On the impact of variability on buffer dynamics in IP networks

Mechanism that create variability

- User behavior
  - Application level variability, e.g., Web
- Network characteristics
  - Different delays, round-trip time, cross traffic
- Feedback control
  - Reliability and adaptivity

Approach

- Study traces from simulations
  - Complete control over all aspects of network
    - Workload model, Network model, Protocol
- Real network traces used as benchmark
  - Simulation setup and trace analysis
- Simulation traces used for trace driven simulation
  - Study queuing dynamic
- Correlation of analysis results to simulation setup
  - Identify network features that cause divergence

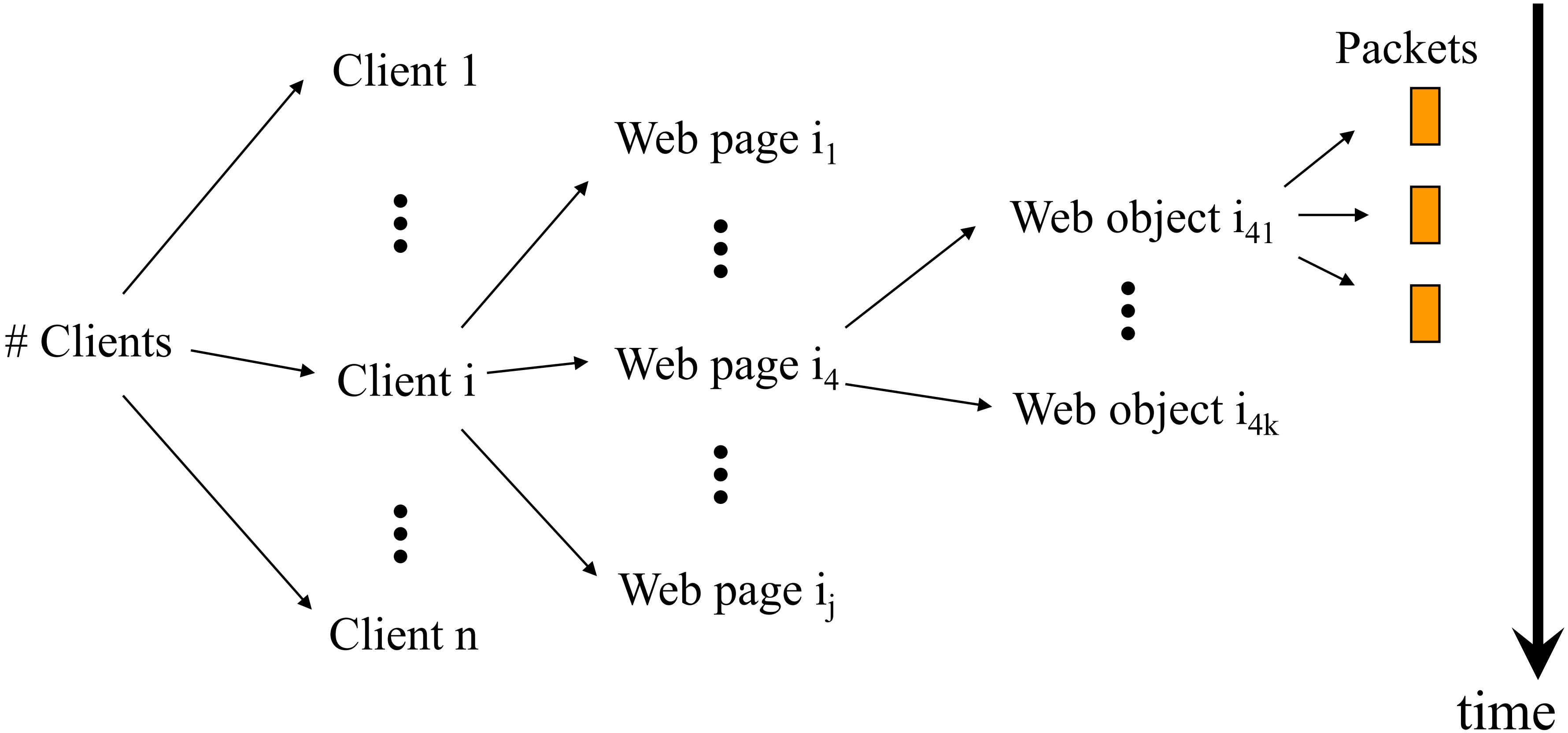
Outline

- Simulation setup
  - Workload model
  - Network
  - Protocol
- Impact of variability at the application layer
  - Mice vs. elephants [V. Jacoson]
- Impact of feedback
  - Open loop vs. closed loop

Workloads

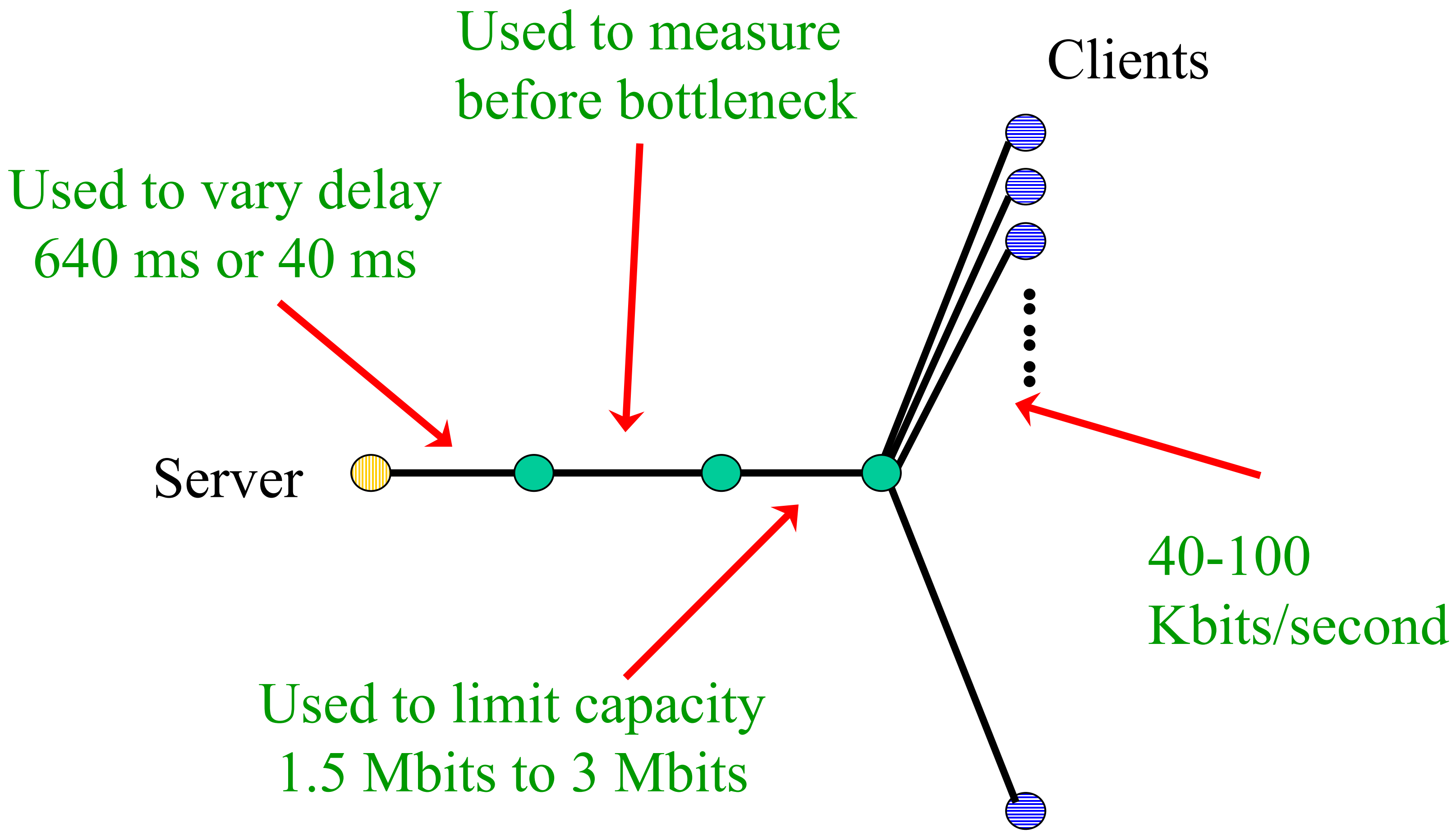
- No variability:
  - Infinite sources
    - 50 clients requesting big files
- High variability:
  - Web sources
    - 350 clients down loading Web pages
- Simulation:
  - Client startup: random time 0-600 seconds
  - Duration: 4200 seconds
  - Analysis: 900-4200 seconds

High variability workload: Web



- Parameters (similar to SURGE [BC98]):
  - Number of clients, pages, objects, packets per object
  - Time between Web pages, Web objects

A simple network topology

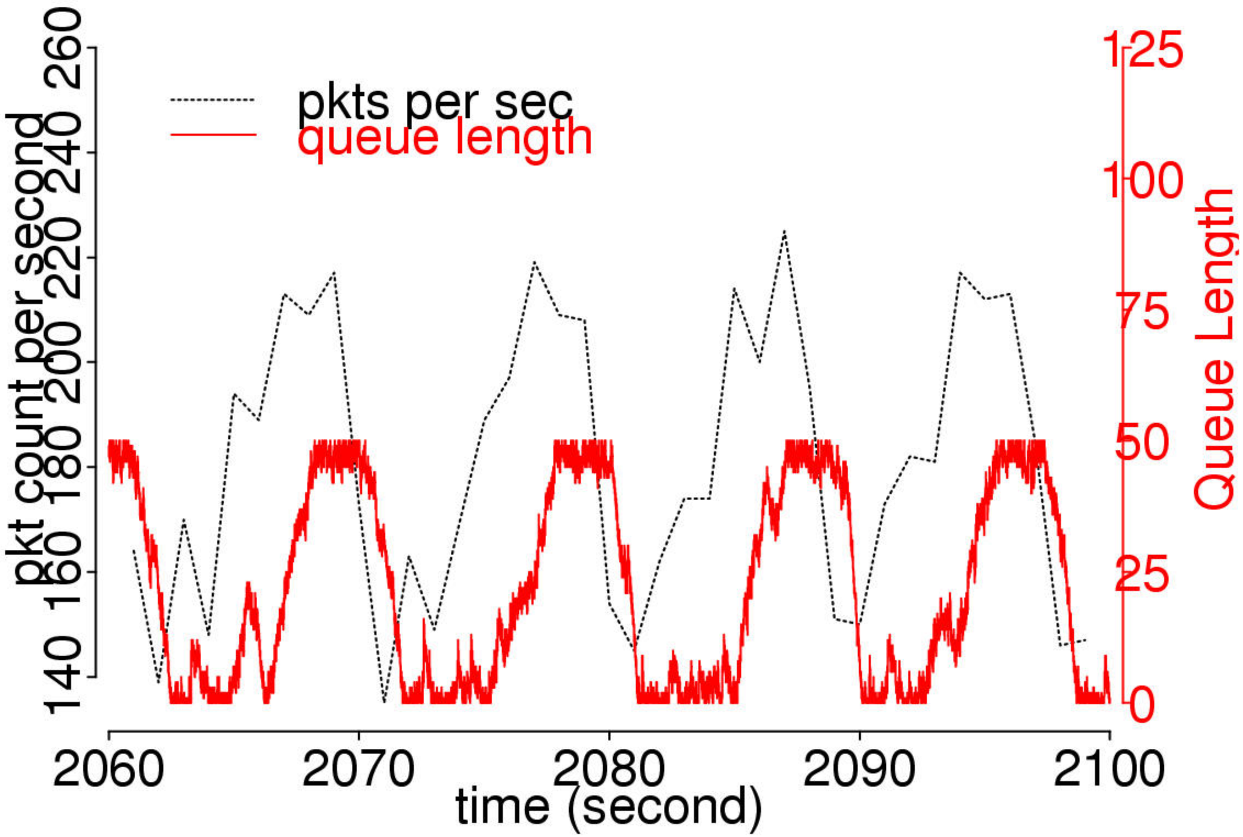


TCP: Reliable byte stream

- Data segmented into segments
- Segments are acked by receiver (cumulative)
- Timer for every segment
- Segments retransmitted
  - Timer goes off
  - Four duplicate Acks received
- Flow control
  - Sliding window protocol avoids losses at receiver
  - Bandwidth limits impose congestion window
    - Slow start increases cwnd exponentially
    - Congestion avoidance increases cwnd linearly
    - Packet losses triggers congestion window changes

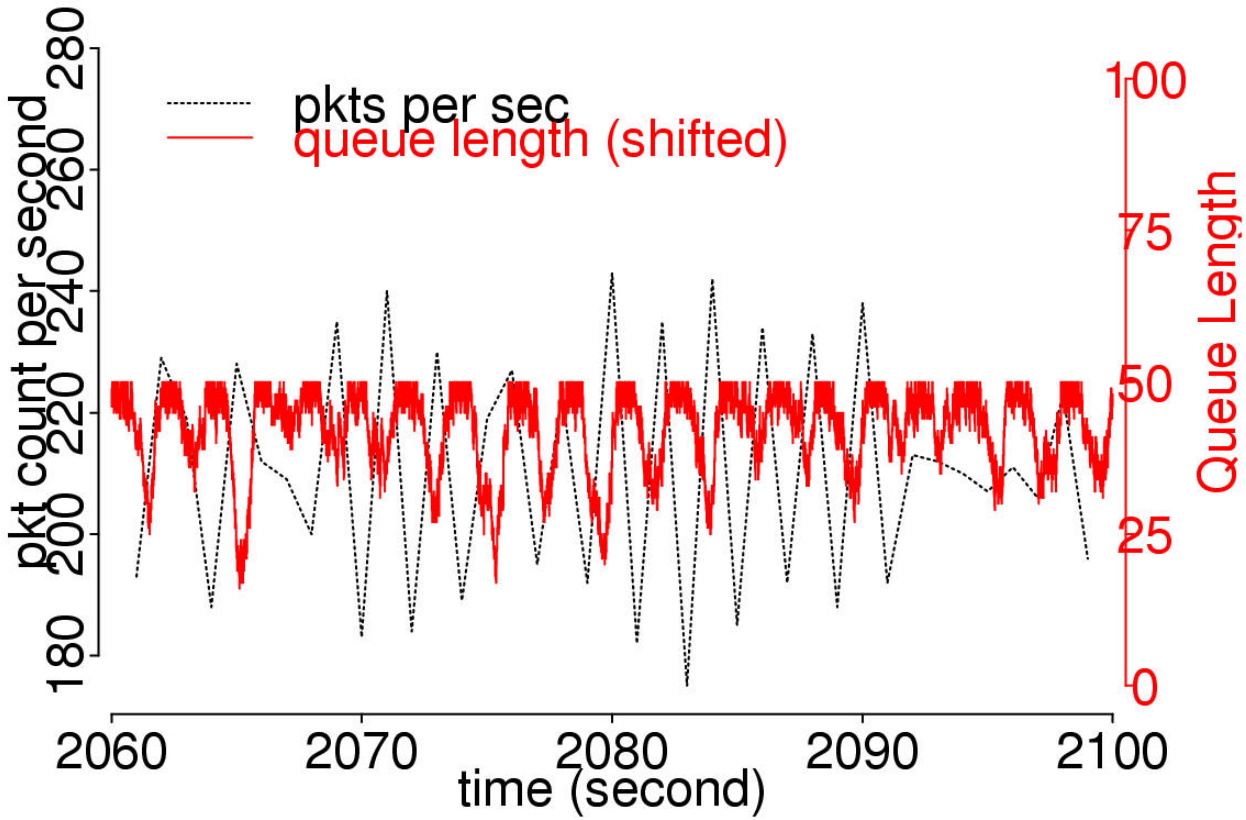
Elephants: Infinite sources

- Packet rate process and buffer occupancy process
  - Network round trip time 1.3 seconds



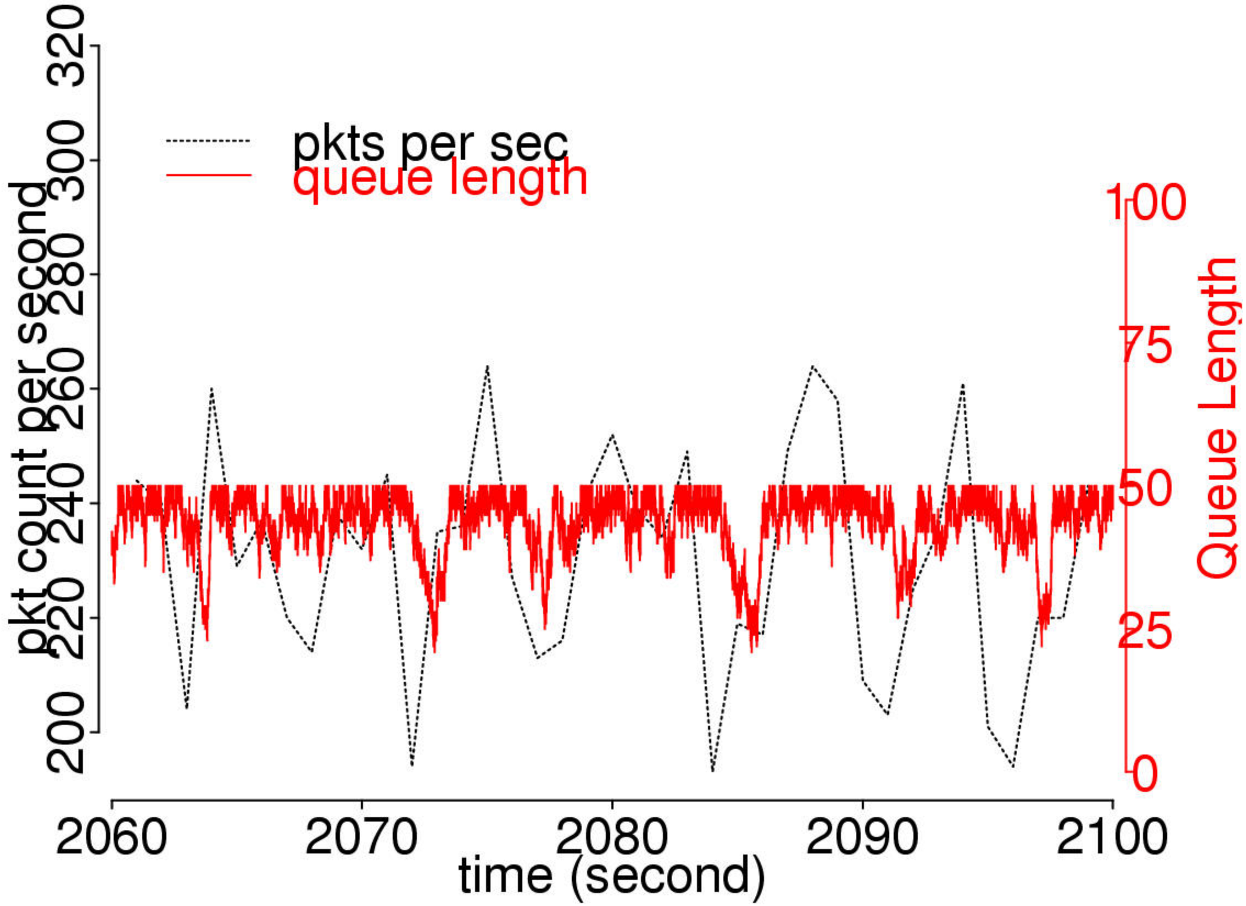
Elephants (cont.)

- Packet rate process and buffer occupancy process
  - Network round trip time 0.14 seconds



Mice and elephants: Web sources

- Significant portion of connections are short

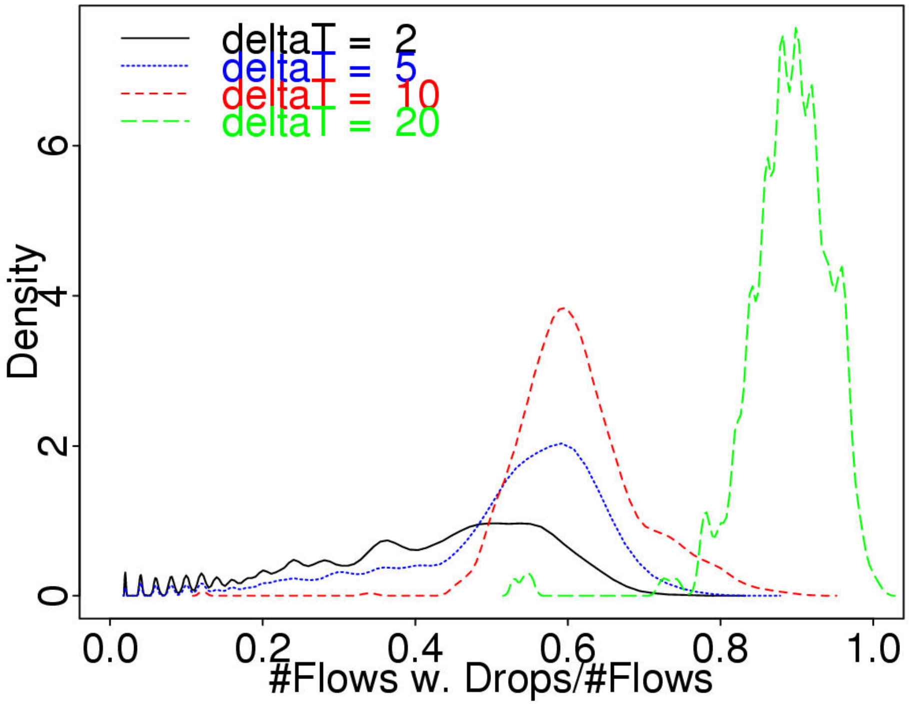


Elephants vs. Mice

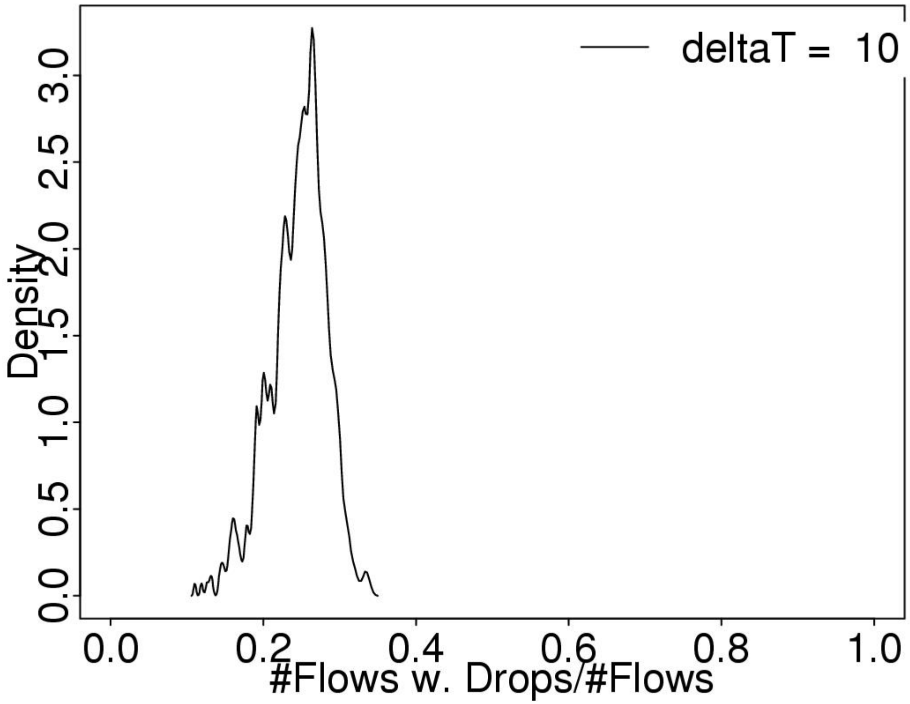
- No variability in workload and network
  - synchronization of packet rate process
  - synchronization of buffer occupancy process
- Mice stop synchronization
  - no apparent synchronization
  - higher packet arrival process
  - higher utilization

Effect of synchronization

- Percentage of connections with losses during ΔT



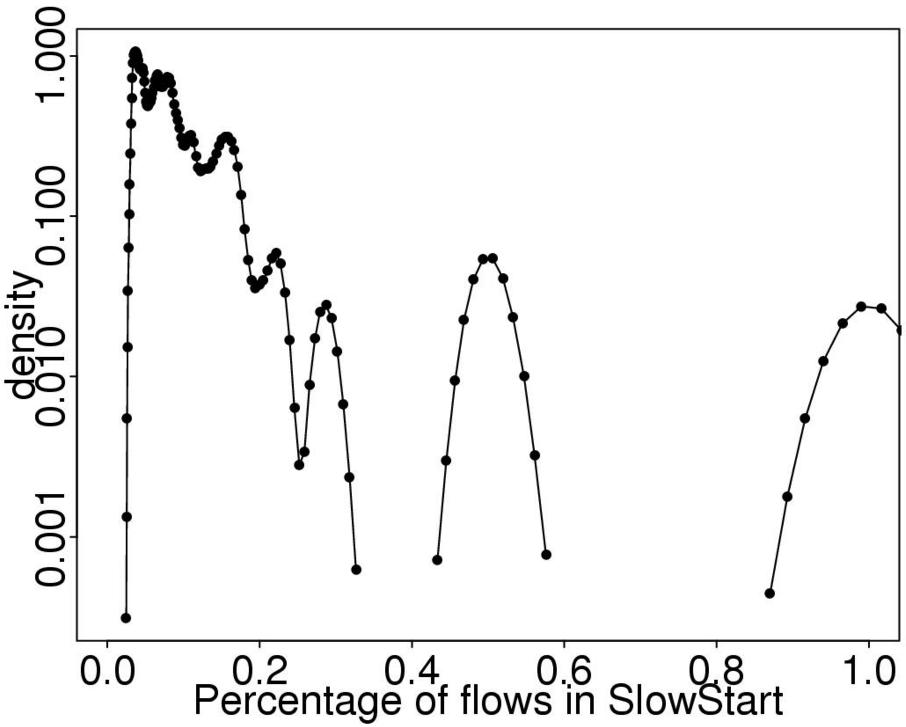
Infinite sources



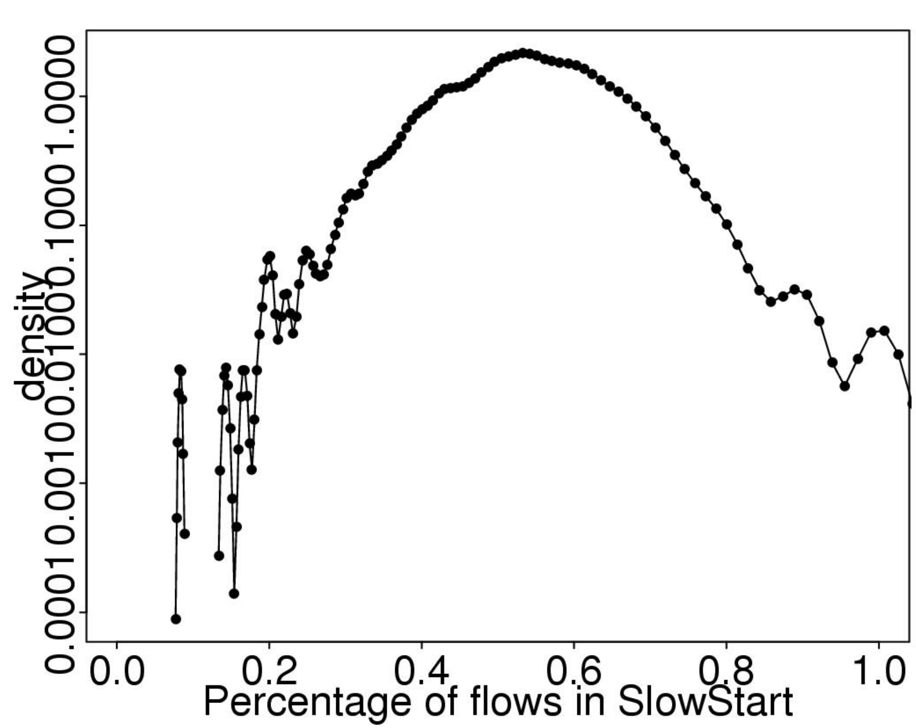
Web sources

Effect of synchronization (cont.)

- Fractions of connections with losses in slow-start



Infinite sources



Web sources

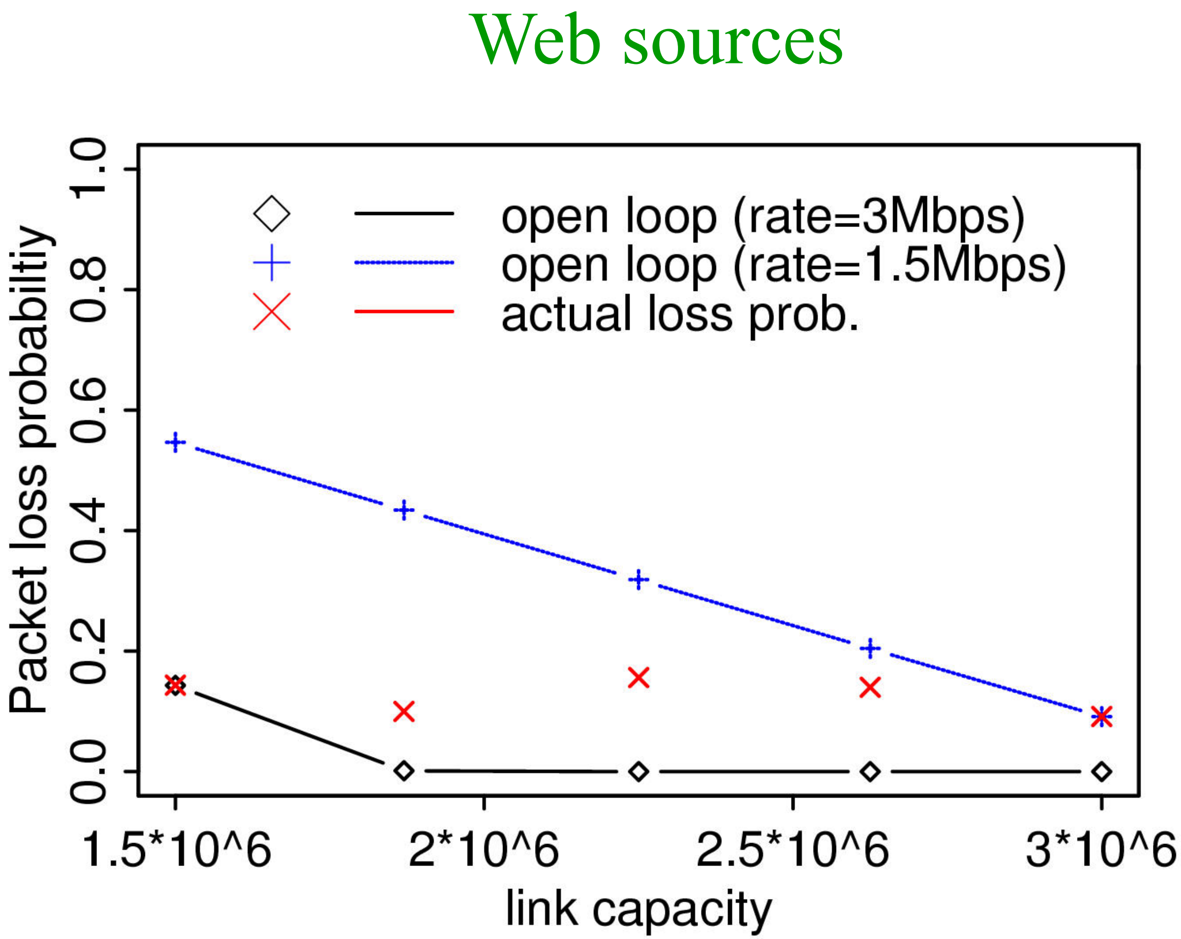
Why mice eliminate synchronization

- Mice
  - Too short for feedback
  - TCP states non-synchronized
  - Arrival highly bursty
  - Large fraction in slow-start
- Elephant
  - Within two cycles losses for almost all connections
  - TCP states synchronized
  - Small percentage in slow start
- Consequence
  - # of burst losses larger for Web than Infinite srcs

Open loop vs. close loop

- Queuing system with finite buffer
  - Change in link capacity can be modeled by change of service time distribution
- A simple experiment
  - NS simulation with approx. finite buffer space (50 pkts)
  - Trace driven queuing analysis of G/D/1 queue with varying service times
- Evaluation
  - Set of ns-2 simulations with different bottleneck speeds
    - Calculate packet loss
  - Compare packet losses from simulations to packet loss predicted from open loop queue system

Open loop vs. close loop (cont.)



- Either extremely conservative or overly aggressive

Open loop assumptions

- Queuing system with infinite buffer
  - Buffer occupancy probability P[Q > x] can approximate finite buffer packet loss
- A simple experiment
  - ns-2 simulation (approx. inf. buffer space 1000 pkts)
  - Trace analysis to calculate buffer occupancy
- Evaluation
  - Set of ns-2 simulations with different finite buffers
  - Compare packet losses to buffer occupancy
- Result:
  - P[Q > x] extremely conservative

Conclusion

- Infinite source models and queue analysis provide necessary simplifications for
  - Analysis
  - Simulations
- Challenge
  - Address variability at
    - User level
    - Network level
  - Judge the impact of feedback