The UNIVERSITY *of* NORTH CAROLINA *at* CHAPEL HILL

Variability in TCP Round-trip Times

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http://www.cs.unc.edu/~jasleen/research/RTT

TCP Round-trip Times (RTTs)

Popular belief:

RTTs do not vary significantly within TCP connections

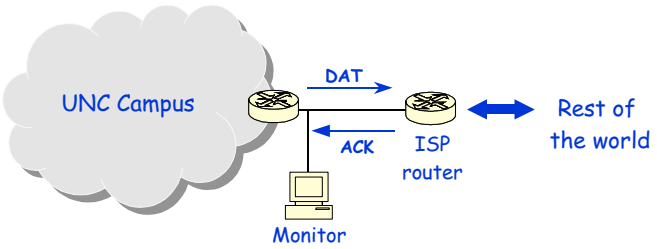
– Mean RTT can be used to approximate per-segment RTTs

- TCP throughput models
  [Altman00, Kumar98, Lakshman97, Mathis97, Padhye98, …]
- Analysis based on TCP behavior
  [Zhang02]

– RTT of initial segments is "typical" for a TCP connection

Do per-segment RTTs vary significantly within a TCP connection?

Data Source



Rich data source!

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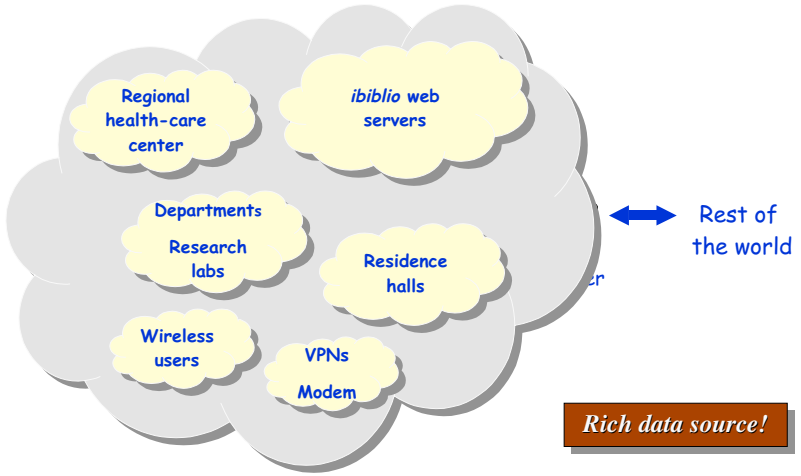
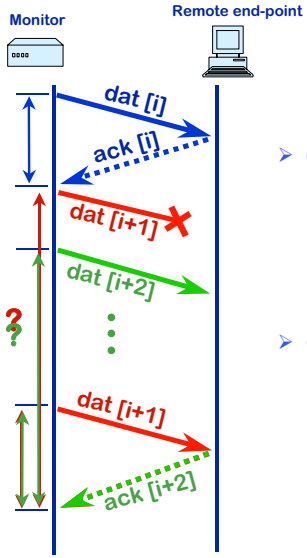


Rich data source!

Extracting Valid RTT Samples



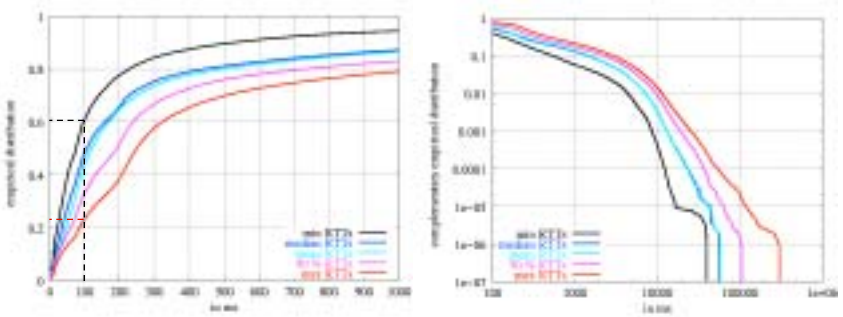
- Guiding principle:
  - Consider only those RTTs where there is unambiguous correspondence between an ACK and the DAT that triggered it.
- Caveat: delayed ACKs
  - Could add 200 – 500 ms to RTT estimates

Trace Statistics

	Connections	Remote hosts	RTT samples	Bytes	Packets
All connections	22.7 million	962 K	252 million	628 GB	511 M
Connections with at least 10 samples	1.1 million	258 K	236 million	581 GB	464 M

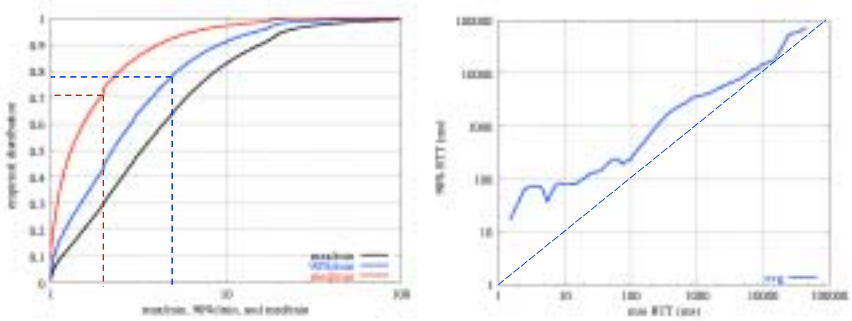
Large data set!

Variability Across Connections



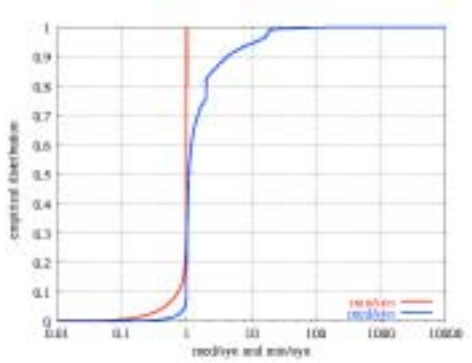
- 60% connections see min RTT less than 100 ms
  - Only 23% see max RTT less than 100 ms
- ACKs can arrive more than 25 s after DAT transmission!
- Mean and median RTTs are comparable measures

Variability Within Connections



- Median RTT:
  - 30% of connections see a median RTT more than twice the min RTT
- 90% RTT:
  - 22% of connections see a 90% RTT more than 5 times the min RTT
  - 90% RTT increases with min RTT

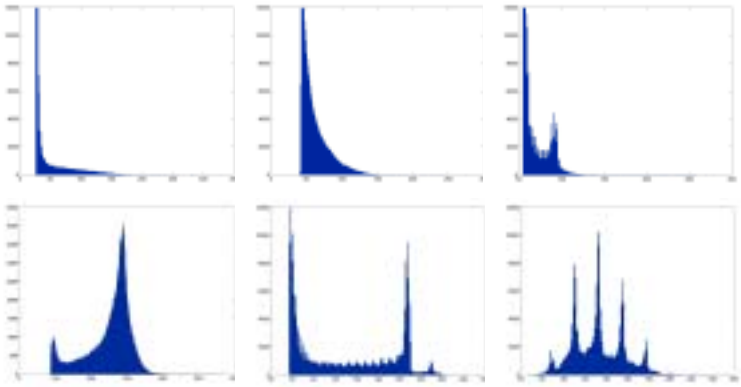
The SYN/(SYN+ACK) RTT



- RTT yielded by the SYN and SYN+ACK pair
  - Differs by more than 10% from min RTT for 14% of connections
  - Differs by more than 10% from median RTT for 50% of connections

Per-Segment RTTs: Mean or Distributions?

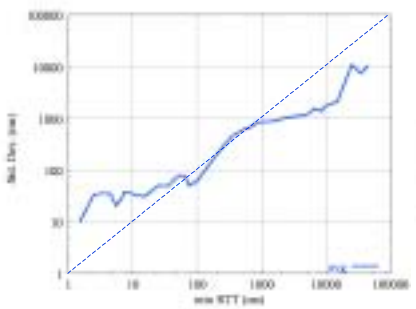
- Is mean RTT a good approximation for per-segment RTTs?
  - TCP analytical models
  - TCP evaluation (simulations)



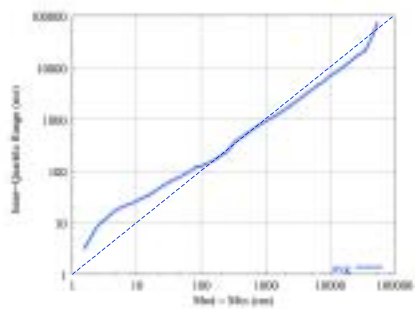
Ongoing Work

- Impact of RTT variability on past work
  - TCP analytical models
  - Delay-based congestion control
  - TCP evaluation (simulations)
  - TCP-based analysis
- Causes of variability
  - Congestion?
  - End-hosts?
- Models for per-connection RTTs
  - Accurate simulation environments

Variability within connections

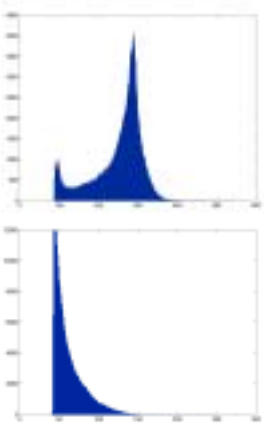


Standard deviation in per-connection RTTs
- Increases rapidly in the range:
  min RTT = 100 ms – 1 s
- Increases less rapidly in other regions



Inter-quartile range
- Increases consistently with (med-min) RTT

Per-Segment RTTs: Mean or Distributions?



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