2.4.2 Go-BACK-N ARQ

- Also known as Sliding Window
- Most popular ARQ today
- Motivation: consider transmission of 4 packets

(1) With Stop and Wait

- Alternative: Let sender send 4 packets before waiting for any ACK

Saves time over stop and wait: \( \text{time wind} / \text{time stop&wait} \approx \text{RTD/2} \) for large \( n \)

Note: Go-Back-N will use:

- \( SN \)
- \( RN \)

just as stop and wait did. But domain of \( SN, RN \) will be \( n+1 \) rather than \( 2 \).

A. Receiver would need to buffer \( m \) packets, and could accept \( SN \) to \( SN + m - 1 \). This is 2.4.3-Selective Repeat.

Algorithm

**Variables**
- Sender: 1) \( SN_{\text{max}} \) (smallest unack pck #)
  - \( SN_{\text{min}} \) (smallest unsent pck #)
2) \( Sn_{\text{max}} \) (smallest unack pck #)

**Sender Algorithm**

**State Machine**

Receiver: \( RN \) (same as meaning as in stop and wait - next \( SN \) expected)

Stop and Wait

**Sender Window**

S2 : Arbitrary, bounded delay between when condition for a state is enabled, and when state’s actions are executed.

[Assume \( n \) times. Could be layer 2 or 4] [3’s denote the “timer” view.]

S3 : If \( SN_{\text{max}} < SN_{\text{max}} + n \) and packet available from higher layer:

- accept packet
- assign packet \( SN_{\text{max}} \)
- set time for packet \( SN_{\text{max}} \)
- transmit packet
- \( SN_{\text{max}} := SN_{\text{max}} + 1 \)

S4 : If error-free frame received from B with \( RN > SN_{\text{max}} \):\n
- \( SN_{\text{max}} := RN \) \[Clear timers for all packets with \( SN < RN \)]

S5 : If \( SN_{\text{max}} < SN_{\text{max}} \) and no frame currently in transmission: [\( SN \)’s timer pops:]

- choose a packet with \( SN_{\text{max}} \leq SN < SN_{\text{max}} \)
- transmit \( SN \) packet
- [reset timer]

Receive Algorithm

S1 : Initially: \( RN = 0 \)

S2 : If error-free frame received from A with \( SN = RN \):

- release packet to higher layer
- \( RN++ \)

S3 : At arbitrary times, but within bounded delay after receiving error free data frame from A:

- transmit frame to A with \( RN \) in request # fold

How is “arbitrary delay” handled?

- Timer:
  - set time for packet \( SN \); resend \( SN \) on pop; clear timer when \( RN = SN \).
- or set time for entire window

You can order operations in above algorithm many ways (e.g., S5 does not require retransmission in ascending \( SN \) order.)
**Go-Back-N**

Some way to handle retransmission in S5 of sender:
1. Set timer. On timer pop, retransmit $SN_{\text{min}} \leq SN \leq SN_{\text{max}} + n$ (for $n = 4$)
2. After A sends entire window, cycle back and resend window
3. A waits for request from B for retransmission.

**Q. When send window closed, what value does $SN_{\text{max}}$ have?**
A. $SN_{\text{max}} + n$: Total range of SN/RN's used is $SN_{\text{min}} \leq SN_{\text{max}} + n$ (for $n = 4$)

**Q. What is max # SN's needed?**
A. $n+1$ (only one old packet can be in transit-see proofs in book)

**Q. How do you select $n$?**
A. Factor of:
   - Sender buffer space and # timers feasible
   - Desired # bits for SN field in header
   - Loop delay: large pipe $\Rightarrow$ larger $n$

**2.4.3 Selective Repeat ARQ**

Go-Back-N retransmits $\geq 1$ RTD of frames upon single error
Bad if:
   - error probability is high (cellular phone)
   - $n$ is very large (satellite or Gbps-fiber)

So in Selective Repeat:

**BG 2.4.3 Selective Repeat**

- Modification of Go back N:
  - Receiver buffers packets received out of order
  - Receiver window:
    - $0 1 2 3 4 5 6 7 8 9 10$
    - Received and Attached
    - Typically receiver window size = sender size
  - BG: “Receiver requests retransmission of any packets missing from received sequence.”
  - TCP: Same meaning of RN ACK's - send upper half of window (wastefully)

**Upper bound on fraction packets successfully derived to B: $n \leq 1 - p$**
where $p$ = probability of frame error.
So if $p = 0.1$, $(1 - 0.1)^n \times 100 = 90\%$ of frames delivered successfully.
In 10 Mbps medium, you get $\lesssim 9$ Mbps. But, you cannot get this bound.

**Q. Why?**
A. Finite time to propagate
   - information from B to A that error occurred
   - retransmission frame
   - $(1 + 2) = \text{RTD}$

Let $\beta = \exp[\text{#frames sent in RTD}]$

$$\eta \leq \frac{1 - p}{1 + p\beta}$$

- $\beta \Rightarrow \infty$; $\eta$ bound approaches 0
- $\beta \Rightarrow 10$; $\eta < (1-p)/2$ or 50% drop (for stop and wait)

More facts on Selective Repeat:
1. SN range is $2n$ (vs $n + 1$ for Go-Back-N)
2. Selective repeat wins due to receiver buffering out of order packets
   - To do even better, put more ACK information than RN into B traffic, to handle multitude-frame errors:
     - B sends lowest j packet #s not yet received. [But this wastes BW due to large header frames.]
     - B sends k bits, one bit per packet after RN. [BIT MAP]