CS425 Computer Networks

Assignment 2

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Problem 1: Write a program (in any language) that generates an $n - bit$ frame for transmission from a $k - bit$ data block D and a $(n - k + 1)$ bit CRC pattern P.

Instruction to compile the code:

```
g++ -o CRC code.cpp
./CRC
```

- The code will ask for data size and the pattern.
- It generates the data randomly of $size = data\_size$ given above.
- It then generates the CRC frame.
- It then generates a random error pattern and infects the CRC data with it and then checks for presence of a error (Accept or Discarded).

Problem 2: In the Go-back-N ARQ mechanism using $k - bit$ sequence numbers, why is the window size limited to $2^k - 1$ and not 2^k ?

The reason for limiting the window size to $2^k - 1$ in k bit sequence number is so that the transmitter upon receiving of a acknowledgment can distinguish between the following cases:

- Is the acknowledgment a cumulative acknowledgment for all the sent frames.
- Or does the acknowledgment mean that hat all sent frames were damaged or lost in transit, and the receiving station is repeating its previous RR.

For eg:

- Consider case of $3 - bit$ sequence number (i.e. sequence number space is 8)
- Suppose sender sends frame 0 and gets back an RR 1.
- Then sender sends frames $1, 2, 3, 4, 5, 6, 7, 0$ and gets another $RR1$.
- This could mean that all eight frames were received correctly and the $RR1$ is a cumulative acknowledgment.

- It could also mean that all eight frames were damaged or lost in transit, and the receiving station is repeating its previous $RR1$.

This problem could be solved by limiting the window size to $2^k - 1$.

Problem 3: What is the maximum window size that can be used in the Selective-Reject ARQ mechanism that uses $k - bit$ sequence numbers? Explain your answer.

The maximum window size that can be used in Selective-Reject ARQ mechanism that used k bit sequence is 2^{k-1}. The reason for this is to prevent the receiver from misidentifying a frame. If the window size is more than 2^{k-1}, then there is an overlap between the sending and the receiving window. So on receiving of a packet the receiver is unable to identify is a packet is a re-transmission of a already acknowledged packet(probably due to lost acknowledgment) or is the received packet a valid new frame being transmitted due to overlap between sender and receiver window.
For eg:

- Consider the case of a 3-bit sequence number size for selective-reject
- Sender sends frames 0 through 6.
- Receiver receives all seven frames and cumulatively acknowledges with $RR7$.
- Because of a noise, the $RR7$ acknowledgment is lost.
- Sender undergoes a timeout and again re-transmits frame 0 because the sender has not yet received any acknowledgment.
- Since the receiver has already acknowledged previous 7 frames(from 0 to 6), its receiving window is currently $7, 0, 1, 2, 3, 4$ and 5.
- On receiving the re-transmitted frame 0, the receiver thinks that it a new frame 0 and that the frame 7 has been lost. Hence it accepts frame 0 and sends $SREJ7$ to sender.

Problem 4: A channel has a data rate of $4kbps$ and a propagation delay of $20ms$. For what range of frame sizes does stop-and-wait give an efficiency of at least 50%?

Solution:

$$data\_rate = 4kbps$$

$$propagation\_delay(t\_prop) = 20ms = 20 * 10^{-3}s$$

$$U = \frac{1}{1 + 2a}$$

Let us assume that the $frame\_size$ is x kb.

$$t_{frame} = \frac{frame\_size(kb)}{data\_rate(kbps)} = \frac{x}{4}s$$

$$a = \frac{t_{prop}}{t_{frame}} = \frac{20 * 10^{-3} * 4}{x} = \frac{8 * 10^{-2}}{x}$$

For efficiency of atleast 50%,

$$U = \frac{1}{1+2a} \geq 0.5 \implies 1 + 2a \leq 2 \implies 2a \leq 1$$

$$a \leq \frac{1}{2} \implies \frac{8 * 10^{-2}}{x} \leq \frac{1}{2} \implies x \geq 0.16kb$$

Hence the minimum frame size should be 160 bits for efficiency of atleast 50%.

Problem 5: Consider a frame consists of one character of 4 bits. Assume that the probability of bit error is 10^{-3} and that it is independent in each bit.

$$P(bit\_error) = 10^{-3}$$
$$P(single\_bit\_no\_error) = 1 - 10^{-3} = 0.999$$

The bit errro probability is independent for each bit.

(a) What is the probability that the received frame contains no errors?

Solution:

$$P(no\_error) = P(1^{st}bit\_no\_error)*P(2^{nd}bit\_no\_error)*P(3^{rd}bit\_no\_error)*P(4^{th}bit\_no\_error)$$
$$P(no\_error) = (0.999)^4 = 0.996$$

(b) What is the probability that the received frame contains at least one error?

Solution:

$$P(at\_least\_one\_error) + P(no\_error) = 1$$
$$P(at\_least\_one\_error) = 1 - P(no\_error) = 1 - 0.996 = 0.004$$

(c) Now assume that one parity bit is added. What is the probability that the frame is received with errors that are not detected?

Solution: One Parity bit is added. We need to calculate probability of frame received with error but not detected.

- **Case 1: Parity bit is correct in received frame**
  In this case there can be even number of bits that can be flipped for the error to remain undetected.

$$P(Undetected\_Error\_Correct\_Parity) = P(Correct\_Parity)*(P(2\_bit\_error)+P(4\_bit\_error))$$
$$= (1 - 0.001) * ({}^4C_2(0.001)^2(0.999)^2 + {}^4C_4(0.001)^4) = 5.98 * 10^{-6}$$

- **Case 2: Parity bit is incorrect in received frame**
  In this case there can be odd number of bits that can be flipped for the error to remain undetected.

$$P(Undetect\_Error\_Incorrect\_Parity) = P(Incorrect\_Parity)*(P(1\_bit\_error)+P(3\_bit\_error))$$

$$= 0.001 * ({}^4C_1(0.001)(0.999)^3 + {}^4C_3(0.001)^3(0.999)) = 3.988 * 10^{-6}$$

So finally,

$$P(Undetected\_Error) = P(Undetected\_Error\_Correct\_Parity)+$$

$$P(Undetected\_Error\_Incorrect\_Parity)$$

$$= 9.968 * 10^{-6}$$

Problem6: For $P = 110011$ and $M = 11100011$, find the CRC.

Solution:

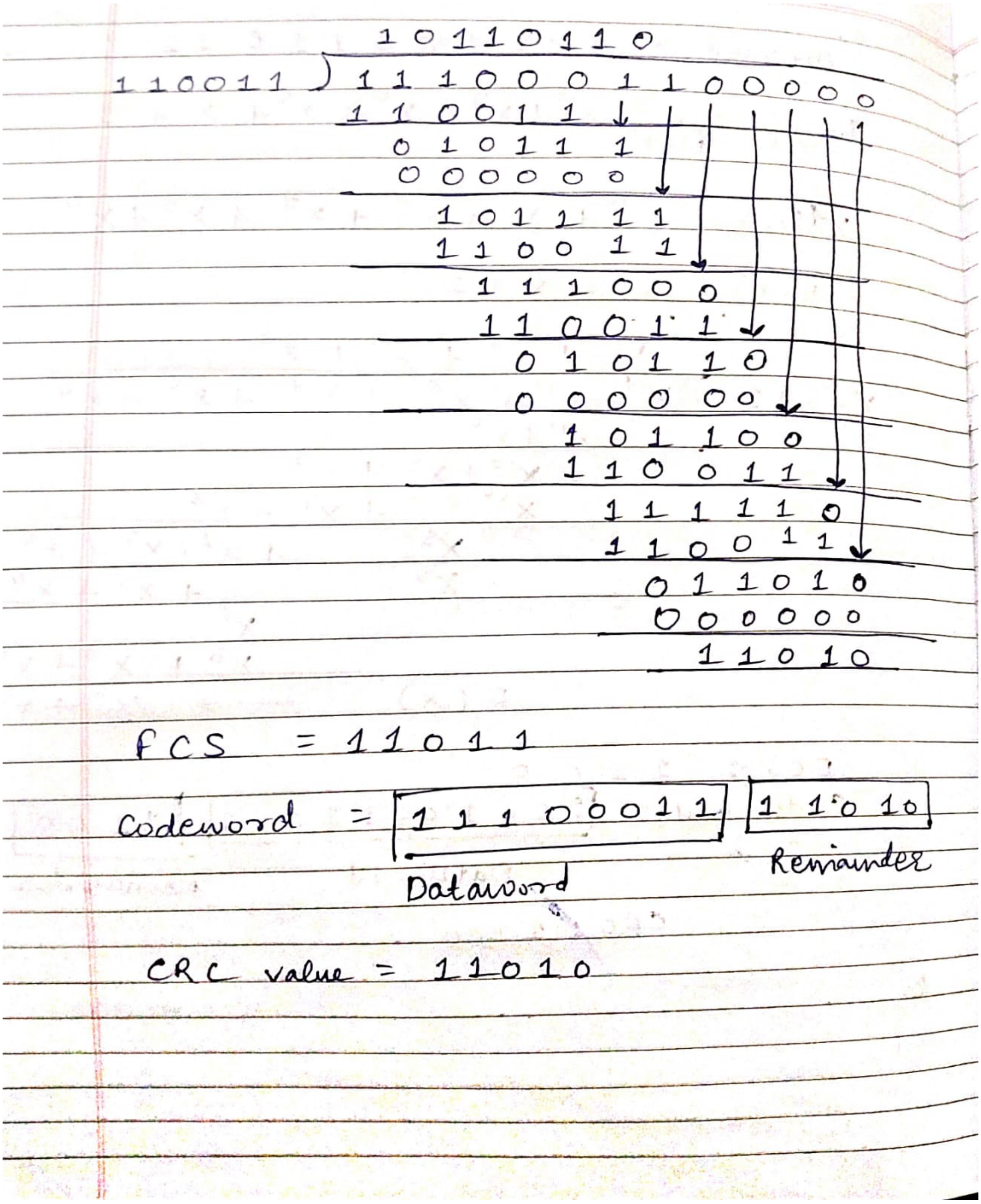
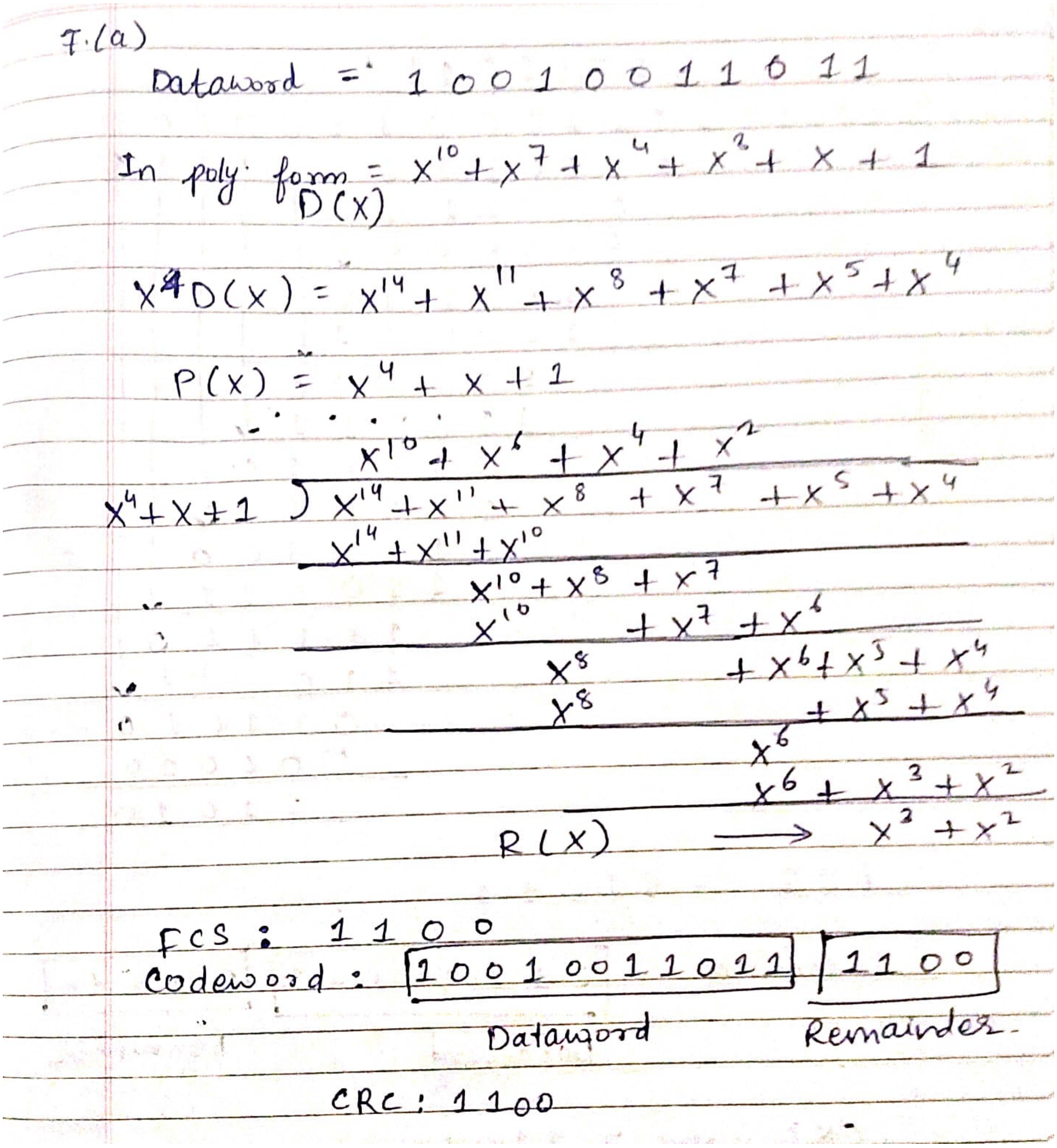


Figure 1: CRC Derivation from Modulo 2 Method

Problem7: (a) In a CRC error-detecting scheme, choose $P(x) = X^4 + X + 1$. Encode the bits 10010011011.



7.(a)

Dataword = 1 0 0 1 0 0 1 1 0 1 1

In poly form $D(x) = x^{10} + x^7 + x^4 + x^3 + x + 1$

$x^4 D(x) = x^{14} + x^{11} + x^8 + x^7 + x^5 + x^4$

$P(x) = x^4 + x + 1$

$$
\begin{array}{r|l}
 & x^{10} + x^6 + x^4 + x^2 \\
\hline
x^4 + x + 1 & x^{14} + x^{11} + x^8 + x^7 + x^5 + x^4 \\
 & x^{14} + x^{11} + x^{10} \\
\hline
 & x^{10} + x^8 + x^7 \\
 & x^{10} + x^7 + x^6 \\
\hline
 & x^8 + x^6 + x^5 + x^4 \\
 & x^8 + x^5 + x^4 \\
\hline
 & x^6 \\
 & x^6 + x^3 + x^2 \\
\hline
 & x^3 + x^2
\end{array}
$$

$R(x) \longrightarrow x^3 + x^2$

FCS : 1 1 0 0

Codeword : $\underbrace{\boxed{1\,0\,0\,1\,0\,0\,1\,1\,0\,1\,1}}_{\text{Dataword}}\ \underbrace{\boxed{1\,1\,0\,0}}_{\text{Remainder}}$

CRC : 1100

Figure 2: CRC Derivation from Polynomial Method

Problem 7: (b) Suppose the channel introduces an error pattern 100010000000000 (i.e., a flip from 1 to 0 or from 0 to 1 in position 1 and 5). What is received? Can the error be detected?

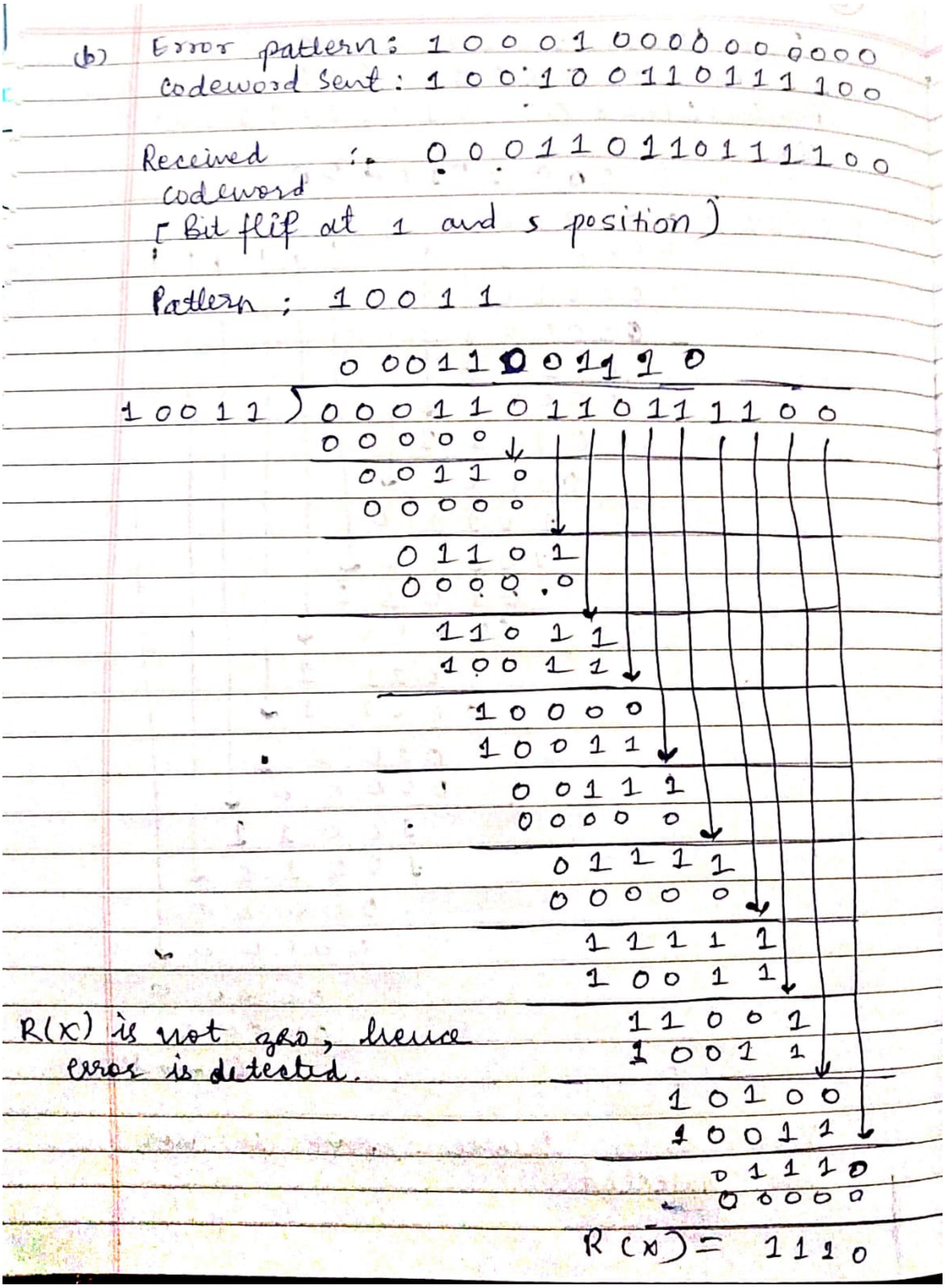


Figure 3: Error Detection

Problem 7: (c). Repeat part (b) with error pattern 100110000000000.

(c) Error Pattern: 1 0 0 1 1 0 0 0 0 0 0 0 0 0 0

Codeword sent: 1 0 0 1 0 0 1 1 0 1 1 1 1 0 0

Received Codeword: 0 0 0 0 1 0 1 1 0 1 1 1 1 0 0

```
                0 0 0 0 1 0 1 0 1 0 0
        ___________________________________
10011 ) 0 0 0 0 1 0 1 1 0 1 1 1 1 0 0
        0 0 0 0 0
        ---------
          0 0 0 1 0
          0 0 0 0 0
          ---------
            0 0 1 0 1
            0 0 0 0 0
            ---------
              0 1 0 1 1
              0 0 0 0 0
              ---------
                1 0 1 1 0
                1 0 0 1 1
                ---------
                  0 1 0 1 1
                  0 0 0 0 0
                  ---------
                    1 0 1 1 1
                    1 0 0 1 1
                    ---------
                      0 1 0 0 1
                      0 0 0 0 0
                      ---------
                        1 0 0 1 1
                        1 0 0 1 1
                        ---------
                          0 0 0 0 0
                          0 0 0 0 0
                          ---------
                            0 0 0 0 0
                            0 0 0 0 0
                            ---------
                                    0 → R(x).
```

R(x) is 0, hence error is not detected.

Figure 4: Error Detection