cariden

the economics of network control

How full is full?

Engineer your network to meet SLA's

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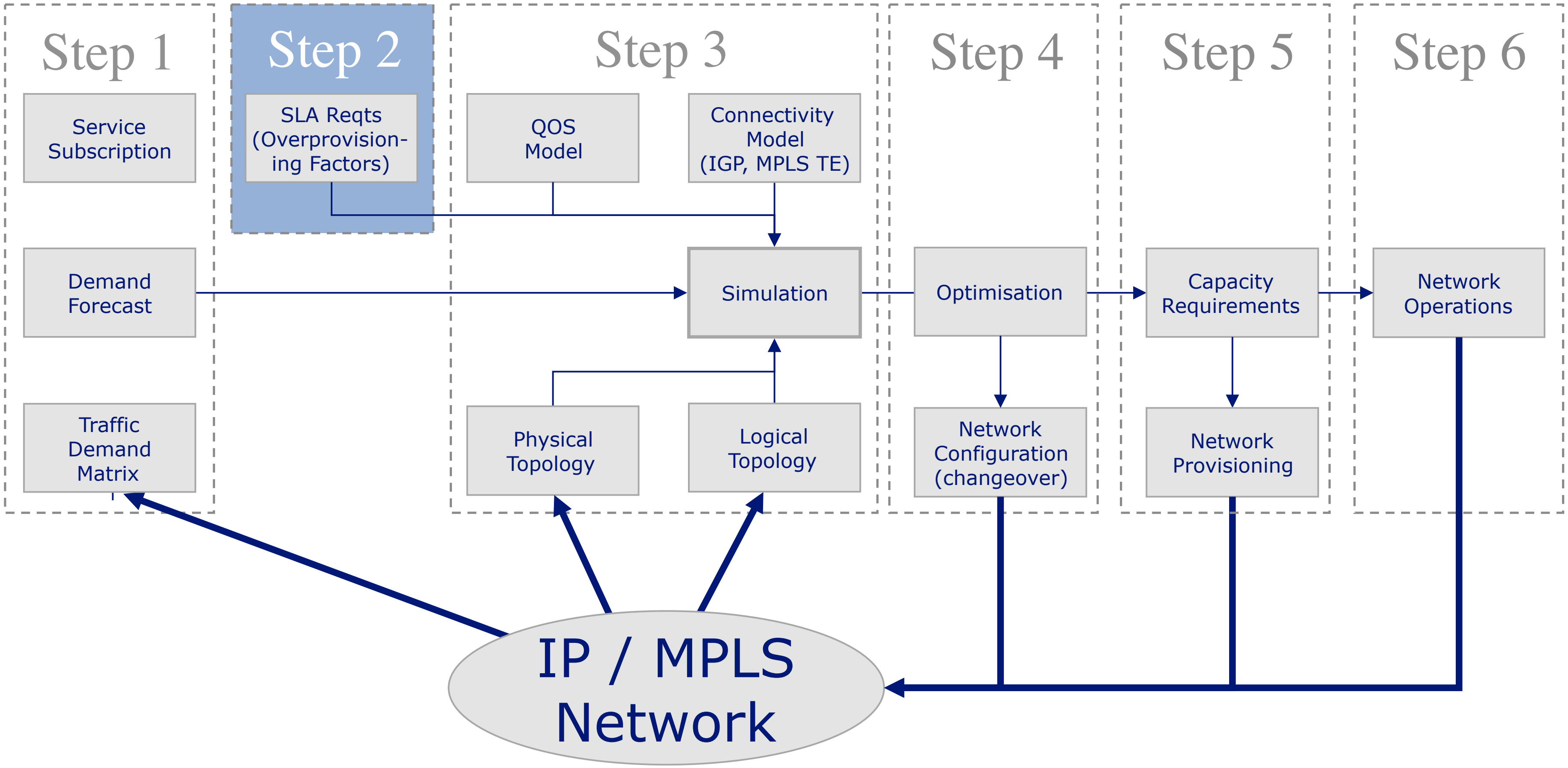
DENOG, Nov. 5th 2009
Frankfurt/Main, Germany

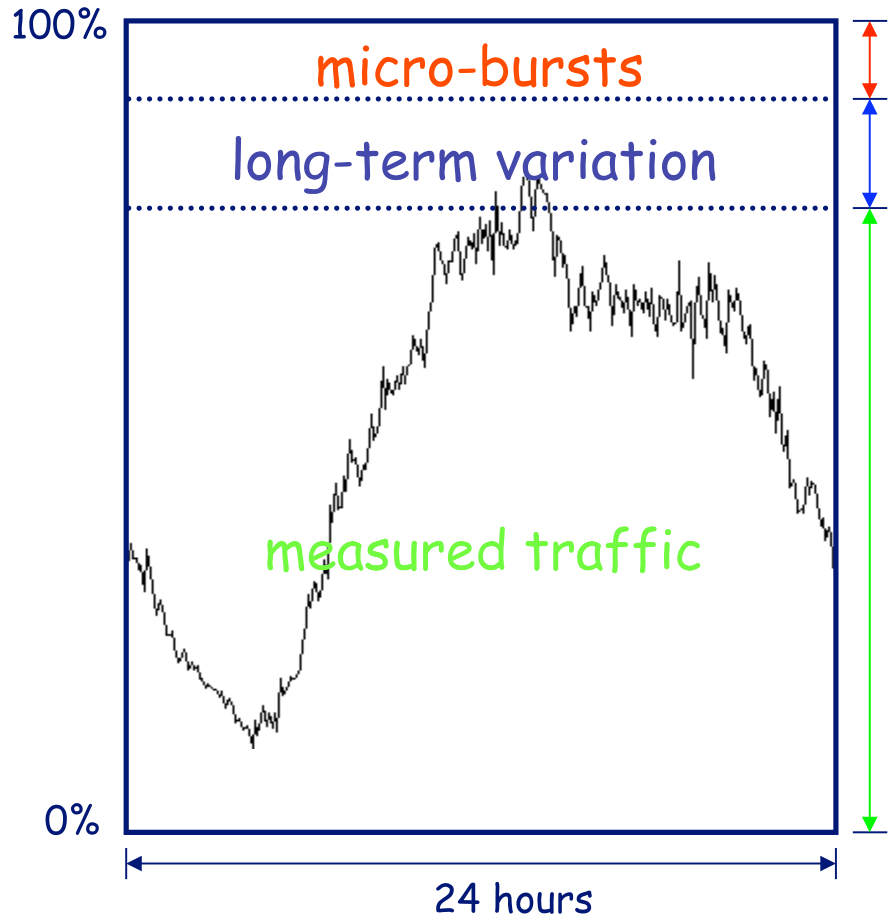
Network Planning Methodology

2. The relationship between SLAs and network planning targets …



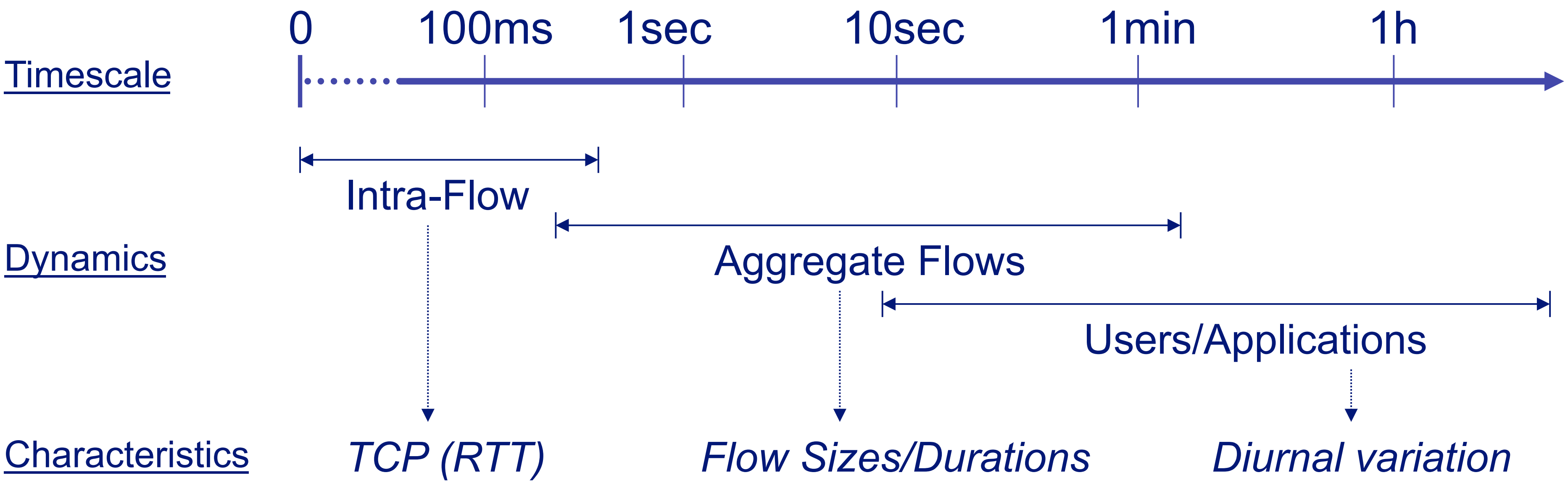
Demand Characterization

- Long-Term
  - Measured Traffic
    - E.g. P95 (day/week)
  - "unforeseen" events and growth
- Short-Term
  - Critical scale for queuing
  - Determine over-provisioning factor that will prevent queue buildup against micro-bursts

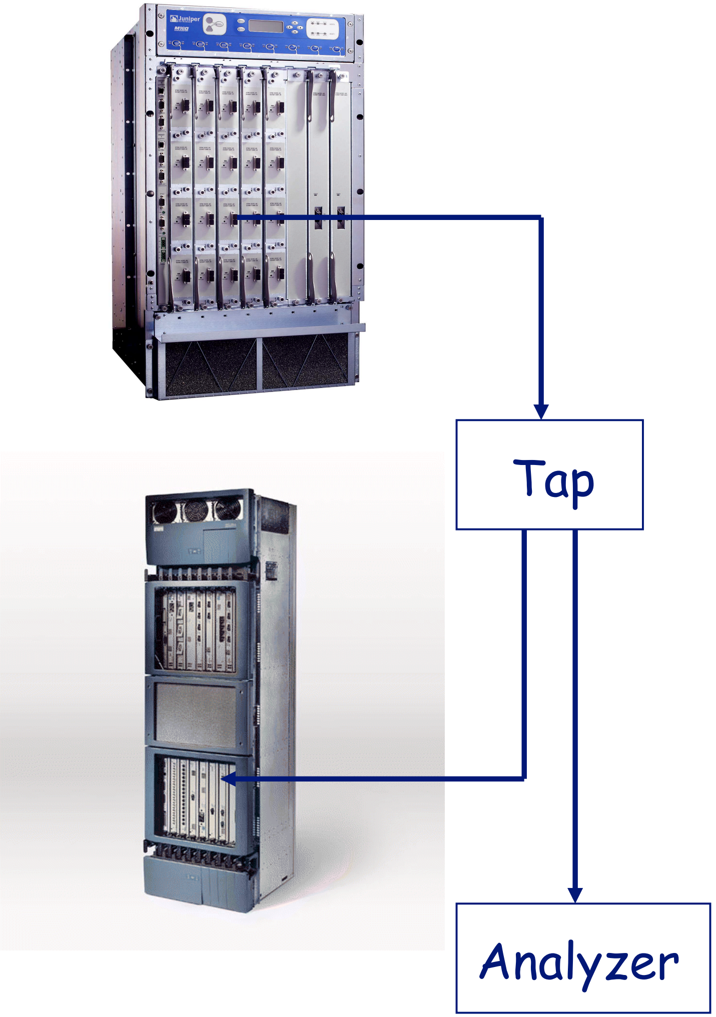


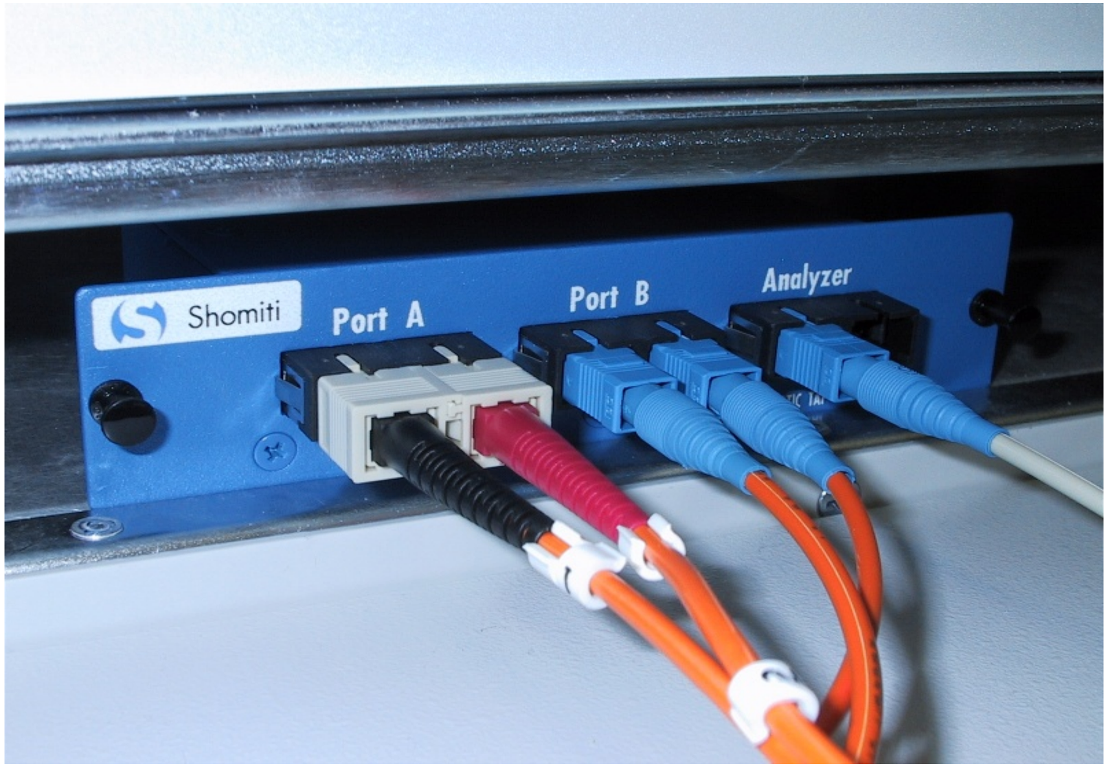
Relevant Timescales

- Long-Term: > 5 minutes
- Short-Term: < 5 minutes



Fiber Tap (Gigabit Ethernet)



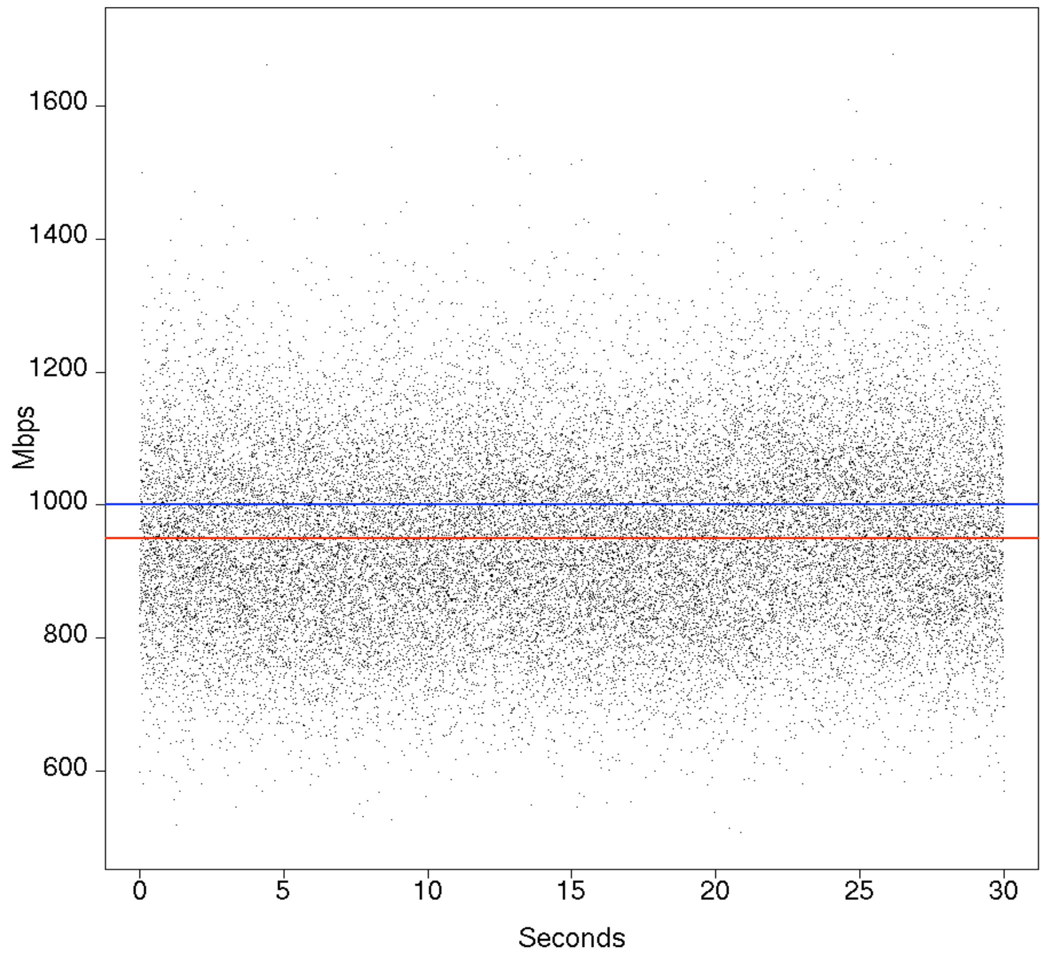


Raw Results
30 sec of data, 1ms scale

- Mean = 950 Mbps
- Max. = 2033 Mbps
- Min. = 509 Mbps

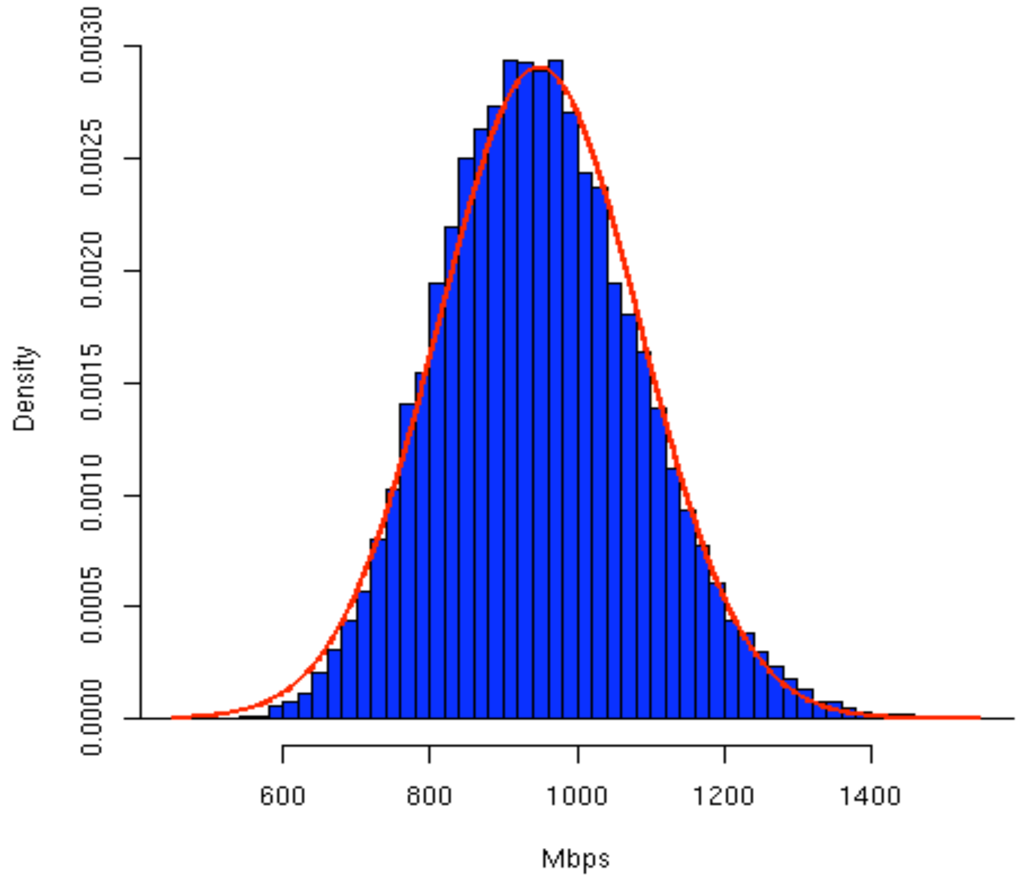
- 95-percentile: 1183 Mbps
- 5-percentile: 737 Mbps

- (around 250 packets per 1ms interval)



Traffic Distribution Histogram (1ms scale)

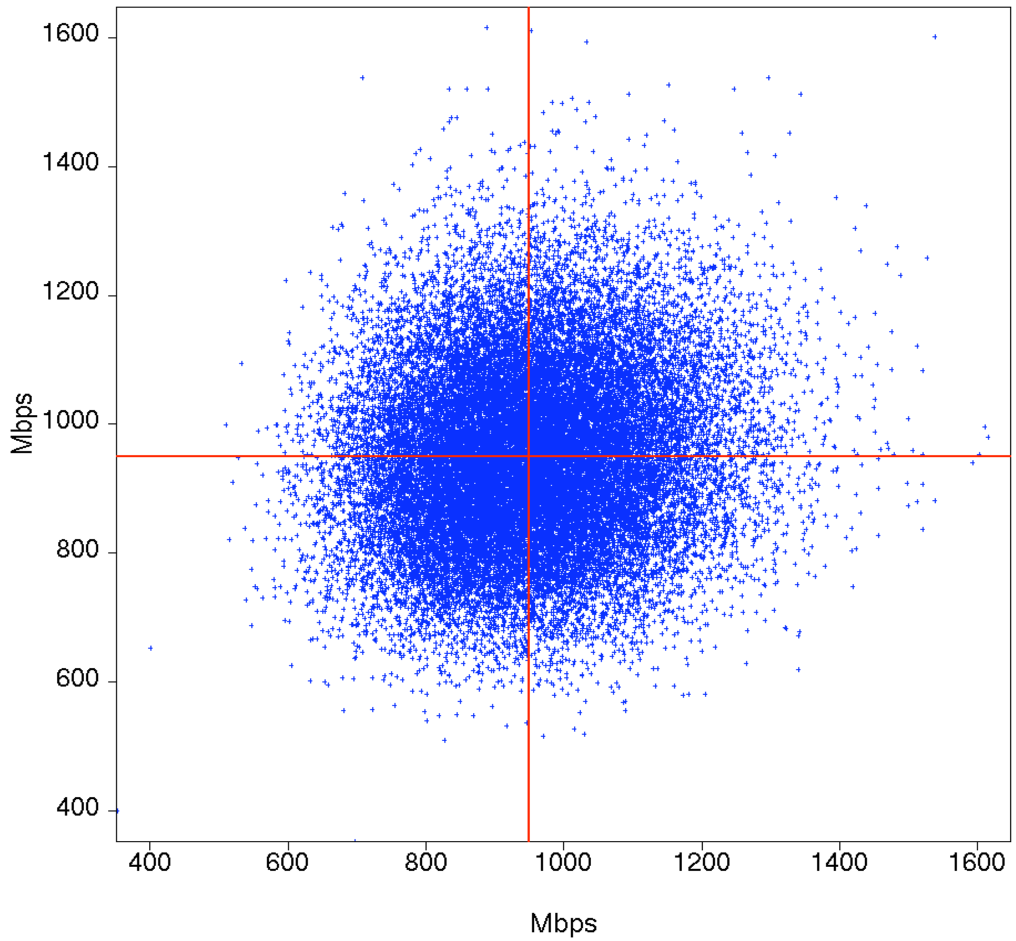
- Fits normal probability distribution very well (Std. dev. = 138 Mbps)
- No Heavy-Tails
- Suggests small overprovisioning factor



Autocorrelation Lag Plot (1ms scale)

- Scatterplot for consecutive samples
- Are periods of high usage followed by other periods of high usage?

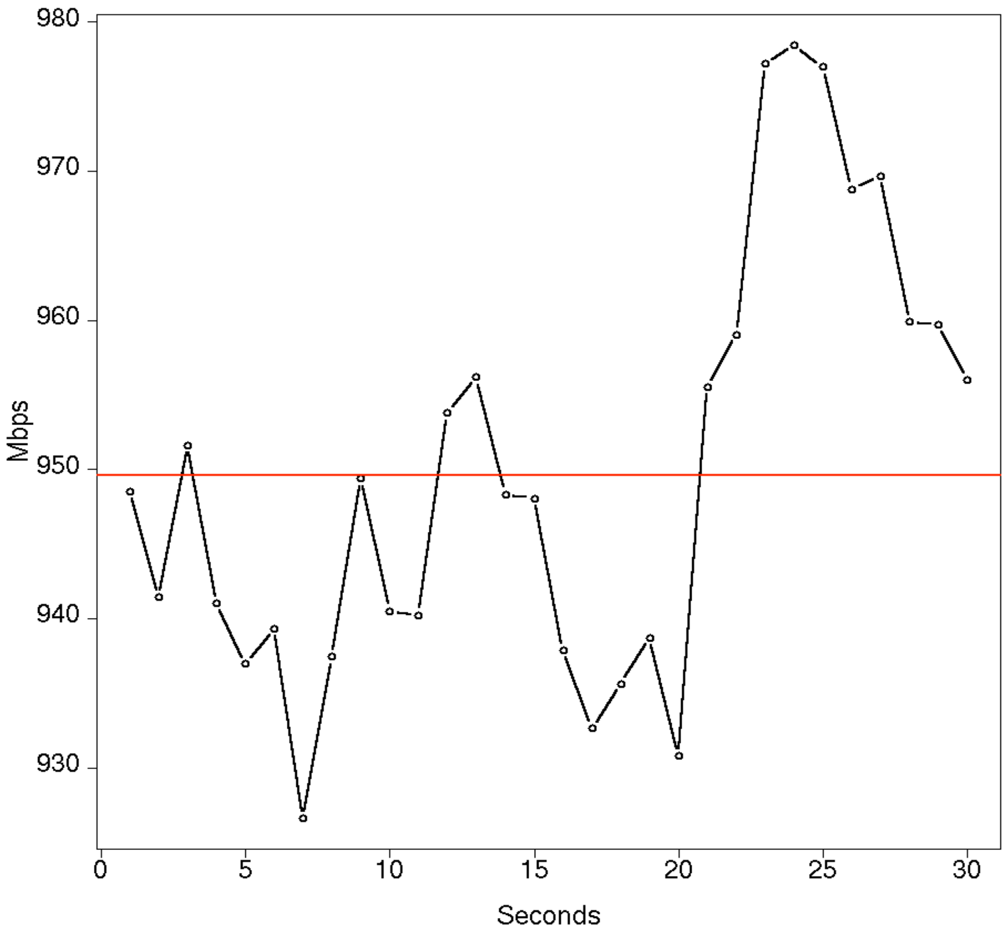
- Autocorrelation at 1ms is 0.13 (=uncorrelated)



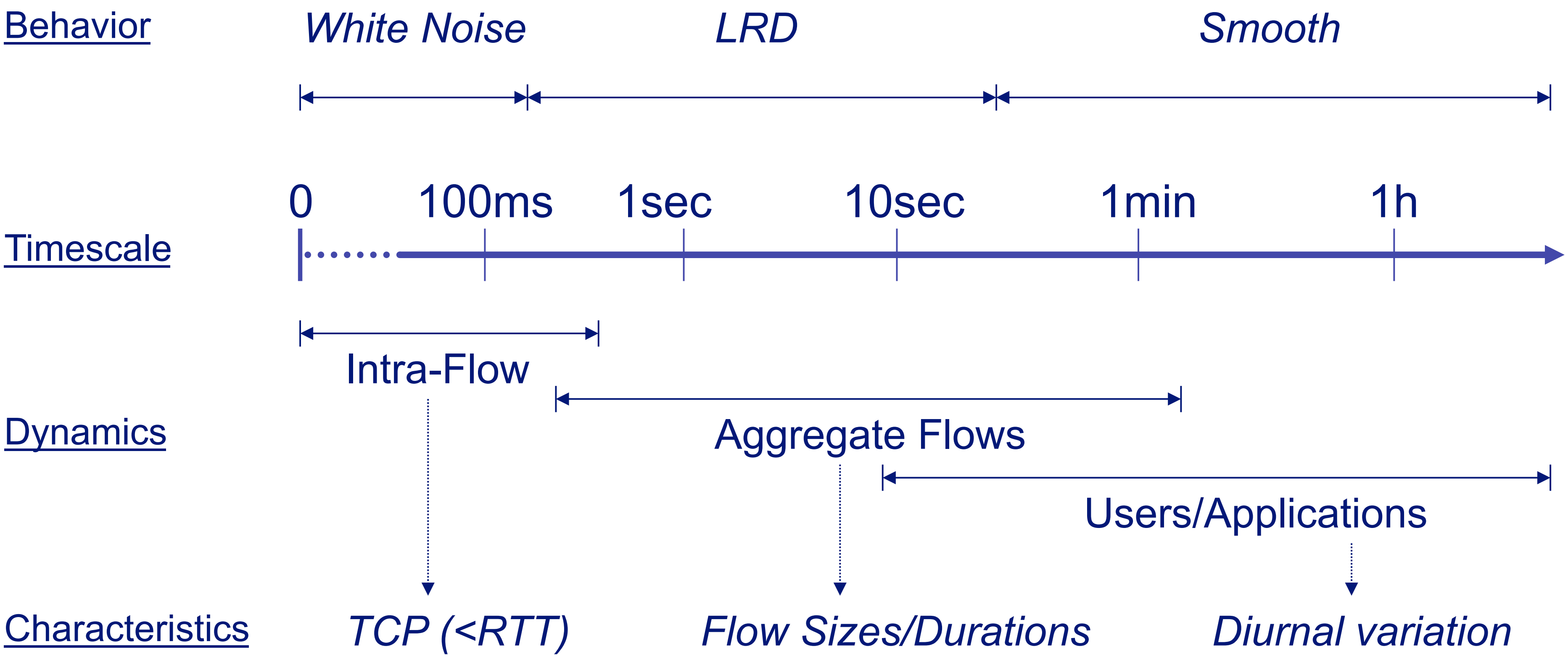
Utilization
30 sec of data, 1 sec scale

- Mean = 950 Mbps
- Max. = 978 Mbps
- Min. = 927 Mbps

- Clearly longer derivations from the mean
- High autocorrelation at 1 sec. (0.68)



Relevant Timescales



Traffic Behavior

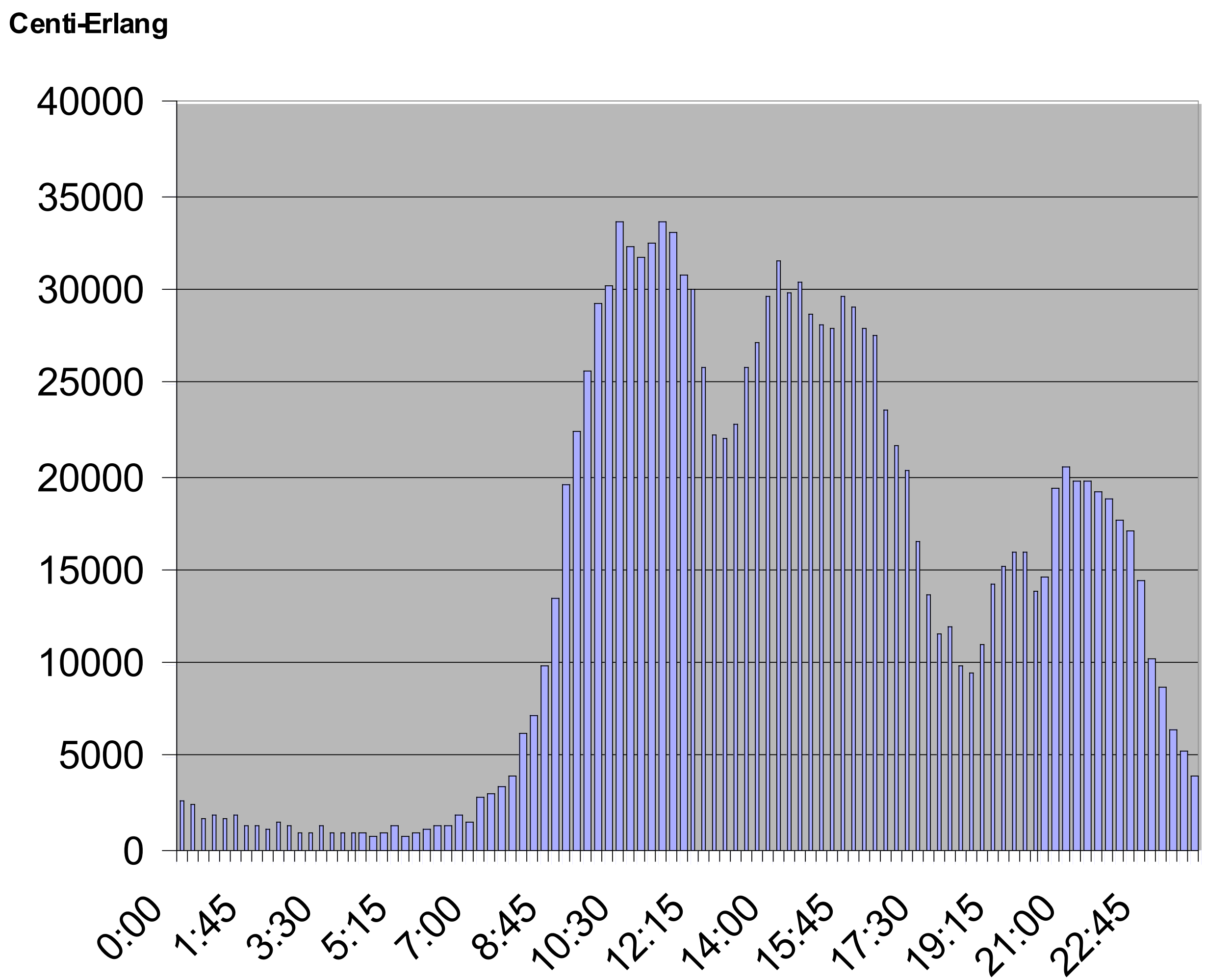
- < 150ms: Gaussian White Noise
  - I.I.D, Normal distribution, no correlation
  - Short-Range Dependent (H=0.5)
- 150ms – 30sec: Long-Range Dependence
  - Non-summable autocorrelation
  - Statistically Self-Similar
  - $X =_d m^{1-H} X^{(m)}$, "Clustering", Fractional Brownian Motion (fBM)
- > 30 sec: Smooth
  - Degenerate case: autocorrelation = 1
  - Almost constant, diurnal variation

Queuing Models/Simulation

- **<u>M/M/1 queuing formula</u>**
- Markovian
  - Poisson-process
  - Infinite number of sources
- “Circuits can be operated at over 99% utilization, with delay and jitter well below 1ms” [2] [3]

- **<u>Self-Similarity</u>**
- Traffic is bursty at many or all timescales
- “Scale-invariant burstiness (i.e. self-similarity) introduces new complexities into optimization of network performance and makes the task of providing QoS together with achieving high utilization difficult” [4]

Telephony Traffic
(inter-city on 6/3/2002)



Voice Capacity Allocation

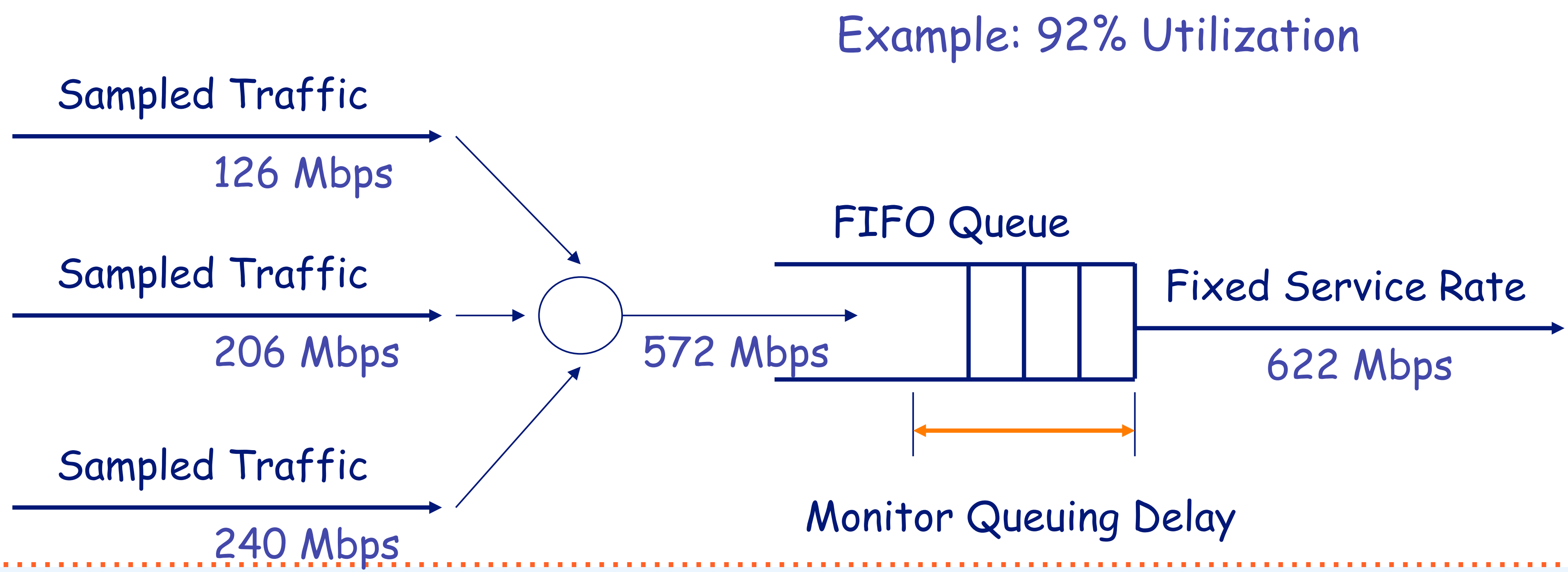
- Erlang traffic model(s)
- 1 Erlang = 1 hour of calls
  - Average numbers of calls in an hour
- Busy Hour Traffic: about 330 Erlang
- Erlang B formula (for 330 Erlang):
  - Blocking 1% -> 354 lines required
  - Blocking 0.1% -> 376 lines required
- Reverse calculation:
  - 100 lines available, blocking 0.1%:
    - 75 Erlang (=average of 75 calls in an hour)

IP Capacity Allocation

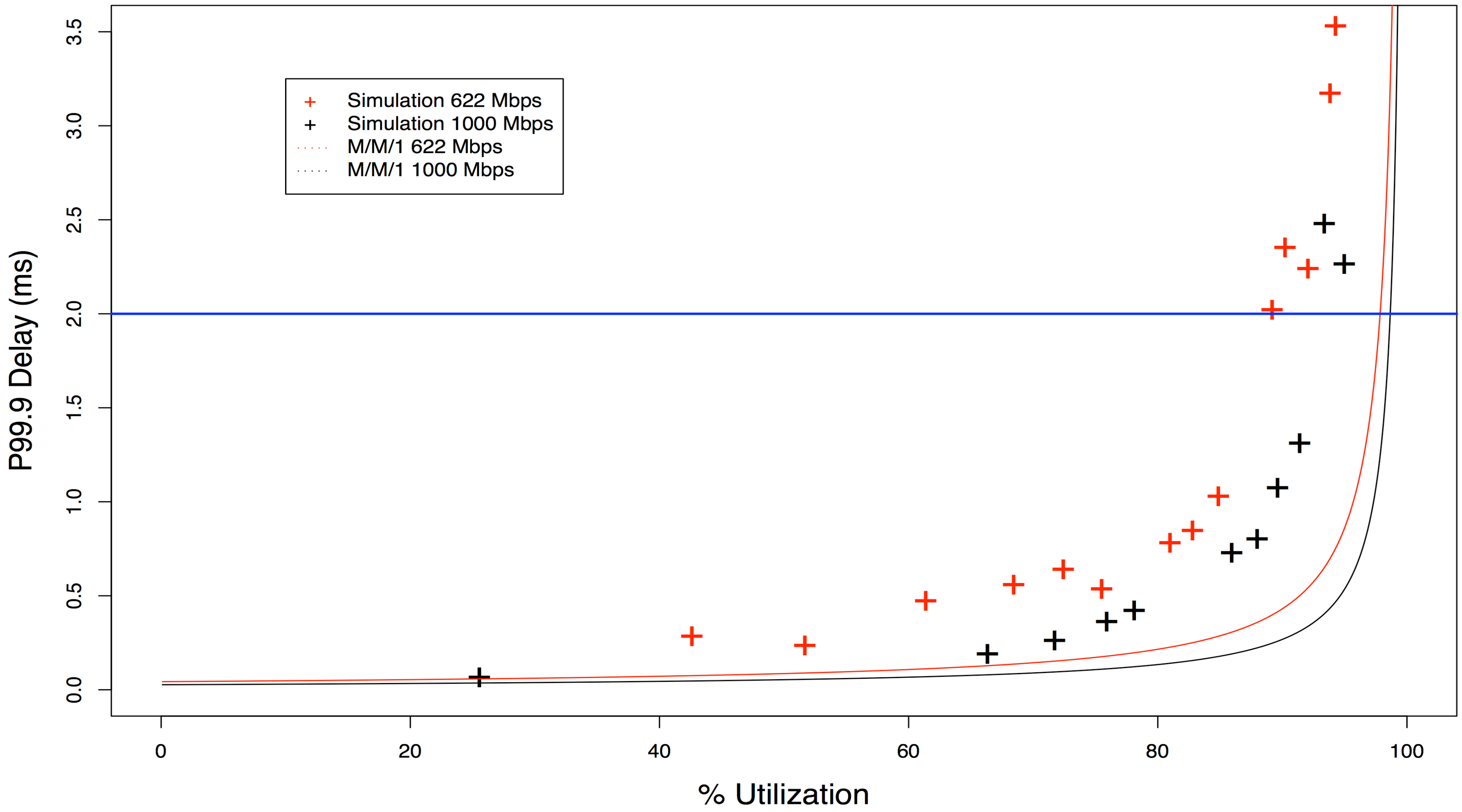
- Measurement data
  - E.g. 5-min average utilization
- Performance objectives
  - E.g. packet loss = 0%, jitter < 10ms
  - End-to-end: convert to per-hop objective
- But we don’t have an “Erlang formula”…
- Two paths towards a solution:
  - 1) Model the traffic, and fit parameters
  - 2) Empirically derive guidelines

Queuing Simulation

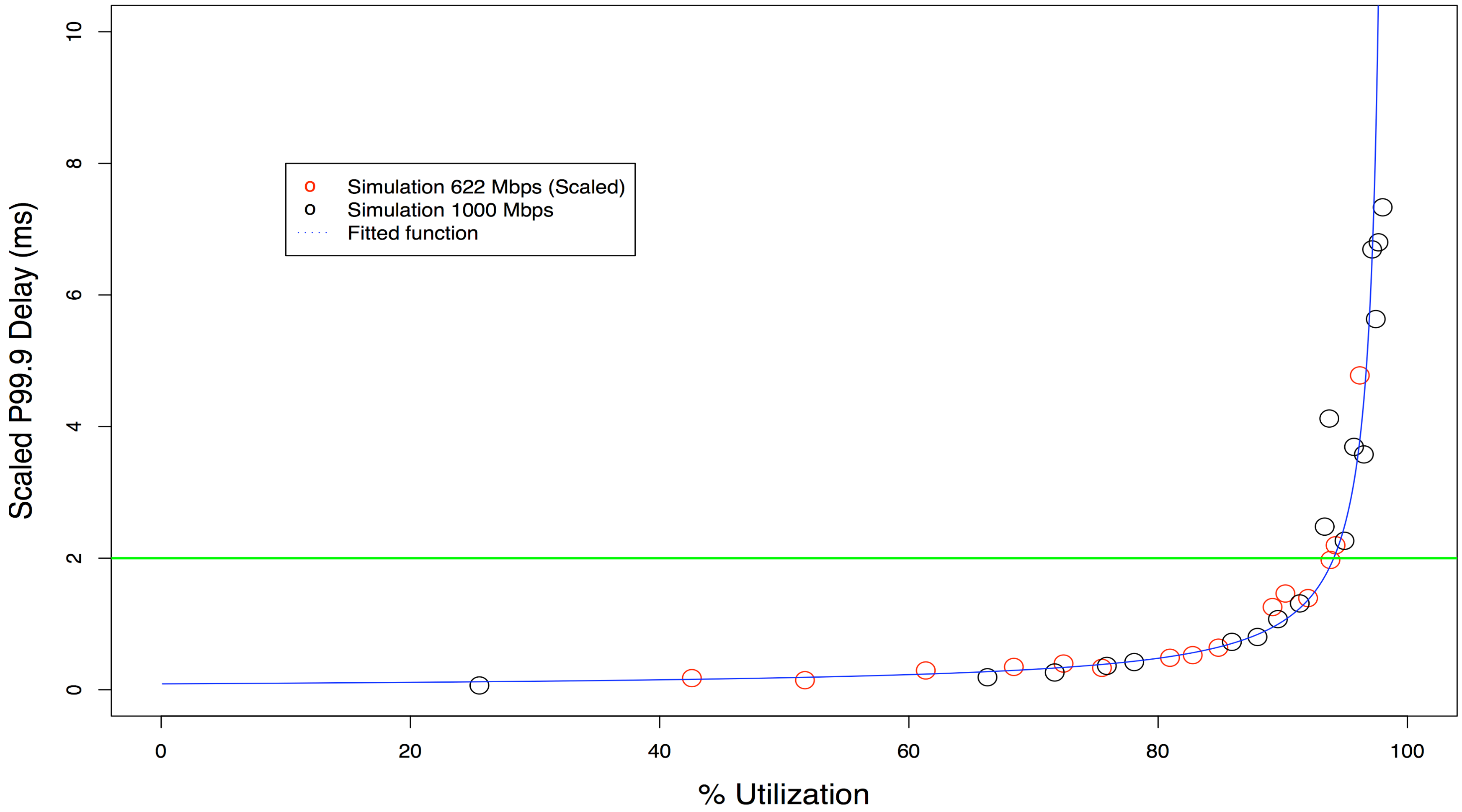
- Feed multiplexed sampled traffic data into FIFO queue
- Measure amount of traffic that violates the delay bound



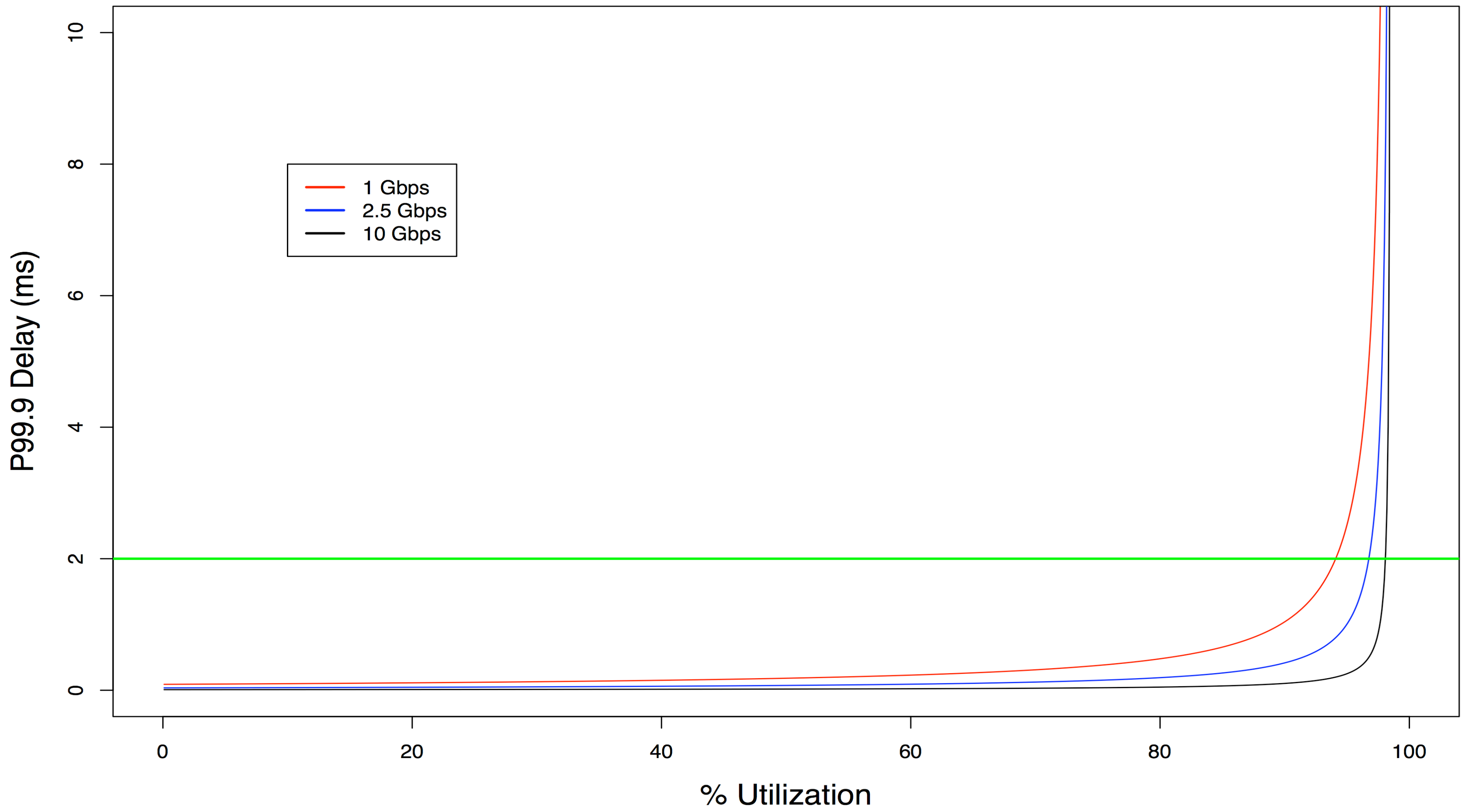
Queuing Simulation: Results



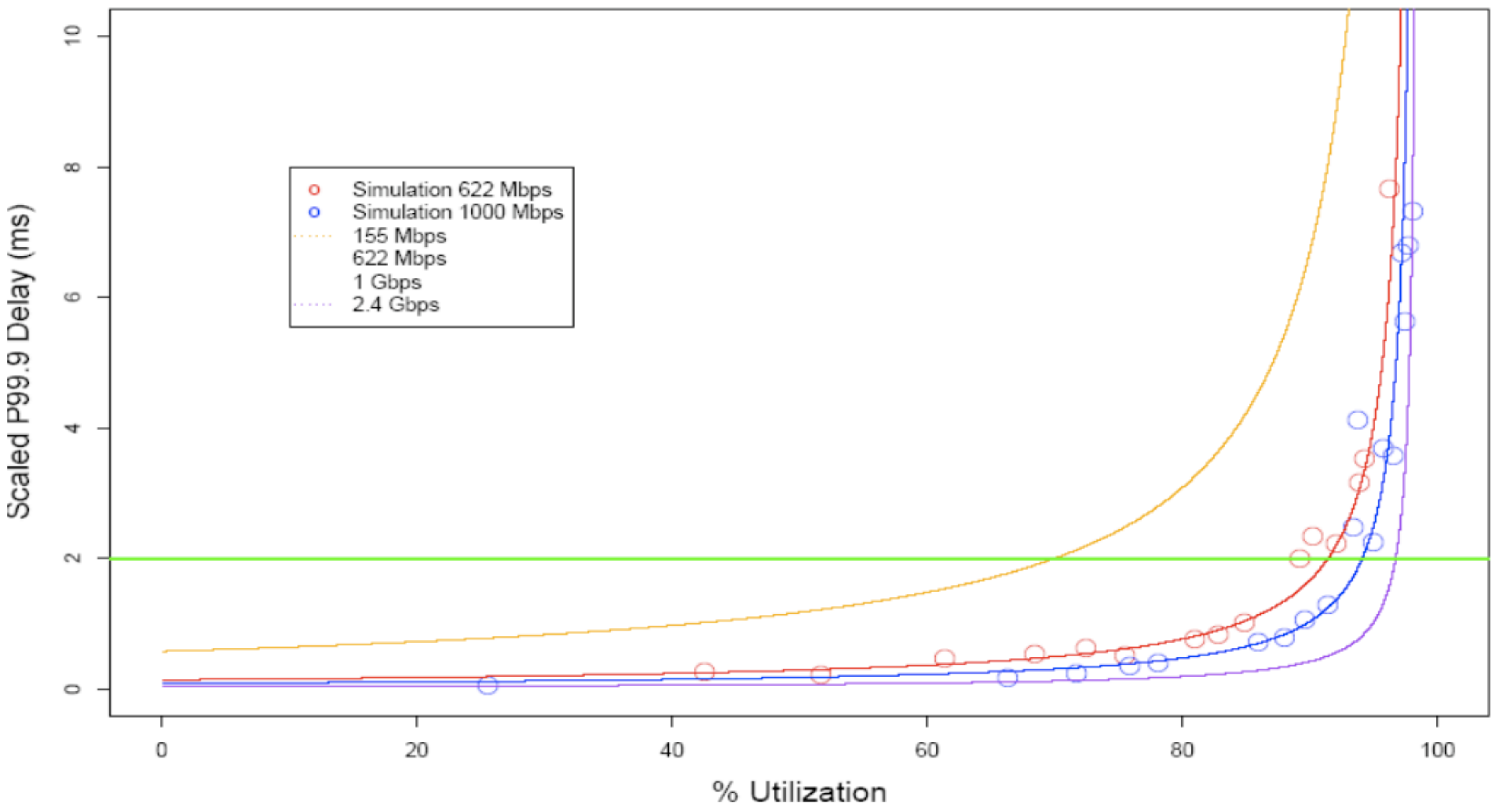
Scaled Delay Function (1G)



P99.9 Delay Function



P99.9 Delay Function

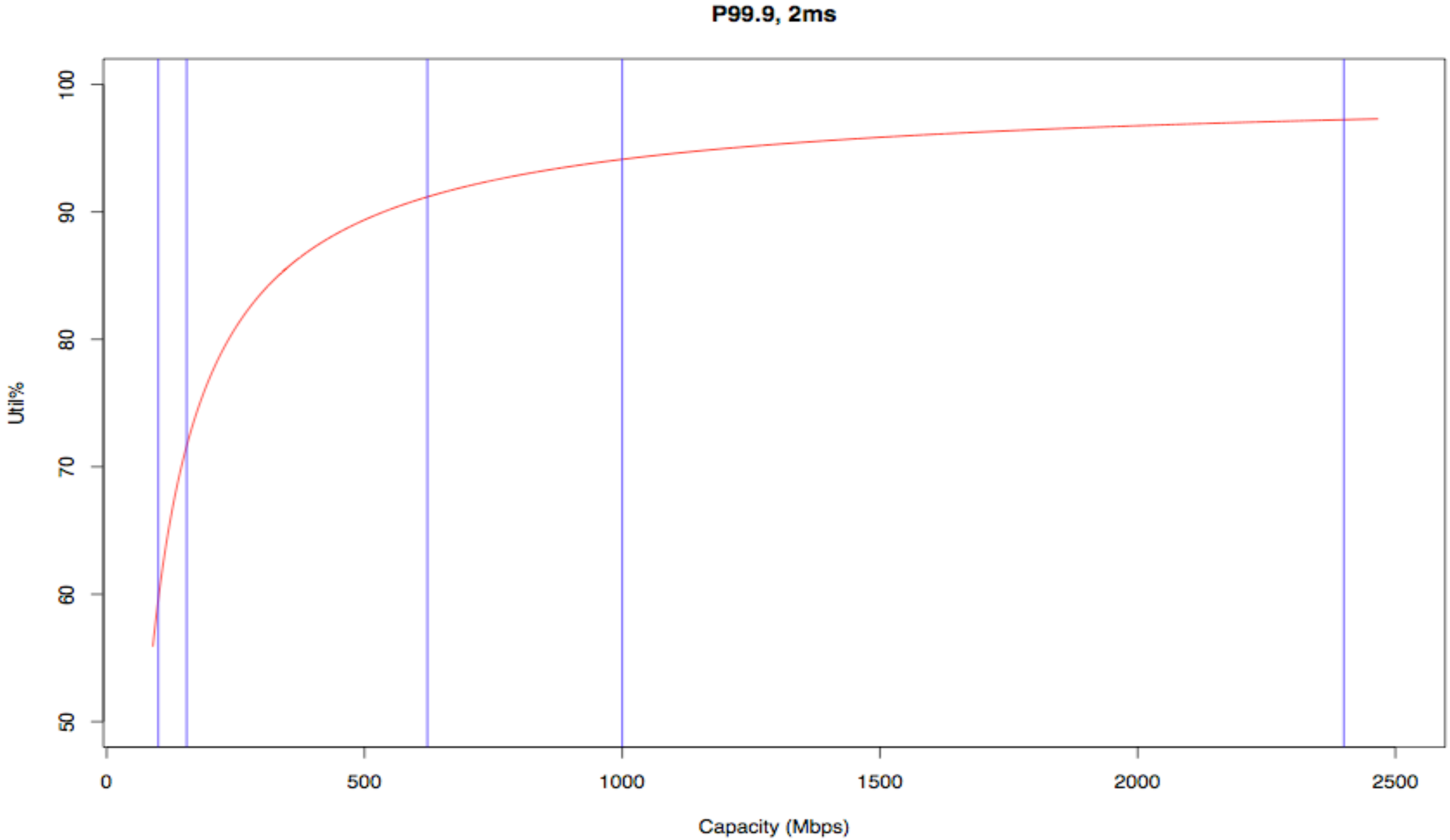


Cao, Cleveland, Sun

- Bandwidth Estimation for Best-Effort Internet Traffic
  - Jin Cao, William S. Cleveland, and Don X. Sun
  - Statist. Sci. Volume 19, Number 3 (2004), 518-543.
- Data:
  - BELL, AIX, MFN, NZIX
- Model depends on:
  - #connections, traffic rate, delay target
  - Avg. bandwidth per connection: 16384 bps
- Best-Effort Delay Formula:

$$\text{logit}_2(u) = o + (o_c + o_{\tau\delta}) \log_2(c) + o_{\tau\delta} \log_2(\gamma_b \delta) + o_\omega(-\log_2(-\log_2(\omega))).$$

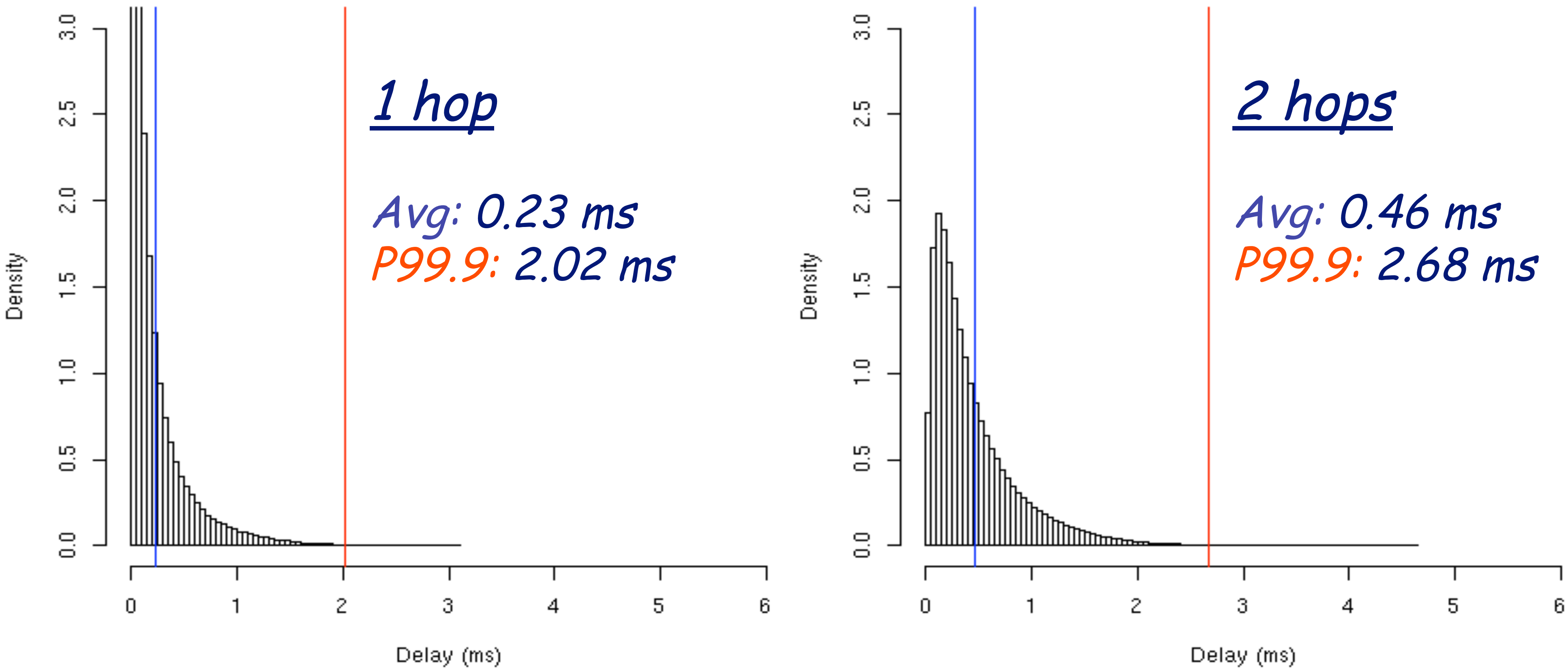
Best-Effort Delay Model



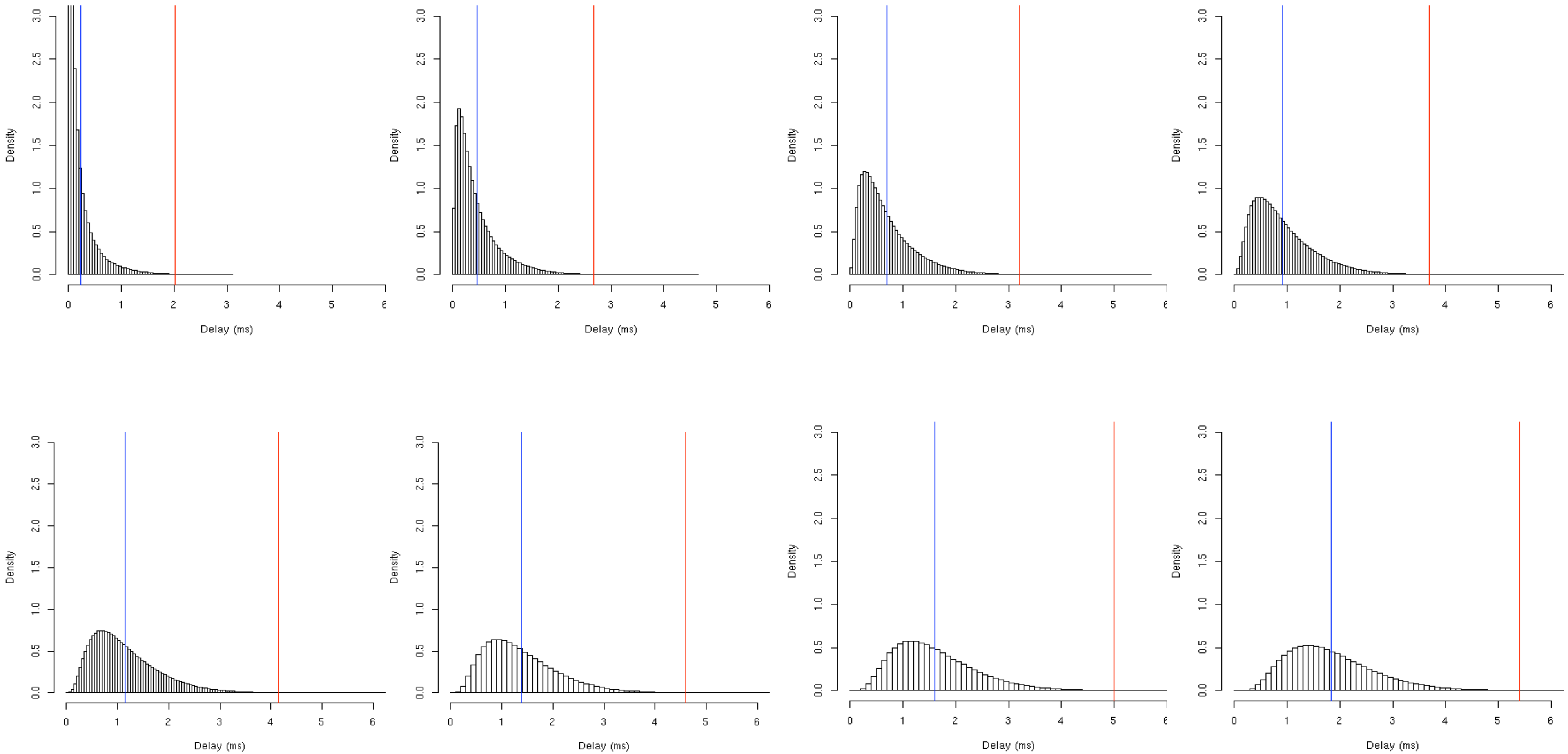
Queuing Simulation: Numeric Results

- 1 Gbps (Gigabit Ethernet)
  - 1 ms delay bound for 999 out of 1000 packets (99.9-percentile):
    - *90% maximum utilization*
- 622 Mbps (STM-4c/OC-12c)
  - 1 ms delay bound for 999 out of 1000 packets (99.9-percentile):
    - *85% maximum utilization*

Multi-hop Queueing



Multi-hop Queueing (1-8 hops)

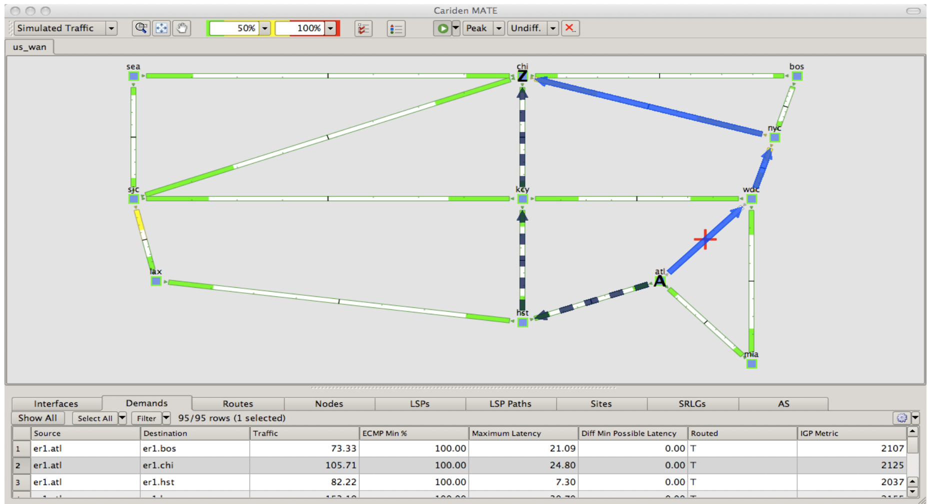


Queueing: Summary

- Queueing Simulation:
  - Gigabit Ethernet (backbone) link
    - overprovisioning percentage in the order of 10% is required to bound delay/jitter to less than 1 ms
  - Lower speeds (<1G)
    - overprovisioning factor is significant,
  - Higher speeds (2.5G/10G)
    - overprovisioning factor becomes very small
- P99.9 multi-hop delay/jitter is not additive

Future work

- Use more conservative delay formula
- Estimate avg. bandwidth per connection (NetFlow?)
- Investigate VoIP traffic (ongoing)
- Integrate numbers in end-to-end planning and engineering process
  - Include DiffServ
  - E.g.using Cariden MATE



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