L41: Lab 5 - TCP Latency and Bandwidth

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4 May 2015

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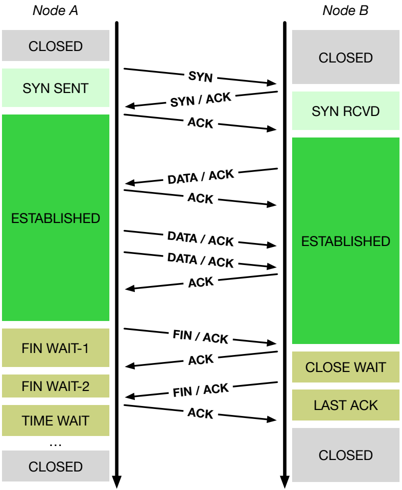
- TCP congestion control
- Latency and bandwidth interactions
- Tracing both protocol and implementation

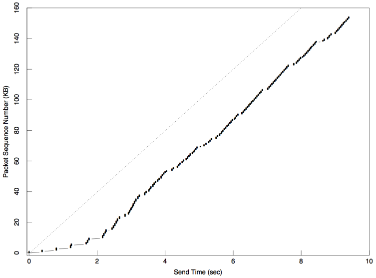
Lect 6: TCP goals and properties



- Reliable, ordered, byte-stream transport protocol over IP
- Three-way handshake: SYN / SYN-ACK / ACK (mostly!)
- Flow control via advertised window size in ACKs
- Congestion control via packet loss and ECN (‘fairness’)
- Network may delay, (reorder), drop, corrupt packets
- Sequence numbers ACK’d; data retransmitted on loss
- Round-Trip Time (RTT) measured to time out loss

Lect 6: TCP congestion control and avoidance

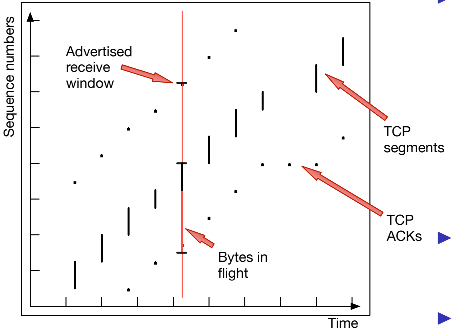
Figure 4: Startup behavior of TCP with Slow-start



Same conditions as the previous figure (same time of day, same Suns, same network path, same buffer and window sizes), except the machines were running the 4.3+TCP with slow-start. No bandwidth is wasted on retransmits but two seconds is spent on the slow-start so the effective bandwidth of this part of the trace is 16 KBps — two times better than figure 3. (This is slightly misleading: Unlike the previous figure, the slope of the trace is 20 KBps and the effect of the 2 second offset decreases as the trace lengthens. E.g., if this trace had run a minute, the effective bandwidth would have been 19 KBps. The effective bandwidth without slow-start stays at 7 KBps no matter how long the trace.)

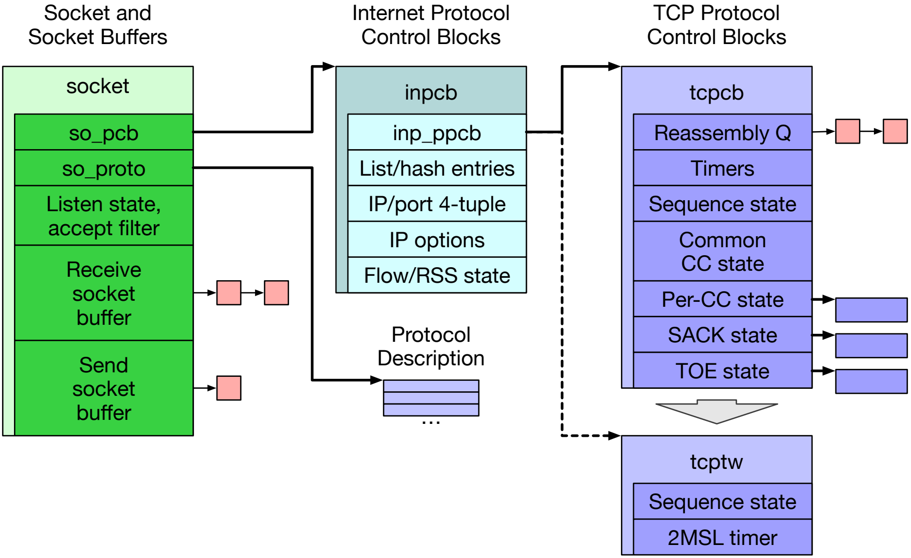
- 1986 Internet CC collapse
  - 32Kbps -> 40bps
- Van Jacobson, SIGCOMM 1988
  - Don't send more data than the network can handle!
  - *Conservation of packets* via *ACK clocking*
  - *Exponential retransmit timer*, *slow start*, *aggressive receiver ACK*, and *dynamic window sizing on congestion*
- ECN (RFC 3168), ABC (RFC 3465), Compound (Tan, et al, INFOCOM 2006), Cubic (Rhee and Xu, ACM OSR 2008)

Lect 6: TCP time/sequence graphs



- Extracted from bi-directional TCP packet traces
  - Sequence numbers in data segments, advertised window, acknowledgments
  - X: time
  - Y: sequence number
- Visualise receive windows, congestion behaviour, RTT, ...
- We can also extract this data using DTrace

Lect 6: Data structures - sockets, control blocks



tcpcb sender-side data-structure fields

Described in more detail in the lab assignment:

snd_wnd Last received advertised flow-control window.

snd_cwnd Current calculated congestion-control window.

snd_ssthresh Current show-start threshold: if snd_cwnd is less than or equal to snd_ssthresh, then TCP is in slow start; otherwise, it is in congestion avoidance.

- Instrument tcp_do_segment using DTrace to inspect TCP header fields and tcpcb state
- Packets on 'client' and 'server'; tcpcb only on 'server'.
- Use as input to time–sequence-number or time–bandwidth plots.
- Make sure to flush the TCP host cache between benchmark runs.

Exploratory questions

- As latency varies, how does overall bandwidth change?
- How does using a fixed rather than auto-resized socket buffer affect advertised receive window? Use a fixed buffer size (1MB).
- How quickly does TCP ready steady state (i.e., shift out of slow start) at a 10ms RTT? Is this a product of the congestion or the socket-buffer limit?

Experimental questions for lab report

- Plot network latency vs. TCP bandwidth. Does linear increase in latency mean linear decrease in bandwidth? How does socket-buffer auto-resizing help/hurt/not change performance?
- Explore the effects of socket-buffer limits and stack graph information on the flow-control versus congestion-control limits. How does socket-buffer auto-resizing help/hurt/not change performance?
- Explore how latency affects the time taken to leave slow start.

This lab session

- Upgrade your SD Card image (again)
- Ensure that you are able to properly extract both TCP header and `tcpcb` fields from the `tcp_do_segment` FBT probe
- Generating the data for a time–bandwidth graph
- Generating the data for a time–sequence-number graph
- Ask us if you have any questions or need help