End-End Layer

Quiz Review Notes 2007
• Network layer provides best effort services
• Packets may be
  – Lost
  – Delayed
  – Reordered
  – Corrupted
  – End-End layer tries to create a more comfortable environment for applications
Techniques for E2E assurances

• At-least once delivery
• At-most once delivery

• Data Integrity
• Flow control
At-least-once delivery

- Add nonce
- Add timer
  - If timer expires before ACK, retransmit and reset the timer
  - Keep trying forever?
No absolute assurances
Timers

• Fixed timers
  – Not a good idea since RTT depends on congestion
• How do you pick the correct value?
• Too small – too many retransmission
• Too large – wait too long
• Use Adaptive timers
  – Dynamically adjust to currently observed conditions
  – Works better but complex
At-most once delivery

- Need to suppress duplicates
- Receiving side keeps track of already seen packets
- If duplicate request -> resend ACK
- Challenges
  - How long to keep these nonces for
  - What if the server crashes
Data Integrity

• Add checksum

• Why is link-layer check sum not enough?
  – Only protects data while it is in transit
Flow Control

• Lock-Step: Send one segment, wait for ACK before sending another
• Too slow – one packet per RTT
• Send a window of packets
  – Ask receiver how much to send (assume receiver bottleneck)
  – Wait for ACKs before sending next window. Still too slow
Sliding Window

- Add space to window on the fly
- Sender advances window as soon as it receives an ACK
- How big should the window be?
- $W_{\text{min}} = \text{RTT} \times \text{bottleneck data rate}$
- What if network is bottleneck – congestion control
Jitter control

- Real-time applications need regular delivery schedule
- Network causes varying transit times – jitter
- Keep a buffer and delay all arriving segments to provide a constant data rate
E2E examples

• E2E – transport + application
• Example transport protocols
• UDP
• TCP
  – Stream of bytes
  – Assurance of delivery, data integrity, order
  – Flow control