TCP Flow Control

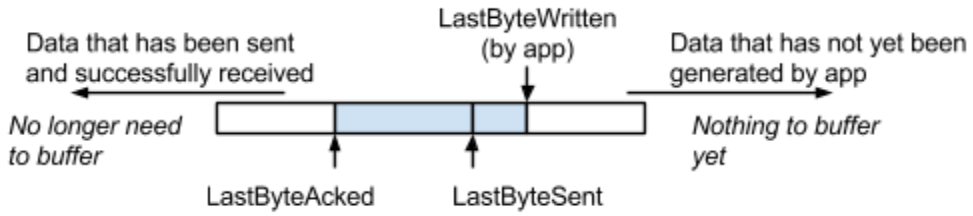
CS640, 2015-03-12

Outline

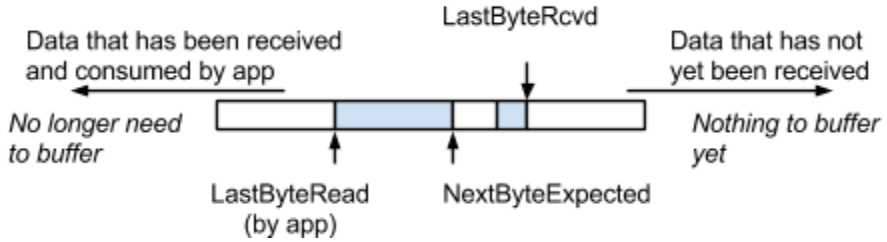
- Flow control
- Triggering transmissions

Flow control

- Sender buffer



  - LastByteAcked ≤ LastByteSent
  - LastByteSent ≤ LastByteWritten
- Receiver buffer



  - LastByteRead < NextByteExpected
  - NextByteExpected ≤ LastByteRcvd+1
- Sliding window -- amount of data that can be sent without waiting for an ACK from the receiver
  - To avoid overflowing receiver buffer:
    LastByteRcvd - LastByteRead ≤ MaxRecvBuffer
  - Amount of buffer capacity remaining:
    RecvBufRemain = MaxRecvBuffer - ((NextByteExpected-1) - LastByteRead)
    - ACKs include AdvertisedWindow -- receiver buffer capacity remaining
- Increment LastByteRcvd when data is received, so the amount of buffer remaining is reduced
  - If app is consuming data as fast as it arrives, then full receiver buffer is always available -- i.e., AdvertisedWindow = MaxRecvBuffer
- Sender must adhere to AdvertisedWindow:
  LastByteSent - LastByteAcked ≤ AdvertisedWindow
  EffectiveWindow = AdvertisedWindow - (LastByteSent - LastByteAcked)
  - EffectiveWindow must be > 0 before source can send more data
  - Also sending application cannot overflow sender buffer:
    LastByteWritten - LastByteAcked ≤ MaxSendBuffer

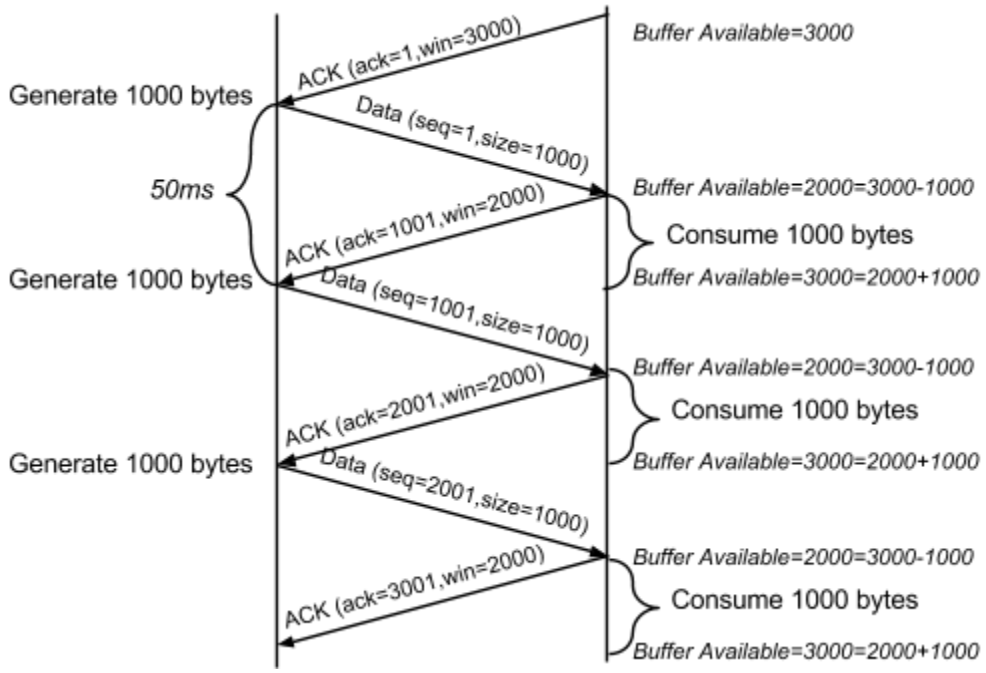
Triggering Transmissions

- Sender can transmit as soon as it has buffered enough bytes to fill a packet
    - Maximum segment size (MSS) = the maximum data bytes that can fit in one packet -- based on maximum packet size physical layer allows minus IP and TCP header size
- App can explicitly request transmission of buffered data
    - Needed for highly interactive apps -- e.g., SSH
    - PSH flag is set in TCP header
- Don't send packets < MSS, unless app requires this, since headers add overhead
    - Send one byte of data per packet
        - Send at least 54 (14 + 20 + 20) bytes of header for each byte of data
        - 1Mbps link effective data throughput <0.017 Mbps
    - Send 1000 bytes of data per packet
        - 1Mbps link effective data throughput ≈0.948Mbps
- SIlly window syndrome
    - When receiver buffer fills, AdvertisedWindow = 0 and no data can be sent
    - As receiver buffer starts to empty, AdvertisedWindow will be > 0, but may be < MSS
    - If we sent a partial packet (<MSS), then receiver will ACK smaller number of bytes and again the window will only open by a small amount
    - The problem can continue to exist indefinitely
- Nagle's algorithm
    - Application writes data to buffer
        - If unsent data in buffer ≥ MSS and advertised window ≥ MSS
            - Send packet with MSS bytes
        - Else
            - If unacked data in buffer
                - Do not send any data now
            - Else
                - Send all new data now
    - When ACK arrives
        - If unsent data in buffer ≥ MSS and advertised window ≥ MSS
            - Send packet with MSS bytes
        - Else
            - Do not send any data now
    - Can disable Nagle's algorithm for interactive apps -- e.g., SSH

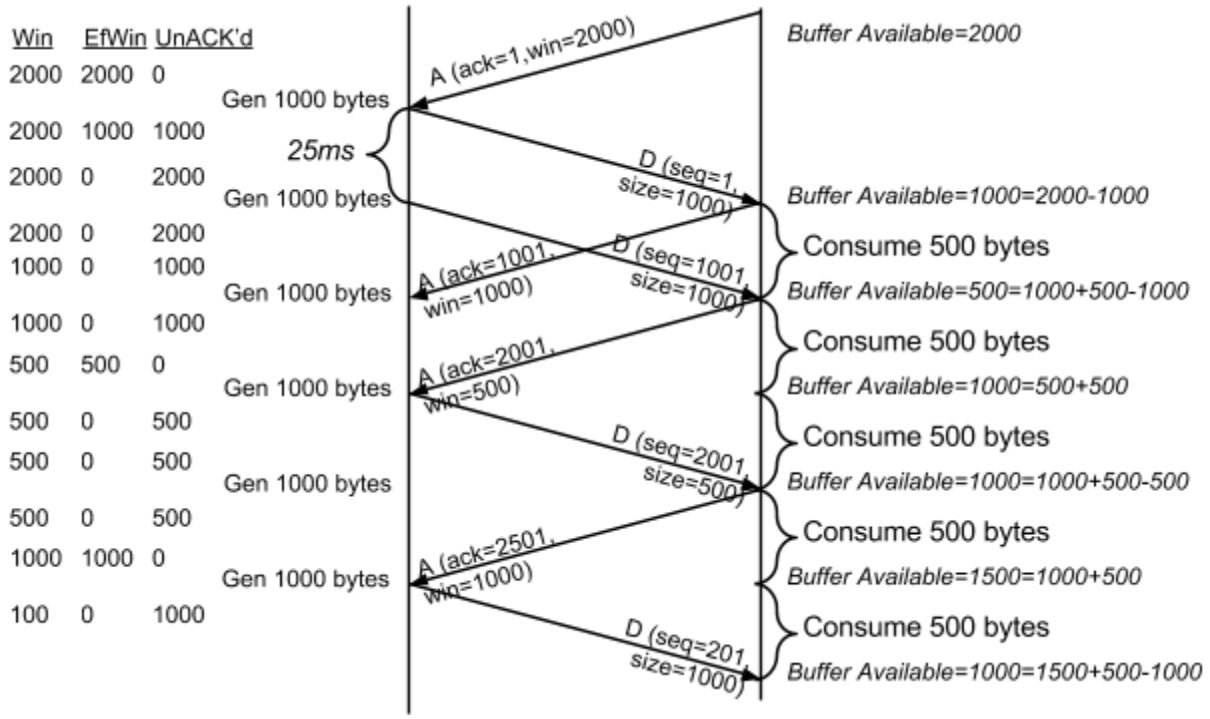
*****Exercises***

- In-class scenario 1: receiver consumes data faster than sender generates data
    - MSS = 1000 bytes
    - RTT = 50 ms
    - Sender generates 1000 bytes every 50ms
    - Receiver consumes 1000 bytes every 25ms
    - Receiver's buffer size = 3000 bytes

- Timeline

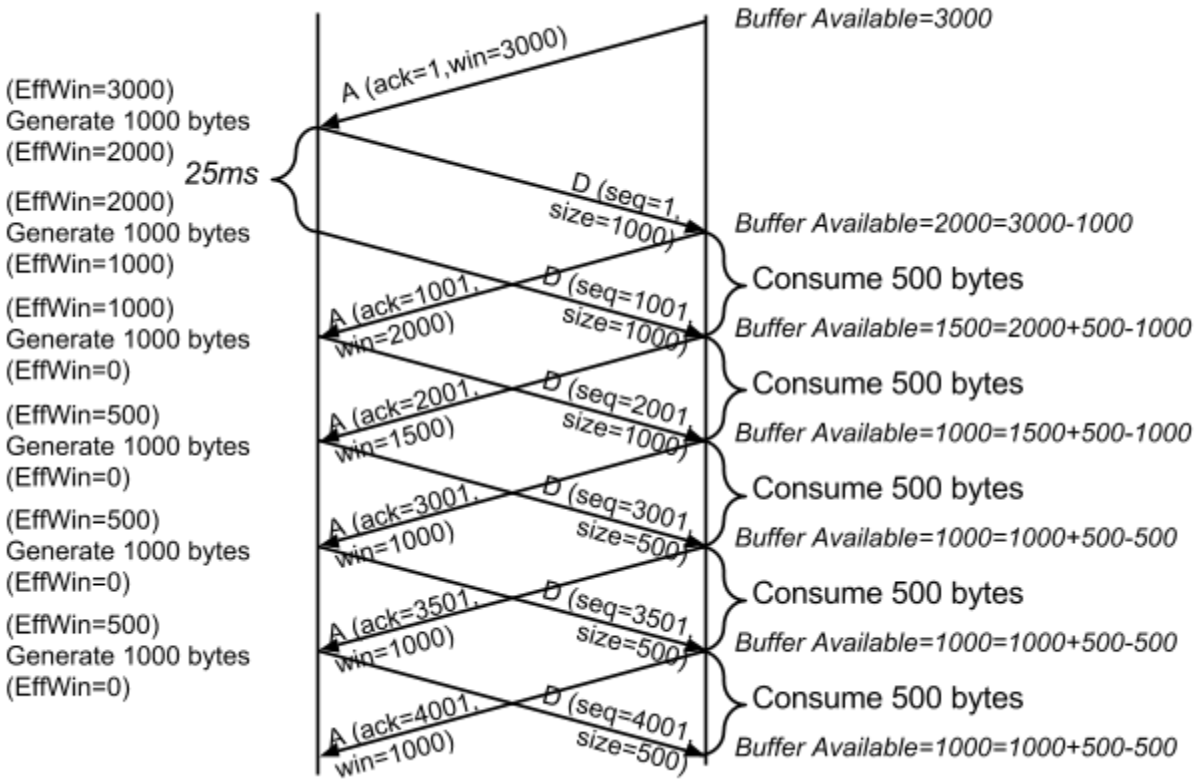


- In-class scenario 2: receiver consumes data slower than sender generates data
  - MSS = 1000 bytes; RTT = 50 ms
  - Sender generates 1000 bytes every 25ms
  - Receiver consumes 500 bytes every 25ms
  - Receiver's buffer size = **2000 bytes**
  - Timeline **with and without** Nagle's algorithm



- Scenario 3:
  - MSS = 1000 bytes; RTT = 50 ms
  - Sender generates 1000 bytes every 25ms
  - Receiver consumes 500 bytes every 25ms
  - Receiver's buffer size = **3000 bytes**

- Timeline **without** Nagle's algorithm



- Timeline **with** Nagle's algorithm