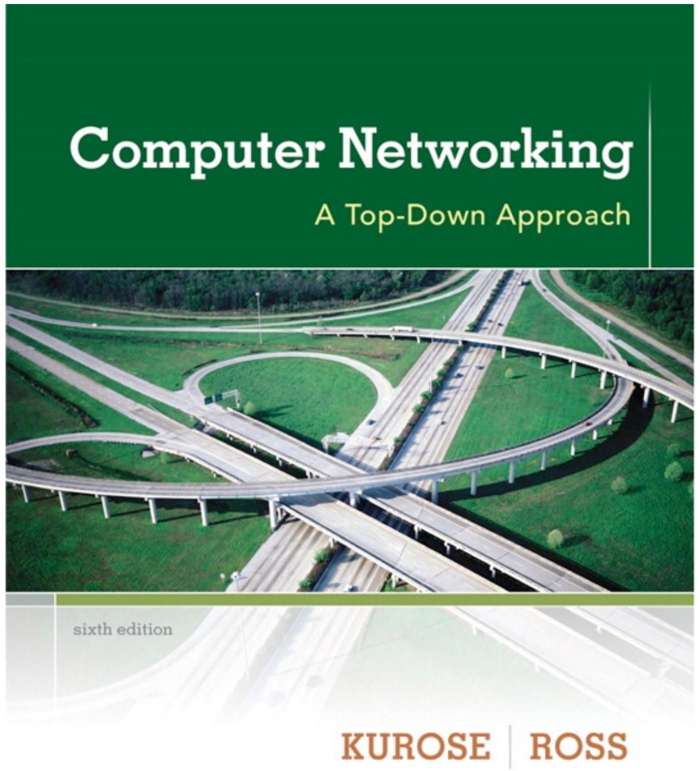
CN-Basic
L21

Reliable Data Transfer
Higher Version

Dr. Ram P Rustagi
rprustagi@ksit.edu.in
http://www.rprustagi.com
https://www.youtube.com/rprustagi

Chapter 3
Transport Layer



A note on the use of these ppt slides:

We're making these slides freely available to all (faculty, students, readers). They're in PowerPoint form so you see the animations; and can add, modify, and delete slides (including this one) and slide content to suit your needs. They obviously represent a *lot* of work on our part. In return for use, we only ask the following:

- If you use these slides (e.g., in a class) that you mention their source (after all, we'd like people to use our book!)
- If you post any slides on a www site, that you note that they are adapted from (or perhaps identical to) our slides, and note our copyright of this material.

Thanks and enjoy! JFK/KWR

Computer Networking: A Top Down Approach
6th edition
Jim Kurose, Keith Ross
Addison-Wesley
March 2012

rdt2.0 has a Fatal Flaw!

- What happens if ACK/ NAK corrupted?
- Sender doesn't know what happened at receiver!
- Two possibilities to handle
  - Add more checksum bits to recover from error
  - Can we just retransmit: possible duplicate pkts?

- Handling duplicates:
- Sender retransmits current pkt if ACK/NAK corrupted
- Sender adds *sequence number* to each pkt
  - Is 1 bit seq num ok?
- Receiver discards (doesn't deliver up) duplicate pkt
- Does ACK/NAK require seq number?

Stop and Wait

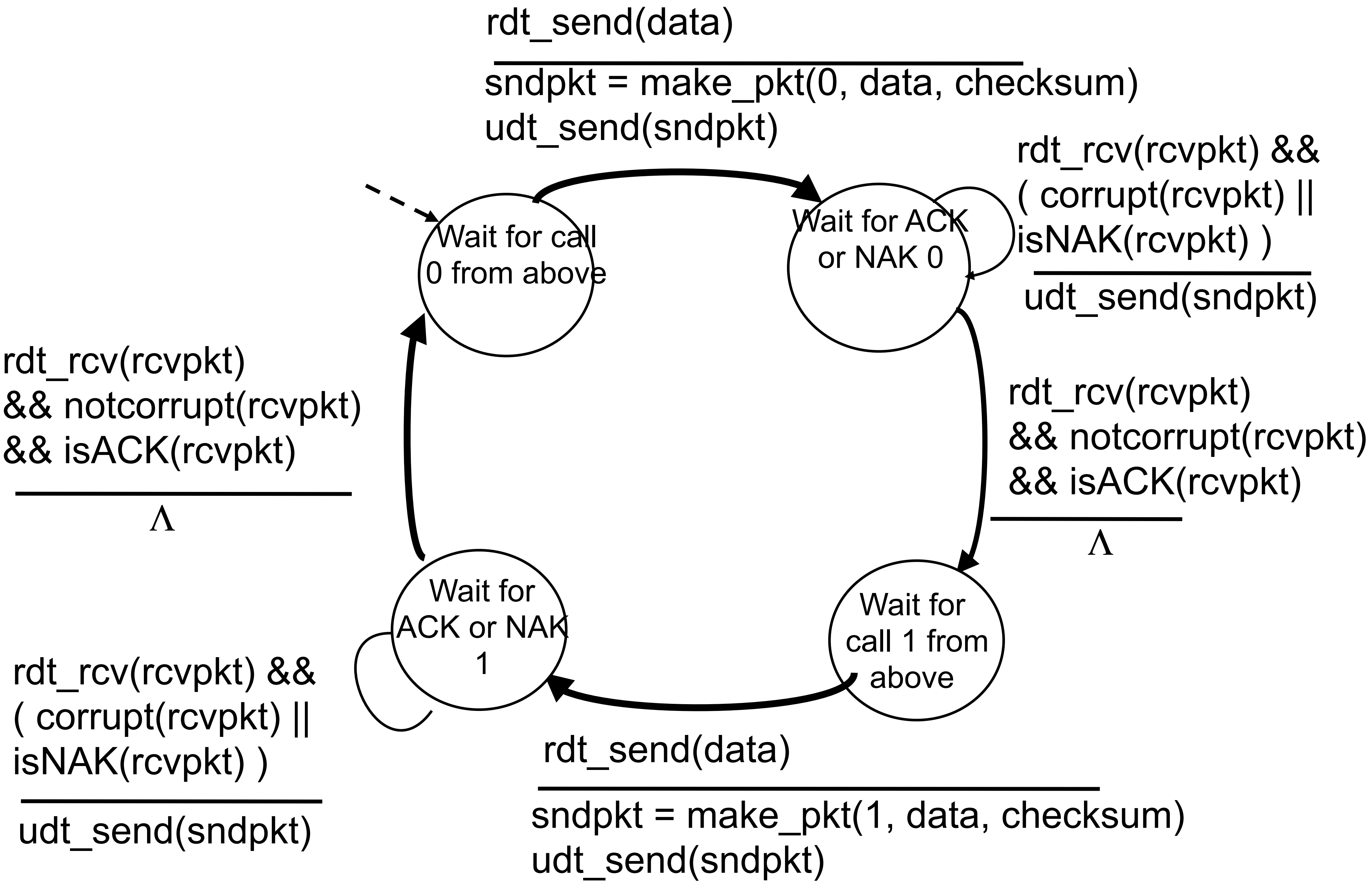
Sender sends one packet,
then waits for receiver response

rdt2.1: discussion

- sender:
- Seq # added to pkt
- Two seq. #'s (0,1) will suffice. Why?
- Must check if received ACK/NAK corrupted
- Number of states?
  - State must "remember" whether "expected" pkt should have seq # either of 0 or 1
  - Should it remain 2 or increase to 4?

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

rdt2.1: sender, handles garbled ACK/NAKs



Wait for call 0 from above

rdt_send(data)

sndpkt = make_pkt(0, data, checksum)
udt_send(sndpkt)

Wait for ACK or NAK 0

rdt_rcv(rcvpkt) &&
(corrupt(rcvpkt) ||
isNAK(rcvpkt))

udt_send(sndpkt)

rdt_rcv(rcvpkt)
&& notcorrupt(rcvpkt)
&& isACK(rcvpkt)

Λ

Wait for call 1 from above

rdt_send(data)

sndpkt = make_pkt(1, data, checksum)
udt_send(sndpkt)

Wait for ACK or NAK 1

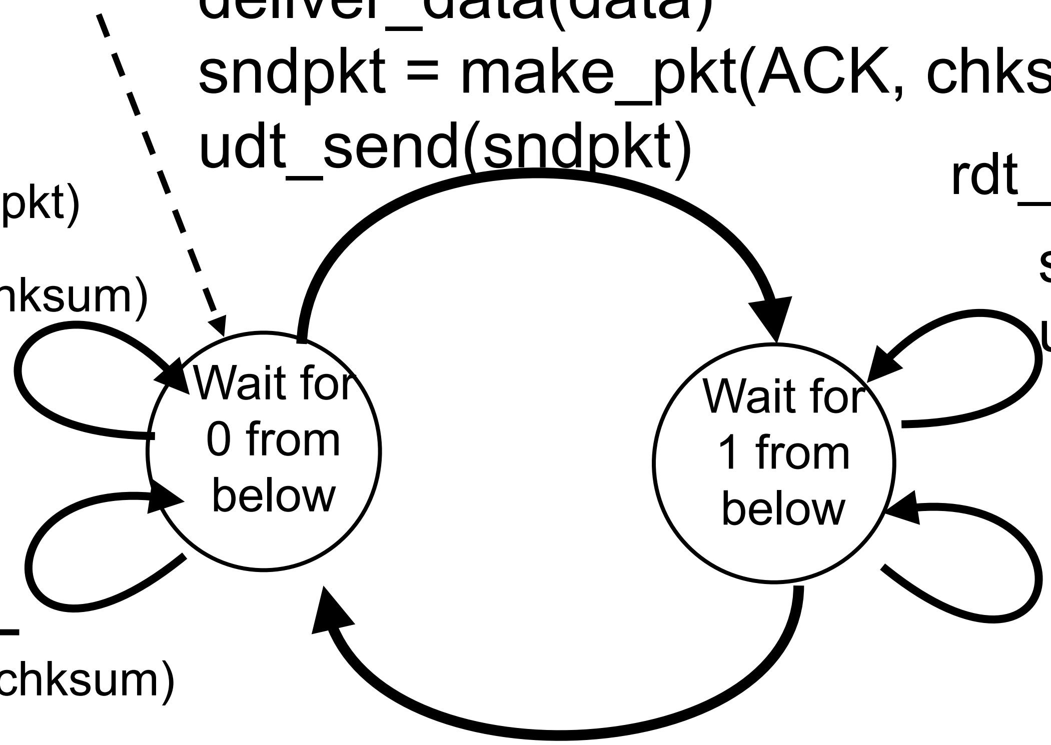
rdt_rcv(rcvpkt) &&
(corrupt(rcvpkt) ||
isNAK(rcvpkt))

udt_send(sndpkt)

rdt_rcv(rcvpkt)
&& notcorrupt(rcvpkt)
&& isACK(rcvpkt)

Λ

rdt2.1: receiver, handles garbled ACK/NAKs



rdt_rcv(rcvpkt) && notcorrupt(rcvpkt)
&& has_seq0(rcvpkt)

extract(rcvpkt,data)
deliver_data(data)
sndpkt = make_pkt(ACK, chksum)
udt_send(sndpkt)

rdt_rcv(rcvpkt) && (corrupt(rcvpkt)

sndpkt = make_pkt(NAK, chksum)
udt_send(sndpkt)

rdt_rcv(rcvpkt) &&
not corrupt(rcvpkt) &&
has_seq1(rcvpkt)

sndpkt = make_pkt(ACK, chksum)
udt_send(sndpkt)

rdt_rcv(rcvpkt) && (corrupt(rcvpkt)

sndpkt = make_pkt(NAK, chksum)
udt_send(sndpkt)

rdt_rcv(rcvpkt) &&
not corrupt(rcvpkt) &&
has_seq0(rcvpkt)

sndpkt = make_pkt(ACK, chksum)
udt_send(sndpkt)

rdt_rcv(rcvpkt) && notcorrupt(rcvpkt)
&& has_seq1(rcvpkt)

extract(rcvpkt,data)
deliver_data(data)
sndpkt = make_pkt(ACK, chksum)
udt_send(sndpkt)

rdt2.1: discussion

- Receiver
  - No of states doubled (two) from one(rdt 2.0)
- Sender
  - No of states doubled (four) from two (rdt 2.0)
- Additional two states are mirror images of first two
  - It differs in use of seq number `1` instead of `0`
  -

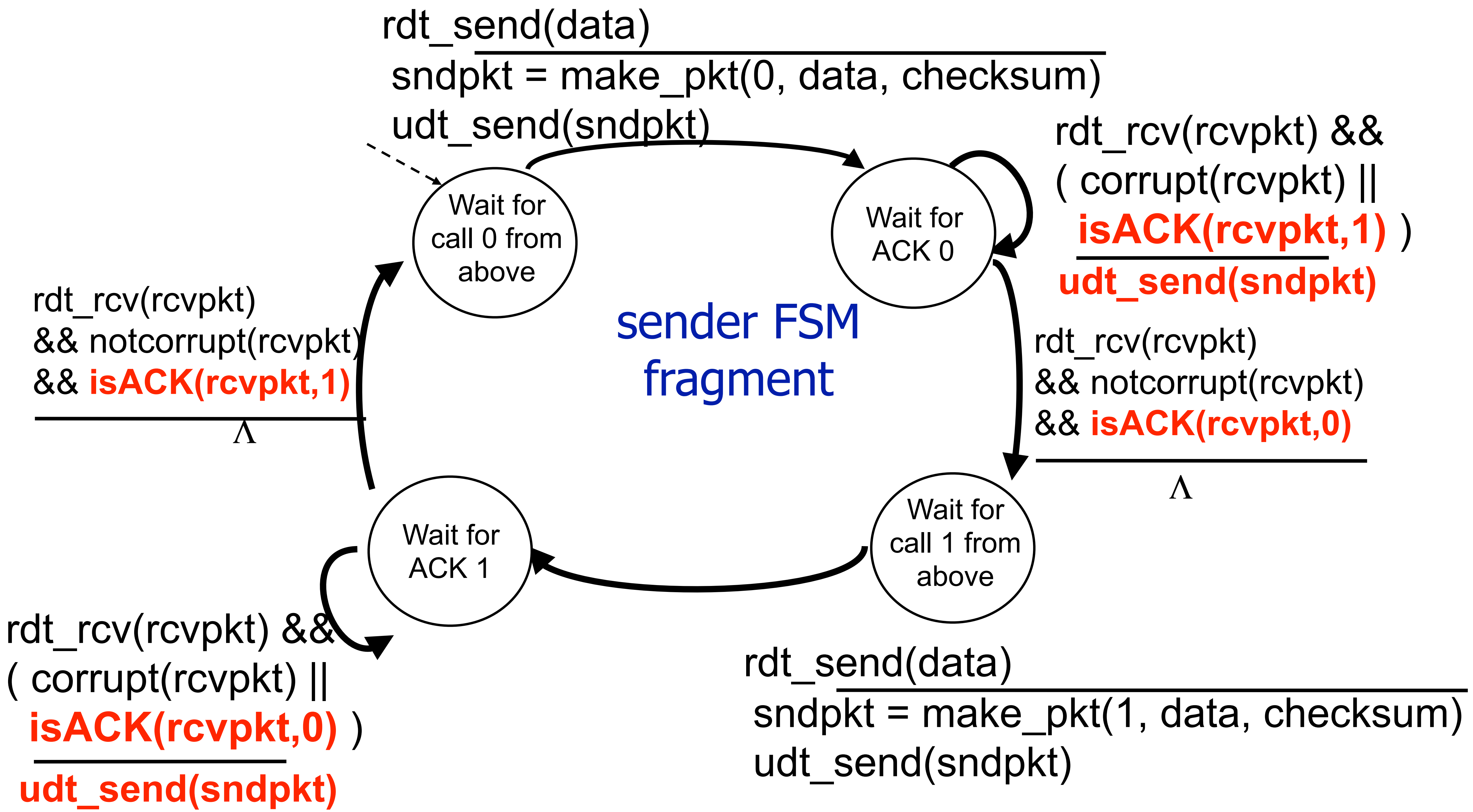
rdt2.1: discussion

- Can we have a NAK free protocol?
  - One less message type to deal with
  - Instead of NAK on receipt of bad packet
    - Send ACK for last received correct packet
    - This ACK may become duplicate
    - Do we need to differentiate between Ack `0` & Ack `1`?
      - ACK must contain sequence number
- Duplicate ACKs
  - Implies to sender
    - Receiver didn't receive newer packets correctly

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



rdt_send(data)
sndpkt = make_pkt(0, data, checksum)
udt_send(sndpkt)

rdt_rcv(rcvpkt) &&
(corrupt(rcvpkt) ||
isACK(rcvpkt,1))
udt_send(sndpkt)

rdt_rcv(rcvpkt)
&& notcorrupt(rcvpkt)
&& **isACK(rcvpkt,1)**
Λ

sender FSM fragment

rdt_rcv(rcvpkt)
&& notcorrupt(rcvpkt)
&& **isACK(rcvpkt,0)**
Λ

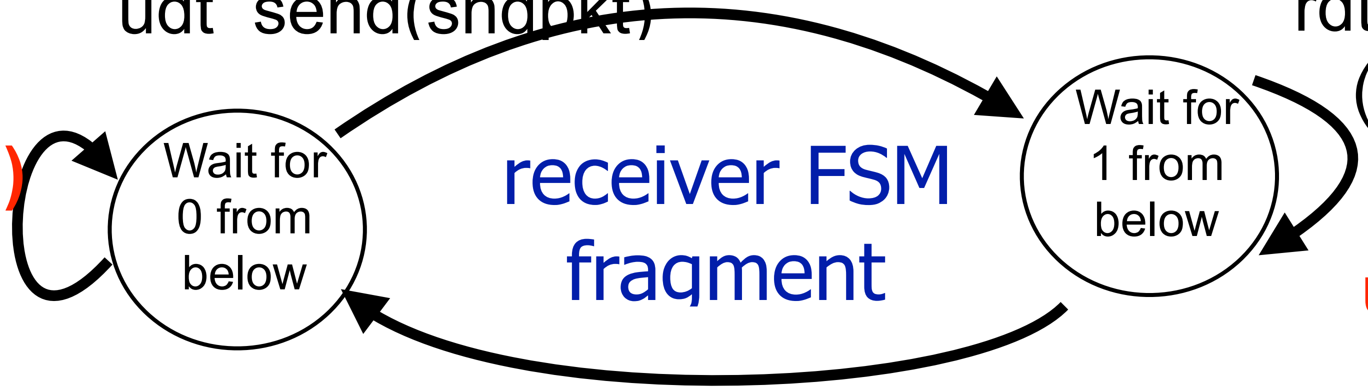
rdt_rcv(rcvpkt) &&
(corrupt(rcvpkt) ||
isACK(rcvpkt,0))
udt_send(sndpkt)

rdt_send(data)
sndpkt = make_pkt(1, data, checksum)
udt_send(sndpkt)

rdt2.2: sender, receiver fragments

rdt_rcv(rcvpkt)
&& notcorrupt(rcvpkt)
&& has_seq0(rcvpkt)

extract(rcvpkt,data)
deliver_data(data)
sndpkt = make_pkt(ACK0, chksum)
udt_send(sndpkt)



rdt_rcv(rcvpkt) &&
(corrupt(rcvpkt) ||
has_seq1(rcvpkt))

udt_send(sndpkt)

rdt_rcv(rcvpkt) &&
(corrupt(rcvpkt) ||
has_seq0(rcvpkt))

udt_send(sndpkt)

rdt_rcv(rcvpkt) && notcorrupt(rcvpkt)
&& has_seq1(rcvpkt)

extract(rcvpkt,data)
deliver_data(data)
sndpkt = make_pkt(ACK1, chksum)
udt_send(sndpkt)

rdt3.0: channels with errors *and* loss

New assumption:

Underlying channel can also lose packets (data, ACKs)

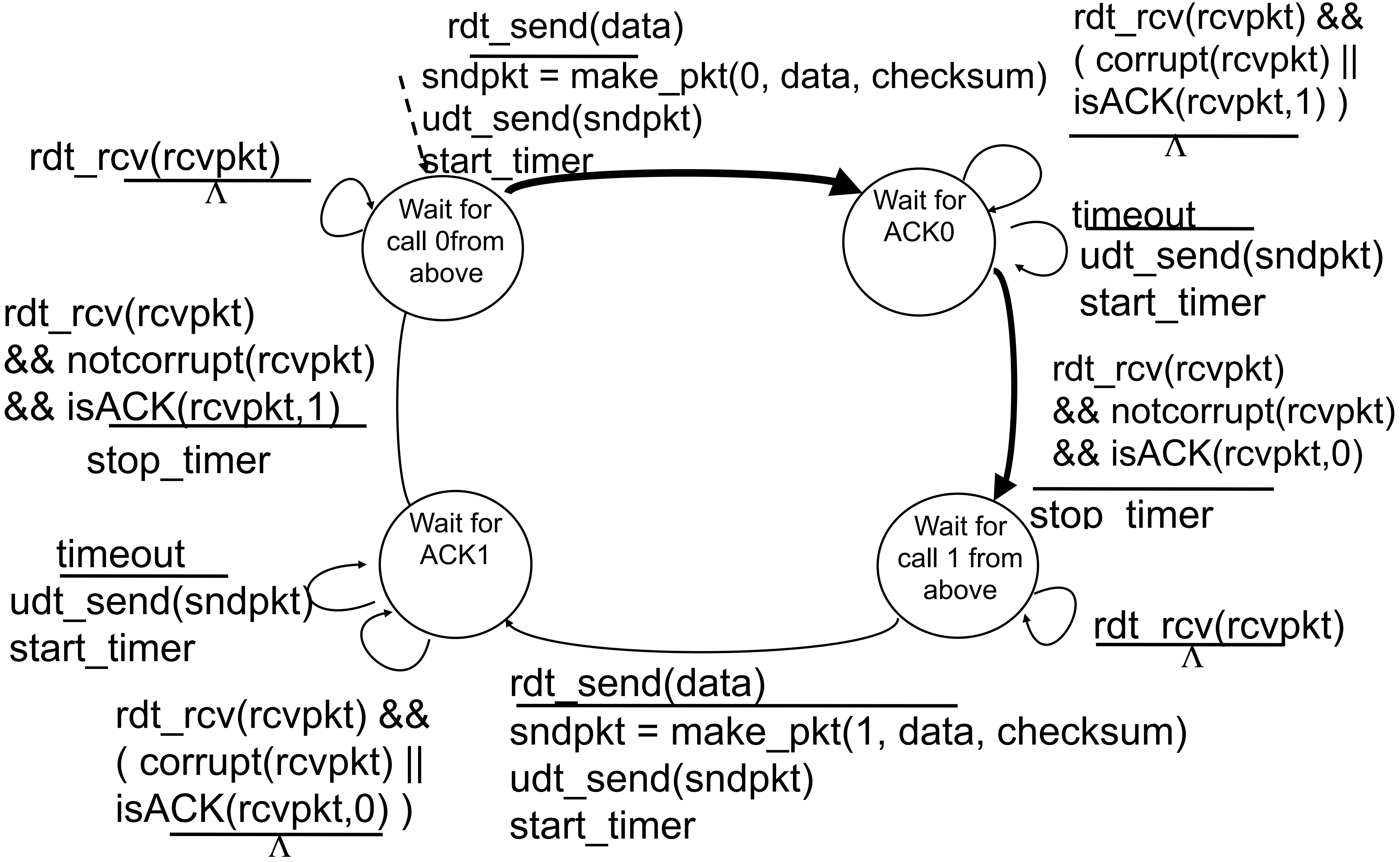
- Checksum, seq. #, ACKs, retransmissions will be of help … but not enough

- 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 seq. #'s already handles this
- Receiver must specify seq # of pkt being ACKed
- Requires countdown timer

rdt 3.0

- Countdown timer
  - Sender starts timer each time a packet is sent
    - Either first time or retransmits
  - Sender responds to timer interrupt
    - retransmits the packet
- **Alternating bit protocol**
  - Another name for rdt 3.0
  - As pkt sequence number alternates
    - between `0` and `1`

rdt3.0 sender



rdt_send(data)

sndpkt = make_pkt(0, data, checksum)
udt_send(sndpkt)
start_timer

rdt_rcv(rcvpkt) && (corrupt(rcvpkt) || isACK(rcvpkt,1))

Λ

rdt_rcv(rcvpkt)

Λ

Wait for call 0from above

Wait for ACK0

timeout

udt_send(sndpkt)
start_timer

rdt_rcv(rcvpkt)
&& notcorrupt(rcvpkt)
&& isACK(rcvpkt,1)

stop_timer

rdt_rcv(rcvpkt)
&& notcorrupt(rcvpkt)
&& isACK(rcvpkt,0)

stop_timer

Wait for ACK1

Wait for call 1 from above

timeout

udt_send(sndpkt)
start_timer

rdt_rcv(rcvpkt)

Λ

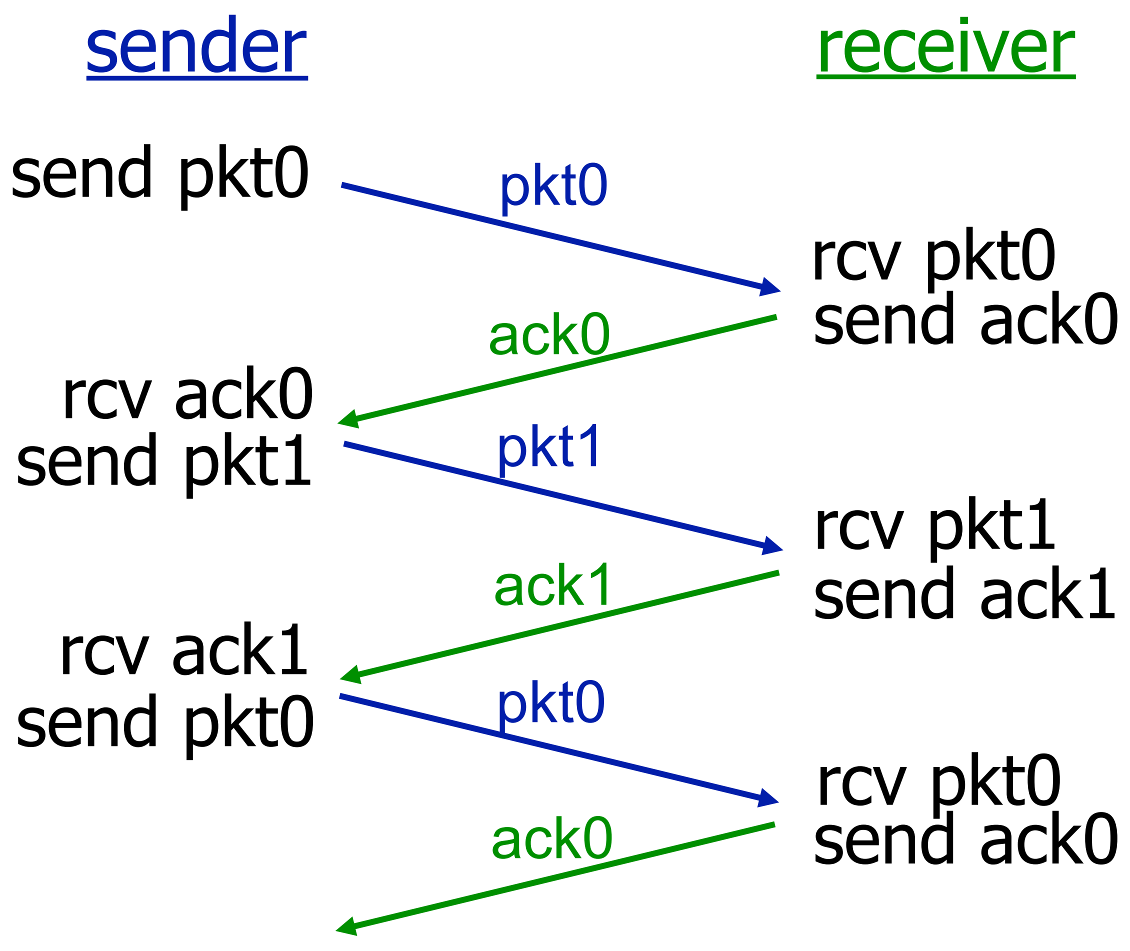
rdt_rcv(rcvpkt) &&
(corrupt(rcvpkt) ||
isACK(rcvpkt,0))

Λ

rdt_send(data)

sndpkt = make_pkt(1, data, checksum)
udt_send(sndpkt)
start_timer

rdt3.0 in action


sender

receiver

send pkt0

pkt0

rcv pkt0
send ack0

ack0

rcv ack0
send pkt1

pkt1

rcv pkt1
send ack1

ack1

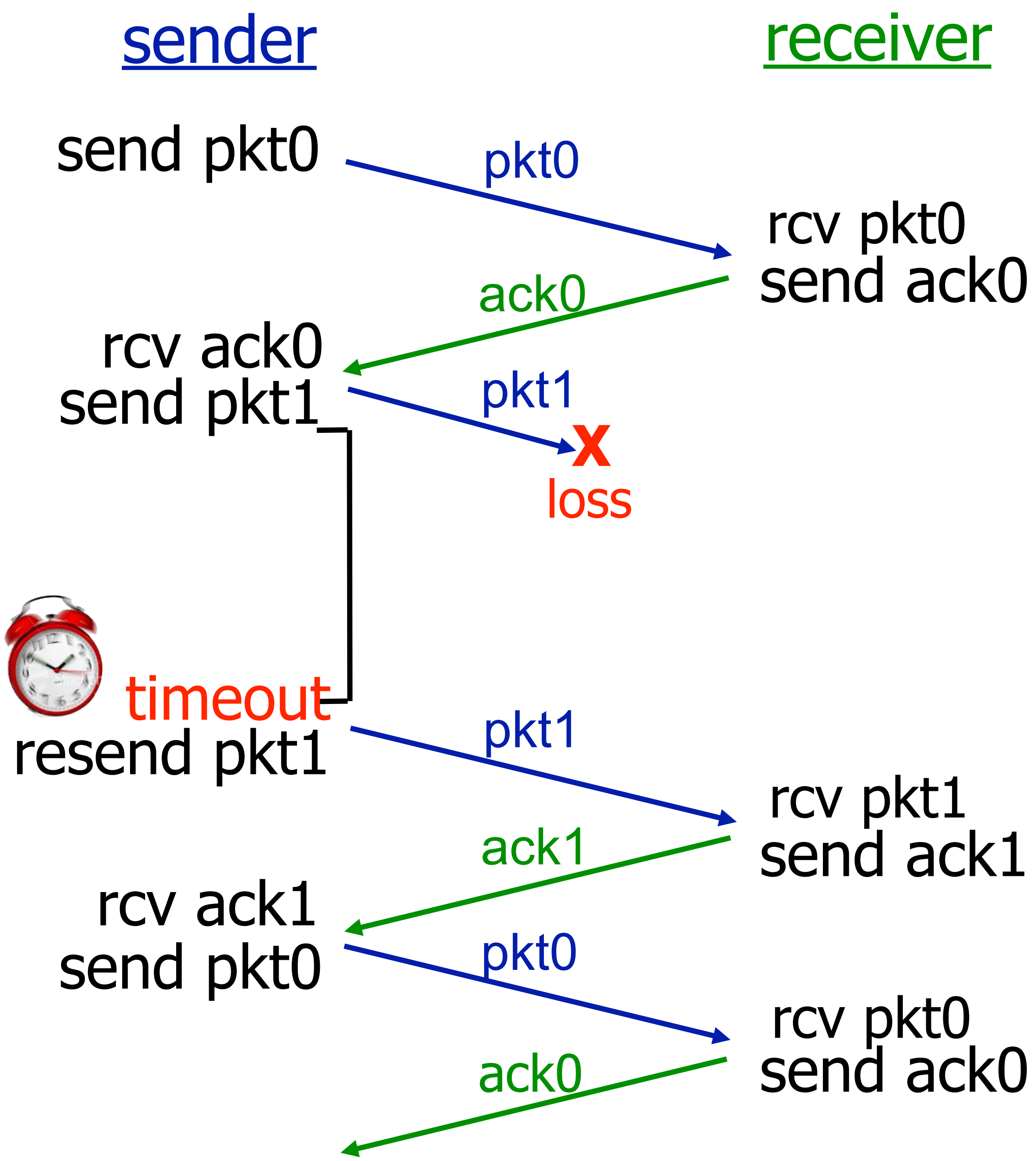
rcv ack1
send pkt0

pkt0

rcv pkt0
send ack0

ack0

(a) no loss


sender

receiver

send pkt0

pkt0

rcv pkt0
send ack0

ack0

rcv ack0
send pkt1

pkt1

X
loss

timeout
resend pkt1

pkt1

rcv pkt1
send ack1

ack1

rcv ack1
send pkt0

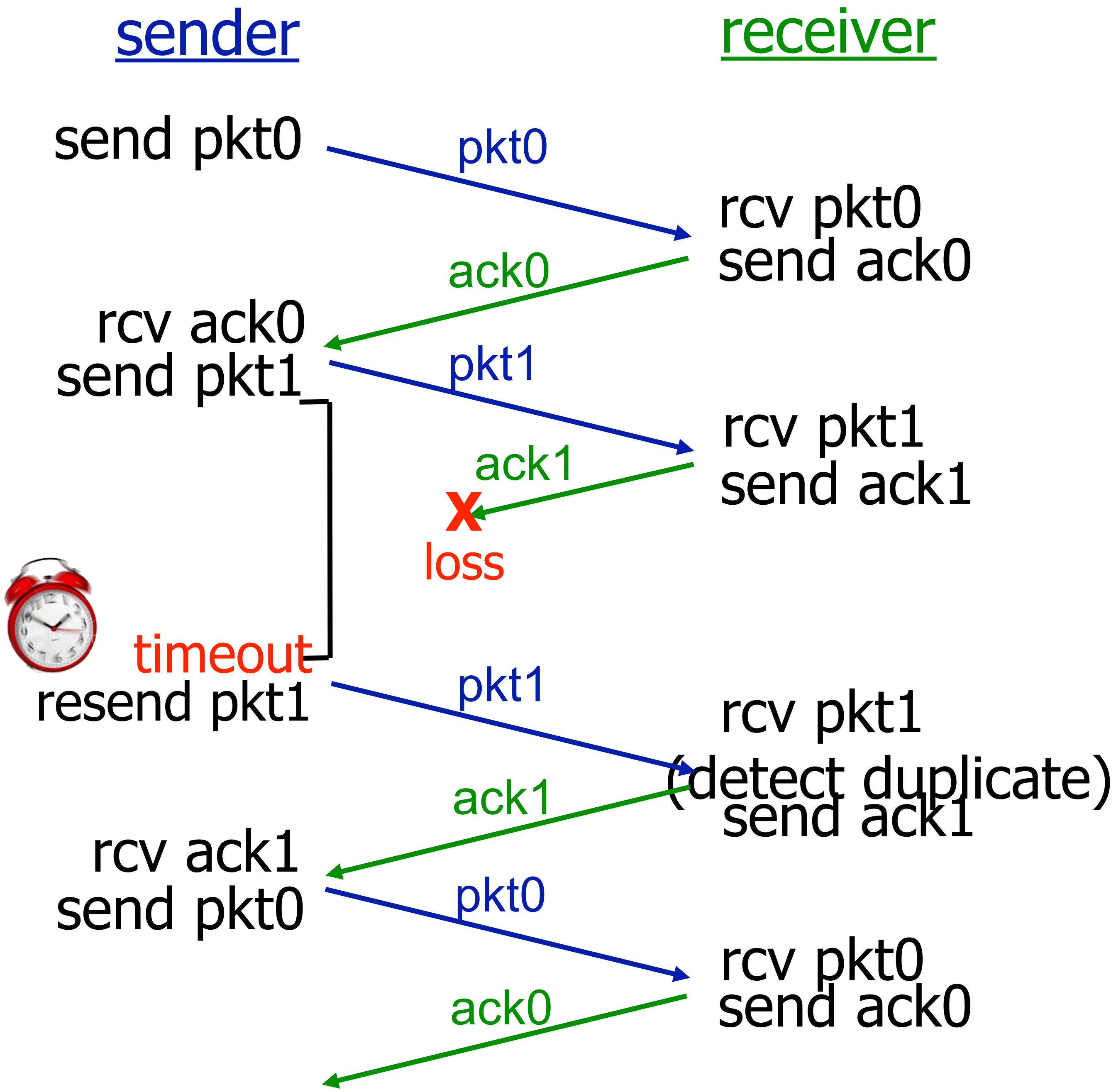
pkt0

rcv pkt0
send ack0

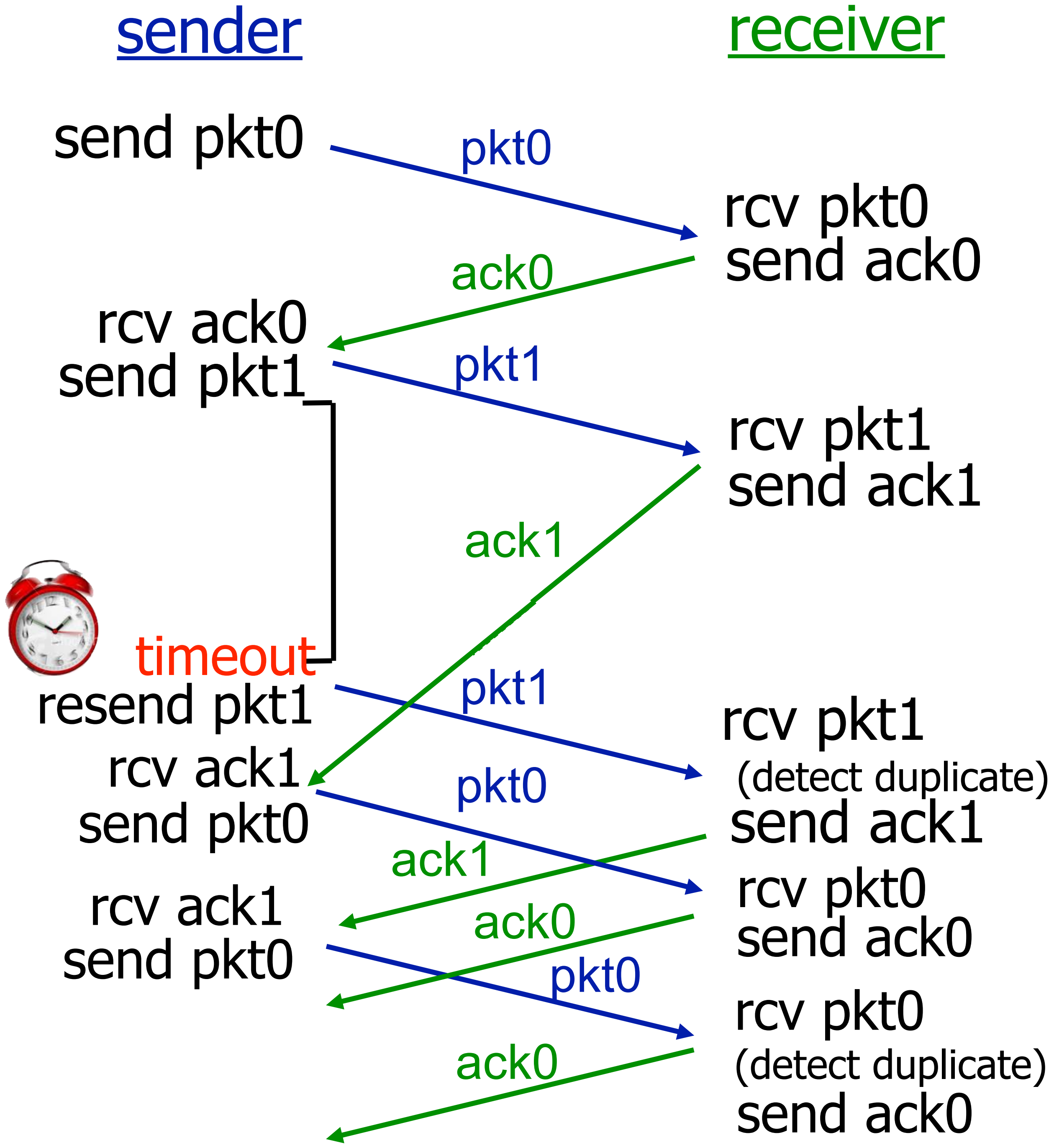
ack0

(b) packet loss

rdt3.0 in action



(c) ACK loss



(d) premature timeout/ delayed ACK

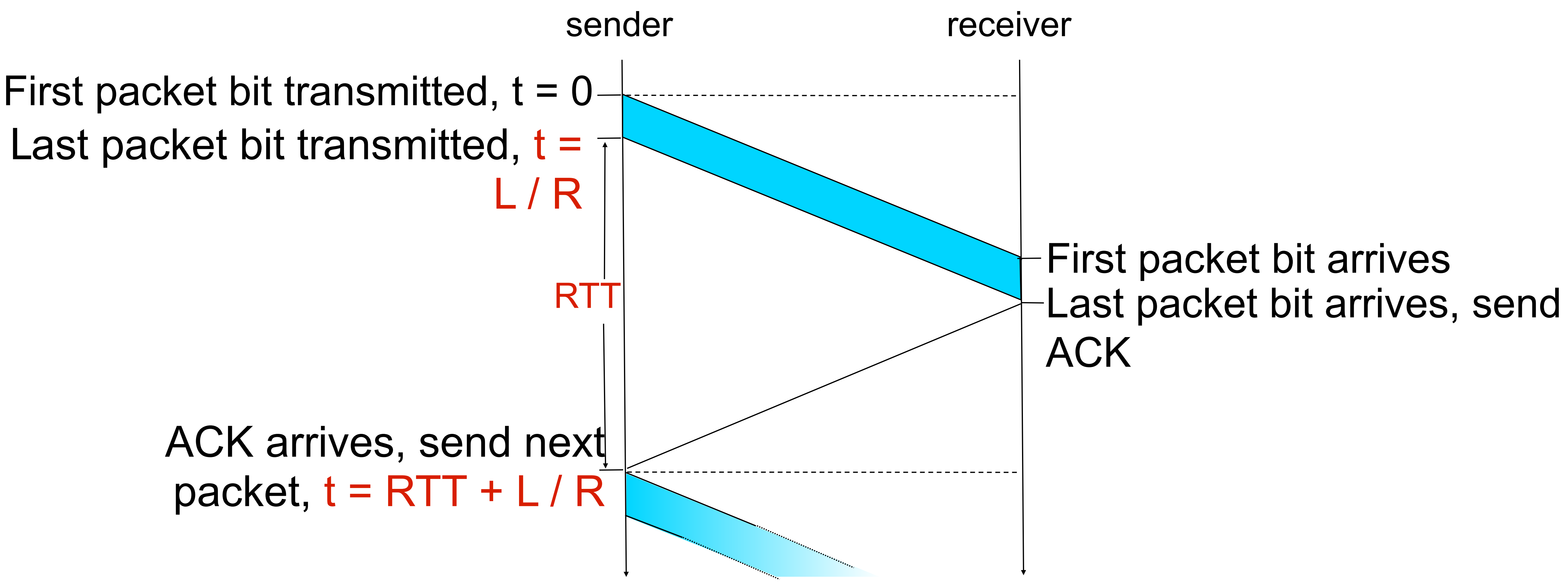
Performance of rdt3.0

- **rdt3.0** is correct, but performance stinks
- e.g.: 1Gbps link, 15 ms prop. delay, 8000 bit packet:

$$D_{trans} = \frac{L}{R} = \frac{8000 \text{ bits}}{10^9 \text{ bits/sec}} = 8 \text{ microsecs}$$

- If RTT=30 msec, 1KB pkt every 30 msec: 33kB/sec thruput over 1 Gbps link
- Network protocol limits use of physical resources!
- Solution: pipelining

rdt3.0: stop-and-wait operation



sender

receiver

First packet bit transmitted, t = 0

Last packet bit transmitted, t = L / R

RTT

First packet bit arrives

Last packet bit arrives, send ACK

ACK arrives, send next packet, t = RTT + L / R

- U $_{sender}$: *utilization* – fraction of time sender busy sending

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

Exercises : Timeline Diagrams

- Ex01: Work out the Timeline sequence diagram for all possible cases of RDT 2.1

- Ex02: Workout the timeline sequence diagram for for all possible cses of RDT 2.2

Exercises:

- Ex 03: Consider the case where network channel can lose the packet but does not corrupt the packet. Let us call this protocol as RDT 2.1b.
  - Design the timeline sequence diagram which deals with packet loss.
  - Design the state transition diagram.

Exercises:

- Ex 4: Consider the case where network channel can loses every second packet in each direction, but doesn't corrupt the packet. Let us call this protocol as RDT 2.1c.
  - Design the timeline sequence diagram which deals with packet loss.
  - Design the state transition diagram.

Summary

- RDT 2.1
- RDT 2.2
- RDT 3.0