CSCE 463/612
Networks and Distributed Processing
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Transport Layer III

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Chapter 3: Roadmap

3.1 Transport-layer services

3.2 Multiplexing and demultiplexing

3.3 Connectionless transport: UDP

3.4 Principles of reliable data transfer (cont)

3.5 Connection-oriented transport: TCP

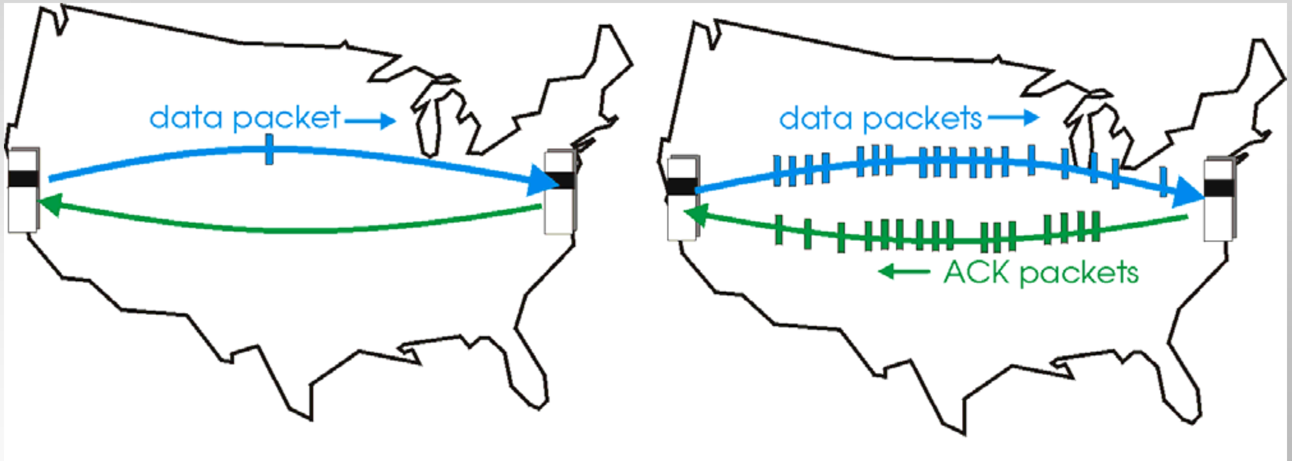
- Segment structure
- Reliable data transfer
- Flow control
- Connection management

3.6 Principles of congestion control

3.7 TCP congestion control

Pipelined Protocols

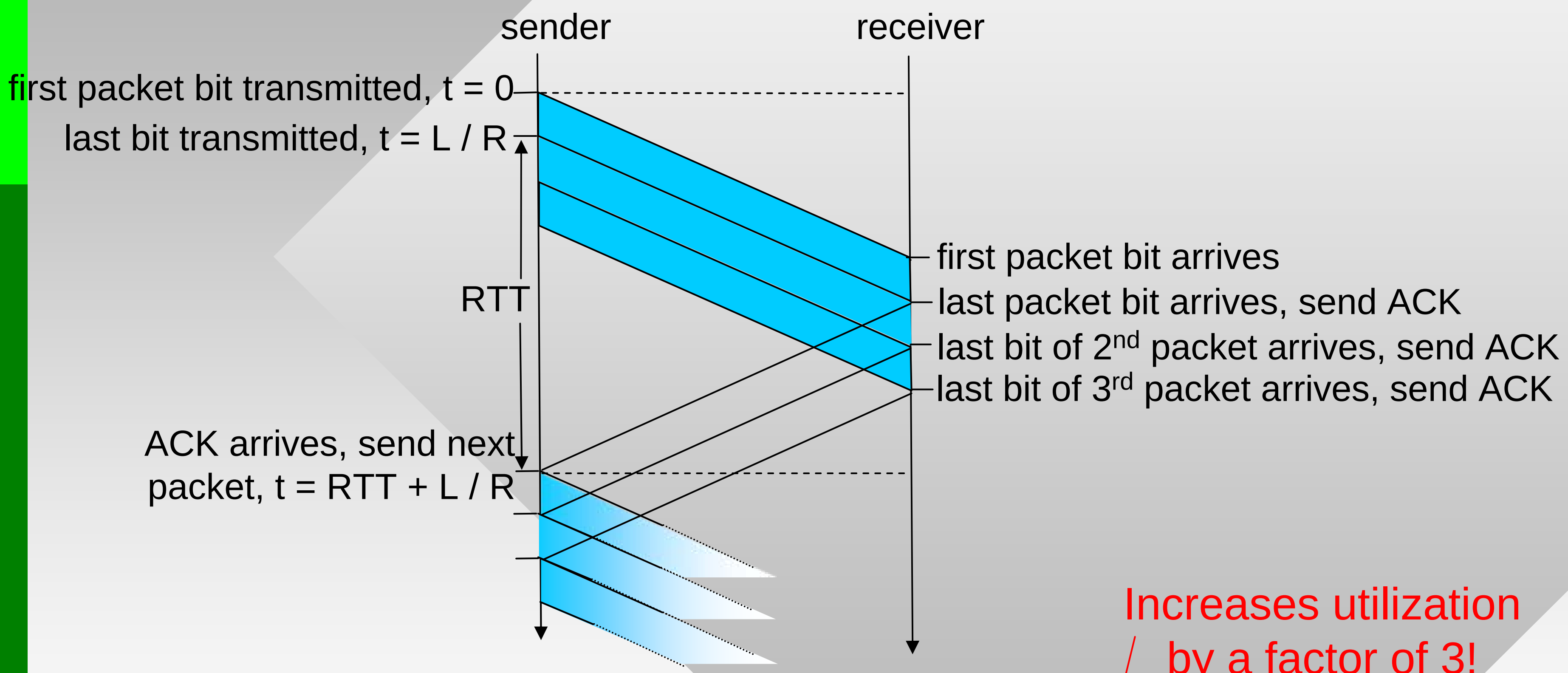
- Pipelining: sender allows multiple, “in-flight”, yet-to-be-acknowledged pkts
  - Range of sequence numbers must be increased
  - Buffering at sender and/or receiver



(a) a stop-and-wait protocol in operation (b) a pipelined protocol in operation

- Two generic forms of pipelined protocols: *Go-Back-N* and *Selective Repeat*

Pipelining: Increased Utilization



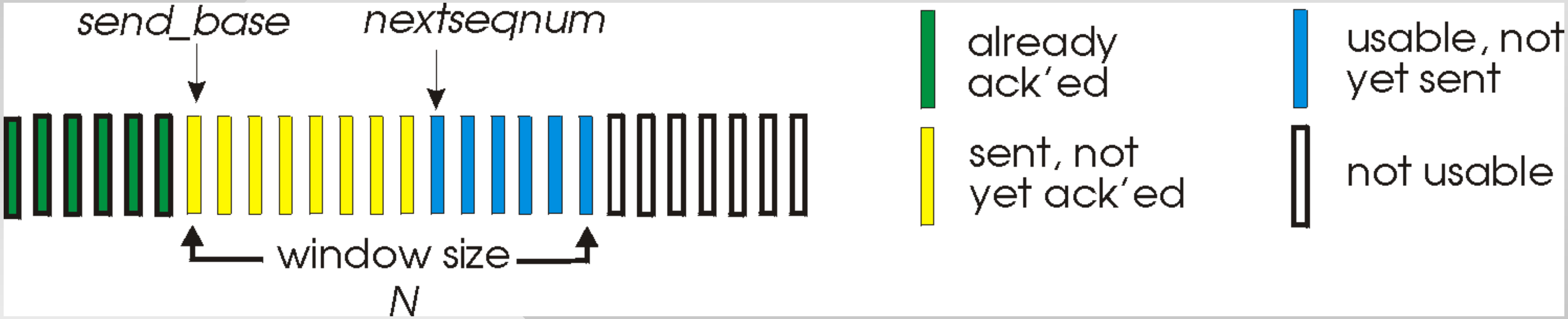
Increases utilization by a factor of 3!

$$U_{sender} = \frac{3 * L / R}{RTT + L / R} = \frac{.024}{30.008} = 0.0008$$

Go-Back-N (GBN)

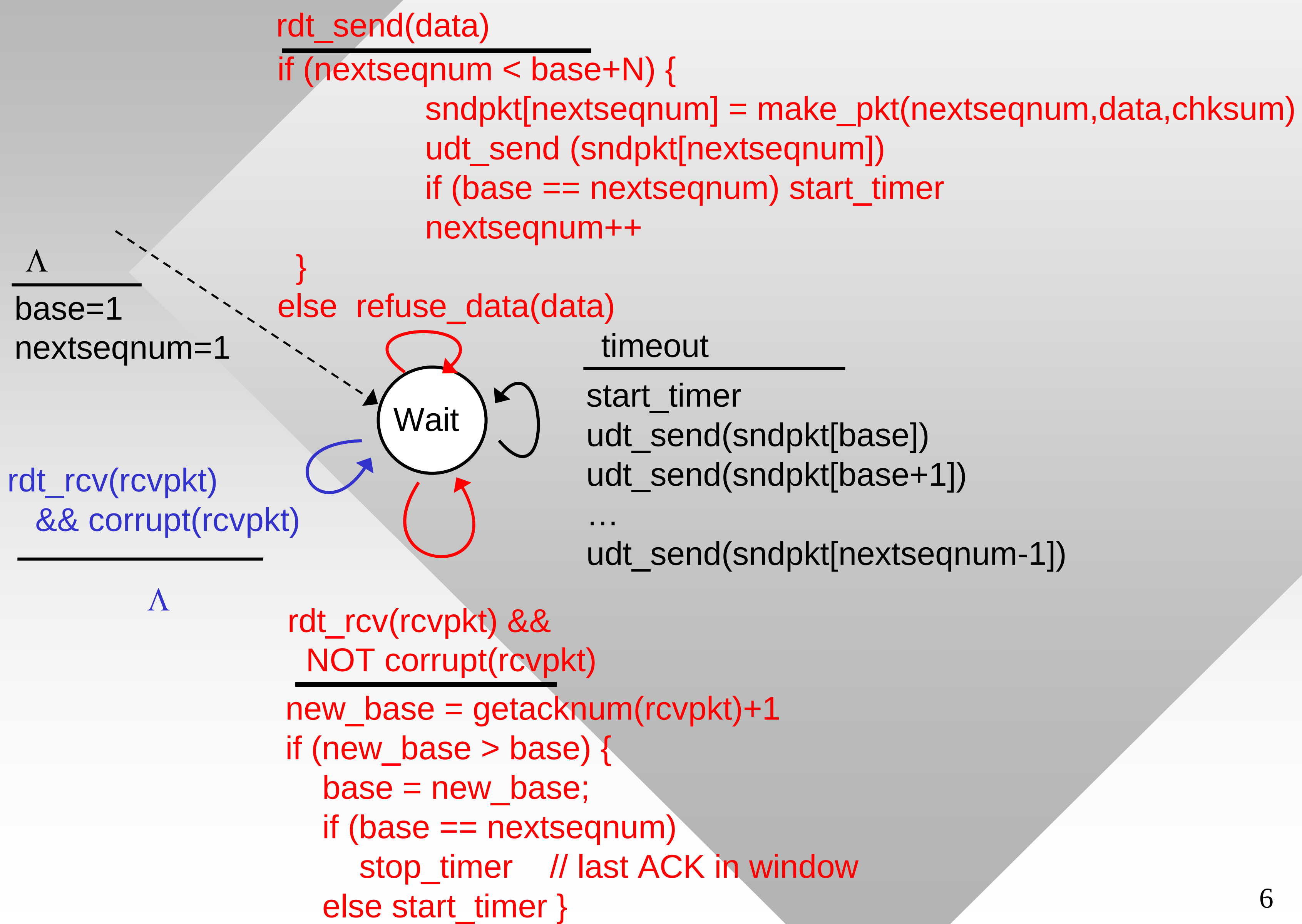
Sender:

- Window of up to *N* consecutive unack'ed pkts allowed
- A field in header that holds *k* unique seq numbers

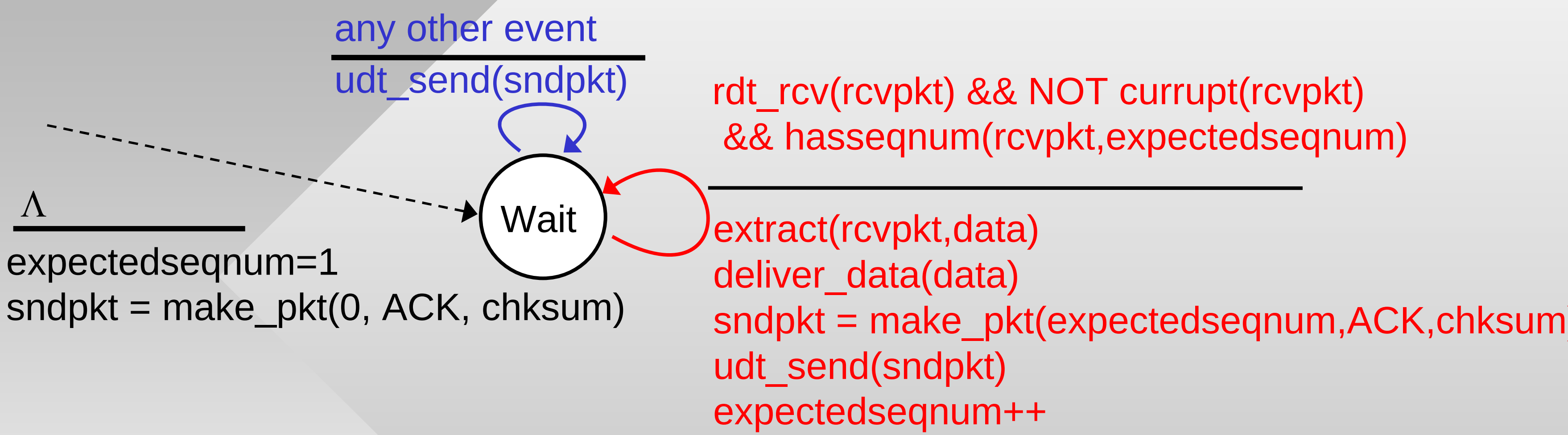


- ACK(n): ACKs all consecutive pkts up to & including seq # n (cumulative ACK)
  - Means packets 1...n have been delivered to application
- Timer for the oldest unacknowledged pkt (send_base):
  - Upon timeout*:* retransmit all pkts in current window (yellow in the figure); reset the timer

GBN: Sender Extended FSM

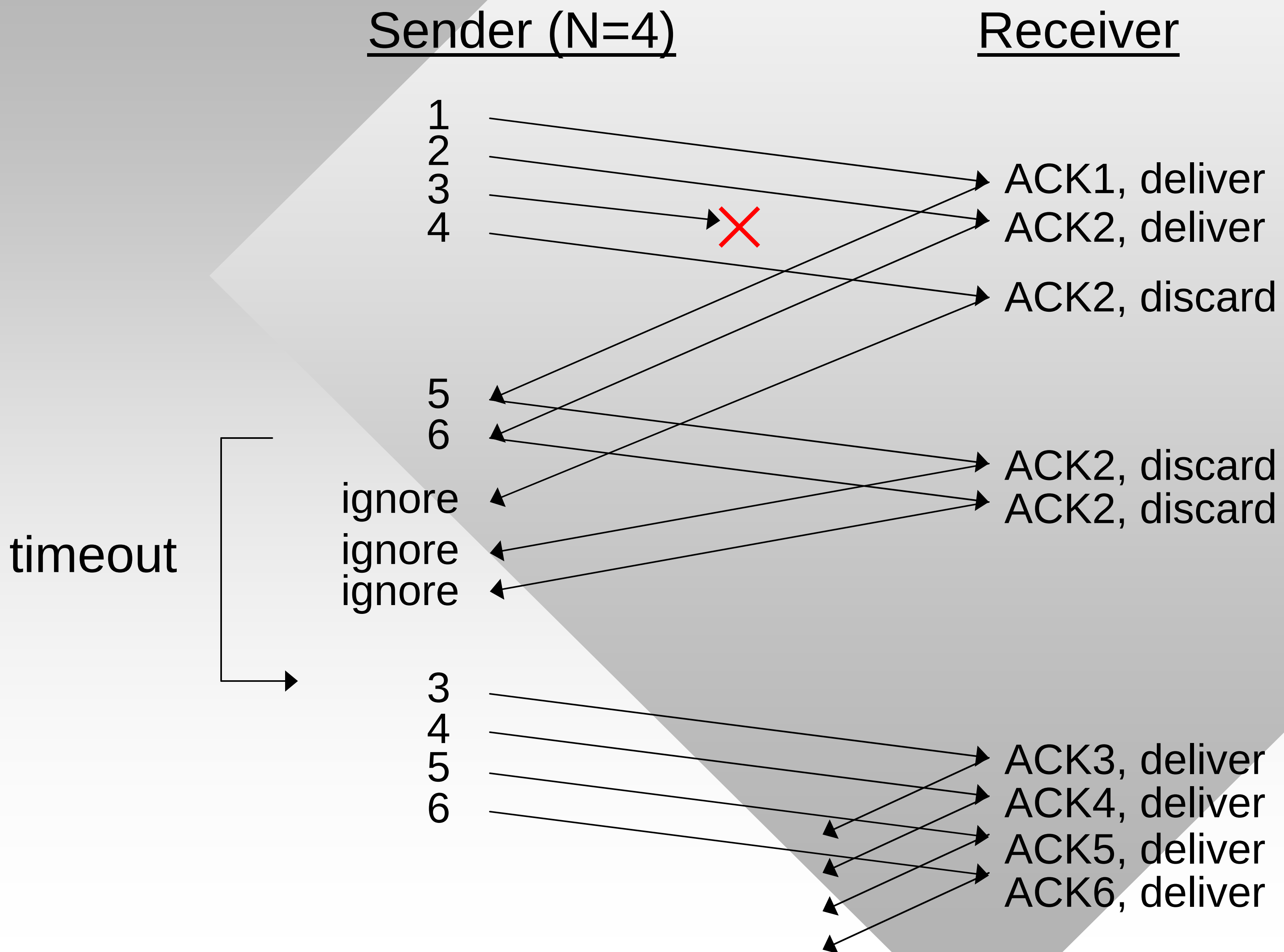


GBN: Receiver Extended FSM



- ACK-only: always send ACK for correctly-received pkt with highest *in-order* seq #
  - Duplicate ACKs during loss
  - Need only remember **`expectedseqnum`**
- Out-of-order pkt:
  - Discard → no receiver buffering!
  - Re-ACK pkt with highest in-order seq #

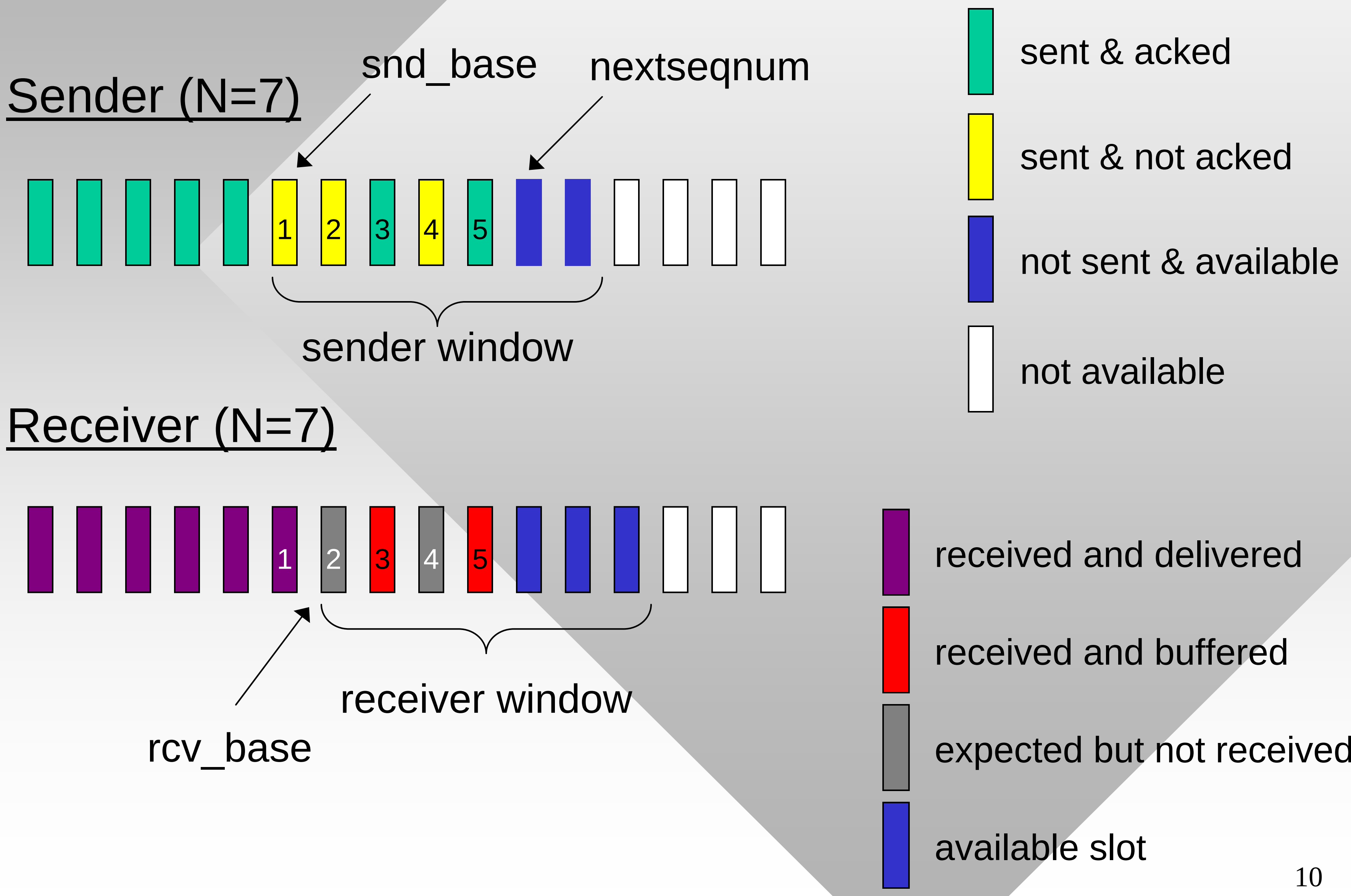
GBN in Action



Selective Repeat

- Receiver *individually* acknowledges all correctly received pkts
  - Buffers pkts, as needed, for eventual in-order delivery to upper layer
- Sender only resends pkts for which ACK was not received
  - Separate timer for each unACKed pkt
- Sender window
  - *N* consecutive packets in [snd_base, snd_base+N-1]

Selective Repeat: Sender, Receiver Windows



Selective Repeat

sender

Data from above :

- If next available seq # in window, send pkt

Timeout(n):

- Resend pkt n, restart timer n

ACK(n) in [snd_base, snd_base+N-1]:

- Mark pkt n as received
- If n == snd_base, advance snd_base to the next unACKed seq #

receiver

Receive pkt n in [rcv_base, rcv_base+N-1]

- Send ACK(n)
- Out-of-order (n>rcv_base): buffer
- In-order (n == rcv_base): deliver, advance rcv_base to next not-yet-received pkt, deliver all buffered, in-order pkts

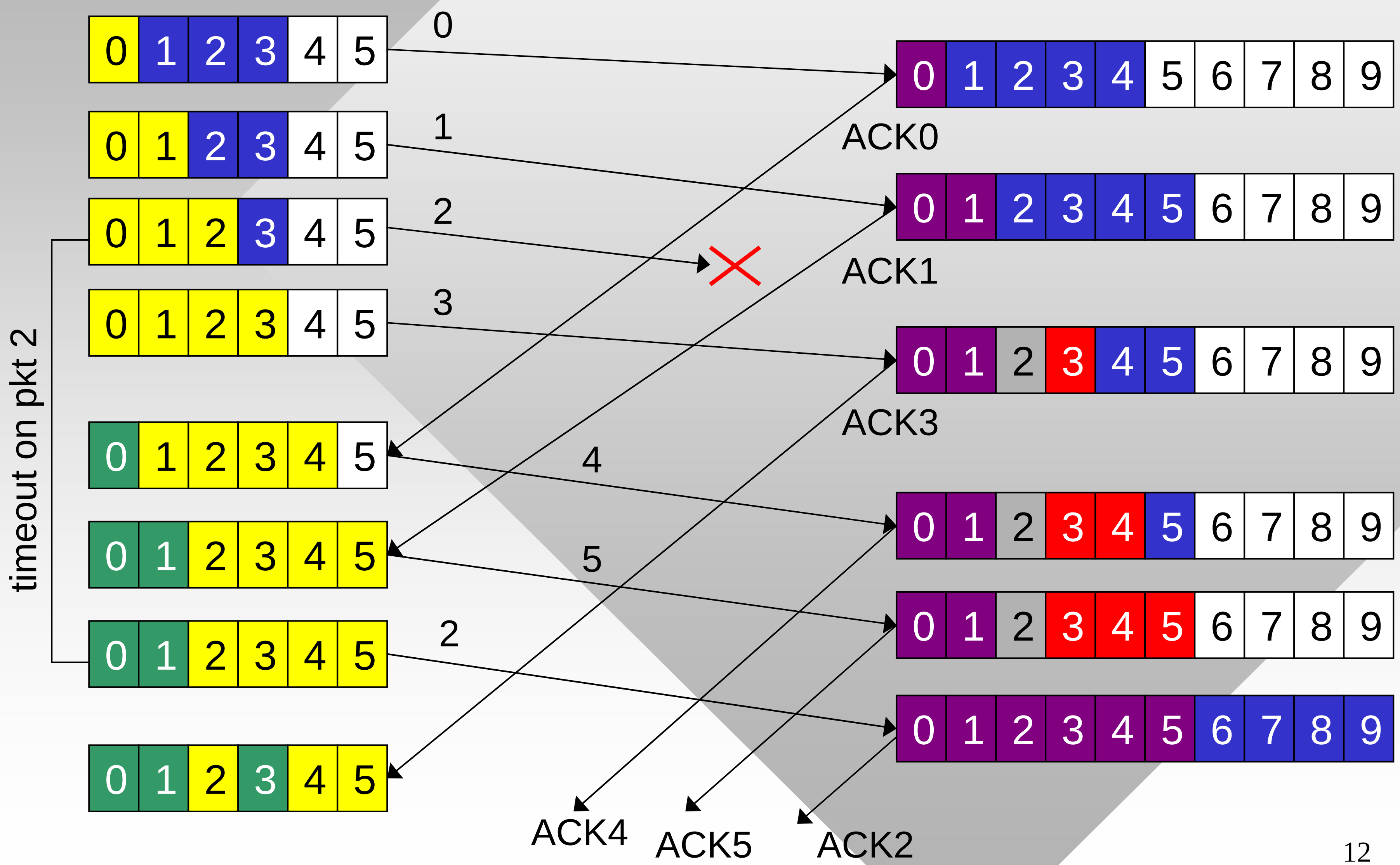
Pkt n in [rcv_base-N, rcv_base-1]

- ACK(n)

Otherwise:

- Ignore

Selective Repeat in Action (N=4)



Selective Repeat: Dilemma

Q: How many distinct seq #s are needed for window size N in selective repeat?

Example:

- Seq #’s: 0, 1, 2, 3
- Window size = 3
- Receiver sees no difference in two scenarios!
- Incorrectly passes duplicate data as new in (a)