TCP Behavior in Networks with Dynamic Propagation Delay

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IEEE Globecom
November, 2000
Overview

- Introduction and Motivation
- Simulation Environment
- RTO Estimator Validation
- Simple TCP Experiments
- Simple Handoff Experiments
- Conclusions
Plenty of researchers have looked at the impact of long, static delays on TCP performance.
- See RFCs 2488, 2760 and references therein.

But, what about situations where the propagation delay changes over time?
- E.g., NASA’s Earth-observing satellites.
Our paper is based on models of satellites sending data to the ground.

However, we believe the results apply to any situation where modest motion is involved.
- We used a variety of spacecraft orbiting in the LEO and MEO bands.
  - These spacecraft send data to TDRS, which transmits the data to Earth.

- We used Satellite Toolkit 4.0 to generate orbital data.

- We introduced a variable delay link into the ns network simulator.
  - The propagation delay along the link changes as a function of time, based on the STK output.
• Simulated topology:
Variable Delay Scenarios
• TCP uses a *retransmission timer* (RTO) to guarantee reliable data delivery.

• The standard RTO estimator:

\[ RTO \leftarrow SRTT + 4 \cdot RTTVAR \]

• RTO measured and calculated using a clock with granularity \( G \).
  - Traditionally \( G = 500 \ ms \)
  - Some have suggested finer grained timers will yield better performance, so we also used \( G = 1 \ ms \).
• Loss is also taken as an indication that the network is congested.
  - Hence, the sending rate is reduced.

• Therefore, one desirable property of an RTO estimator is that it not retransmit segments too early and cause a needless reduction in sending rate.
Simple RTO Experiments (cont.)

• Do the variable delay scenarios used in our experiments confuse the RTO estimator?
  - Set the maximum TCP window size to 1 segment.
  - Run a TCP transfer for the length of the scenario.
  - Watch for retransmissions.

• Answer: No. The RTO estimator is able to cope with the changing propagation delays we tested.
  - But, what about a slightly more dynamic environment with queueing delays?
Single Flow Tests

- Tested various file sizes (4–10,000 packets).
- The transfer start time was roughly every 60 seconds over the course of the scenario.
- Started with $G = 500 \text{ ms}$
Single Flow Tests (cont.)
Single Flow Tests (cont.)

- As expected...
  - Small files underutilize the capacity.
  - Large files nearly fully utilize the capacity.
  - More throughput variation in small files.
- Also, no unnecessary retransmits were detected.
• What about using a fine-grained timer?
  - Small transfers (4–200 packets) did not cause needless retransmissions.
    • Small transfers do not build queues – and we know that fine-grained timers work well with no queues on our delay scenarios.
    • $RTTVAR$ is initially $\frac{RTT_{\text{meas}}}{2}$, which inflates the RTO at the beginning of a transfer, providing some protection against spurious retransmits.
  - Large transfer do experience needless retransmits.
2,000 packet transfer

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November, 2000
• Our last scenario models a perfect (no loss, no reordering) handoff that essentially moves from a single GEO hop to a double hop and back.

• $G = 1 \text{ ms}$ cannot cope with the drastic change in RTT caused by moving from a single hop to a double hop.

• $G = 500 \text{ ms}$ does not needlessly retransmit even when crossing the large jump in throughput.
Conclusions

- With a large minimum RTO (e.g., as we get with $G = 500\ m/s$) TCP performs quite well in the environments examined.

- Fine-grained timers reduce performance for long transfers.

- As in more static environments, short transfers often underutilize the capacity of the network path.

- The throughput obtained by short transfers is somewhat variable depending on start time.
Future Work

• Consider more realistic handoffs where reordering and/or loss may occur.

• When a satellite is moving, typically the signal strength is changing, as well as the propagation delay. This will yield different BERs at different points in the curve. This should be investigated.

• A more realistic traffic pattern should be obtained and used.