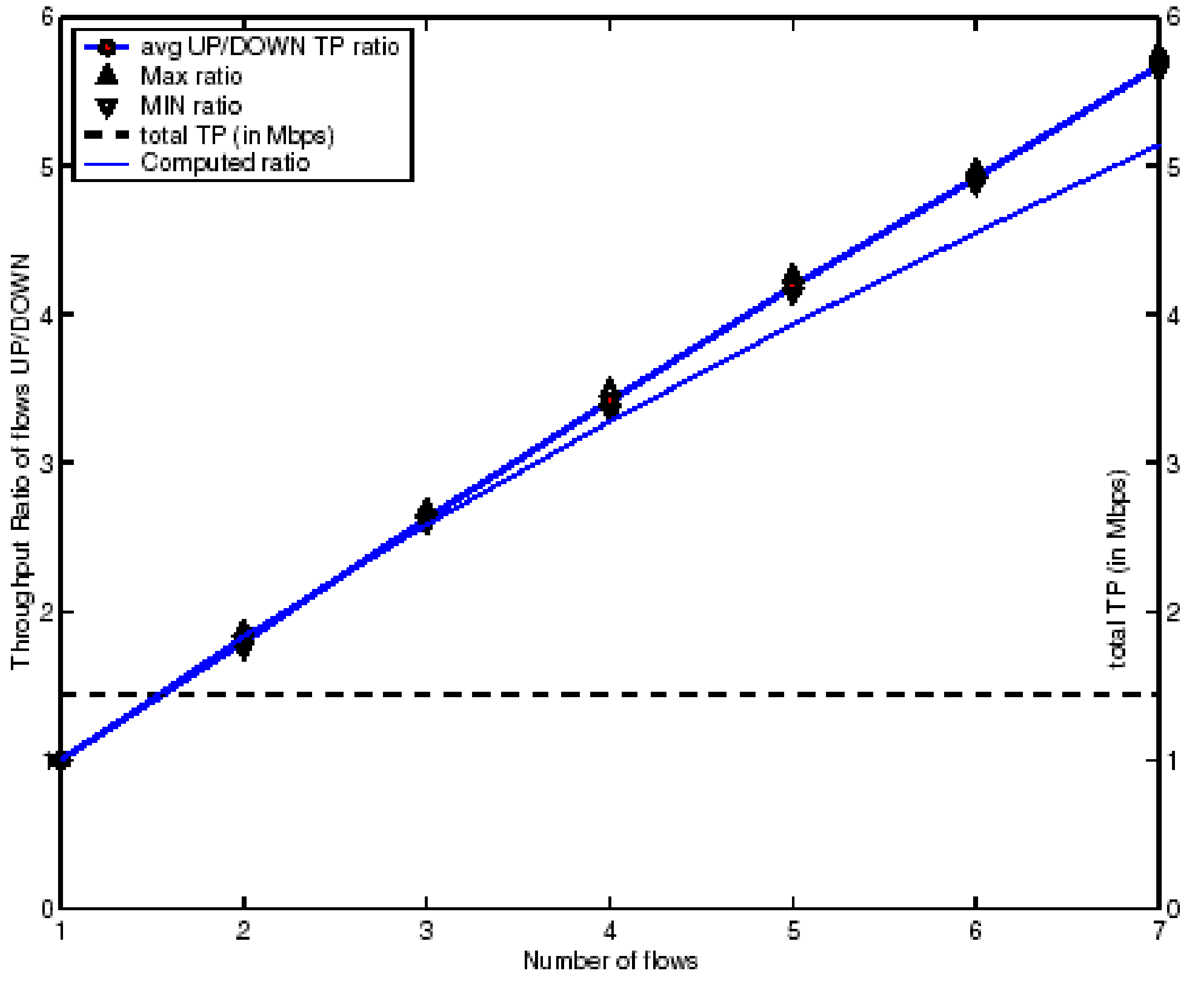
- For multiple flows, the ratio $\bar{R}_n$ between the upstream flow and each of the n downstream flows is:

$$\bar{R}_n = \sqrt{\frac{3\alpha}{2npw^2} + \frac{3(B - \alpha w)}{4nw}}$$

a: ACK packets per data packet, usually has default value 1

p: drop rate

TCP access model (cont'd)



One upstream and multiple downstream flows

TCP access model (cont'd)

- Factors that affect most the ratio between upstream and downstream flows:
  - Buffer size at the base station
  - TCP receiver window size

Solution

- Solutions that change the MAC layer involve expensive hardware upgrades
- Solution 1:
  - Increase the buffer size of the base station
  - Unfeasible solution since there is no way to know how big should the buffer be

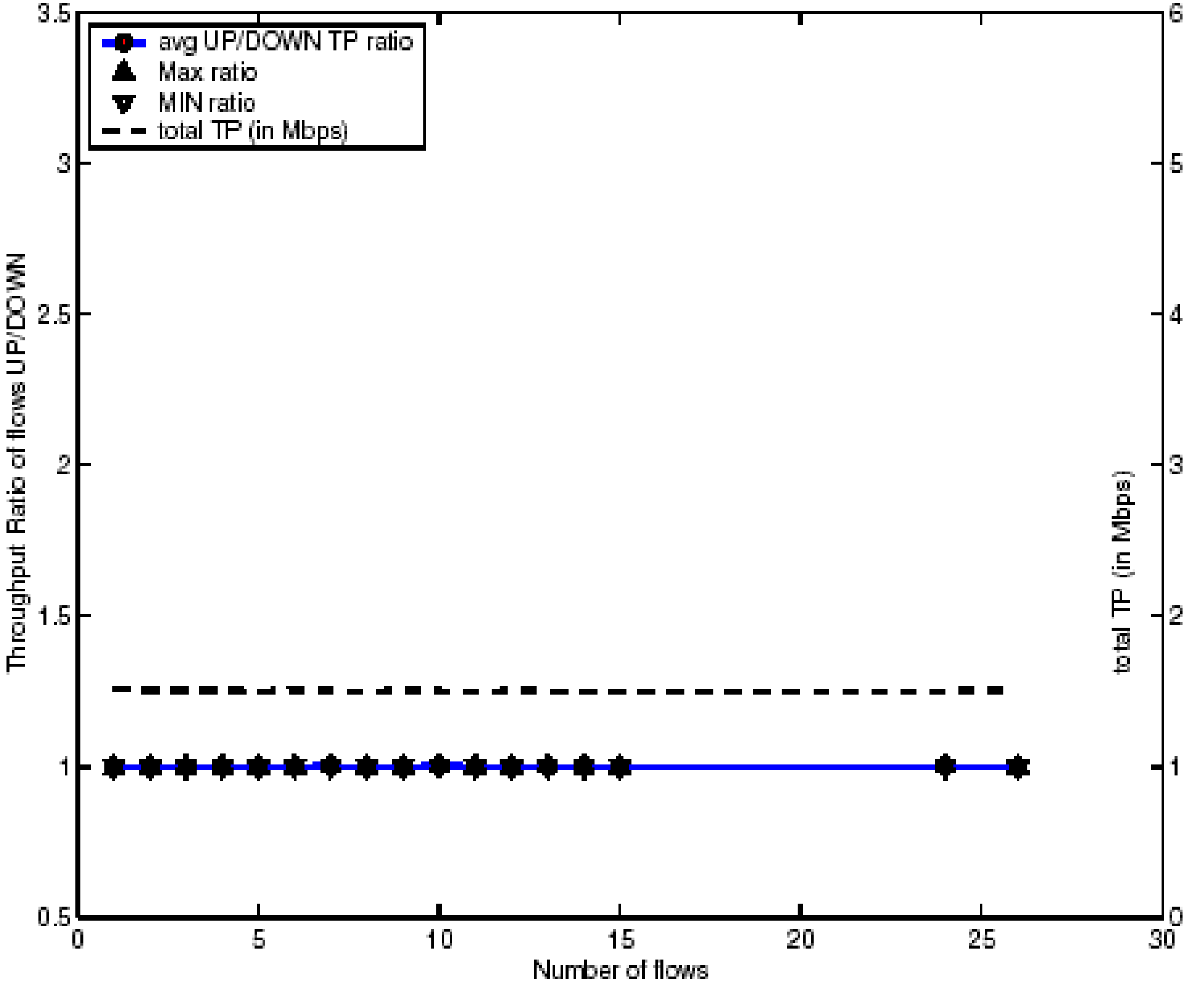
Solution (cont'd)

- Solution 2:
  - Fake duplicate ACK packets to force TCP to reduce the upstream window size
  - Discard data packets of the upstream flow
  - Bandwidth waste and unnecessary ACK packets that use the limited resources

Solution (cont'd)

- Solution 3:
  - Use the advertised receiver window field in the ACK packets towards the TCP sender
  - By manipulating the receiver window at the base station to ensure that the TCP sender window is limited to the value we decide
  - If there are n flows and the BS has a buffer of size B, we can set the receiver window to be B/n

Solution (cont'd)



Discussion

- Only loss caused by buffer overflow is considered
- The distance between the mobile nodes and the base station
- When security mechanism is applied, the solution may not work

Conclusion

- The buffer size at the base station plays a key role in the TCP unfairness over Wireless LAN
- By manipulating the receiver window size, we can limit the sender window size, thus achieve fairness between TCP upstream and downstream flows in WLAN