rdt2.0 has a fatal flaw when ACK/NAK may corrupt

what happens if ACK/NAK corrupted?

- sender doesn't know what happened at receiver!
- can't just retransmit: possible duplicate

handling duplicates:

- sender retransmits current pkt if ACK/NAK corrupted
- sender adds *sequence number* to each pkt
  - rdt2.1 uses {0,1} for seq #
- receiver discards (doesn't deliver up) duplicate pkt

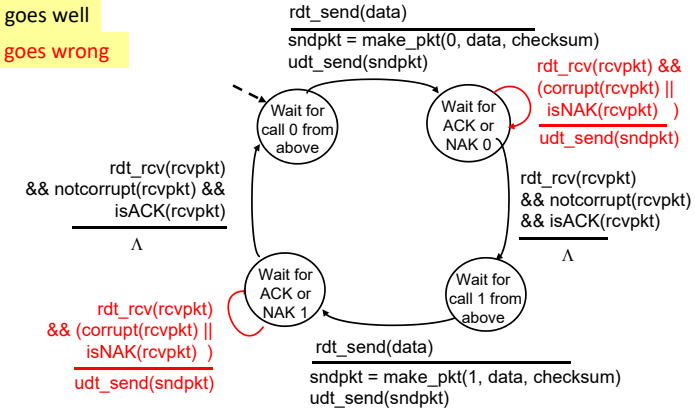
stop and wait

sender sends one packet,
then waits for receiver response

rdt2.1: sender, handling garbled ACK/NAKs

If everything goes well

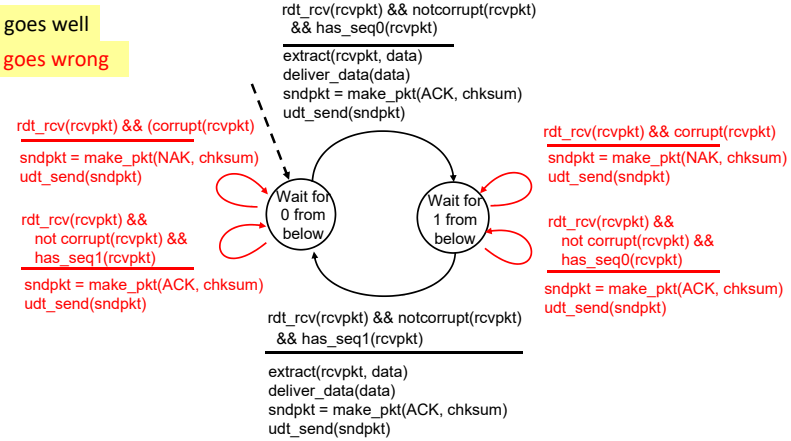
If something goes wrong



rdt2.1: receiver, handling garbled ACK/NAKs

If everything goes well

If something goes wrong



rdt2.1: discussion

sender:

- seq # is added to pkt
- two sequence numbers {0,1} will suffice. Why?
  - for receiver to distinguish *duplicate* or *new* packet
    - in case ACK/NAK is corrupted
- must check if received ACK/NAK corrupted
- twice as many states
  - state must "remember" whether "expected" pkt should have seq # of 0 or 1

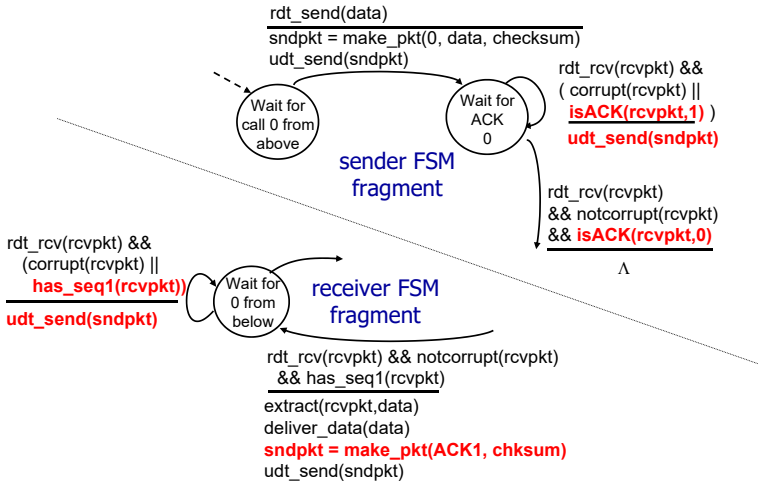
receiver:

- *cannot* know if its last ACK/NAK received OK at sender
- must check if received packet is duplicate
  - state indicates whether 0 or 1 is expected pkt seq #

rdt2.2: a NAK-free protocol

- same functionality as rdt2.1, using ACKs only
- instead of NAK, receiver sends ACK for last pkt received OK
  - receiver must *explicitly* include seq # of pkt being ACKed
- duplicate ACK at sender results in same action as NAK: *retransmit current pkt*
- As we will see, (rdt 3.0 and the following rdt including) TCP uses this approach to be NAK-free

rdt2.2: sender, receiver fragments



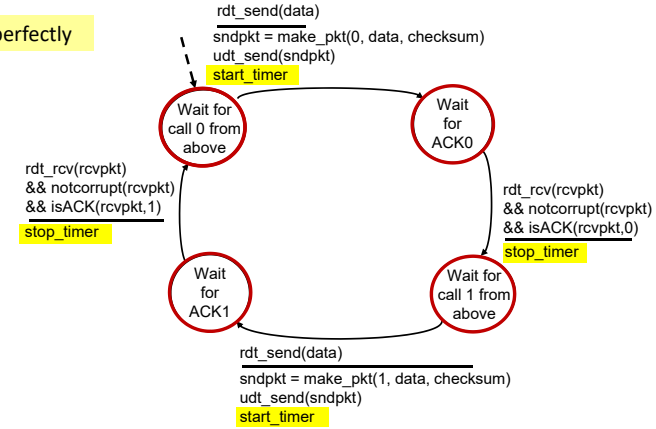
rdt3.0: channels with errors *and loss*

- new channel assumption: underlying channel can also
  - *drop/lose* packets (data, ACKs)
  - delay packets (but still in-order)
- checksum, sequence #, ACKs, retransmissions are not enough to handle it
- new approach: sender waits for "reasonable" amount of time for ACK
  - uses countdown timer and retransmits data packet once (and only if) timeout
    - timeout means that no ACK is received in this interval and the timer expires
    - do nothing when receiving an ACK with wrong seq #
  - if a packet or ACK is just over-delayed (instead of lost):
    - after timeout, sender will retransmit the data packet
    - receiver detects a duplicate transmission, because seq # already handles this!

timeout

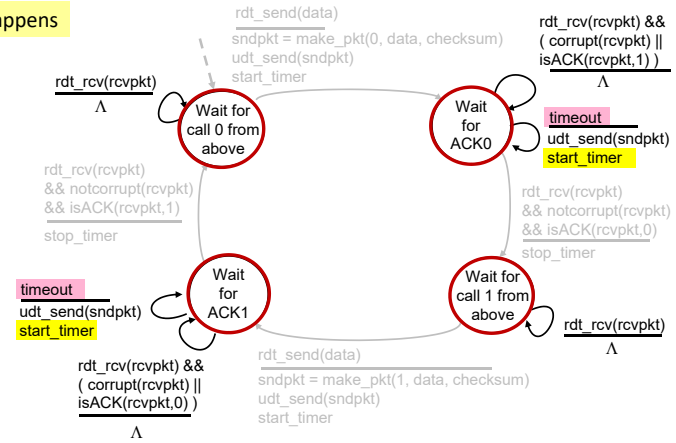
rdt3.0 sender

If everything goes perfectly



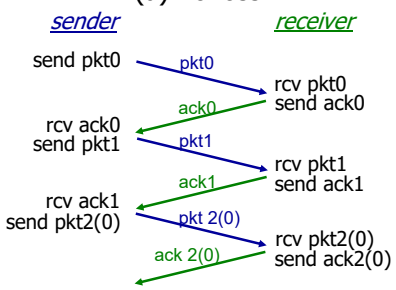
rdt3.0 sender

If something bad happens

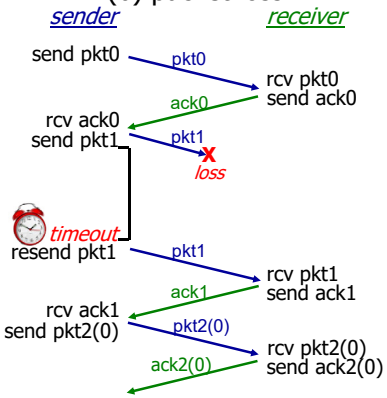


rdt3.0 in action

(a) no loss

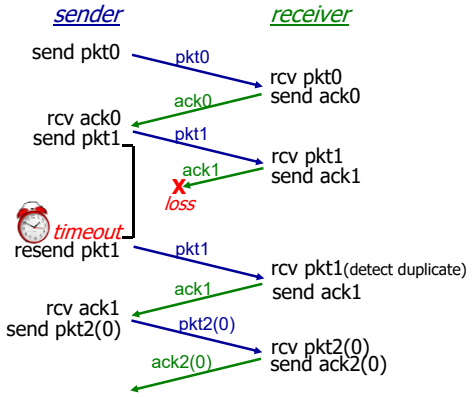


(b) packet loss

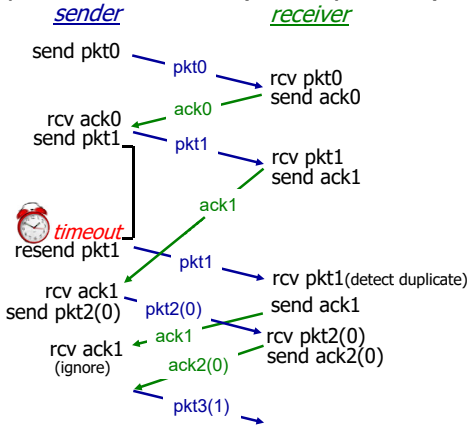


rdt3.0 in action

(c) ACK loss

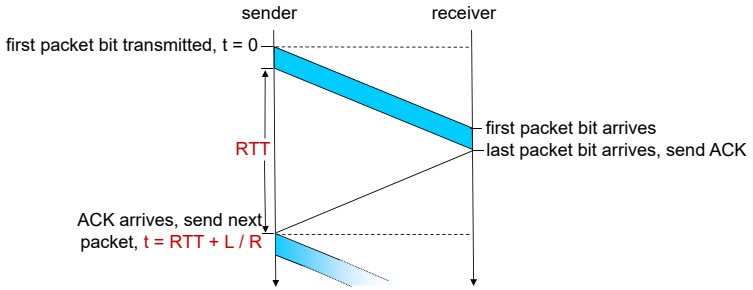


(d) premature timeout (or delayed ACK)



Performance of rdt3.0 (which is stop-and-wait)

- U_{sender} : *utilization* – fraction of time sender is busy sending

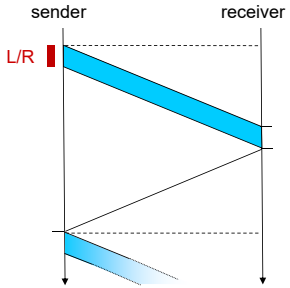


rdt3.0: stop-and-wait operation

example: 1Gbps link, 15ms propagation delay, 8000-bit packet

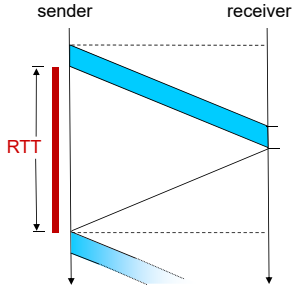
- transmission time:

$$\frac{L}{R} = \frac{8000 \text{ bits}}{10^9 \text{ bits/s}} = 8\ \mu s = 0.008\ ms$$



- RTT (round-trip propagation time):

$$RTT = 2 \cdot 15\ ms = 30\ ms$$



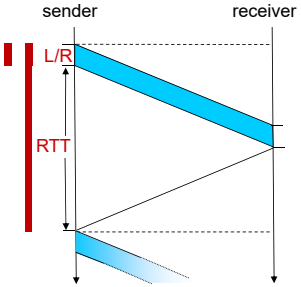
rdt3.0: stop-and-wait operation

example: 1Gbps link, 15ms propagation delay, 8000-bit packet

- Utilization:

$$U_{\text{sender}} = \frac{\frac{L}{R}}{\frac{L}{R} + RTT}$$

$$= \frac{0.008}{0.008 + 30} = 0.00027$$



- rdt 3.0 protocol performance stinks!
- Protocol limits performance of underlying infrastructure (channel)