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]
Workloads

- No variability:
  - Infinite sources
    - 50 clients requesting big files

- High variability:
  - Web sources
    - 350 clients downloading 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

- Used to limit capacity
  - 1.5 Mbits to 3 Mbits

- Used to vary delay
  - 640 ms or 40 ms

- Used to measure before bottleneck

Server

Clients

40-100 Kbits/second
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 $\Delta T$

**Infinite sources**

**Web sources**
Effect of synchronization (cont.)

- Fractions of connections with losses in slow-start

Infinite sources  Web sources
Effect of synchronization (cont.)

- Distribution of number of consecutive packet drops
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
Conclusion

- Infinite source models and queue analysis provide necessary simplifications for
  - Analysis
  - Simulations

- Challenge
  - Address variability at
    - User level
    - Network level