# Network Simulation in the Classroom for Teaching Networking Fundamentals

George F. Riley
Georgia Institute of Technology

# History

- ECE6110
  - “CAD For Computer Networks”
  - First taught circa 1999
- 1999 – 2001
  - Opnet Network Modeler
- 2001-2004
  - NS-2
- 2005-2009
  - GTNetS
- 2010 – Present
  - NS-3

# Purpose (intended)

- How to design and create a network simulator
- Discrete Event Processing and Event Handlers
- Models for various Network Components
  - Channels
  - Network Interfaces
  - Lots of others
- Construct Topologies
  - Nodes
  - Links
  - Queues
- Data demands (Applications)
- Metrics
  - Goodput, link utilization, packet loss, overhead, etc.

# Purpose (actual)

- Understand Behavior of Packet-Based Networks Under a variety of conditions
- Use Simulation as a tool, but moreover use it to measure some network behavior as independent variables are adjust, and anticipate and explain measured resuts.
- For example,
  - What is the performance of a TCP flow as a function of kernel buffer size (receiver window), segment size, and queue limit?
  - How does performance vary if queue limit is in units of packets versus units of bytes?
  - Under what conditions will the RED queuing method perform better than the standard "FIFO" (Drop Tail) approach?

# Assignment 1

- Measure performance (goodput) of a single TCP flow through a single bottleneck link
- Vary the following parameters:
  - Segment size 128, 256, 512
  - Queue Limit 2000, 8000, 32000, 64000 bytes
  - Window Size 2000, 8000, 32000, 64000 bytes
- Part 2 – 10 Simultaneous flows
  - Random start times for a short interval (0 to 100ms)
  - Observe and report on fairness

# Lab 1 – Sample Results

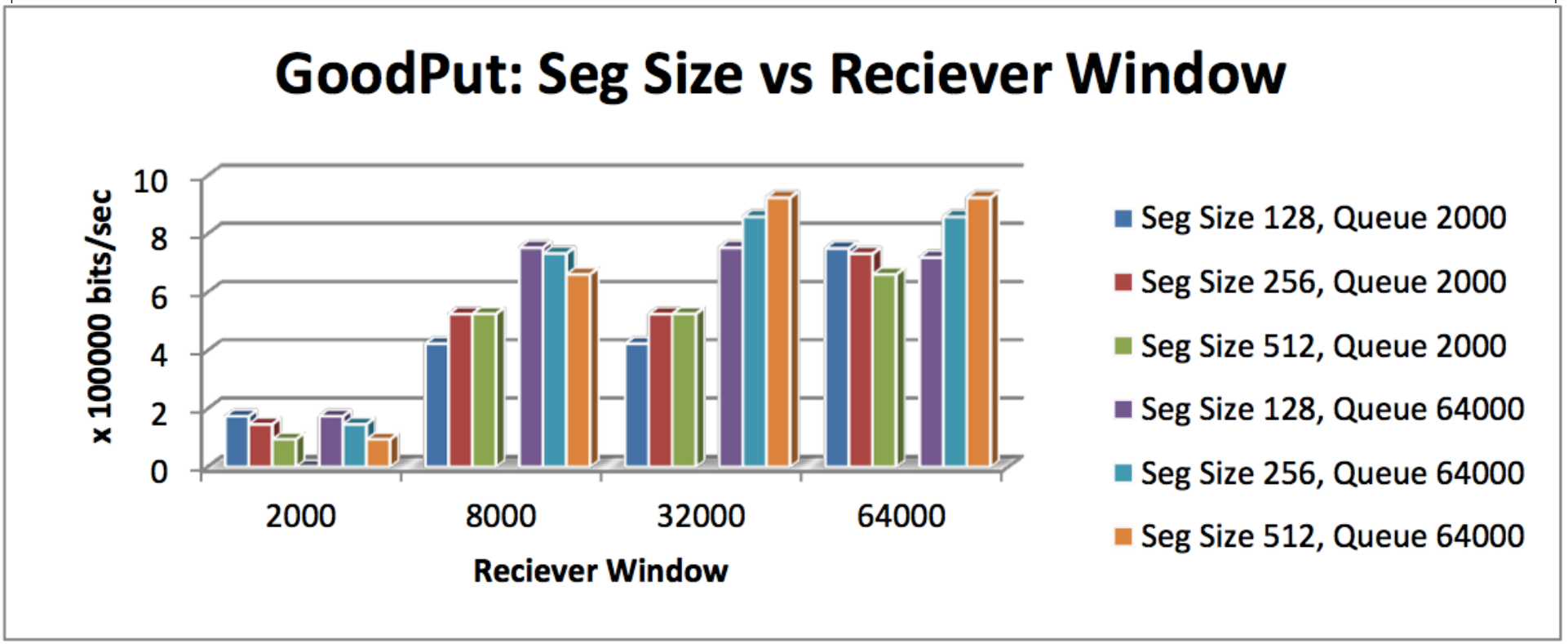
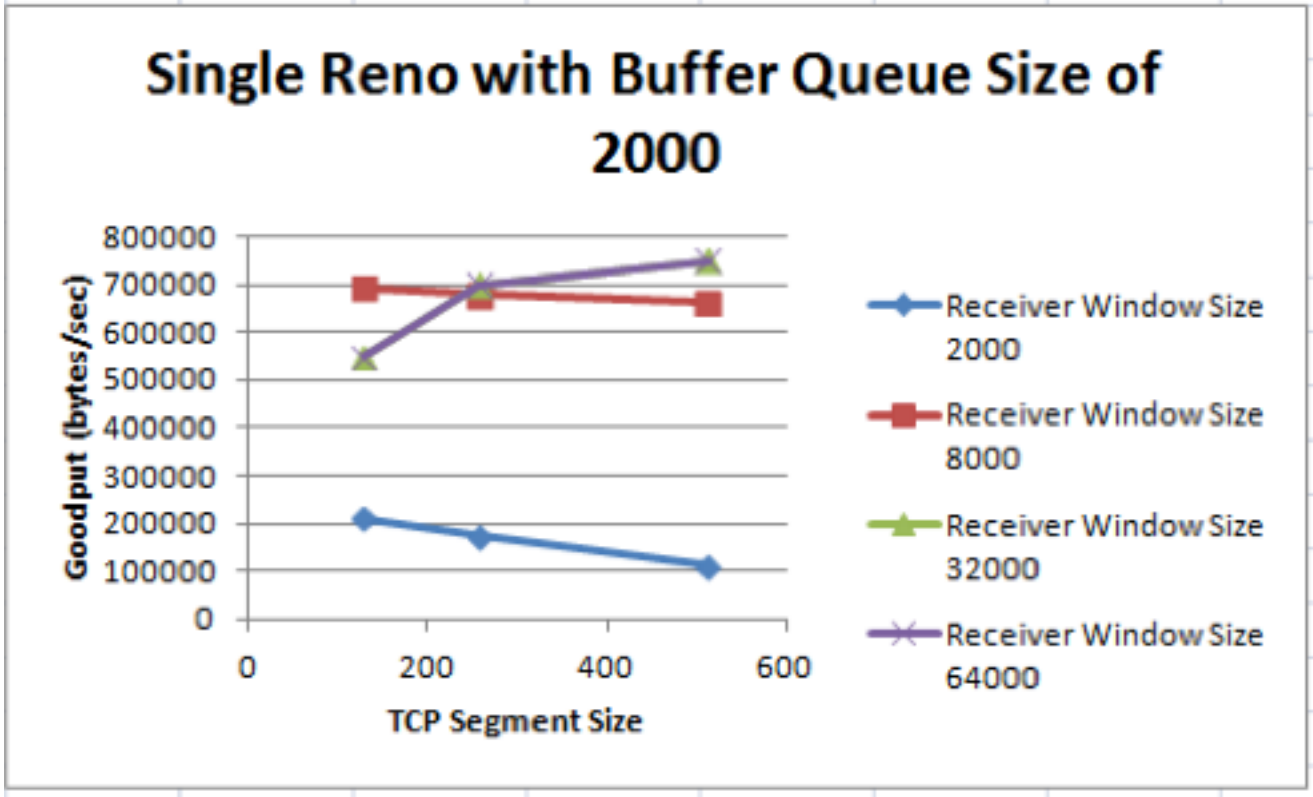



Figure 2. Goodput as a function of SegSize vs RcvWin

# Lab 1 – Sample Results



# Kevin Jeffay's "Tuning Red" Paper

- Laboratory Experiment to compare RED vs. DropTail
- Realistic? Web browsing models
- "Simulated" performance of up to 4000 simultaneous web browsing sessions
- 100Mb to 10Mb bottleneck link
- Varying queue size (DropTail)
- Varying RED parameters (minTh,maxTh,maxP, Wq)
- Compare Response Time

# Jeffay's Topology

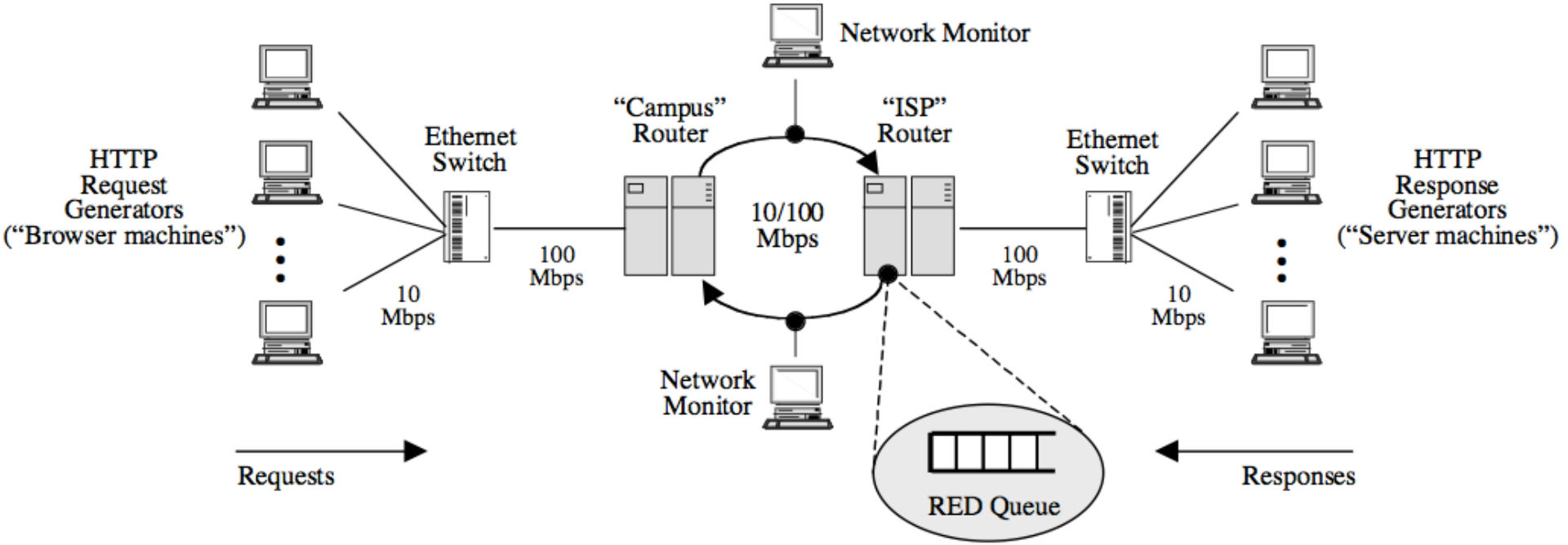



**Figure 2:** Experimental laboratory network diagram.

# Sample “Tuning Red” Result

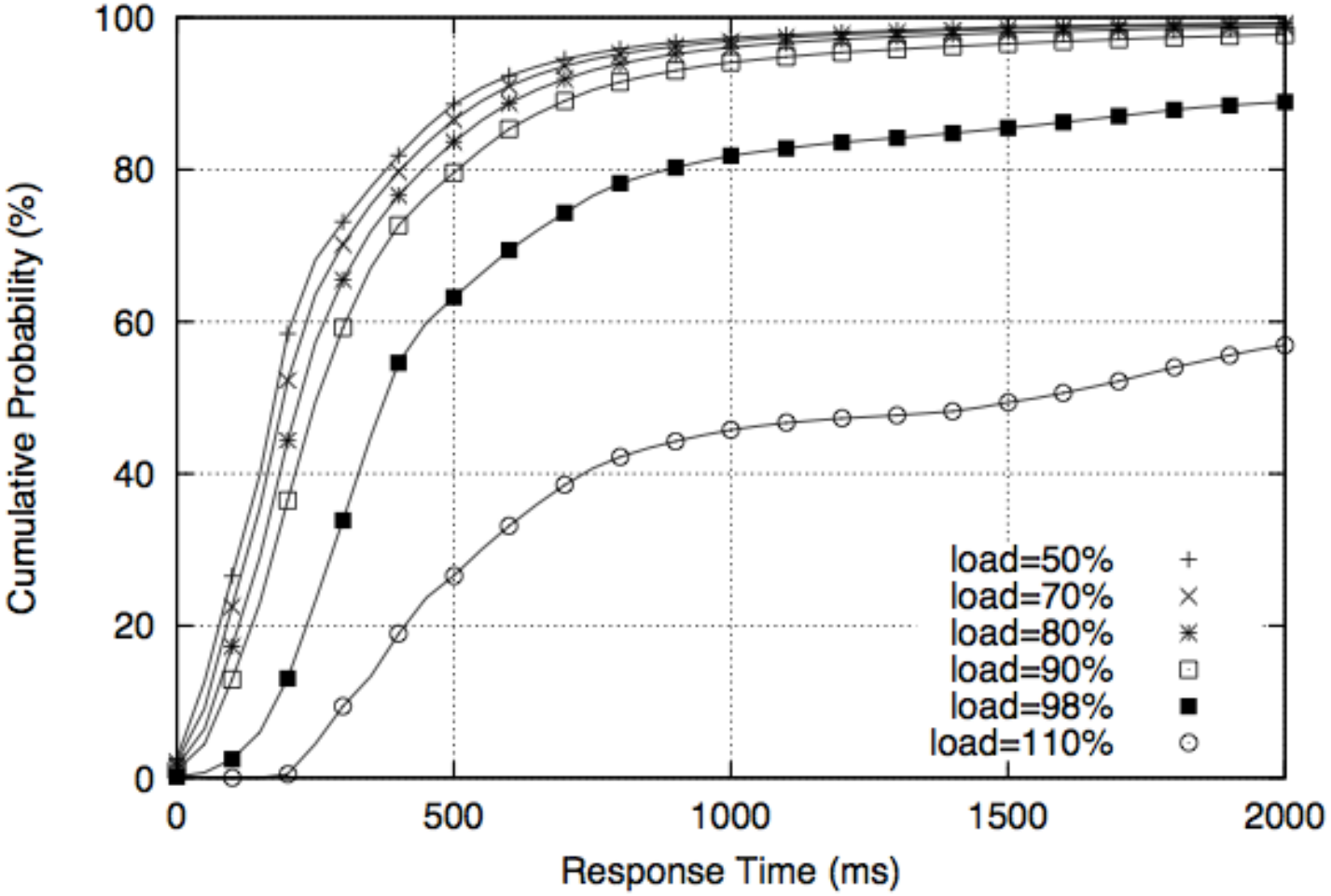



**Figure 10**: FIFO performance for different loads with a queue length of 120 elements.

# Sample “Tuning Red” Result

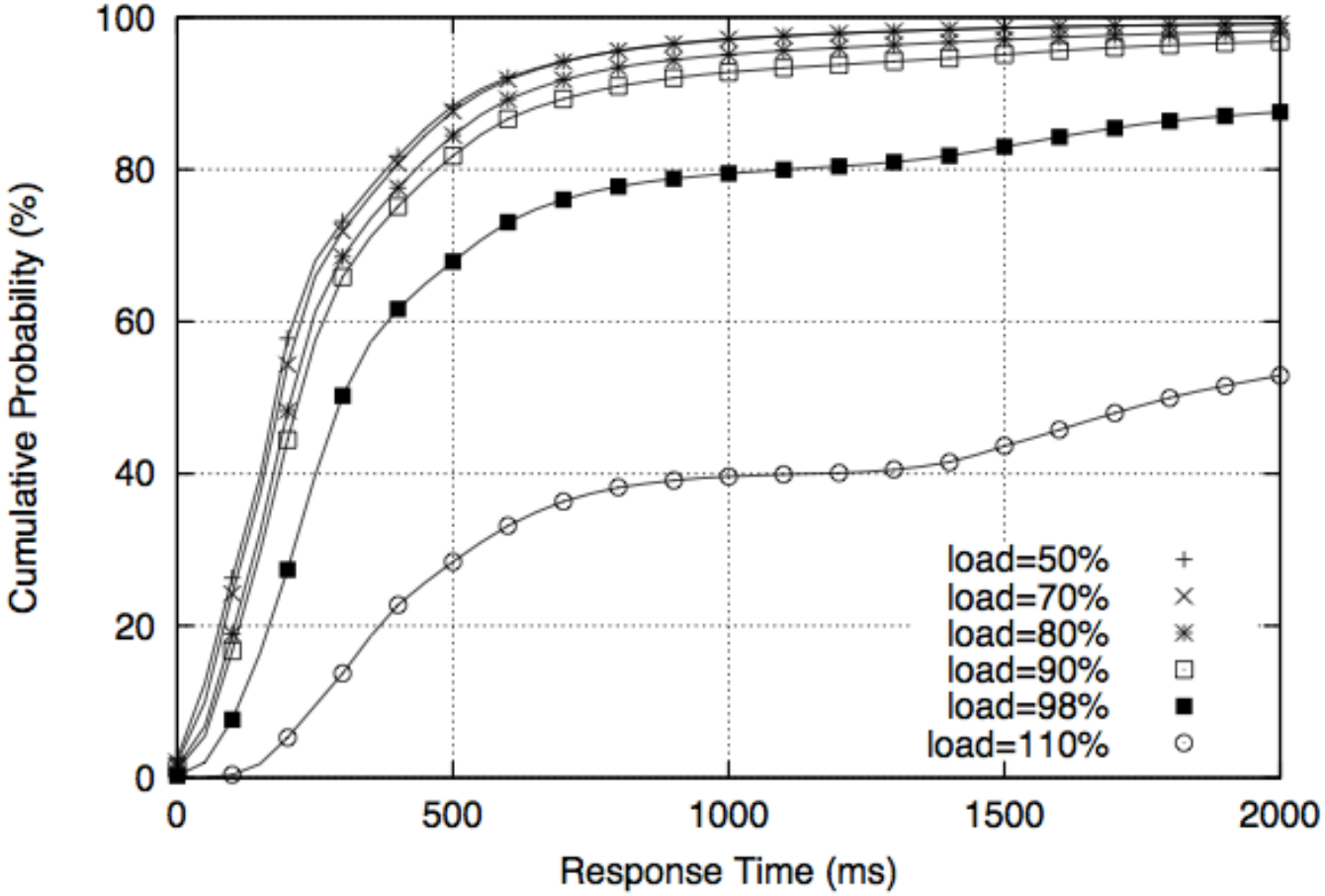
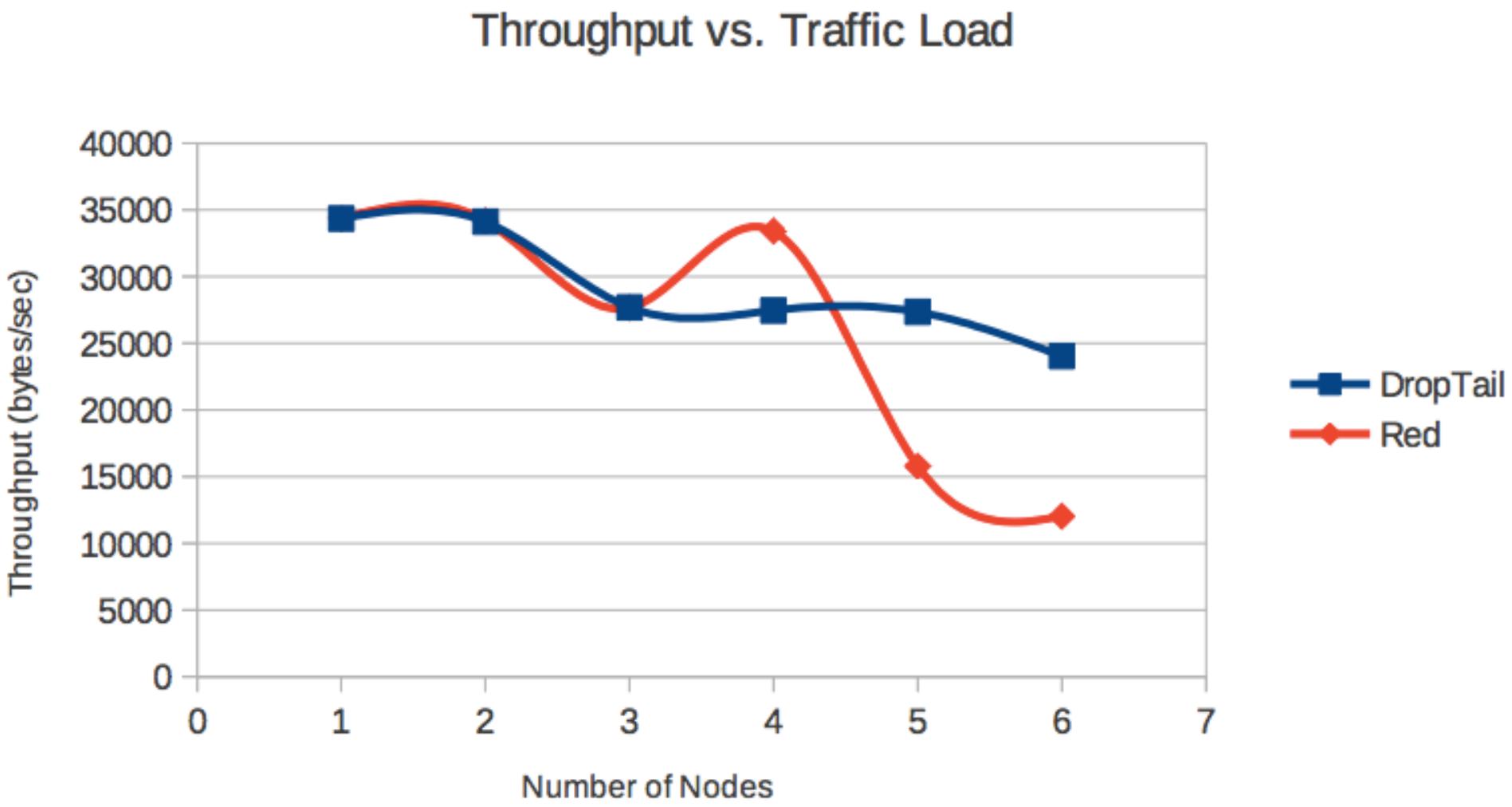



**Figure 11**: The performance of RED at different loads. $w_q$=1/512, $max_p$=1/10, $min_{th}$=30, $max_{th}$=90, $qlen$=480.

# Lab 2 – Compare RED to DropTail

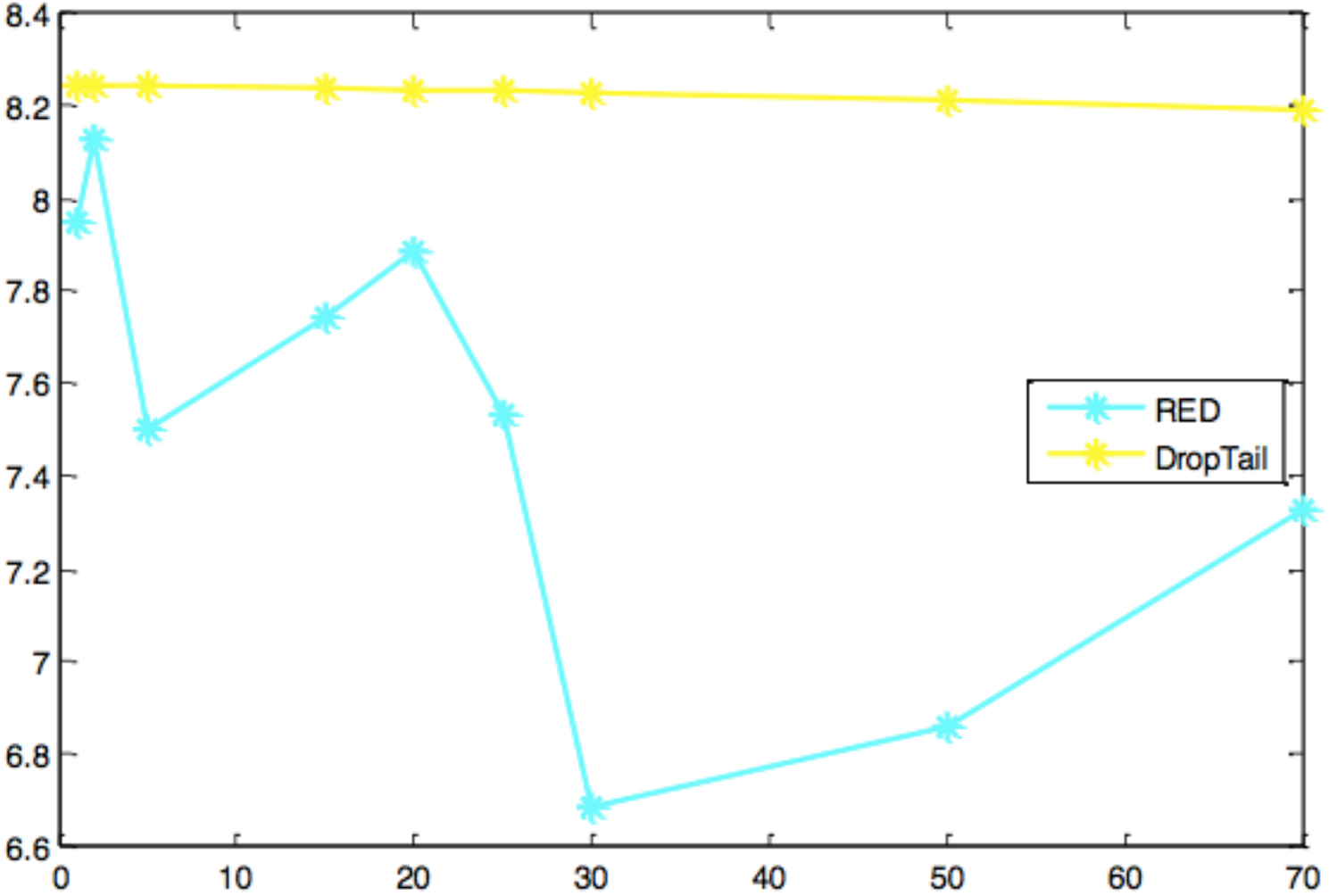
- Construct arbitrary topology
  - At least two bottleneck links for every flow
  - Compare "Goodput" as a function of Red (various parameters) and Drop Tail
- Form a Conclusion!
  - Which is better, RED or DropTail
  - Provide metrics to support the claim

# Lab 2 Sample Results



# Lab 2 Sample Results

*Figure: RED V.S. Droptail, Varying Bottleneck Link Delay*

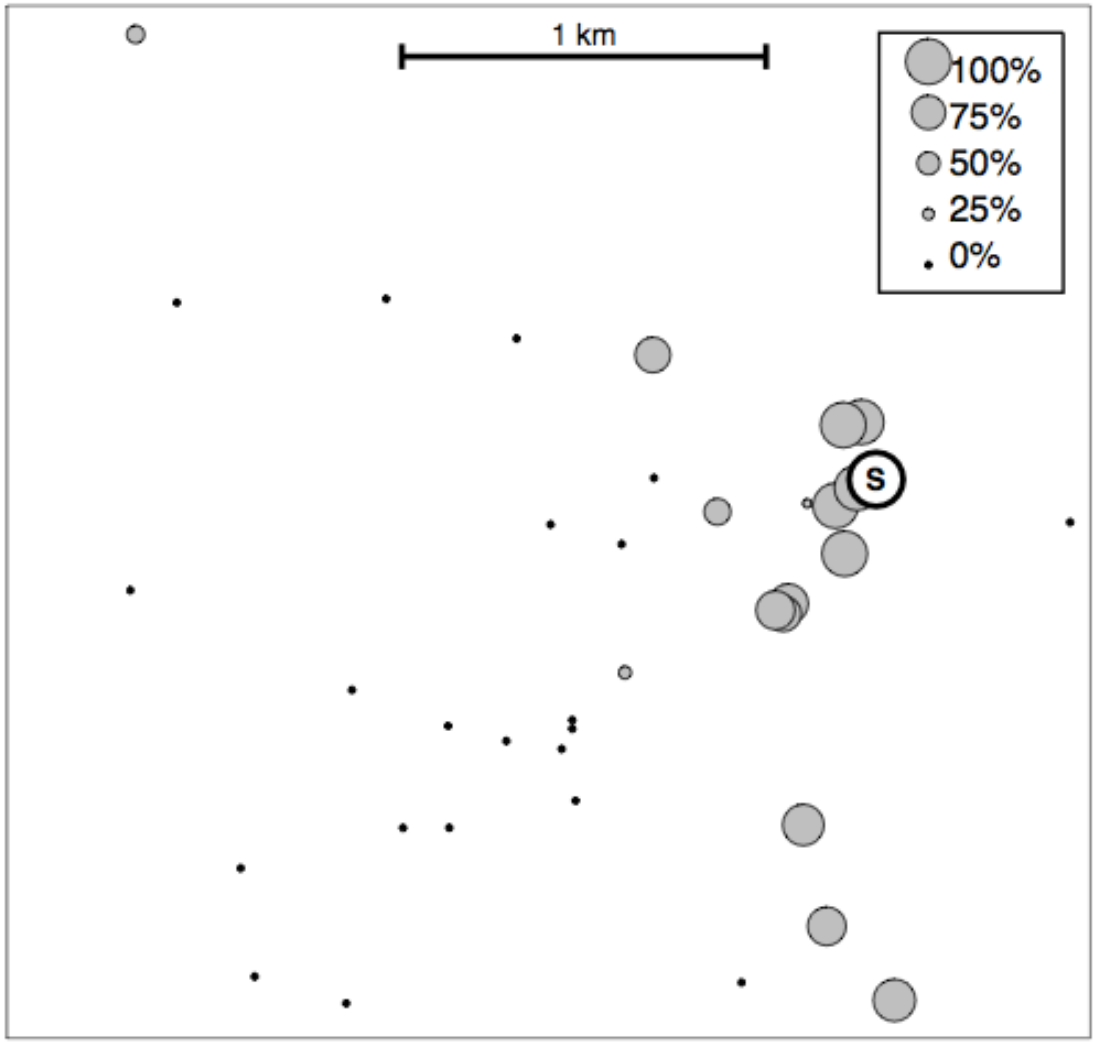


# Wireless Measurements - RoofNet

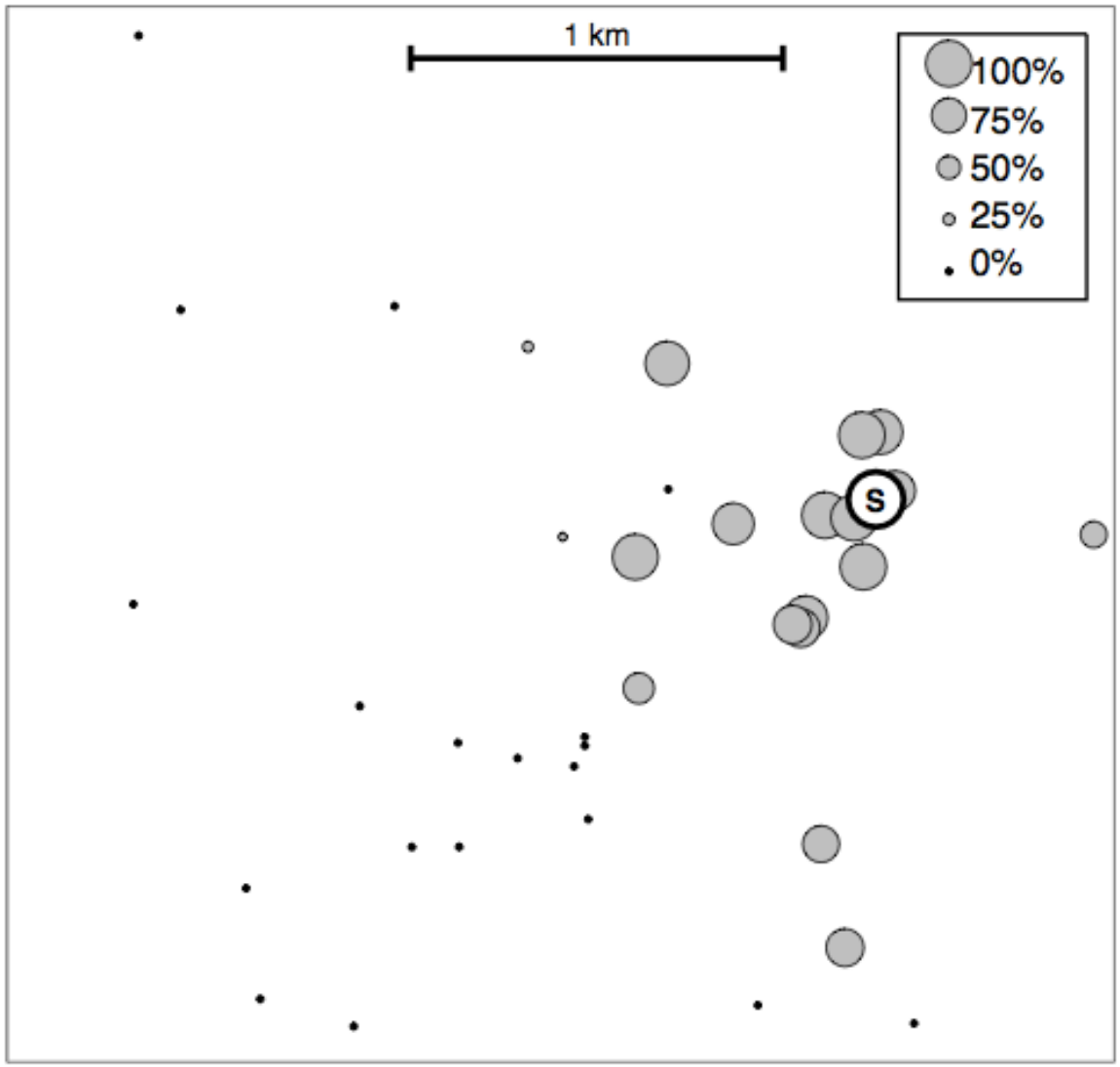
- Aguayo, SigComm 2004
- Reports on a measurement study of Cambridge "RoofNet"
- "Active measurement" approch
  - Generate UDP traffic and random sources, measure packet delivery ratio at all others.
- Results highly variable and inconclusive
- Performance of actual physical medium difficult to model

# The RoofNet Network

# RoofNet Sample Results



# RoofNet Sample Results 2



# Lab 3 – Wireless Efficiency Measurements

- Construct Mobile Wireless Network
  - 1km x 1km; 2km, 2km regions
  - Varying node count 20 to 1000
  - Varying Transmitter power (1mW to 500mW)
  - Varying traffic intensity (0.1 to 0.9)
  - Varying routing protocol, OLSR, AODV
- Measure and report on "efficiency"

# Final Projects

- Worm Model Propagation
  - Recreate results from Sharif/Riley, 2005
- Compare network simulators 802.11 model
  - NS2, GTNetS,NS3
  - Similar to Reddy/Riley 2006
- Tuning Red
  - Recreate the results from Jeffay 2004
- Compare ns-3 wireless models

# Jeffay Final Project, Sample Results

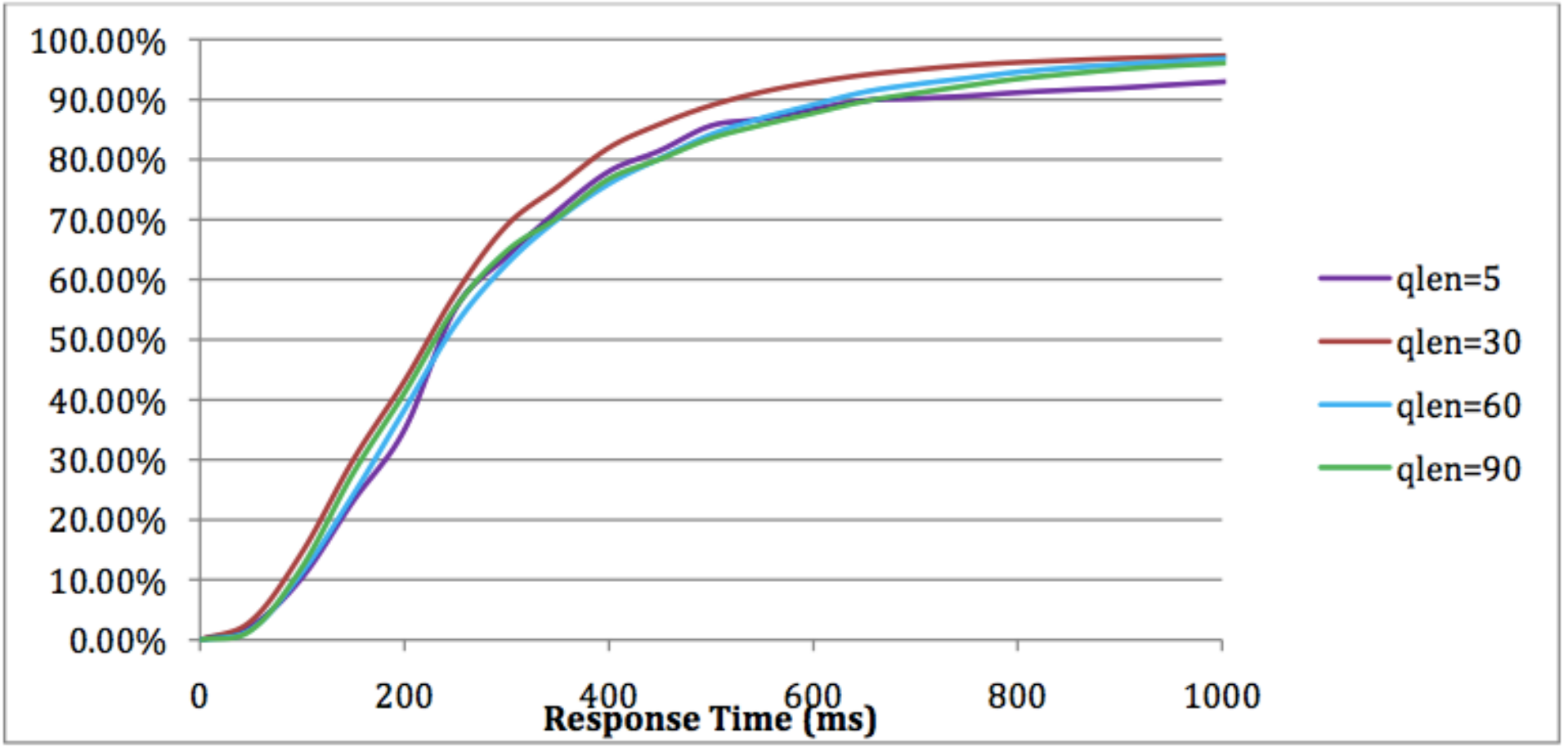



Figure 5 Drop tail queue @ 95% load 2.1 Mbps bottleneck link

# Questions?