Analysis of the phenomenon of several slow start phases in TCP

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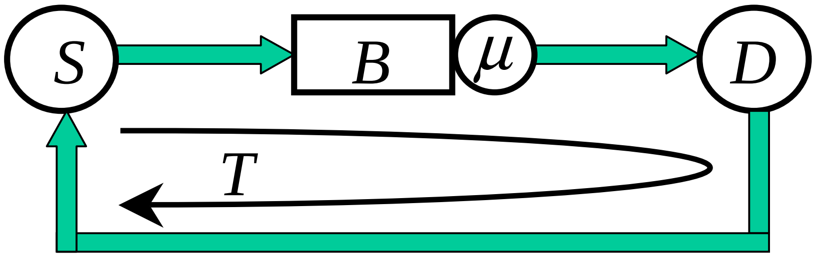
Burstiness of TCP during slow start

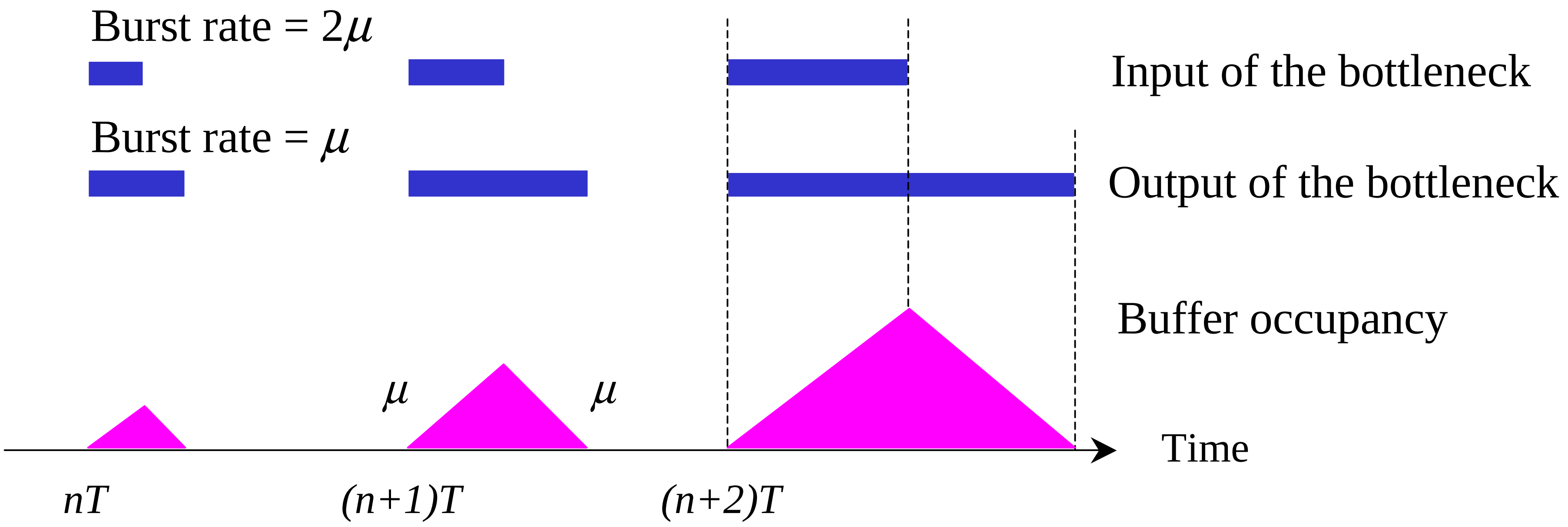
- Causes:
  - The fast window increase (one packet per ACK)
  - The ACK-clock based transmission

➡ The source transmits at twice the available bandwidth (case of no Delay ACK)

- Result:
  - In case of small buffers in routers, an early buffer overflow and an underestimation of the available bandwidth

The model


S
B
μ
D
T


Burst rate = 2μ
Input of the bottleneck
Burst rate = μ
Output of the bottleneck
Buffer occupancy
μ
μ
Time
nT
(n+1)T
(n+2)T

The overflow window W_B

Due to these bursts, *B* overflows at a window [Lakshman et al. 1997, Barakat et al. 1999]

$$W_B = 2^{n_B - 1} + B$$

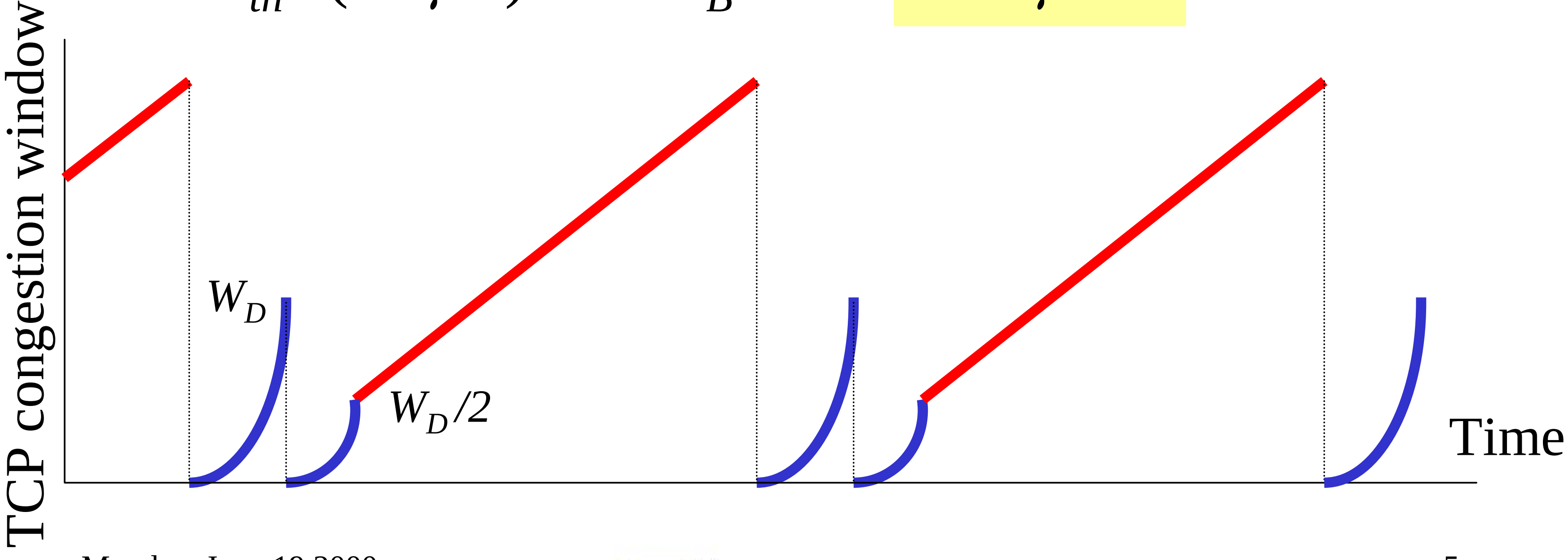
$$2^{n_B - 2} < B \leq 2^{n_B - 1}$$

And losses are detected at a window

$$W_D = \min\left(W_{th}, 2W_B\right)$$

Double slow start phenomenon

- Observed in [Altman et al. 1995, Lakshman et al. 1997] for the Tahoe version of TCP.
- For $W_{th}=(B+\mu T)/2 < W_B \quad \Leftrightarrow \quad B < \mu T/3$



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Triple slow start phenomenon

Although $W_D/2 < W_B$, three consecutive slow start phases are seen in some simulations

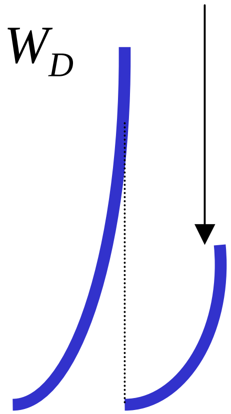
- **Cause**: Packets stored in the receiver buffer at the beginning of the second slow start phase
- **Explanation**: Different window evolution during the second slow start phase and thus different W_B
- **Consequence**: Further deterioration in performance

Analysis of triple slow start

Methodology

A detailed analysis of the window evolution and the buffer occupancy during the second slow start phase

Second slow start



We distinguish four consecutive phases

1- The window is multiplied by 1.5 every T

2- A burst of packets of size $2^{n_B-1} - B + 2$

3- The window is multiplied by 1.5 every T

4 - Normal slow start: The window is multiplied by two every T

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Results

- Losses cannot appear before phase 4
- In phase 4, losses cannot appear if $B > \mu T/7$
- For $B < \mu T/7$, a sufficient condition for losses

$$\left(2^{n_B-1} - B + 2\right)\left[2(1.5)^n - 1\right] > 2B - 1$$

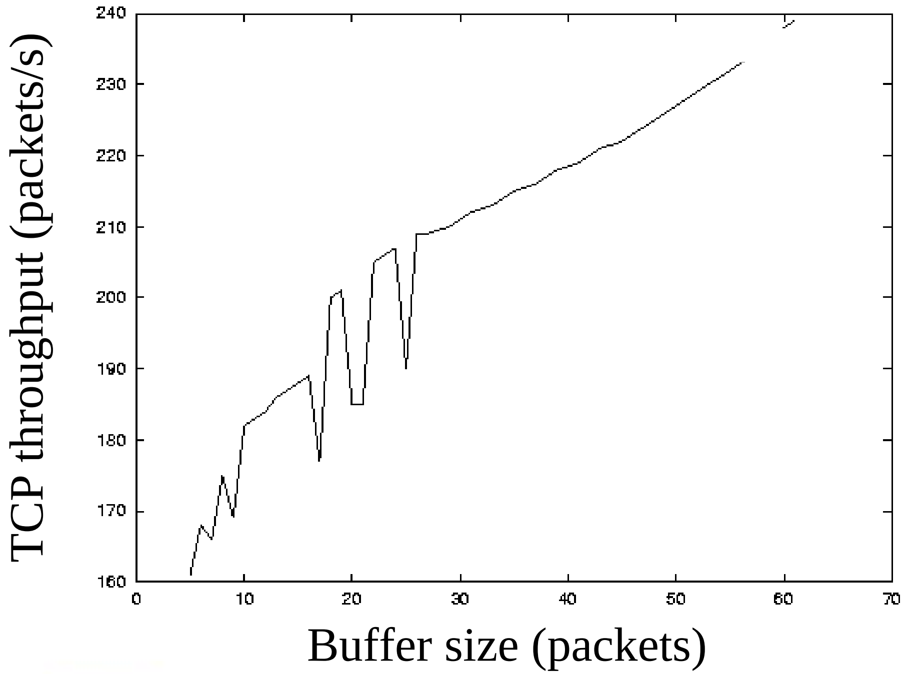
where n is the smallest integer number satisfying

$$\left(2^{n_B-1} - B + 2\right)\left[(1.5)^{n+1} - 1\right] > B + 1$$

Periodicity of the phenomenon

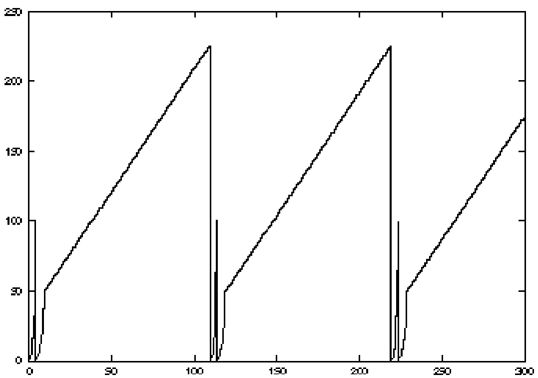
While increasing *B* from 0 to $\mu T/7$, the losses during the second slow start phase appear and disappear in a periodic manner causing an oscillation in the throughput

`ns` simulator
μ=1.5 Mbps
T=560 ms
MSS = 512 bytes

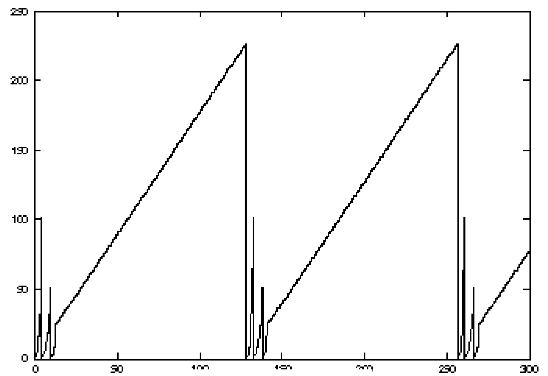


Results

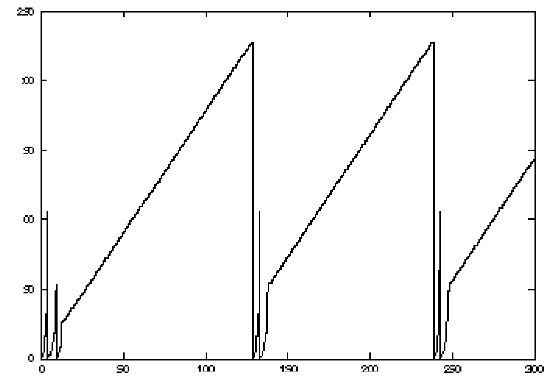
TCP congestion window vs. Time



B=19 packets



B=20 packets



B=22 packets

Conclusions:

- The problem of TCP slow start burstiness (C. Barakat and E. Altman, "Performance of short TCP transfers", Networking 2000, May 2000)
- Slow start has different behavior when some packets are stored in the receiver buffer