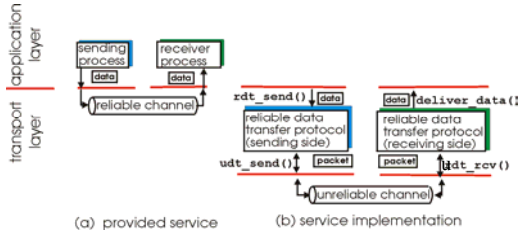
Reliable Data Transfer

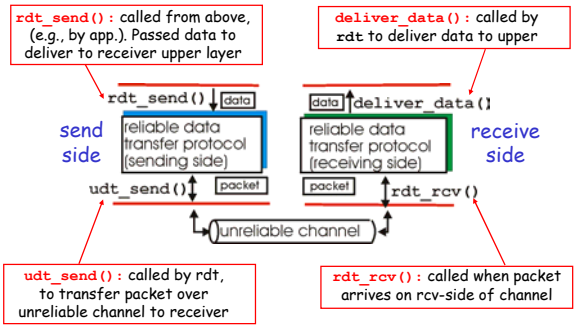
Principles of Reliable data transfer

- Important in app., transport, link layers
- Top-10 list of important networking topics!



- Characteristics of unreliable channel will determine complexity of reliable data transfer protocol (rdt)

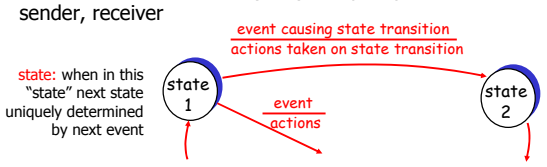
Reliable data transfer: getting started



Reliable data transfer: getting started

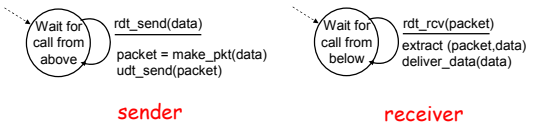
We'll:

- Incrementally develop sender, receiver sides of reliable data transfer protocol (rdt)
- consider only unidirectional data transfer
  - But control info will flow on both directions!
- Use finite state machines (FSM) to specify sender, receiver



Rdt1.0: reliable transfer over a reliable channel

- Underlying channel perfectly reliable
  - No bit erros
  - No loss of packets
- Separate FSMs for sender, receiver:
  - Sender sends data into underlying channel
  - Receiver read data from underlying channel



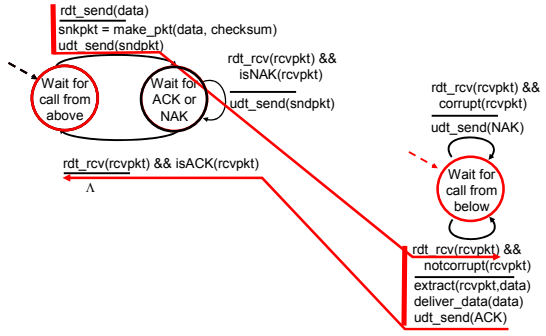
Rdt2.0: channel with bit errors

- Underlying channel may flip bits in packet
  - Recall: UDP checksum to detect bit errors
- *The* question: how to recover from errors:
  - *Acknowledgements (ACKs):* receiver explicitly tells sender that pkt received OK
  - *Negative acknowledgements (NAKs):* receiver explicitly tells sender that pkt had errors
  - Sender retransmits pkt on receipt of NAK
  - Human scenarios using ACKs, NAKs?

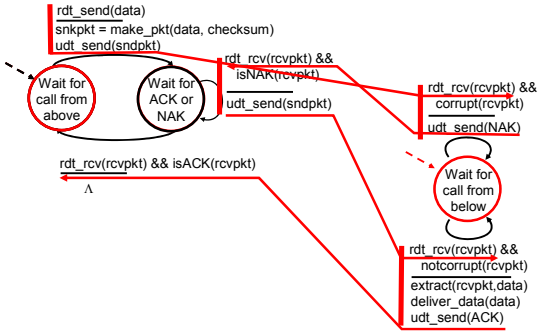
New mechanisms in `rdt2.0` (beyond `rdt1.0`):

- Error detection
- Receiver feedback: control msgs (ACK,NAK) rcvr->sender

rdt2.0: operation with no errors



rdt2.0: error scenario



rdt2.0 has a fatal flaw!

What happens if ACK/NAK corrupted?

- Sender doesn't know what happened at receiver!
- Can't just retransmit: possible duplicate

What to do?

- Sender ACKs/NAKs receiver's ACK/NAK? What if sender ACK/NAK lost?
- Retransmit, but this might cause retransmission of correctly received pkt!

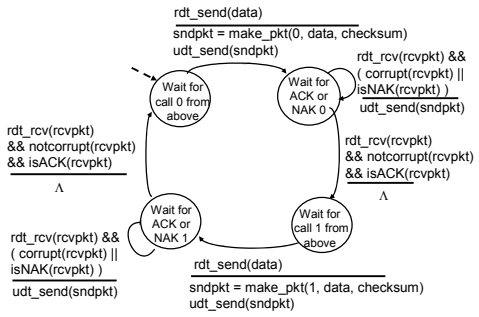
Handling duplicates:

- Sender retransmits current pkt if ACK/NAK garbled
- Sender adds *sequence number* to each pkt
- Receiver discards (doesn't deliver up) duplicate pkt

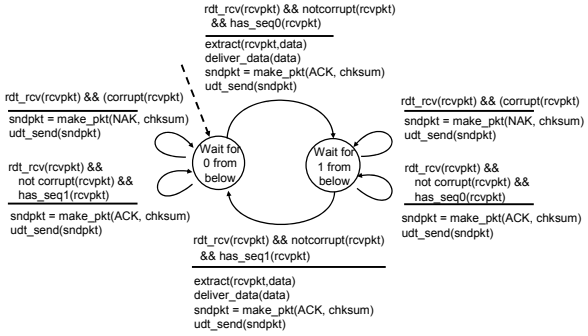
stop and wait

Sender sends one packet, then waits for receiver response

rdt2.1: sender, handles garbled ACK/NAKs



rdt2.1: receiver, handles garbled ACK/NAKs



rdt2.1: discussion

Sender:

- Seq # added to pkt
- Two seq. #'s (0,1) will suffice. Why?
- Must check if received ACK/NAK corrupted
- Twice as many states
  - State must "remember" whether "current" pkt has 0 or 1 seq. #

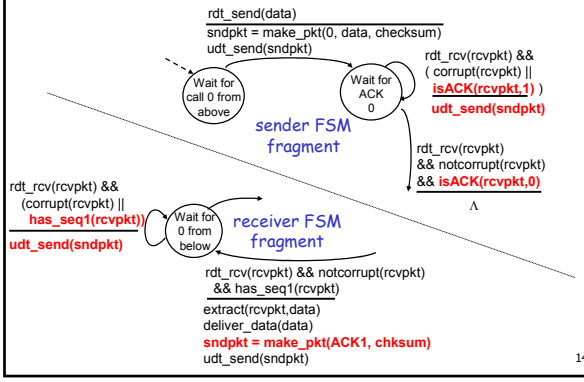
Receiver:

- Must check if received packet is duplicate
  - State indicates whether 0 or 1 is expected pkt seq #
- Note: receiver can *not* know if its last ACK/NAK received OK at sender

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*

rdt2.2: sender, receiver fragments



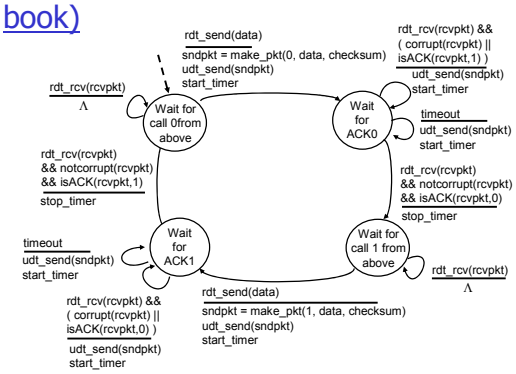
rdt3.0: channels with errors *and* loss

New assumption: underlying channel can also lose packets (data or ACKs)
- Checksum, seq. #, ACKs, retransmissions will be of help, but not enough

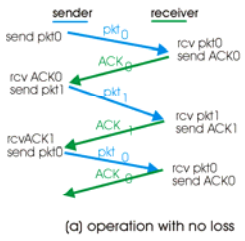
Q: How to deal with loss?
- Sender waits until certain data or ACK lost, then retransmits

Approach: sender waits "reasonable" amount of time for ACK
- Retransmits if no ACK received in this time
- If pkt (or ACK) just delayed (not lost):
  - Retransmission will be duplicate, but use of seq. #'s already handles this
  - Receiver must specify seq # of pkt being ACKed
- Requires countdown timer

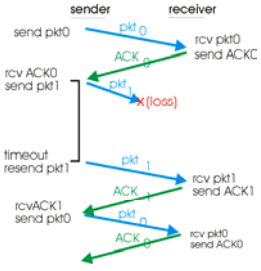
rdt3.0 sender (sligthly different from book)



rdt3.0 in action

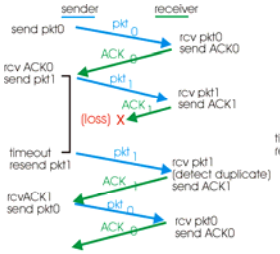


(a) operation with no loss

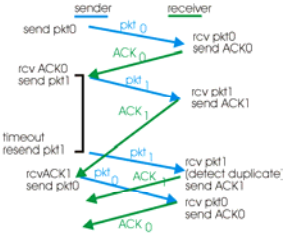


(b) lost packet

rdt3.0 in action



(c) lost ACK



(d) premature timeout

Performance of rdt3.0

- rdt3.0 works, but performance stinks
- Example: 1 Gbps link, 15 ms e-e prop. delay, 1KB packet:

$$T_{transmit} = \frac{L \text{ (packet length in bits)}}{R \text{ (transmission rate, bps)}} = \frac{8kb/pkt}{10^{**}9\ b/sec} = 8 \text{ microsec}$$

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

$$U_{sender} = \frac{L / R}{RTT + L / R} = \frac{.008}{30.008} = 0.00027$$

  - 1KB pkt every 30 msec -> 33kB/sec thruput over 1 Gbps link
  - Network protocol limits use of physical resources!

rdt3.0 sender in perl

- use IO::Select for timer
- do a can_read() with appropriate timeout
- when can_read() returns:
  - timeout expired? ==> retransmit, repeat can_read()
  - socket ready? ==> read packet
    - corrupt? ==> retransmit, repeat can_read()
    - wrong ACK# ==> retransmit, repeat can_read()
    - not corrupt and correct ACK# ==> wait for call from above