Introduction to Computer Networks

Retransmissions (ARQ) (§3.3)

David Wetherall (djw@uw.edu)
Professor of Computer Science & Engineering
UNIVERSITY of WASHINGTON

Topic

- Two strategies to handle errors:

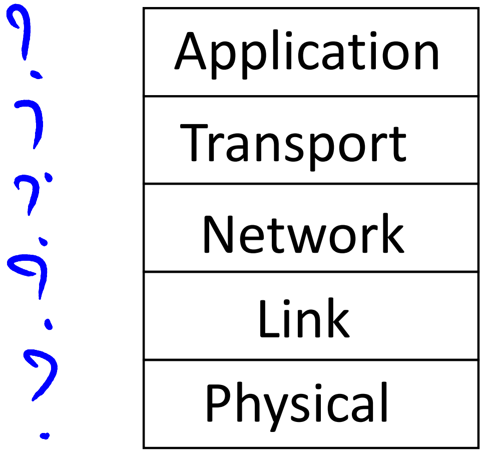
1. Detect errors and retransmit frame (Automatic Repeat reQuest, ARQ)

2. Correct errors with an error correcting code

Done this

Context on Reliability

- Where in the stack should we place reliability functions?



? Application

? Transport

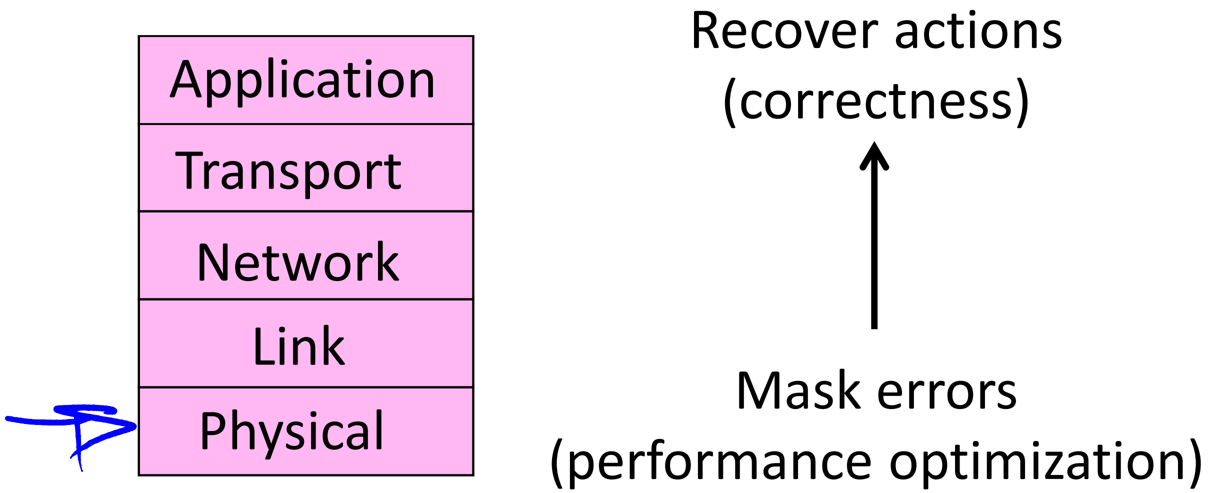
? Network

? Link

? Physical

Context on Reliability (2)

- Everywhere! It is a key issue
  - Different layers contribute differently



Application

Transport

Network

Link

Physical

Recover actions (correctness)

Mask errors (performance optimization)

ARQ

- ARQ often used when errors are common or must be corrected
  - E.g., WiFi, and TCP (later)

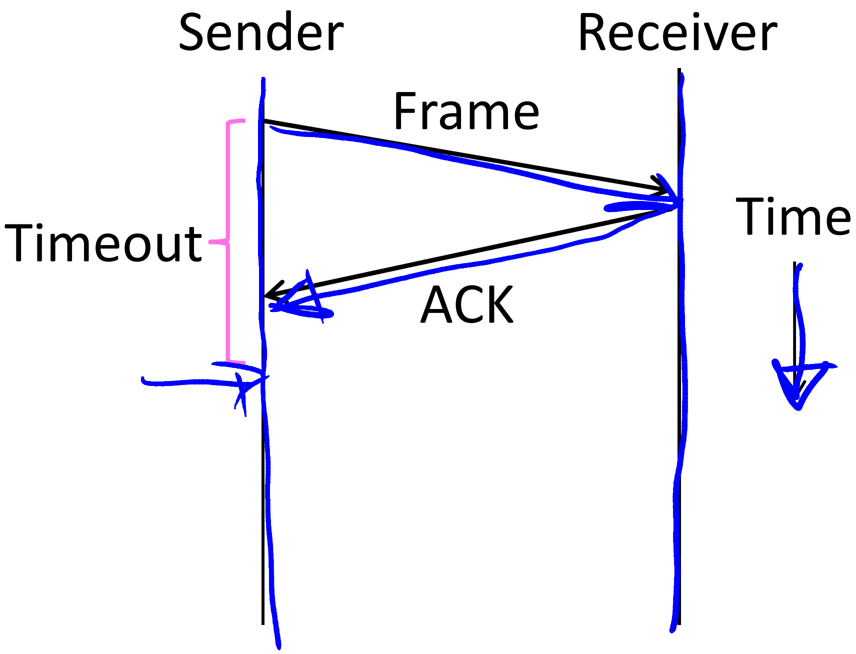
- Rules at sender and receiver:
  - Receiver automatically acknowledges correct frames with an ACK

hears no ACK

  - Sender automatically resends after a timeout, until an ACK is received

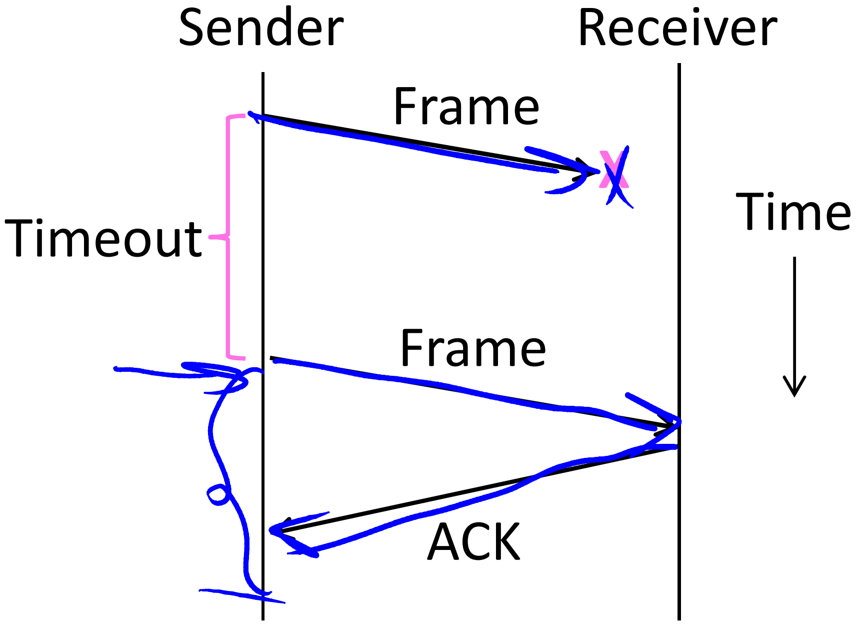
ARQ (2)

- Normal operation (no loss)



ARQ (3)

- Loss and retransmission



So What’s Tricky About ARQ?

- Two non-trivial issues:
  - How long to set the timeout? »
  - How to avoid accepting duplicate frames as new frames »

- Want performance in the common case and correctness always

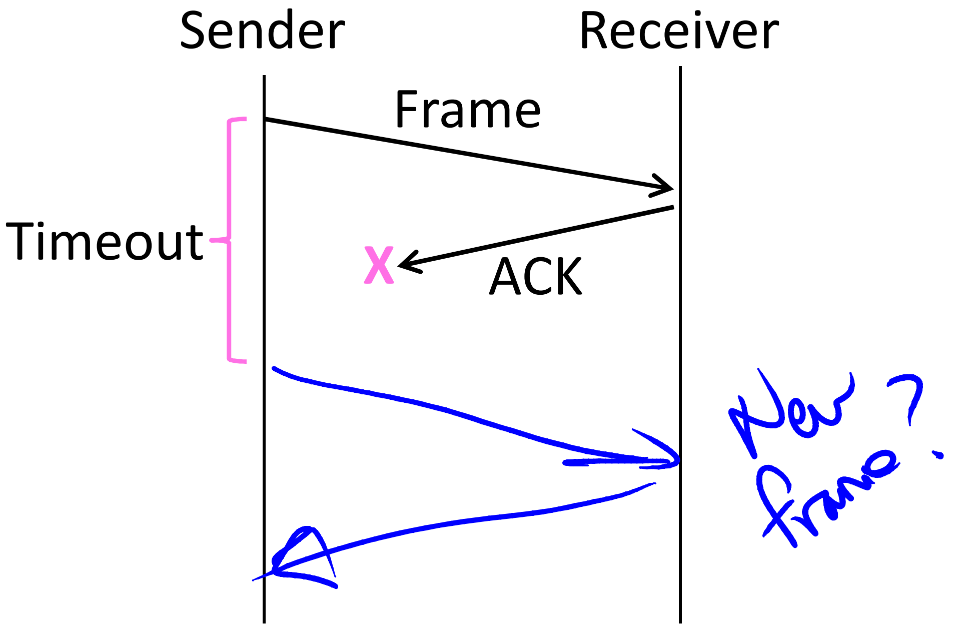
Timeouts

- Timeout should be:
  - Not too big (link goes idle)
  - Not too small (spurious resend)

- Fairly easy on a LAN
  - Clear worst case, little variation
- Fairly difficult over the Internet
  - Much variation, no obvious bound
  - We'll revisit this with TCP (later)

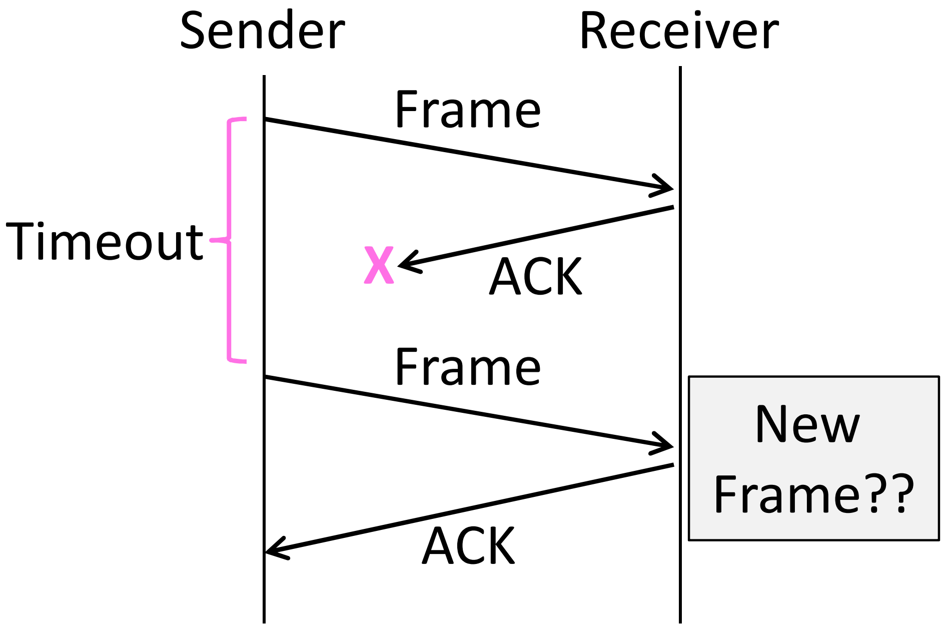
Duplicates

- What happens if an ACK is lost?



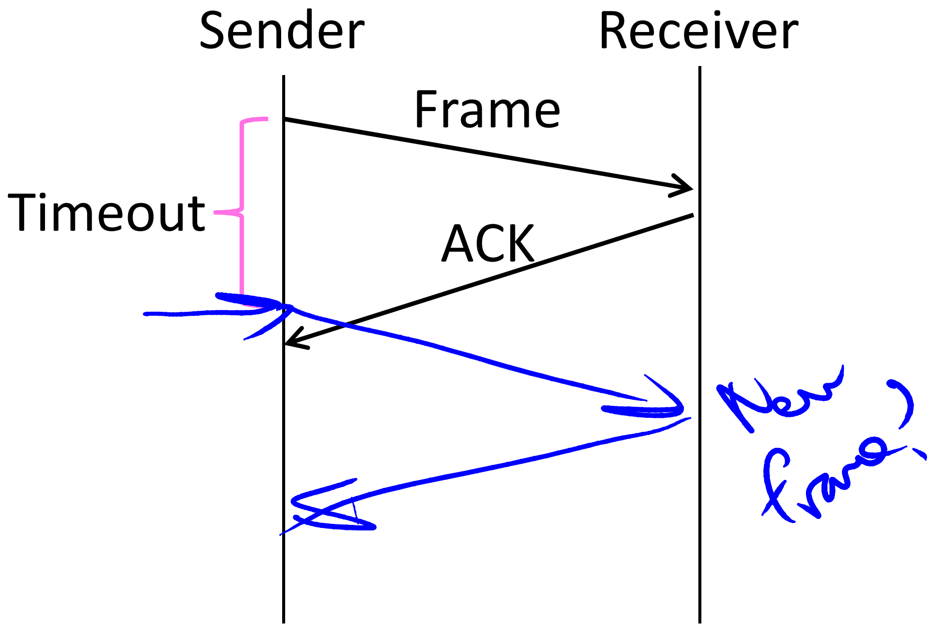
Duplicates (2)

- What happens if an ACK is lost?



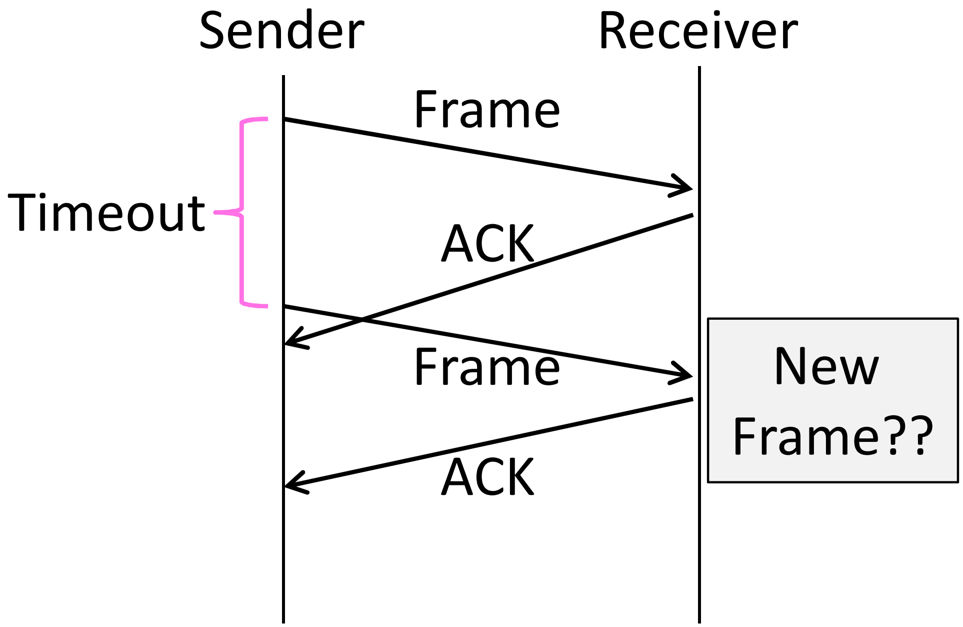
Duplicates (3)

- Or the timeout is early?



Duplicates (4)

- Or the timeout is early?



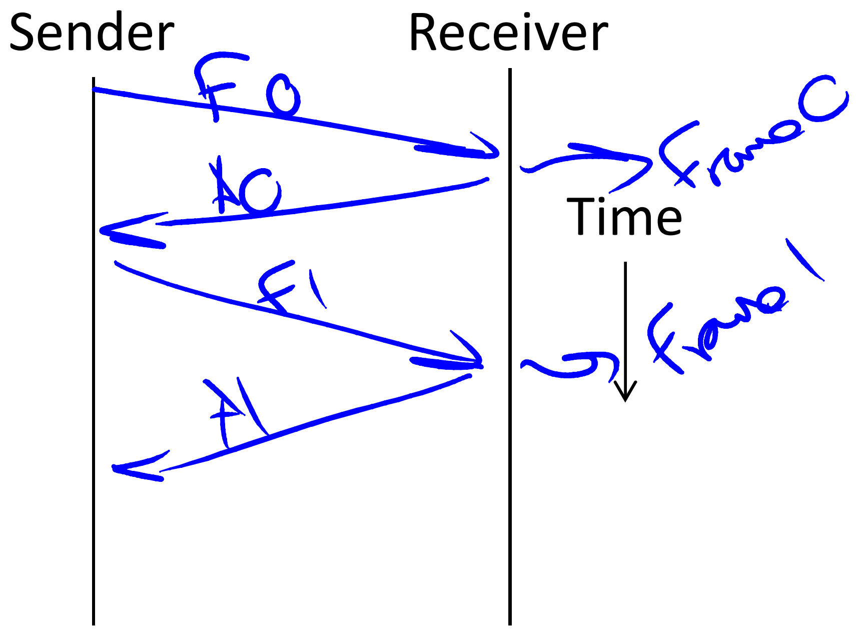
Sequence Numbers

- Frames and ACKs must both carry sequence numbers for correctness

- To distinguish the current frame from the next one, a single bit (two numbers) is sufficient
  - Called Stop-and-Wait

Stop-and-Wait

- In the normal case:



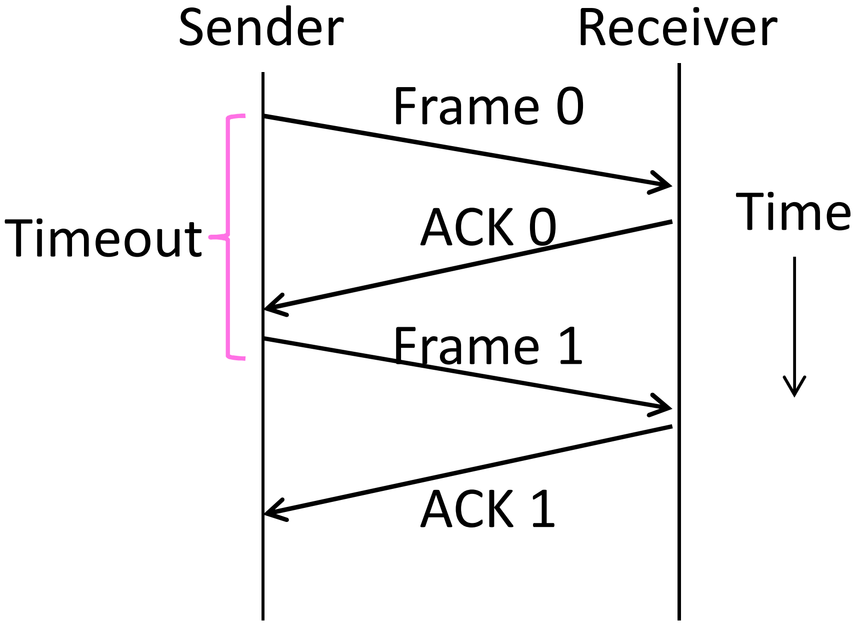
Sender

Receiver

Time

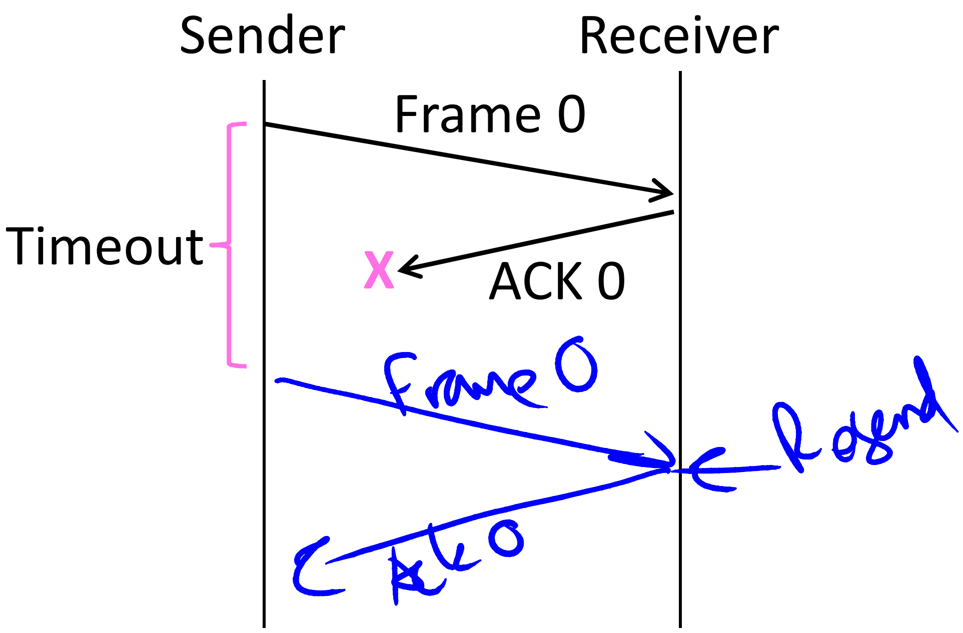
Stop-and-Wait (2)

- In the normal case:



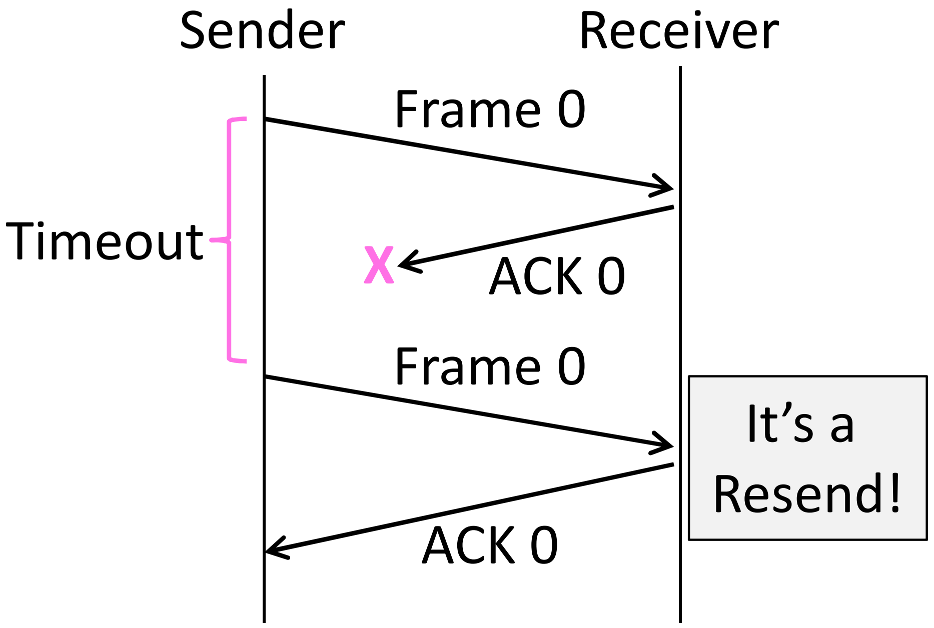
Stop-and-Wait (3)

- With ACK loss:



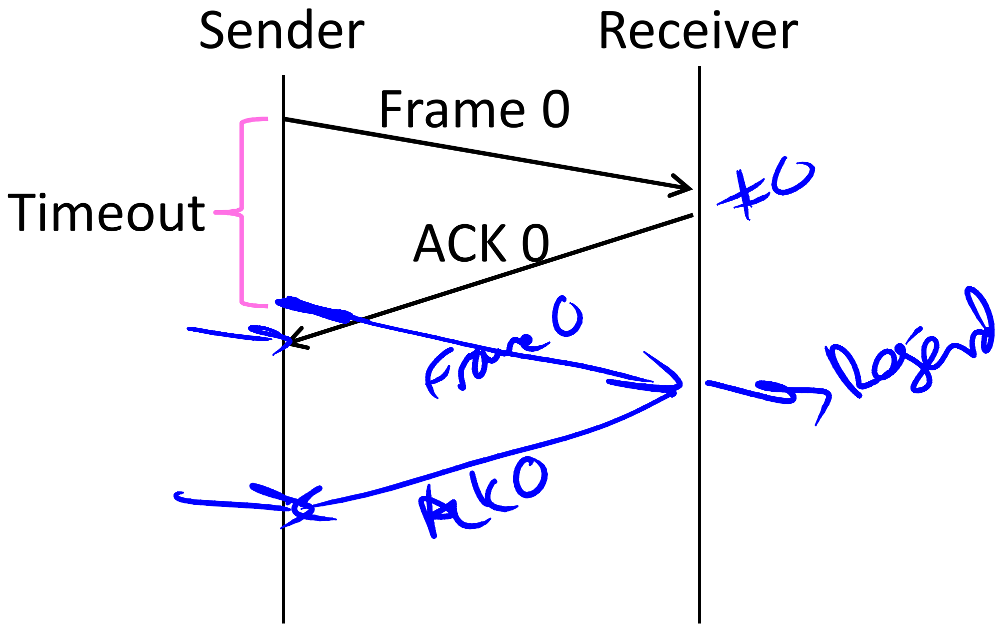
Stop-and-Wait (4)

- With ACK loss:



Stop-and-Wait (5)

- With early timeout:



Sender

Receiver

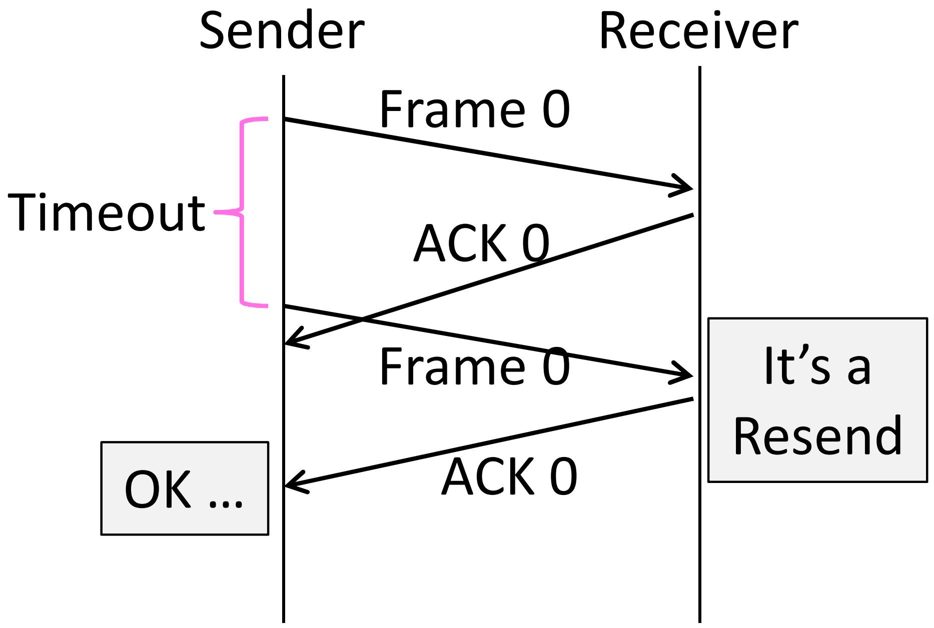
Frame 0

Timeout

ACK 0

Stop-and-Wait (6)

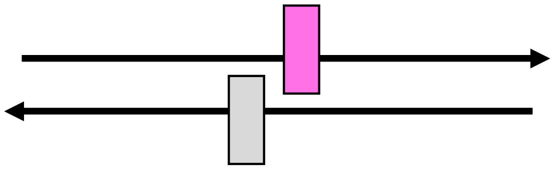
- With early timeout:



Limitation of Stop-and-Wait

- It allows only a single frame to be outstanding from the sender:
  - Good for LAN, not efficient for high BD

bandwidth delay



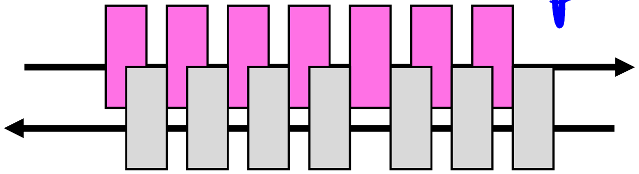
- Ex: R=1 Mbps, D = 50 ms 2D = 100 ms
  - How many frames/sec? If R=10 Mbps?

10 ~ 150Kbps

Sliding Window

- Generalization of stop-and-wait
  - Allows W frames to be outstanding
  - Can send W frames per RTT (=2D)

Round Trip Time



  - Various options for numbering frames/ACKs and handling loss
    - Will look at along with TCP (later)

END

W UNIVERSITY of WASHINGTON

Slide material from: TANENBAUM, ANDREW S.; WETHERALL, DAVID J., COMPUTER NETWORKS, 5th Edition, © 2011.
Electronically reproduced by permission of Pearson Education, Inc., Upper Saddle River, New Jersey