The Impact of Network Variabilities on TCP Clocking Schemes

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Outline

- Motivation
- Why pacing could be more bursty?
- The impact of network variabilities on the behavior of TCP clocking schemes
- Conclusion

TCP Clocking Schemes

- Self-clocking (a.k.a. ack-clocking)
  - ACKs “self-clock” the data to the rate of the bottleneck link
- Pacing
  - resembles to a rate control mechanism but preserves the concept of window control
  - a common implementation: release a window of packets evenly within each round-trip time
- In intuition, pacing will result in more smooth traffic, and smooth traffic will lead to better performance, however, …

Motivation

- Aggarwal, Savage, Anderson found pacing often results in *lower throughput* and *higher latency*.
- We are motivated to evaluate ack-clocking and pacing schemes with more fundamental behavioral analysis, especially on the aspect of traffic burstiness.

Our main results

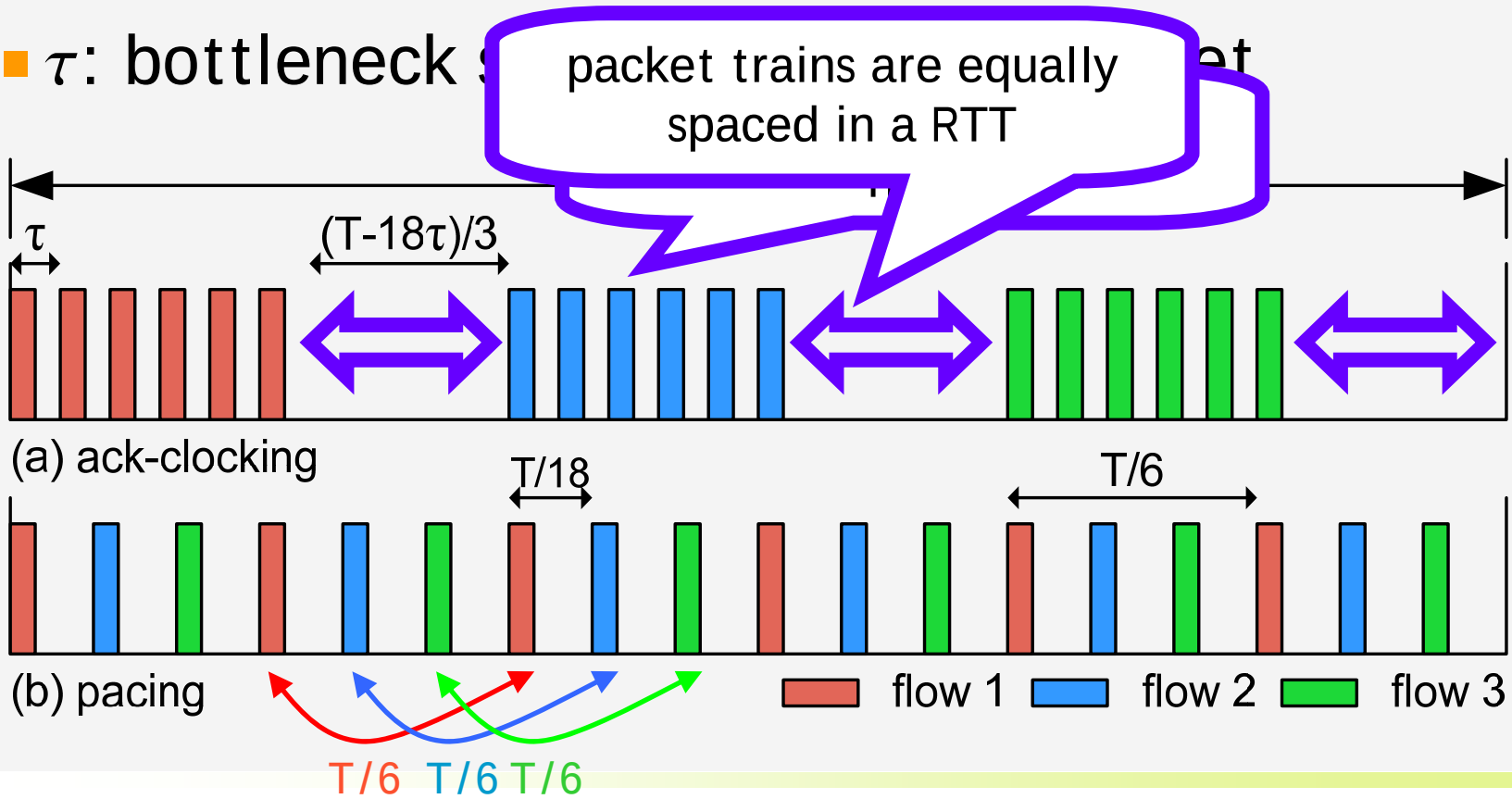
- Pacing traffic could be more bursty than ack-clocking traffic.
- The comparative traffic burstiness of TCP clocking schemes are largely affected by network path properties
  - whether the round-trip times (RTT) are the same
  - the number of flows
- Pacing is generally *less bursty* than ack-clocking with realistic settings, i.e., heterogeneous RTT flows.

Why pacing could be more bursty?

- Intuitively, pacing should be no more bursty than ack-clocking.
- We shall illustrate why the phenomenon could happen by behavioral models.

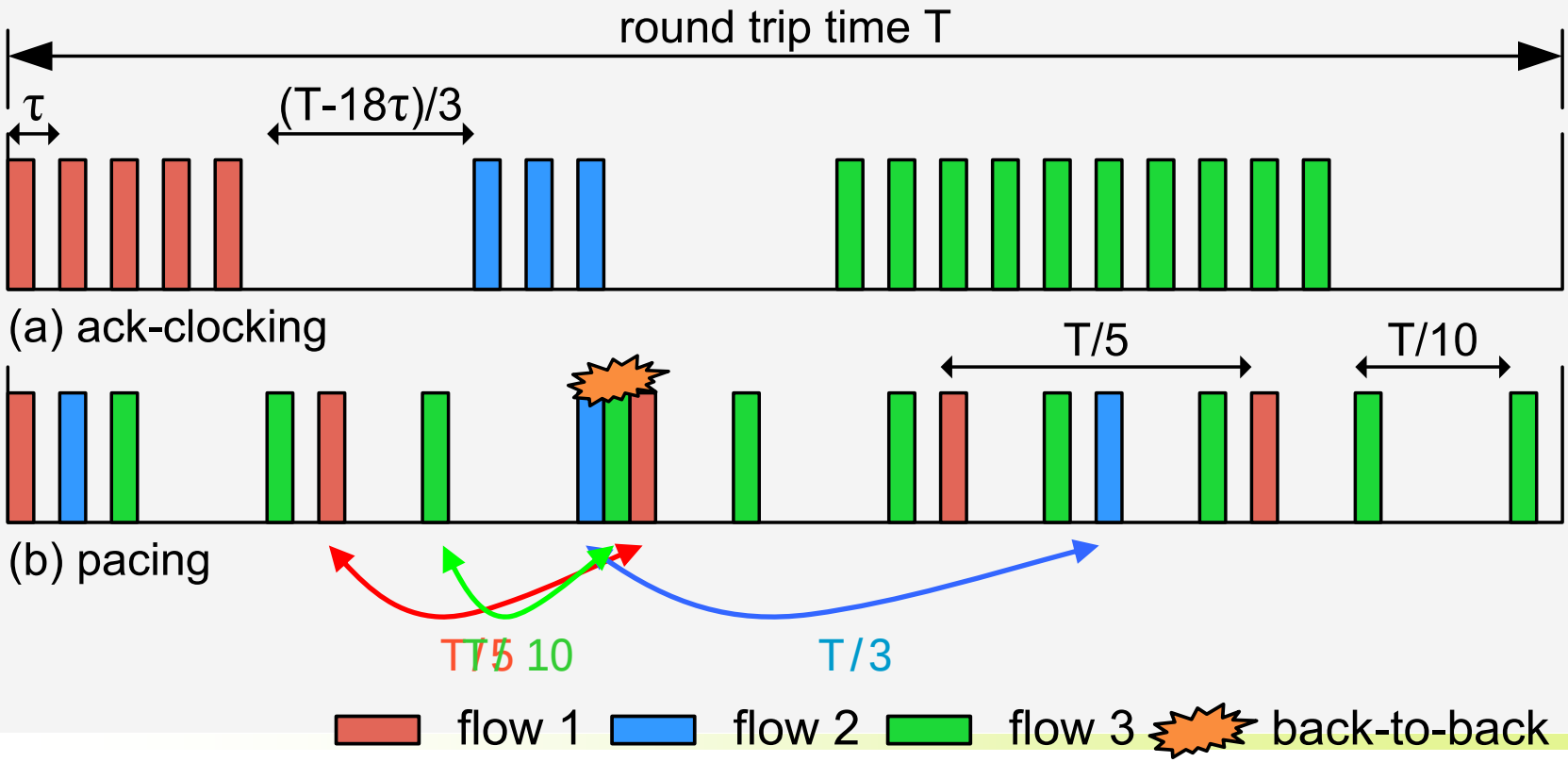
Behavioral models – equal window size

- Assumption: 3 flows, the same RTT, equal window size = 6
- τ: bottleneck s… …et



Behavioral models – different window size

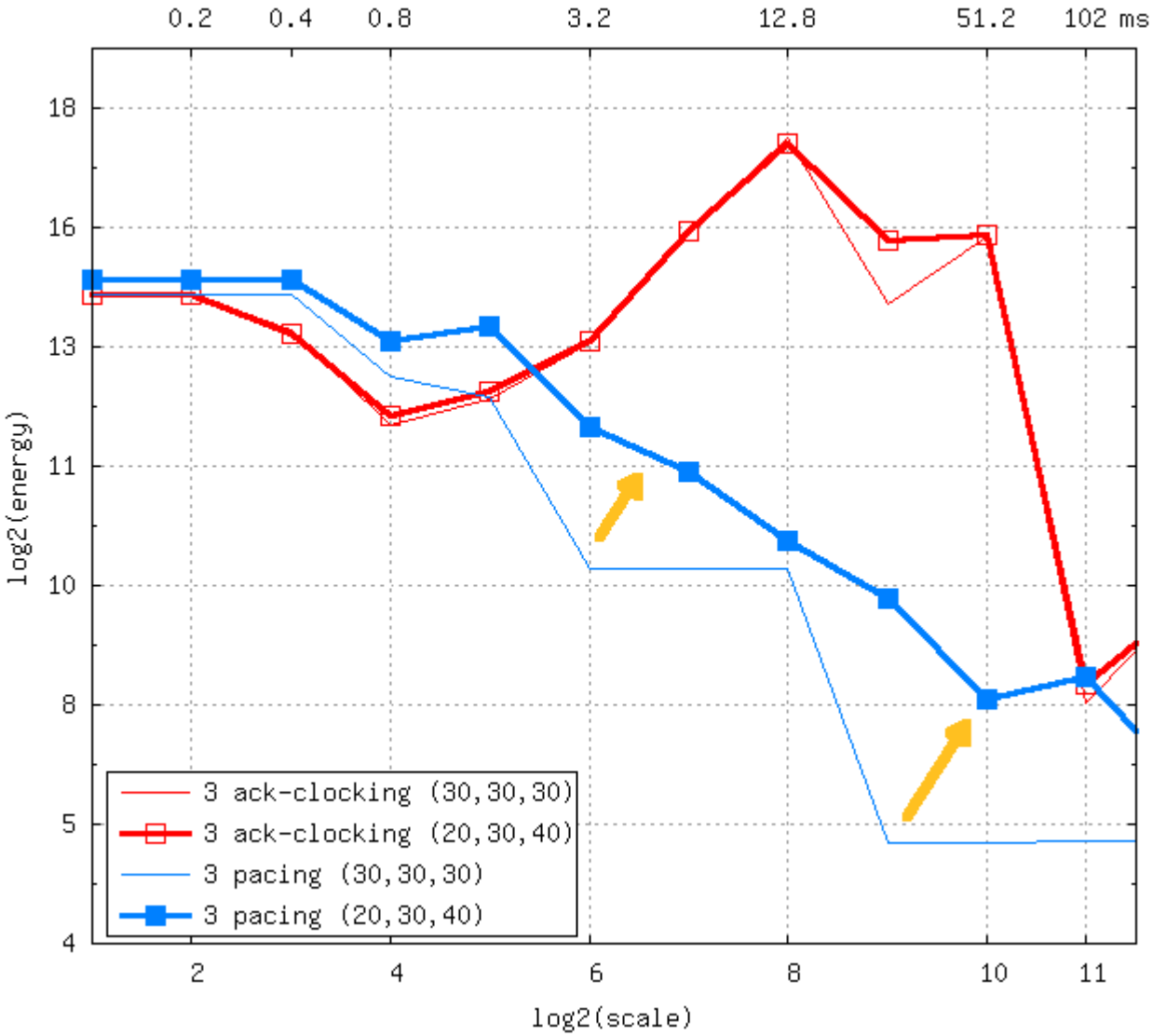
- Assumption: 3 flows, the same RTT, *different* windows size = 5, 3, 10, respectively.



The effect of window un-synchronization

- Generate packet arrival sequences by the behavioral models
  - T = 100 ms, τ = 0.1 ms, 3 flows
  - compare two cases
    - synchronized windows: 30, 30, 30
    - un-synchronized windows: 20, 30, 40
- Observe traffic burstiness based on the wavelet-based MultiResolution Analysis (MRA) for the synthesized traffic.

The energy plot



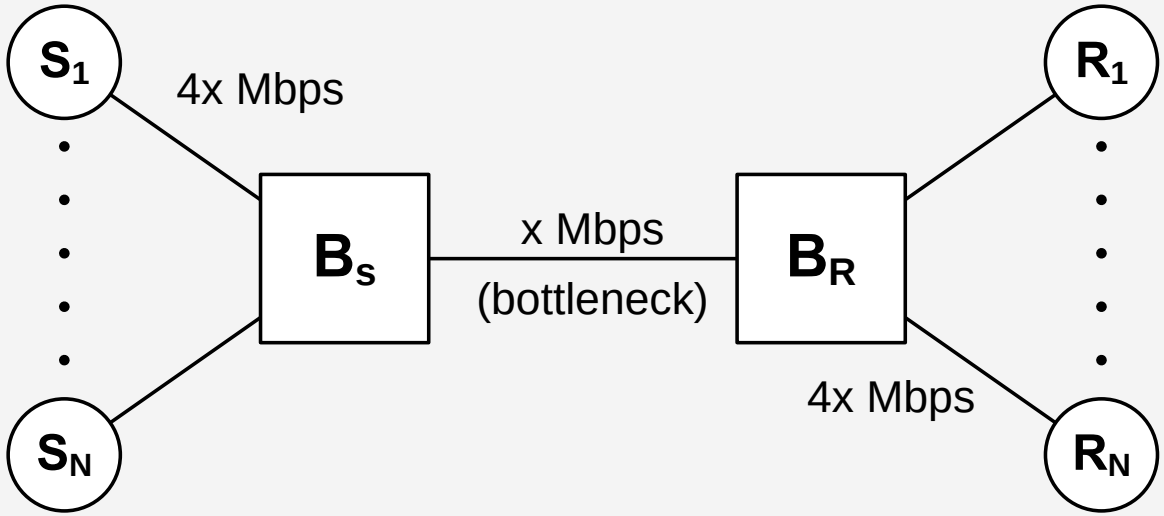
- Ack-clocking nearly remains its burstiness
- Pacing become more bursty
- The effect can be amplified by more flows (show later)

Validation and Simulations

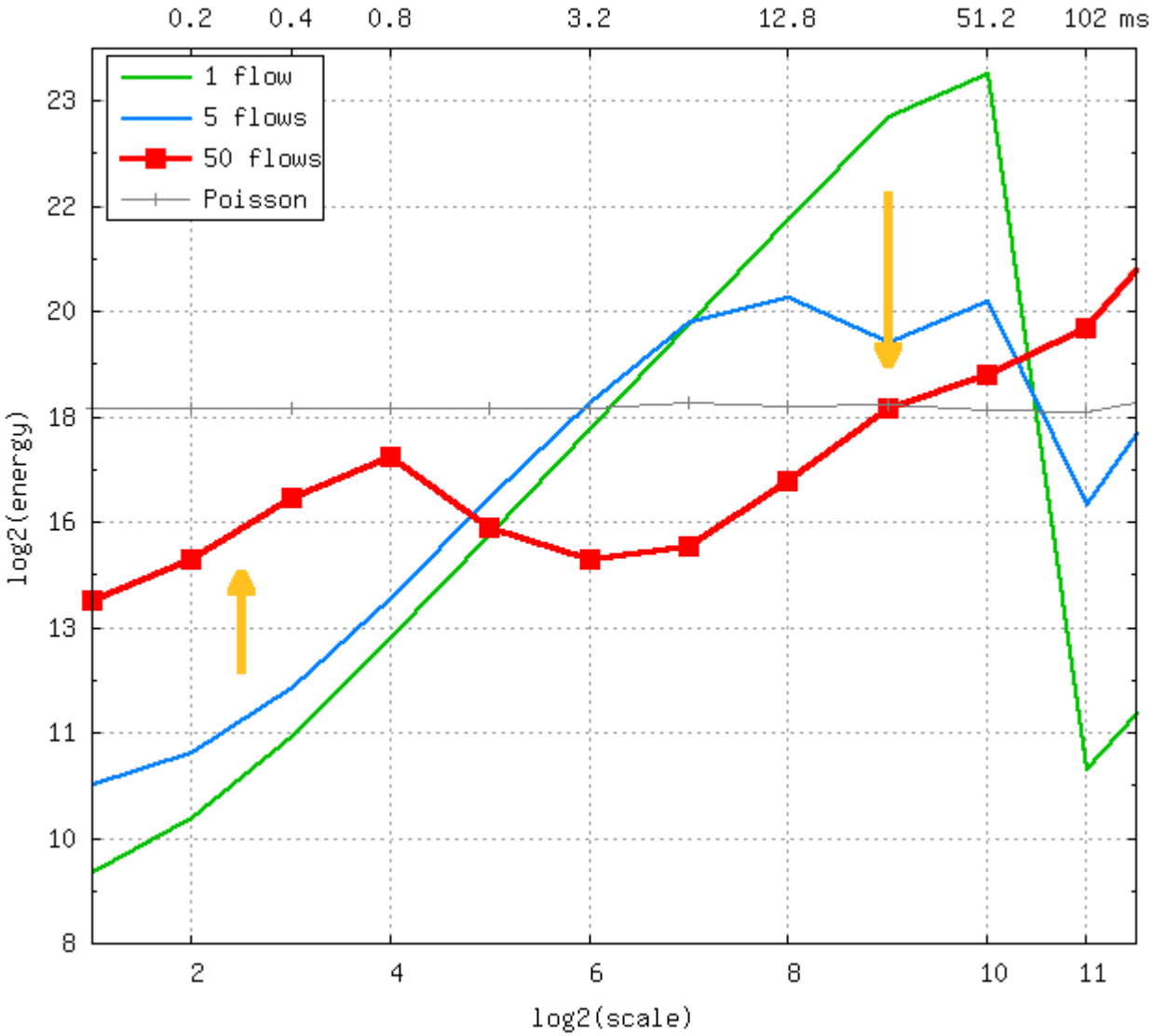
- Observation: window un-synchronization can raise burstiness of pacing traffic.
- We conduct network simulations to:
  - validate the observation
  - examine the impact of flow multiplexing
  - examine the impacts of other variabilities

Simulation Setup

- the network simulator is *ns-2*
- 1--50 flows, RTT are fixed to 100 ms
- network topology

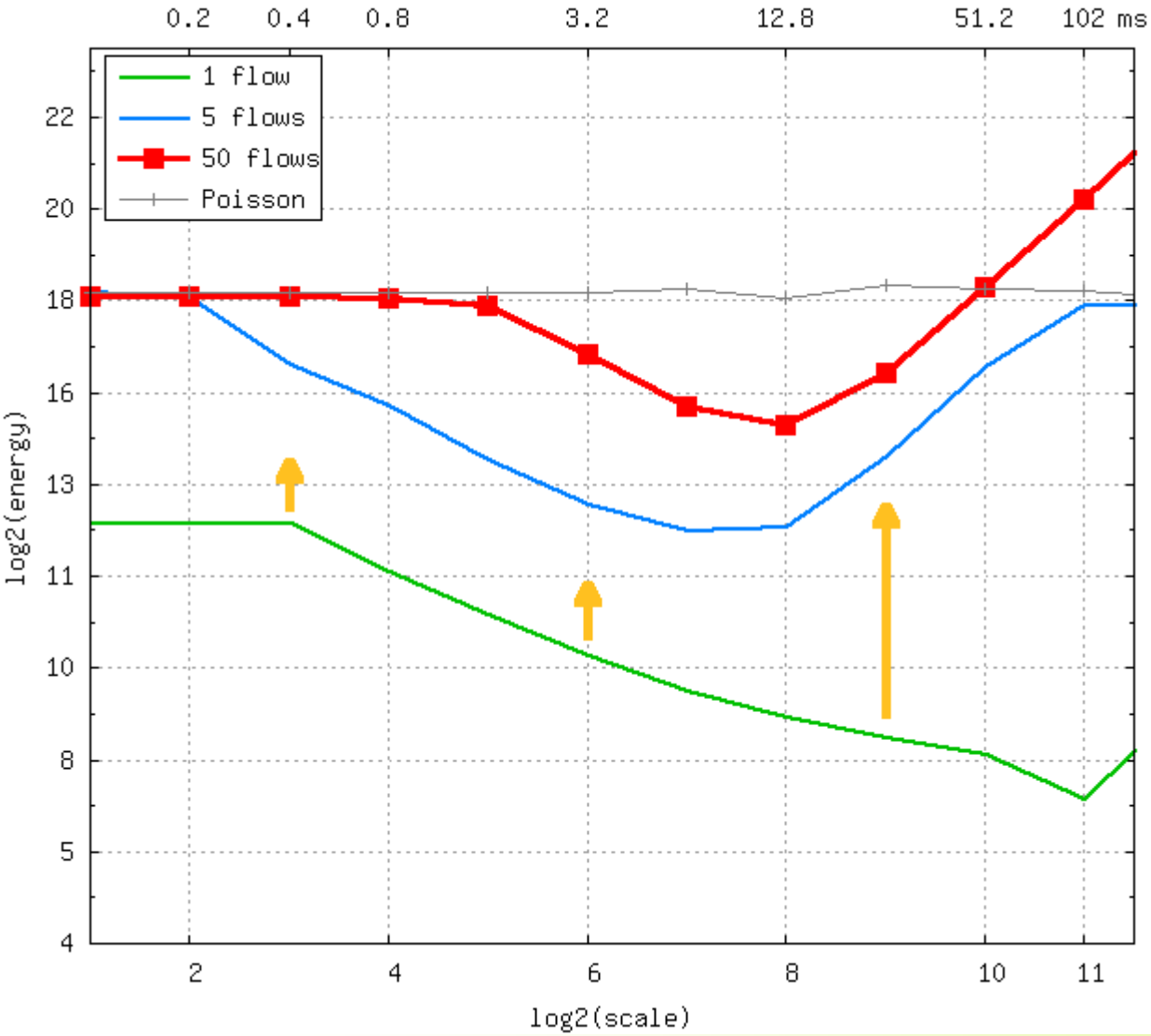


The Effect of Multiplexing – Ack-clocking



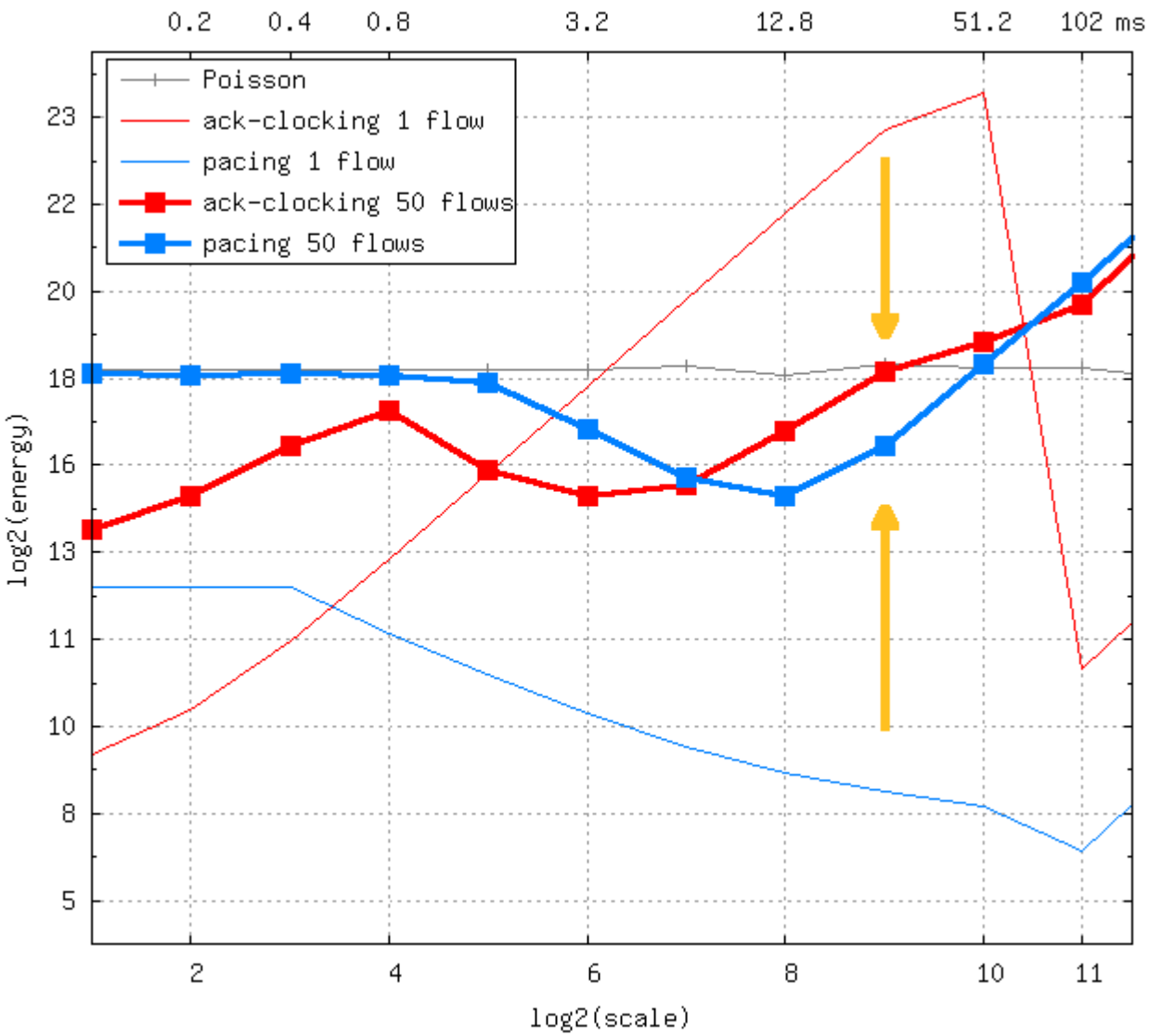
- more bursty in small scales (still less bursty than Poisson)
- much less bursty in large scales

The Effect of Multiplexing – Pacing



- burstiness raises in all sub-RTT time scales
- due to the effect of window un-synchronization.

The Effect of Multiplexing – A Comparison

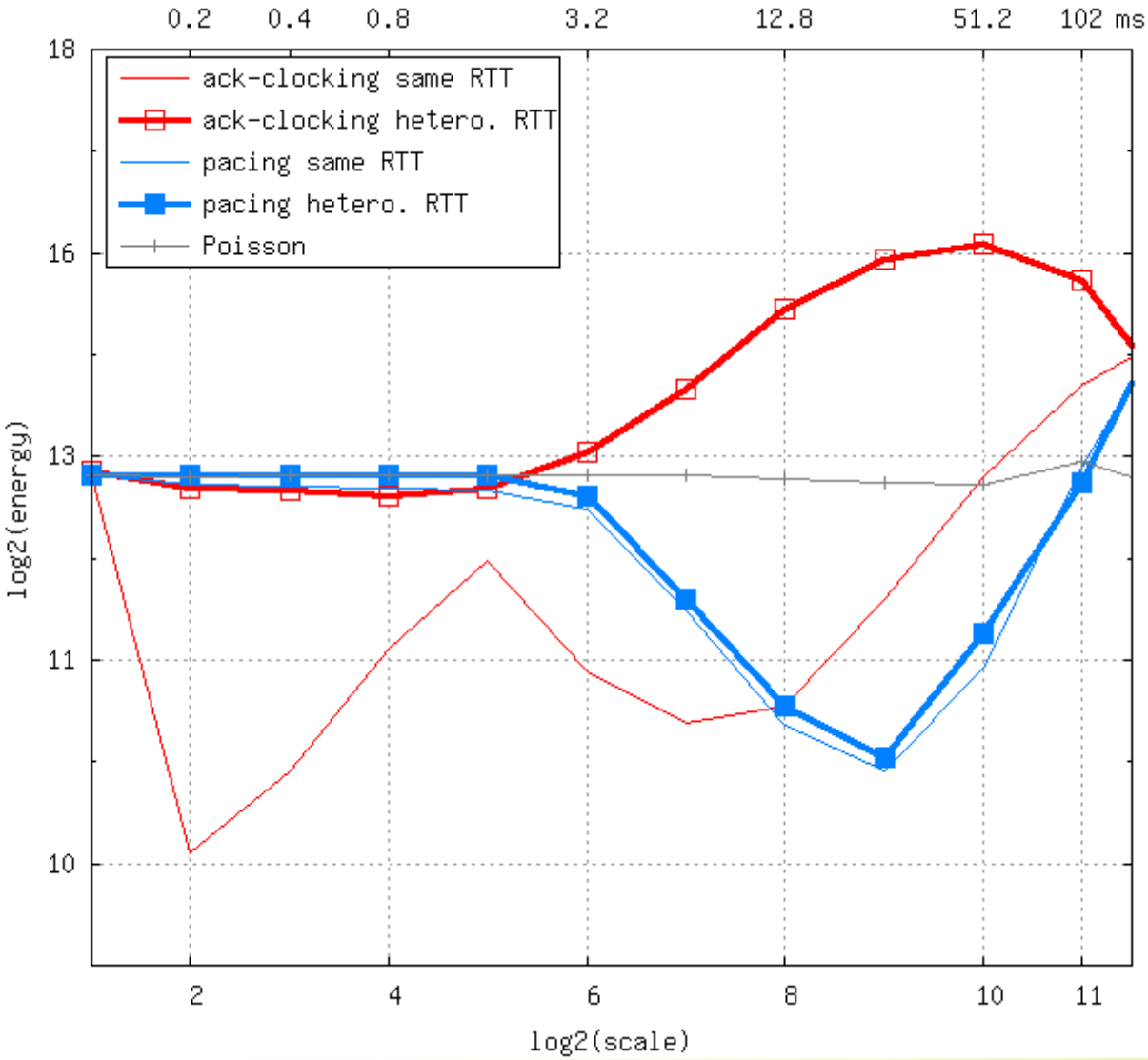


- 50 flows ⇒ pacing is more bursty in most of sub-RTT time scales
- the comparative burstiness of two schemes are very different with and without flow multiplexing

Examine the effect of RTT heterogeneity

- The simulation setup is almost the same except:
  - fixed to 50 flows
  - RTTs are drawn from an uniform distribution over (100 ms, 300 ms)

The Effect of RTT Heterogeneity



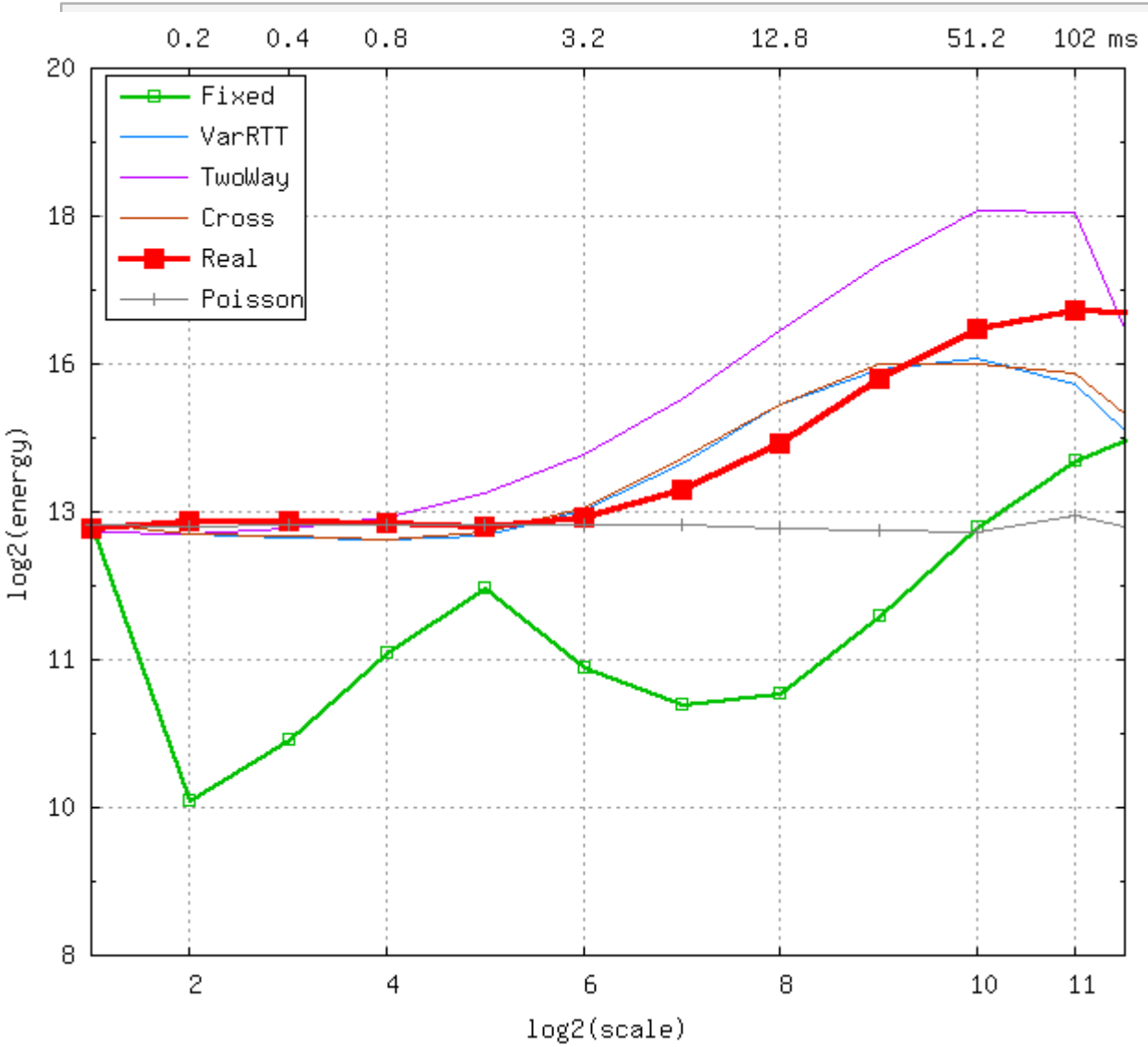
- Ack-clocking is much more bursty
  - mismatch of round trip times
  - ack-solicited pkts are no longer spaced by τ
- Pacing is unaffected
  - RTT/window is *already* randomized by unsynchronized windows

More Network Variabilities

- Simulations with additional factors:
  - multi-hop, two-way traffic, cross-traffic, and their combinations

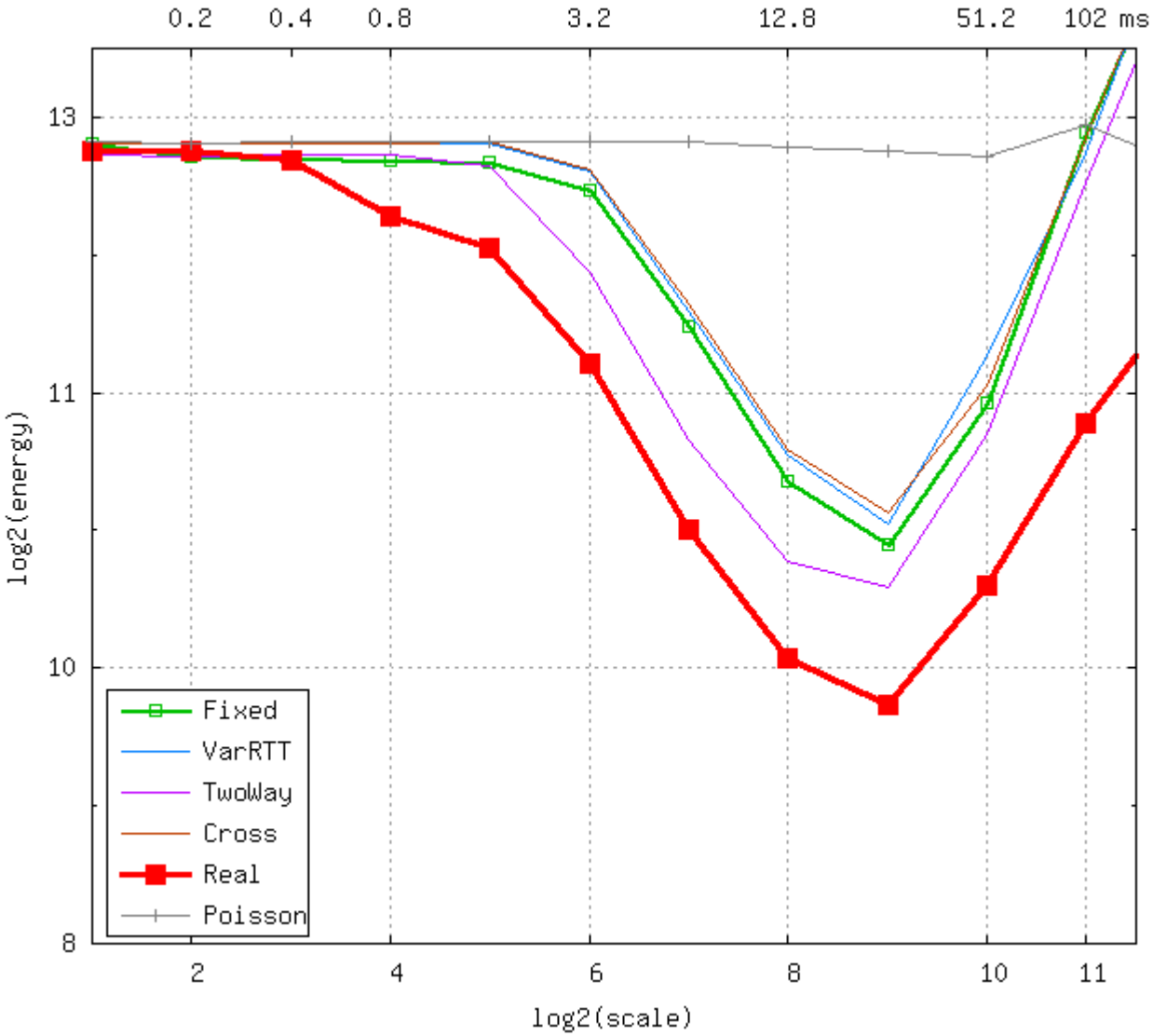
ID	*Topology*	*RTT Heter.*	*Two-Way Traffic*	*Cross Traffic*
Fixed	Dumbbell	-	-	-
VarRTT	Dumbbell	✓	-	-
TwoWay	Dumbbell	✓	✓	-
Cross	Dumbbell	✓	-	✓
Real	Parking-lot	✓	✓	✓

Network Variabilities on Ack-clocking



- The heterogeneity in flows RTT is a deciding factor.

Network Variabilities on Pacing



- None of variabilities significantly affect pacing's behavior
- As long as RTTs are heterogeneous:
  - Ack-cloking is no less bursty than Poisson
  - Pacing is no more bursty than Poisson

⇒*Pacing is less bursty*

Conclusion

- Provided physical explanation for 'why pacing could be more bursty than ack-clocking'
- Comparative burstiness of the TCP clocking schemes are network condition dependent, especially *RTT heterogeneity* and *flow multiplexing*.
- It's critical to include sufficient variabilities in performance evaluation of TCP based protocols.

Thank You!