Zero Queueing Flow Control

(Or, How to Get the Most Out of a High-Bandwidth Internet Connection)

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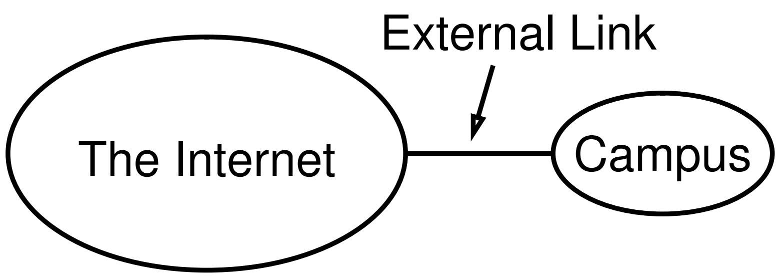
Presentation Outline

- **Campus Internet Connection Scenario**
- **Possible Low Utilization due to TCP Unfairness Problems**
- **"Real" TCP Simulator**
- **Zero Queueing Flow Control (ZQFC): A Solution to Solve the Low-Utilization Problem**
- **Simulation Results for Performance Comparison**

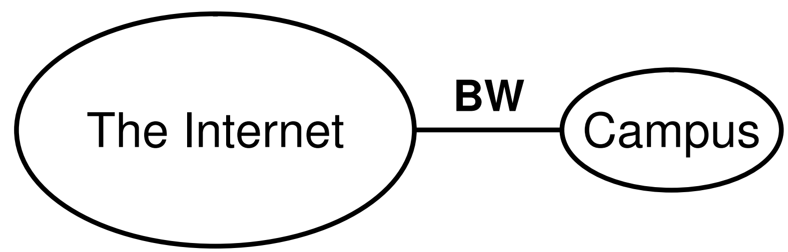
A Campus Internet Connection Scenario



For Harvard, the link is currently 10 Mbps.

For Harvard's Faculty of Arts and Sciences, measurements show 2 Mbps IN, and 1 Mbps OUT.

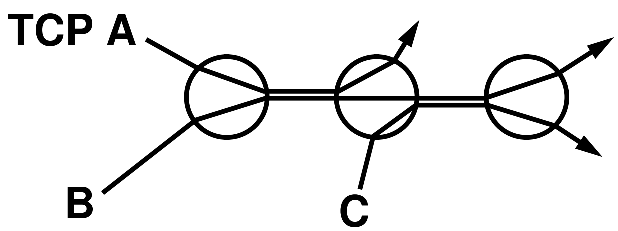
High Utilization Is Important



High BW connection is $$$. (A recent Harvard proposal on Internet connection calls for an annual cost of $250K per institution for OC-3.)

BW SHOULD BE EFFICIENTLY USED.

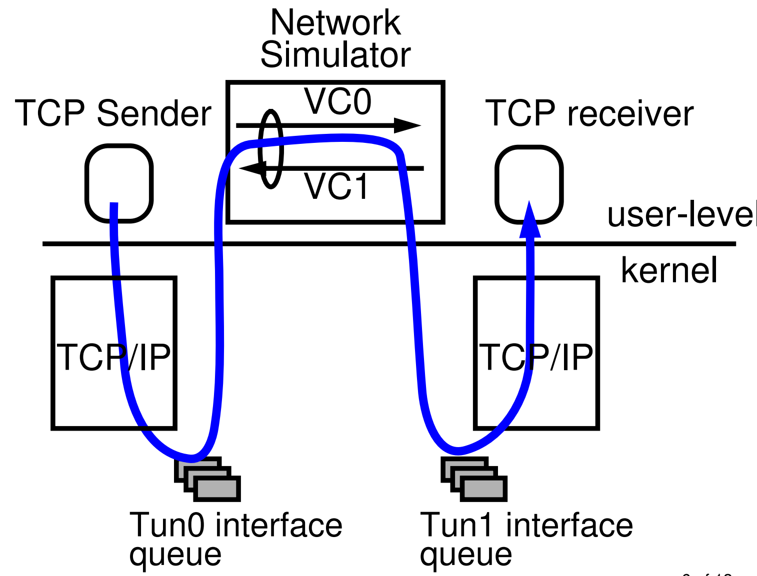
Possible Low Utilization Due to TCP Unfairness Problems



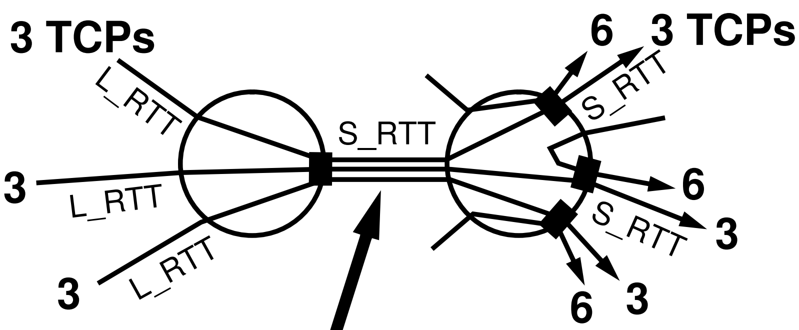
- **TCPs with long RTTs lose to those with short ones (e.g., A wins B).**
- **TCPs with more congestion bottlenecks lose to those with fewer ones (e.g., C wins B).**

(Papers by Floyd, Jacobson, etc.)

"Real" TCP Simulator w/ Off-the-Shelf "Reno" TCP Code



Low TCP Performance under Large RTT Disparity

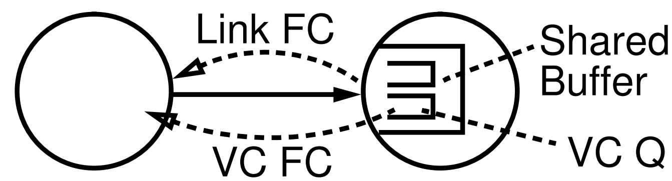


L_RTT	Utilization
1000	50%
3000	19%
4000	2%

- **ATM switches with EPD & PPD**
- **S_RTT=160 cell times**
- **Port Buf = 960 cells**
- **TCP Win = 64 kB**

Zero Queueing Flow Control (ZQFC)

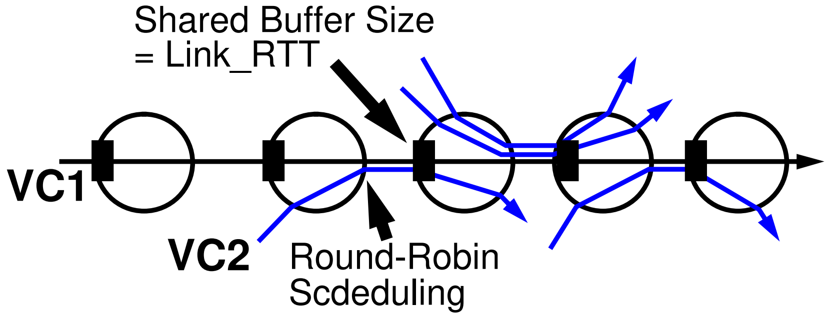
Simultaneous link and VC flow control:



- If VC Q builds up & available space in the shared buffer is < Link_RTT, then reduce VC buffer allocation (equivalently, rate of the VC) rapidly.
- If VC Q is empty, then increase VC buffer allocation slowly.

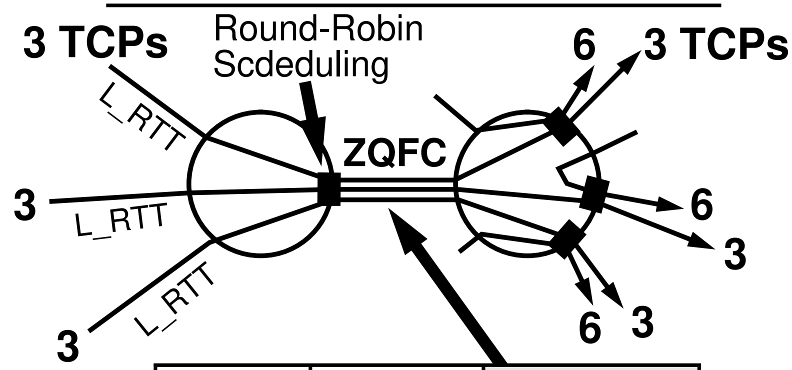
Zero queue occupancy (almost); each VC gets its maximum fair share; idle VCs get full buffer allocation (thus instant ramp up)

ZQFC Avoids HOL Blocking



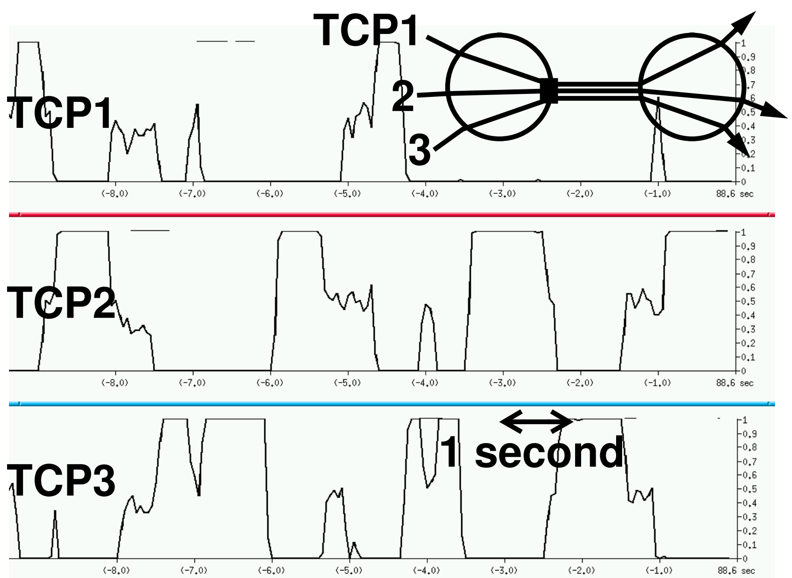
	Achieved BW for VC2
w/o ZQFC Rate Adaptation	1/3
w/ ZQFC Rate Adaptation	1/2

High TCP Performance under ZQFC Applied to a Single Link

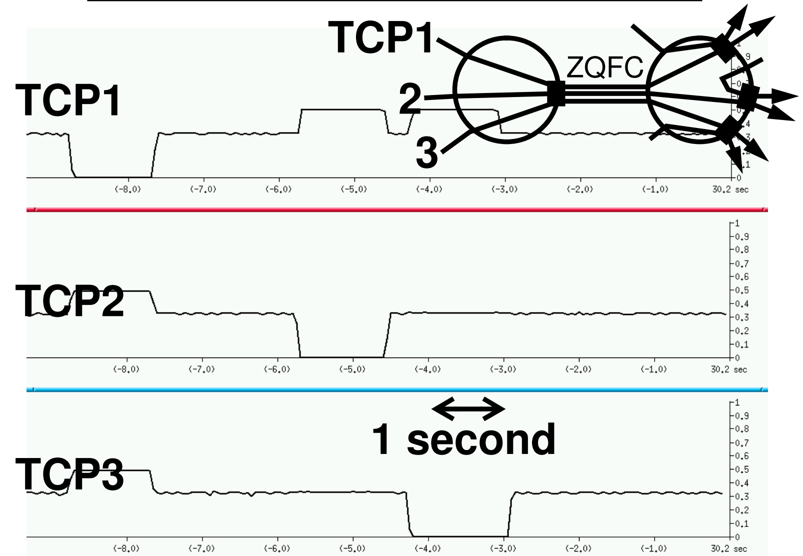


L_RTT	Old Util.	New Util.
1000	50%	89%
3000	19%	84%
4000	2%	85%

Bursty Behavior of TCP



Smooth Behavior of TCP under ZQFC



Conclusions

- The bursty behavior of a TCP at a congestion point (p. 11) makes it difficult for the TCP to cope with the next congestion.
- This can cause a large reduction in link utilization when RTT disparity is large (p. 7).
- Single-link ZQFC can solve the low-utilization problem (p. 10 and 12). The solution applies naturally to high-bandwidth external Internet connections for a campus (p. 3).