Basics of Reliable Transmission

- Building it from the ground up over a FIFO lossy & erroneous (unreliable) unidirectional channel
- Add flow control (stop-and-wait)
- Dealing with corruption – add checksum
- Dealing with loss – add timer
- Add recovery by retransmission (ARQ)
- Dealing with duplicates – add sequence numbers
- Formally specify protocol using FSM

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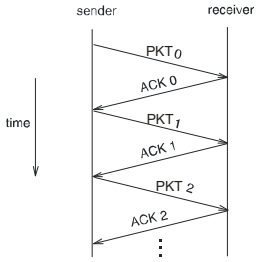
Stop-and-Wait (Idle RQ)

- Sender sends only one packet at a time

ARQ Automatic Repeat Request



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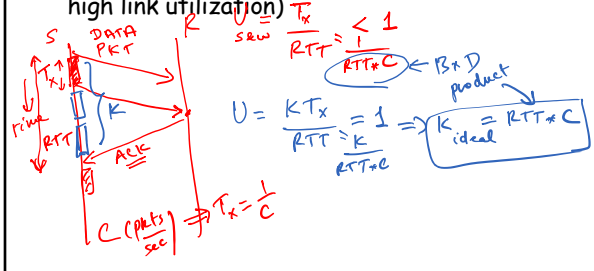
Stop-and-Wait (cont'd)

- Problem: Keeping the pipe full (*i.e.* maintain high link utilization)



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Stop-and-Wait (cont'd)

- Problem: Keeping the pipe full (*i.e.* maintain high link utilization)
- Example: Assuming packet size of 1KB, 1.5Mbps link, 40ms (per-packet) RTT

$K_{ideal} = \left\lceil \frac{1.5\,M}{1\,KB} * 40\,ms \right\rceil = \lceil 7.5 \rceil = 8$

$U_{s\&w} = \frac{1}{8}$ Throughput$_{s\&w} \approx \frac{1}{8} * 1.5$ Mbps ≈ 0.2 Mbps

- BxD ~ 8 packets.

  Stop-and-wait uses about 1/8 of the link's capacity. Want the sender to be able to transmit up to 8 packets before having to wait for an ACK

  What is the effective throughput?

  Answer: 1.5M/8 ~ 0.2 Mbps!!

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Continuous RQ (pipelining)

- Achieves higher link utilization than stop-and-wait
- Sender sends multiple packets without waiting for an ACK
- In practice, there is a limit for flow control
- Sender needs more memory to buffer outstanding unacked packets

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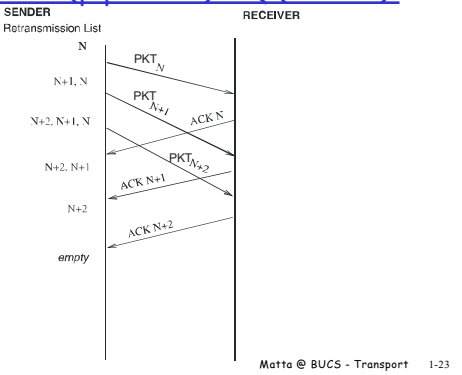
Continuous (pipelined) RQ (cont'd)



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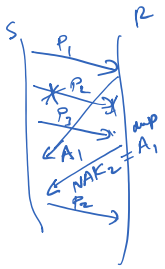
Pipelined RQ (cont'd)

Two retransmission strategies:

- Selective Repeat: Only corrupted/lost packets are retransmitted
- Go-Back-N: Packets received correctly may be retransmitted

- NAK or duplicate ACK to improve utilization



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Selective Repeat

- Packets transmitted continually (when available) without waiting for ACK, up to K outstanding unACKed packets
- A different sender timer associated with each unACKed packet
- Receiver:
  - ignores (implicit retransmission) or NAKs (explicit retransmission) missing packets
  - ACKs correct (possibly out-of-order) packets
  - buffers out-of-order packets so as to deliver packets in-order to higher layer
- Sender:
  - on timeout or NAK for packet N, or ACK for packet > N, just retransmit N

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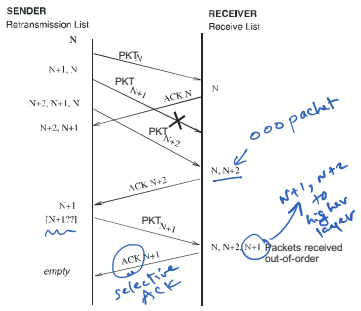
Selective Repeat, Implicit Retransmission

- Example: lost/corrupted packet



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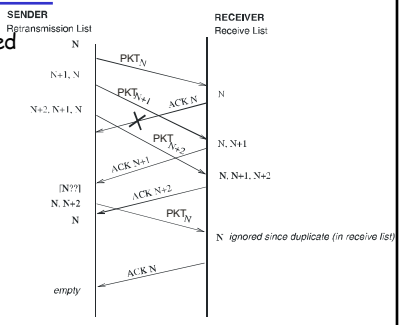
Selective Repeat, Implicit Retransmission

- Lost / corrupted ACK



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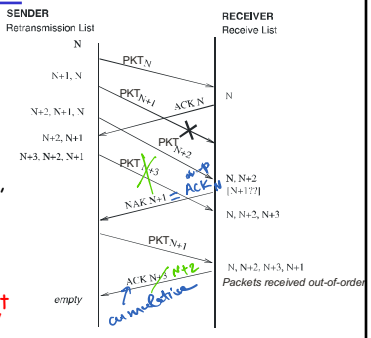
Selective Repeat, Explicit Retransmission

- Example: lost / corrupted packet
- ACK for packet N implicitly acknowledges up through N (i.e. ***cumulative*** ACK)
- While in NAK state, receiver does not ACK - why?
- A timer associated with NAK?
- What happens if pkt N+3 also gets lost / corrupted?



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Go-Back-N

- Unlike Selective Repeat, Go-Back-N saves receiver buffering by requiring packets to arrive in-order
- As in Selective Repeat:
  - Packets transmitted continually (when available) without waiting for ACK, up to K outstanding unACKed packets
  - A different sender timer associated with each unACKed packet, although a single timer implementation for Go-Back-N is common
  - Receiver ignores or NAKs missing packets
- Unlike Selective Repeat:
  - Receiver ACKs only correctly received and in-order packets, passes them to higher layer
  - On timeout or NAK for packet N, sender retransmits from N all over again (all outstanding packets)

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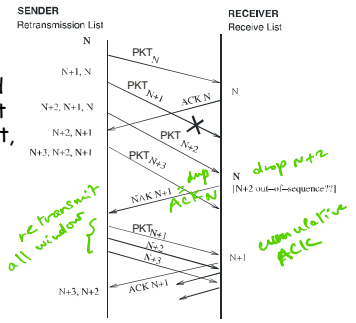
Go-Back-N (cont'd)

- Example: lost / corrupted packet
- A timer associated with NAK, or if not and the NAK is lost, what will happen?



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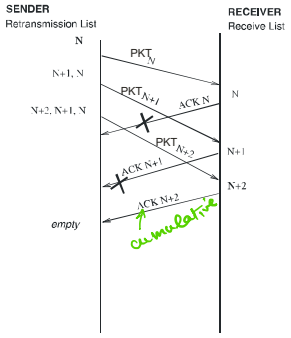
Go-Back-N (cont'd)

- Example: lost / corrupted ACK
- ACK for packet N implicitly acknowledges up through N (i.e. ***cumulative*** ACK)



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Pros and Cons of Go-Back-N

- No receiver buffering with Go-Back-N
  - Saves resources at receiver
  - Avoids large bursts of packet delivery to higher layers
- Simplicity in buffering and protocol processing at sender and receiver, e.g. can easily detect duplicates if an out-of-sequence packet is received
- Consumes more link capacity by retransmitting correctly received packets
- Tradeoff between host buffering/processing complexity and link capacity

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