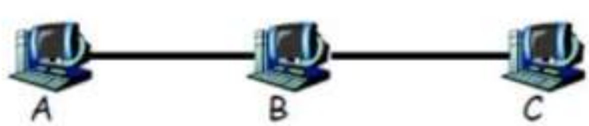
Device A is sending frames to device C via another device B. Devices A and B use a Go-back-N Sliding window protocol with SWS = 3. Devices B and C use SR sliding window with SWS=RWS=4. There are a total of 7 frames (starting with F_0 and ending with F_6) generated at device A and destined to device C. The following information is given:

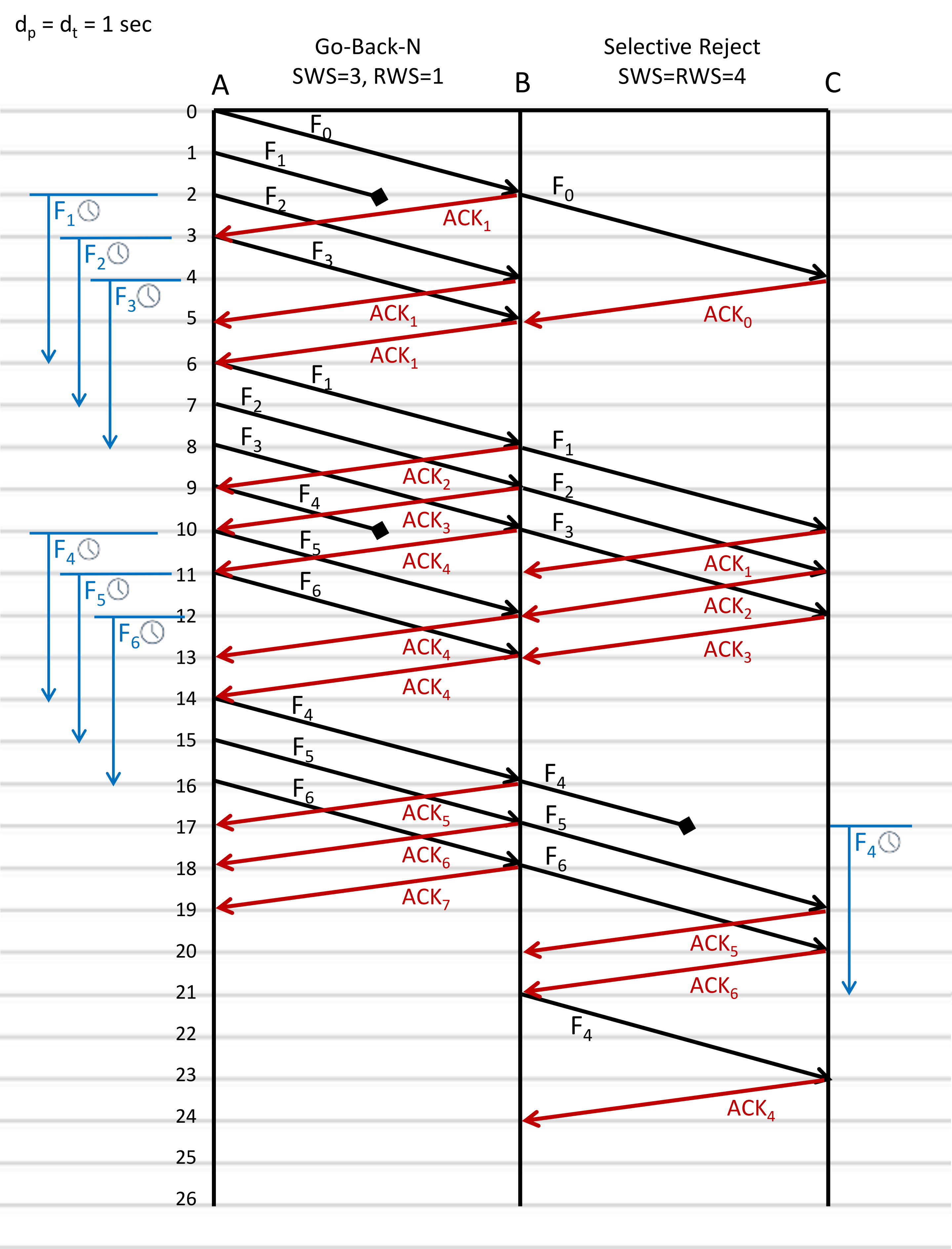
- Frame length = 1000 bits
- Frame Transmission Time = 1 sec
- One-way Propagation Delay (on each link) is 1 sec.
- Transmission Time for Acknowledgment = 0 (negligible)
- Processing/Queuing Delay = 0 (negligible, at any node)
- Time-out (at both devices A and B) is 4 seconds. The timer, for any frame, starts immediately after the device finish transmitting that frame.
- On the first link which employs Go–back–N ARQ, the sequence number of the ACK is that of the next frame the receiver expects to receive. On the second link (which uses SR ARQ, the sequence number of the ACK is the same as the frame just received. In addition, the receiver in SR can acknowledge out of order frames individually.
- No accumulative acknowledgements are used (i.e. each frame is acknowledged separately)

Sketch, side-by-side, the Timing diagram for frame transmissions over links A---> B and B---> C under the following scenario:

F_1 and F_4 get lost in their first transmission from A---> B
F_4 gets lost in its first transmission from B---> C

Calculate the Throughput over each link and the end-to-end throughput.





$d_p = d_t = 1$ sec
Go-Back-N
SWS=3, RWS=1
Selective Reject
SWS=RWS=4
A
B
C
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
F_0
F_1
F_2
F_3
F_4
F_5
F_6
ACK_0
ACK_1
ACK_2
ACK_3
ACK_4
ACK_5
ACK_6
ACK_7

A -> B Throughput = 7 x 1000 bits / 19 sec = 368.4 bps

B -> C Throughput = 7 x 1000 bits / 22 sec = 318.2 bps

A -> C Throughput = 7 x 1000 bits / 24 sec = 292 bps

Q2) Consider a link that uses Go-Back-N ARQ protocol with SWS=7. Suppose the transmission time of a frame is 1 second. **Each frame** uses a time-out mechanism of 2 seconds (**The time-out timer starts when you transmit the last bit of your frame**). Assume that one-way propagation delay is 0.5 seconds. Neglect the processing delay. Upon receiving a frame, the receiver will **wait**1 second and send an accumulative ACK for all frames received with no errors up to that point in time. Neglect the transmission time of the ACK frame. Assume that station A begins with frame F_o. Draw the frame-exchange-timing diagram for the following sequence of events (Hint: Divide the time-line into 0.5 seconds intervals). Be sure to label each data frame with a sequence number and each ACK with a sequence number indicating the next frame expected to be received. There is no NAK in this implementation of the protocol. Assume that each frame is 1000 bits long. Consider the following scenario:

- Station A sends 5 frames in a row, starting at t=0. **Frame F_2 was received and detected to be in error and F_4 was lost in transmission**. Calculate the throughput and the link utilization. Assume that node A has only those 5 frames to transmit.

Solution:

Throughput = 5000/10 = 500 bps

Link Utilization = 5/10 = 50%

Time	Action @ Transmitter	Action @ Receiver	Time
0	Fo is transmitted		0
0.5			0.5
1	F1 is transmitted		1
1.5		Fo is received (No errors)	1.5
2	F2 is transmitted		2
2.5		F1 is received. ACK2 is sent	2.5
3	F3 is transmitted, ACK2 is received		3
3.5		F2 is received and detected to be in error. Receiver drop the frame	3.5
4	F4 is transmitted. This frame is lost		4
4.5		F3 is received but dropped (out of sequence). ACK2 is sent	4.5
5	F2 is timed out and is retransmitted. ACK2 is received		5
5.5			5.5
6	F3 is transmitted		6

6.5		F2 is received (No errors)	6.5
7	F4 is transmitted		7
7.5		F3 is received. ACK4 is sent	7.5
8	ACK4 is received		8
8.5		F4 is received (No errors)	8.5
9			9
9.5		ACK5 is sent	9.5
10	ACK5 is received. End of Transmission		10

1)

- Sender wants to transmit MSG=10011010
  MSG=10011010 , n=8 corresponds to $M(x) = x^7 + x^4 + x^3 + x^1$
  Divisor=1101 , k=3 corresponds to $G(x) = x^3 + x^2 + 1$
- Multiply $M(x)$ by x^k
  In this example, we get:
  $M(x).x^3 = x^{10} + x^7 + x^6 + x^4$ =10011010000
- Divide result by $G(x)$ =1101 (Subtraction or addition is XOR in polynomial arithmetic)
  The remainder is $E(x) = x^2 + 1$ = 101
- Send $P(x) = M(x).x^k + E(x)$ which is exactly divisible by $G(x)$
  i.e. Send 10011010000 + 101 = 10011010101, since this is exactly divisible by $G(x)$ =1101