TCP Congestion Control

1. How does a sender sense congestion?
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2. How does a sender determine its sending rate?
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3. What algorithm is used to change the send-rate?
   - Many phases and alternatives...

Reaction to Loss Events

- Exponential increase switches to linear increase when CongWin gets to the ‘threshold’ value (size)
TCP Congestion Control Algorithm

Increase Sending Rate Phase Options:
1. When CongWin is below Threshold, sender in slow-start phase, window grows exponentially.
2. When CongWin is above Threshold, sender is in congestion-avoidance phase, window grows linearly.

Decrease Sending Rate Phase Options:
1. When a triple duplicate ACK occurs, Threshold set to CongWin/2 and CongWin set to Threshold.
2. When timeout occurs, Threshold set to CongWin/2 and CongWin is set to 1 MSS.

Summary TCP reaction to loss

- Loss indicated by timeout
  - cwnd set to 1 MSS
  - ssthresh set to cwnd/2
  - Window (cwnd) grows exponentially (slow start) to the threshold, then grows linearly

- Loss indicated by 3 duplicate ACKs
  - Network capable of delivering some segments, so...
  - cwnd is cut in half (=ssthresh)
  - Window grows linearly

TCP Congestion Control Algorithm

Three major phases / mechanisms:
1) Slow start – at 1 max segment size
   • But increase ________
2) Congestion Avoidance phase
   • AIMD = additive incr, multiplicative decr
   • Using cwnd and ssthresh
3) Fast Recovery
   • Increase of cwnd each round trip time
   • Slow start: __________
   • Congestion avoidance: __________
Similar to Next HW - Able to Identify?

![Graph]

Transport Layer Review

- The transport layer services are:
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Transport Layer Review

- The transport layer does not provide:
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Transport Layer Review

- Compare TCP and UDP (pros and cons?)
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Transport Layer Review
Transport Layer Review

- TCP Connection Management includes
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Transport Layer Review

- Elements of TCP reliability:
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Transport Layer Review

- Elements of congestion control algorithm
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TCP Flow Control

- Source port #
- Dest port #
- Sequence number
- Acknowledgement number
- Header length (not used in TCP)
- TCP flags:
  - URG: urgent data (generally not used)
  - ACK: ACK # valid
  - PSH: push data now (generally not used)
  - RST, SYN, FIN: connection estab (setup, teardown commands)
- Internet checksum (as in UDP)
- Options (variable length)
- Application data (variable length)

- Counting by bytes of data (not segments!)
- # of bytes rcvr willing to accept
TCP flow control (quick & easy!)

- **Receiver** "advertises" free buffer space by including `rwnd` value in TCP header of receiver-to-sender segments
  - `RcvBuffer` size set via socket options (typical default is 4096 bytes)
  - Many operating systems auto-adjust `RcvBuffer`
- **Sender** limits amount of un-ACKed ("in-flight") data to receiver's `rwnd` value
  - Guarantees receive buffer will not overflow

TCP flow control

The application may remove data from the TCP socket buffers ...

... slower than the TCP receiver is delivering it into the buffers (sender is sending)

flow control to the rescue!

receiver controls sender, so sender won't overflow receiver's buffer by transmitting too much, too fast

Transport Layer Review

- Other questions?

A fun tangent...

Finite State Machines
TCP sender events:

(1) data received from application:
   1. Create a segment and assign a SEQ number
      ▷ SEQ # is byte-stream number of first data byte in segment
   2. Start timer if it is not already running
      ▷ Timer is for the oldest un-acked segment
      ▷ Expiration interval: TimeOutInterval

(2) timeout:
   1. Retransmit segment that caused the timeout
   2. Restart the timer

(3) ACK received:
   ▶ For previously unacked segments
      1. update what is known to be acked
      2. start timer if there are outstanding segments

TCP Congestion Control: FSM
Transport Layer Summary

- TCP (and UDP) Services
- Defining and implementing a reliable transport service
- Checksum
- Connection management
- Congestion control
- Detect loss and retransmit
  - Detect out-of-order and retransmit
- Flow Control

Network Layer: Routing and Forwarding

- Create versus use the forwarding table

Transport services and protocols

- Provide logical communication, a virtual connection

...between application processes running on different hosts

*This is not* a physical path including routers