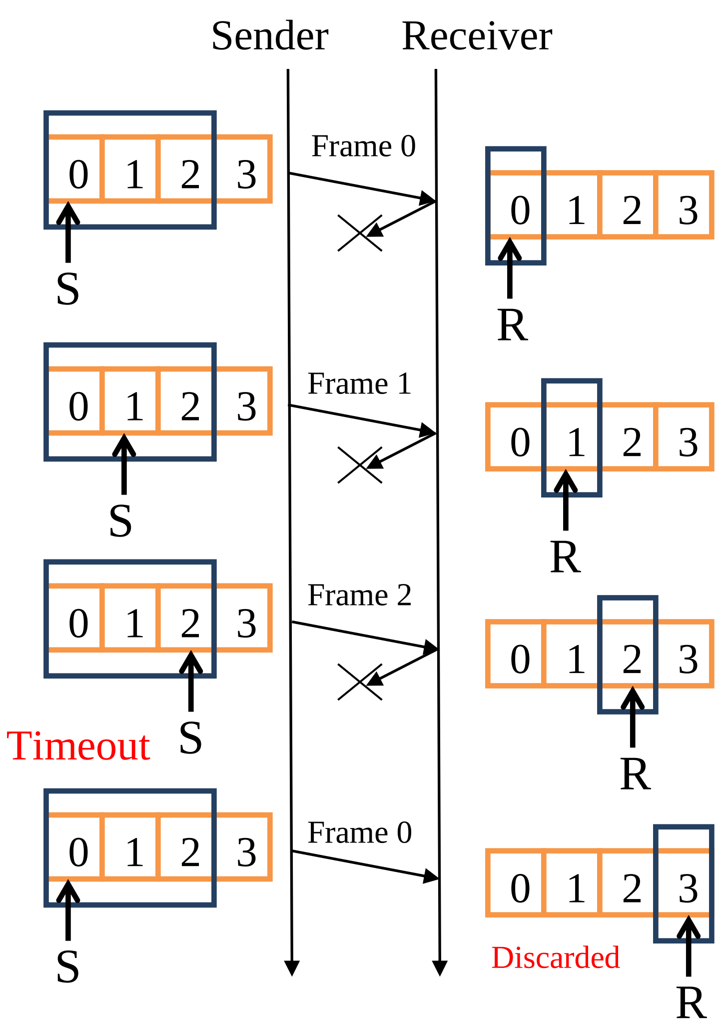
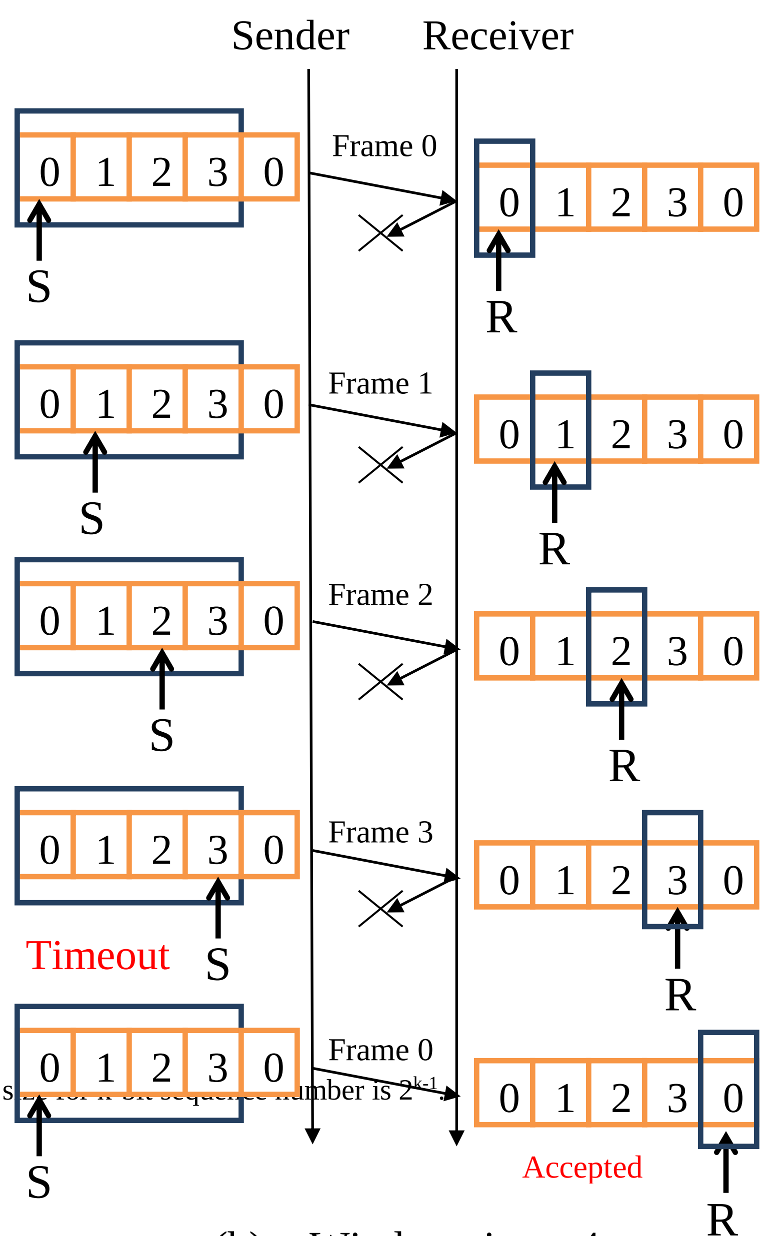
CS425: Computer Networks

Solution of Homework Assignment 4

2) In Go-back-N ARQ mechanism, for a k-bit sequence, the window size should be limited to $2^k - 1$, not 2^k. As an example, if we choose k = 2, i.e. the maximum window size is 3 ($2^k - 1$). Next we compare the window size of 3 and 4 (2^k) as follows:
If the window size is 3 and the acknowledgements of frame 0, 1 and 2 are lost and the frame 0 timer expires, then frame 0 is resent. However the receiver is expecting frame 3, not frame 0, thus this duplicate frame is correctly discarded.
On the other hand if the window size is 4 and the acknowledgements of frame 0, 1, 2 and 3 are lost, the sender sends frame 0 again. This time the receiver expects frame 0. Thus the receiver will erroneously accept frame 0 as the first frame of the next cycle.
This is shown in the following figure **S** and **R** means the sequence number of the frame recently sent and the sequence number of the frame the receiver is expecting respectively.





(a) Window size = 3 (b) Window size = 4

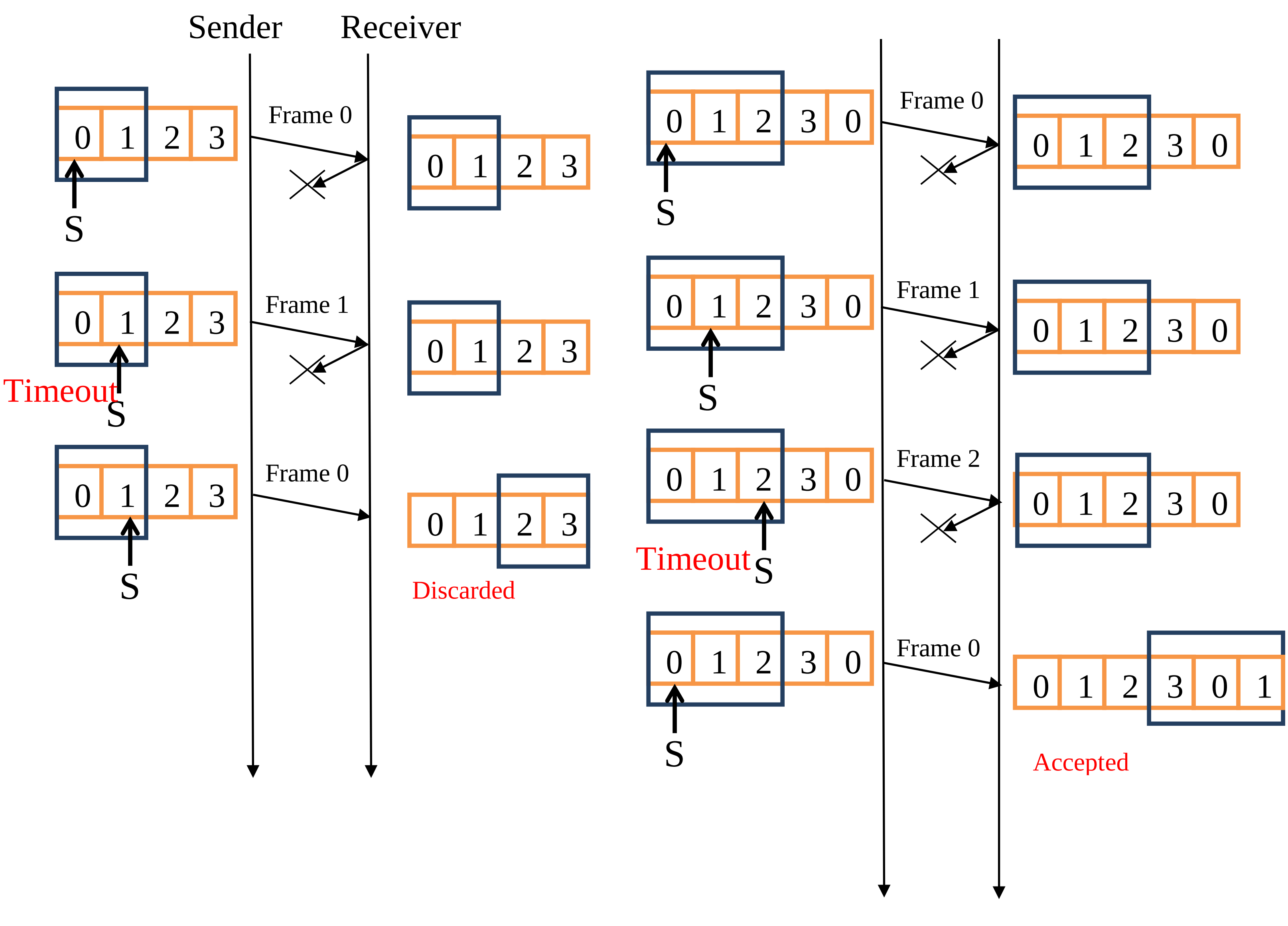
3) In selective-reject ARQ, the maximum window size for k-bit sequence number is 2^{k-1}.

As an example if k = 2, the size of the window should be at most 2 (2^{k-1}). Let us compare the window size of 2 and 3 (2^{k-1} + 1) as follows:

If the window size is 2 and the acknowledgements of frame 0 and 1 are lost and the frame 0 timer expires, then frame 0 is resent. However the receiver is expecting frame 2, not frame 0, thus this duplicate frame is correctly discarded.

On the other hand if the window size is 3 and the acknowledgements of frame 0, 1 and 2 are lost, the sender sends frame 0 again. This time the receiver expects frame 0. Thus the receiver will erroneously accept frame 0 as the first frame of the next cycle.

This is shown in the following figure:



(a) Window size = 2 (b) Window size = 3

4) Let L be the number of bits in a frame. Then, we can write the following equation:

$$a = \frac{\text{Propagation Delay}}{\text{Transmission Time}} = \frac{20 \times 10^{-3}}{L/\left(4 \times 10^{3}\right)} = \frac{80}{L}$$

Given that efficiency is at least 50%. Thus,

$$U = \frac{1}{1+2a} = \frac{1}{1+\left(160/L\right)} \geq 0.5$$

$$L \geq 160$$

Therefore, an efficiency of at least 50% requires a frame size of at least 160 bits.

5) A) Probability that 1 bit is in error is 10^{-3}.

➔ Probability that 1 bit is not in error is $1 - 10^{-3}$.

➔ Probability that 4 bits are not in error is $\left(1 - 10^{-3}\right)^4 = 0.996$ (as probability of error is independent in each bit)

∴ Probability that received frame contains no error is 0.996.

B) Probability that received frame contains at least 1 error = 1 – 0.996 = 0.004.

C) 1 parity bit can detect all odd number of errors but cannot detect any even number of errors. As the frame consists of 5 bits (4 data bits + 1 parity bit), 2 and 4 bit error will remain undetected. Thus, Probability that the frame is in error cannot be detected

= Probability that 2 bits are in error + Probability that 4 bits are in error

$= {}^{5}C_{2} \times \left(10^{-3}\right)^{2} \times \left(1 - 10^{-3}\right)^{3} + {}^{5}C_{4} \times \left(10^{-3}\right)^{4} \times \left(1 - 10^{-3}\right) = 9.97 \times 10^{-6}$.

6)

```
              10110110
110011 / 1110001100000
         110011
         ------
           101111
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```
 110011
  111000
  110011
     101100
     110011
       111110
        10011
          11010
```

Thus, CRC = 11010

7)**a.** Divide $X^{10} + X^7 + X^4 + X^3 + X + 1$ by $X^4 + X + 1$. The remainder is $X^3 + X^2$. The CRC bits are 1100. The string 100100110111100 is sent.

b. The string 000110110111100 is received, corresponding to $X^{11} + X^{10} + X^8 + X^7 + X^5 + X^4 + X^3 + X^2$. The remainder after division by $X^4 + X + 1$ is $X^3 + X^2 + X$, which is nonzero. The errors are detected.

c. The string 000010110111100 is received, corresponding to $X^{10} + X^8 + X^7 + X^5 + X^4 + X^3 + X^2$. The remainder after division by $X^4 + X + 1$ is zero. The errors are not detected.