Data Link Layer: Reliable Data Transfer

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Recap

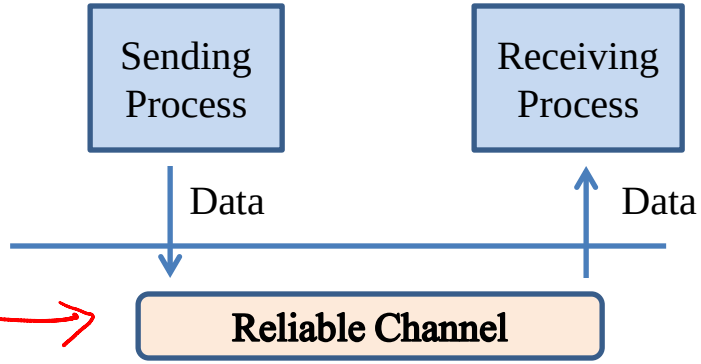
- Frame-by-Frame next-hop delivery
  - Frames can get corrupted or lost
  - Error Detection helps detect corrupted frames
  - What next?
- Recover the corrupted/lost frames → Reliable Data Transfer

Link Layer ✓
Transport Layer

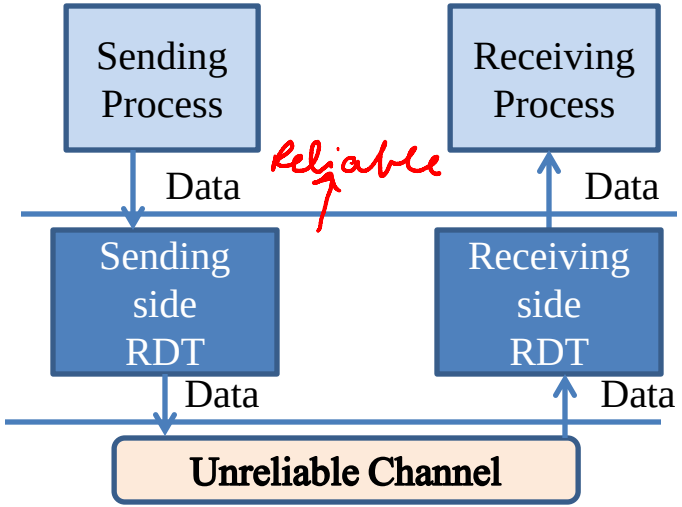
  - One of the most researched problem in networking

Outline

- Develop a Reliable Data Transfer protocol (RDT)
  - Unreliable channel with bit errors
  - Unreliable channel with bit errors and losses



a) Service



b) Implementation

RDTv1.0: Channel with bit errors

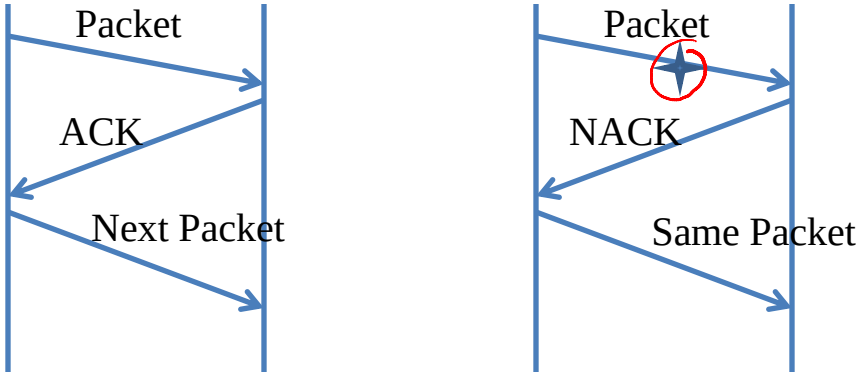
- Telephone Analogy
- Receiver Feedback
  - Positive: aha, ok, hmm → ACK
  - Negative: repeat that, didn't follow, what did you say? → NACK
  - Do we need both?
- Sender retransmits on NACK

Required Functionality:

- Error Detection mechanism
  - Checksum, CRC etc
- ?

Automatic Repeat Request (ARQ)

- Protocols based on Feedback and retransmissions



RDTv1.0

Required Functionality:

- Error Detection mechanism
  - Checksum, CRC etc
- Receiver Feedback
  - ACK + NACK

RDTv1.0 has a fatal flaw!

- What if the ACK/NACK got corrupted?
  - What should sender do then?
- Send next packet? If prev. pkt is lost, RDT not providing reliability
- Send previous packet? If prev. pkt is not lost, creates duplicates

Required Functionality:

- Error Detection mechanism
  - Checksum, CRC etc
- Receiver Feedback
  - ACK + NACK
  - Data Sequence Numbers

RDTv2.0

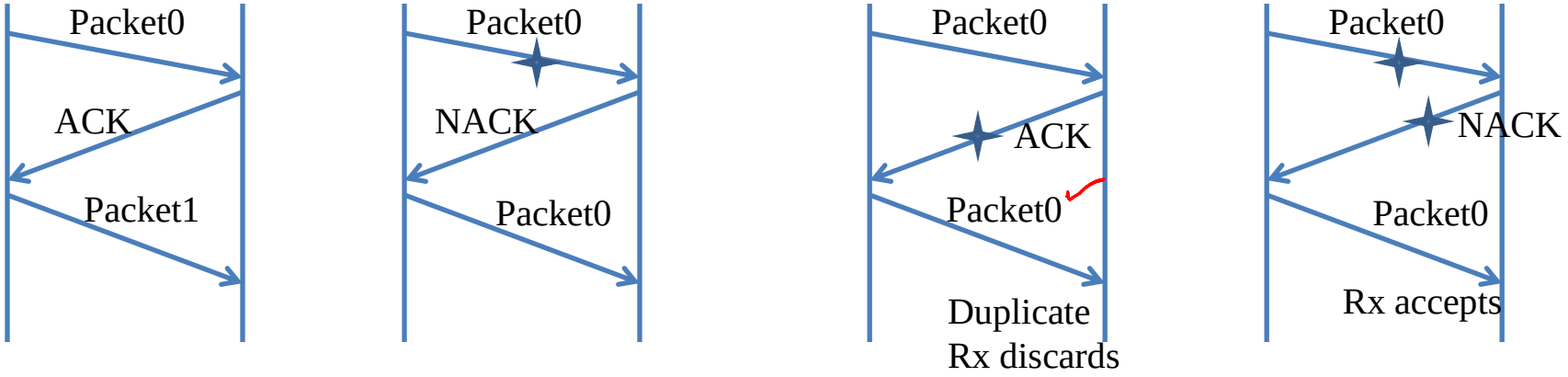
- Receiver gives feedback (ACK, NACK)
- Sender retransmits ‘sequenced’ packet on NACK, garbled ACK/NACK
- Receiver discards duplicates if any based on sequence number

Required Functionality:

- Error Detection mechanism
  - Checksum, CRC etc
- Receiver Feedback
  - ACK + NACK
  - Data Sequence Numbers

RDTv2.0

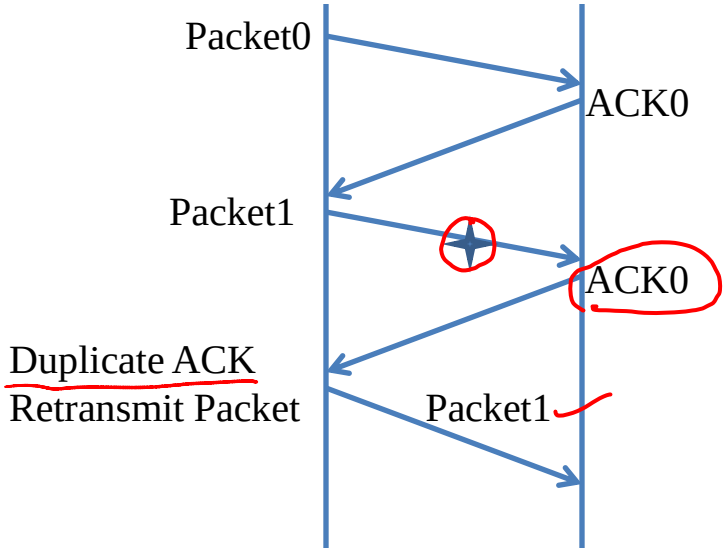
- What is the sequence number space?
  - Just two seq #s “0 , 1” will suffice



RDTv2.1

- Optimization: NACK free operation
  - Convey same information as NACK but through ACK. How?
- Instead of NACK, receiver sends ACK of last correctly received packet
  - Receiver must explicitly include seq # of packet being ACKed
- Duplicate ACK at sender results in same action as NACK: retransmit current packet

NACK Free Protocol



RDTv2.1

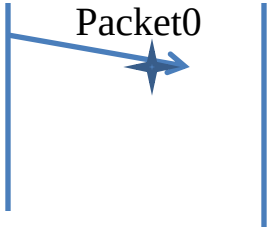
Required Functionality:

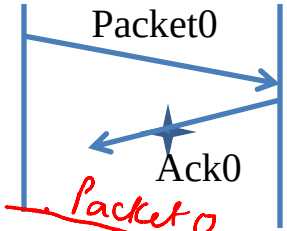
- Error Detection mechanism
  - Checksum, CRC etc
- Receiver Feedback
  - ACK + ~~NACK~~
- Data Sequence Numbers
- ACK carries sequence number of data packets

SNR

RDT: Channel with Errors and Losses

- Will RDTv2.1 work?
- Sender gets no feedback: Need a Timeout mechanism
- How long to wait?





↳ Link, Tx time, Prog time, Processing TO Packet0

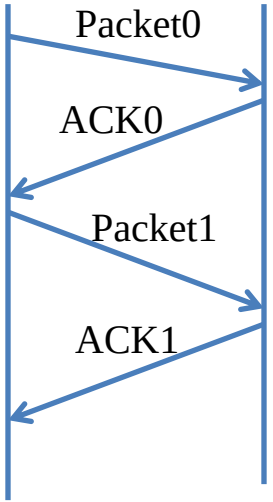
RDTv3.0

- 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, seq. #'s help resolve this

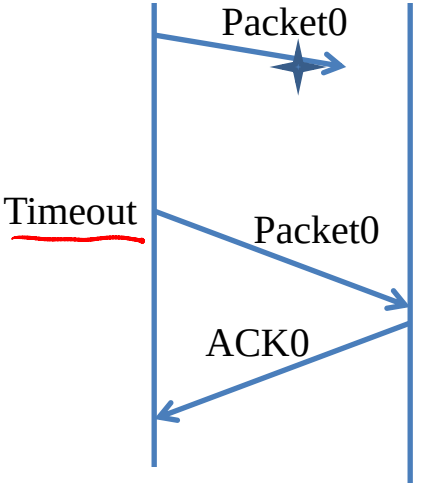
Required Functionality:

- Error Detection mechanism
  - Checksum, CRC etc
- Receiver Feedback
  - ACK + NACK
- Data Sequence Numbers
- ACK carries data seq. No.
- Timeout Timer

RDTv3.0: Stop and Wait Protocol In Action



(a) No Loss

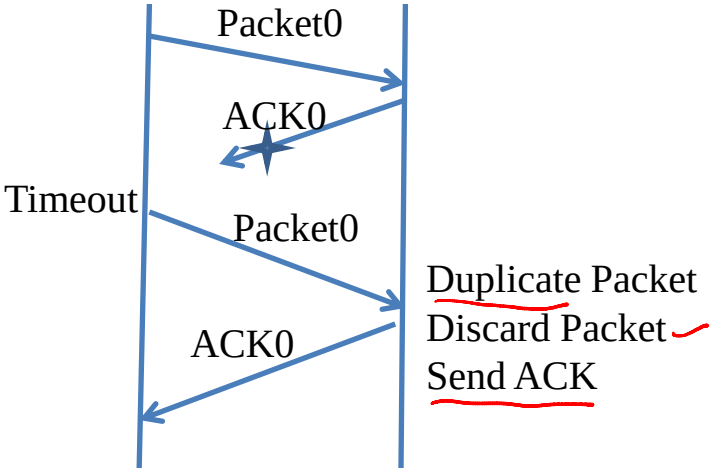


(b) Lost Packet

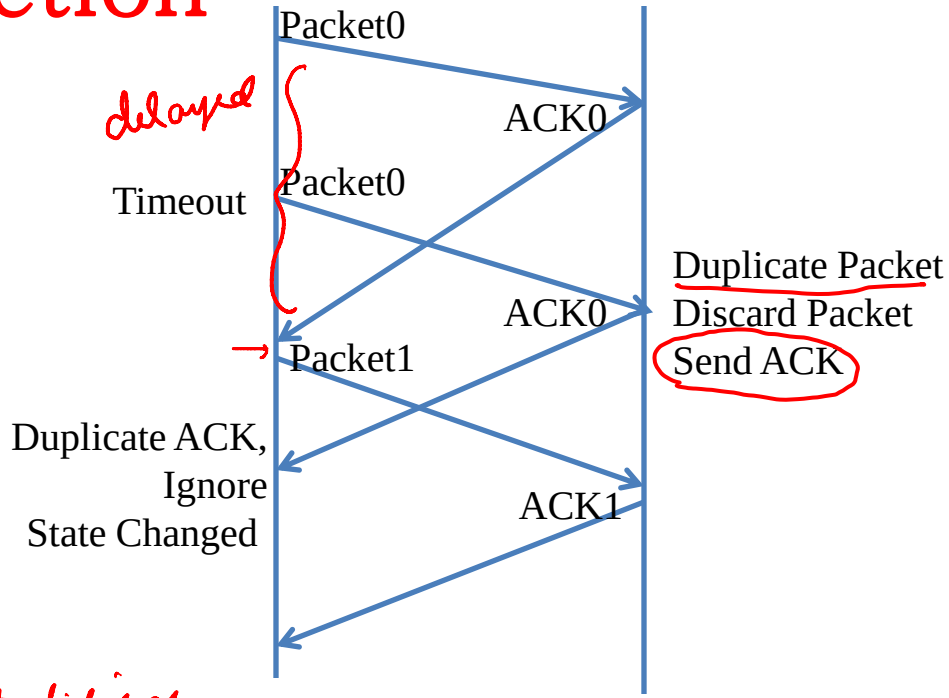
0, 1

Also called Alternating Bit Protocol

RDTv3.0: Stop and Wait Protocol In Action



(c) Lost ACK



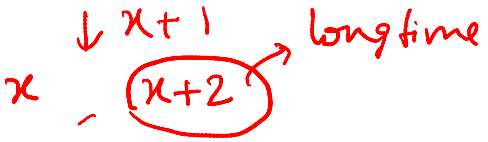
RDTv2.1
↳ state didn't change

(d) Premature Timeout

Design of RDT protocols

- Many challenges to handle
  - ACKs/Packet loss, ACKs/Packet delayed, Duplication of packets, Reordering, Incorrect timeout timer settings, Receiver capabilities
  - Protocol has to work correctly and efficiently in spite of all this

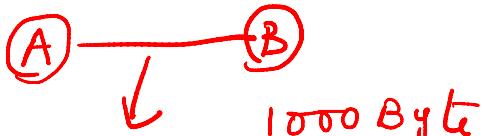
NACK vs ACK



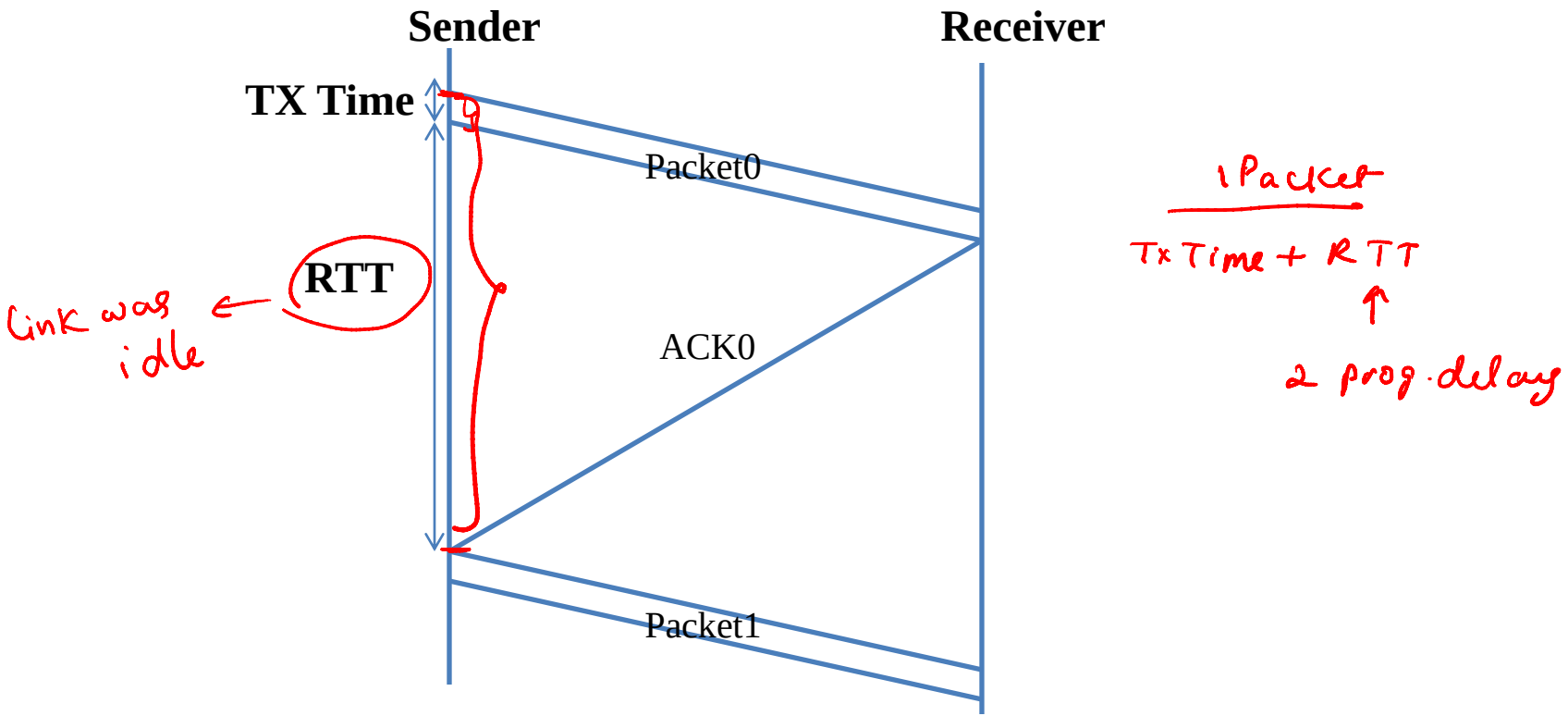
- Can conclude packet loss on detecting 'holes'
  - Long delay between some packets can slow down recovery
  - What if the last packet in the flow is lost? deadlock
    - Receiver doesn't generate NACK, sender assume 'all is well'
- Advantage of NACK: If errors are infrequent, reduces overhead of feedback NACK + ACK

RDT v3.0

Performance of Stop and Wait Protocol



- What is the achieved throughput?
  - 10 Mbps link, 10 ms prop. delay, 1KB packet, ACK too small (ignore its Transmission time)
- Throughput: 8000 bits / [(8000/10^7)+2*0.010] = 384.6Kbps
- Utilization = 384.6kbps/10000kbps = 3.8%



Utilization = Transmission time / (Transmission time + RTT)

Summary

- Reliable data transfer protocols provide 'reliable channel' service abstraction to higher layers
- We incrementally determined the required functionality needed in RDT protocols
- The current protocol designed is inefficient
- Future: Build on this framework to design better protocols