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(a)
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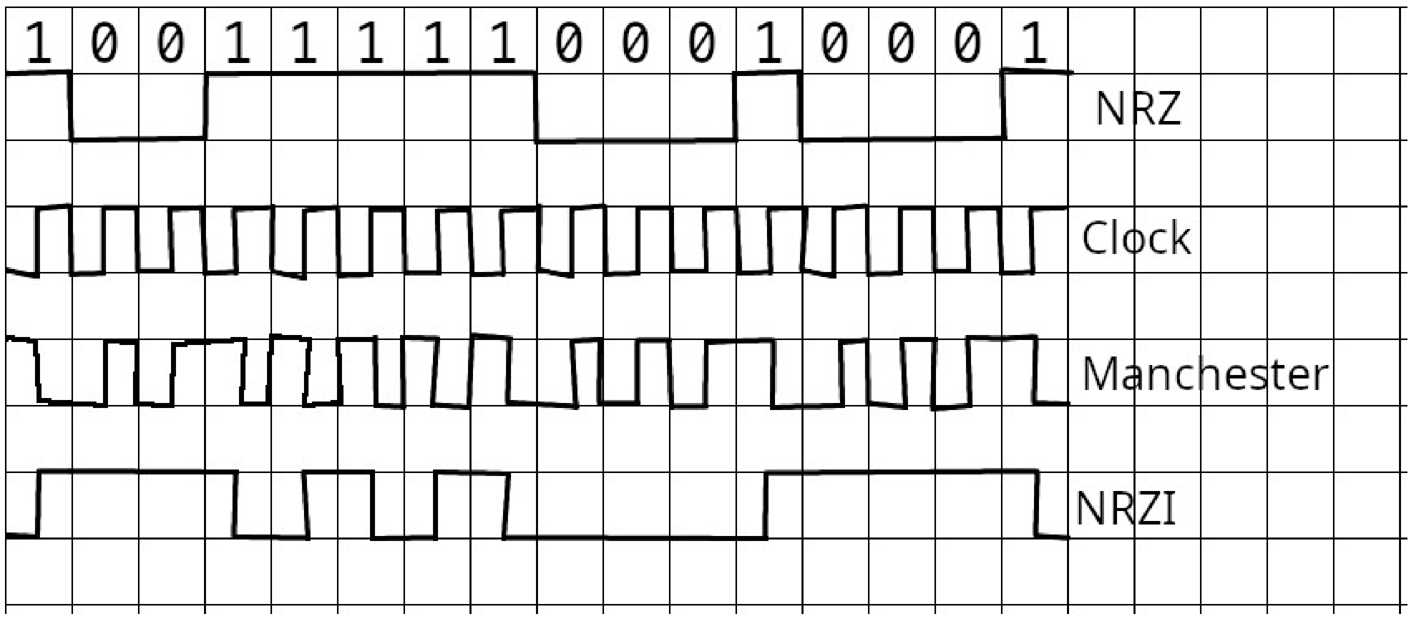
Question 12:

Question 1.

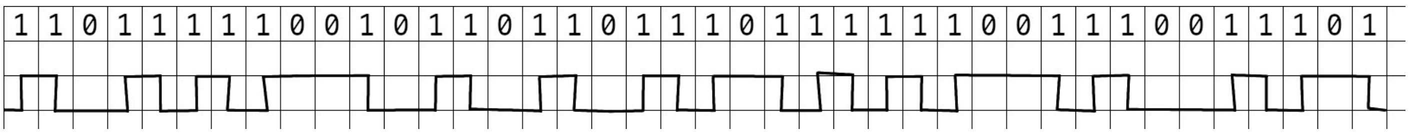


Question 2.

`1101 1110 1010 1101 1011 1110 1110 1111`

`turns into:`

`11011 11100 10110 11011 10111 11100 11100 11101`



Question 3.

(a)

`01111110 10100111 11111000 11110010 10011111 10111111 11100101`

`turns into:`

`011111010 10100111 110111000 11110010 100111110 101111101 11100101`

(b)

`00111111 01110001 11110011 11111100 10101010 11001111 11100001`

`turns into:`

`001111101 01110001 111100011 111011100 10101010 11001111 101100001`

(c)

`11111111 11111111 11111111 11111111 11111111 11111111 11111111`

`turns into:`

`111110111 1101111101 111101111 1011111011 111011111 0111110111 1101111101`

Question 4.

```
011010111110101001111111011001111110
turns into:
01101011111101001111111011001111110
                      ^ error, there's 7 consecutive 1's
```

Question 5.

(a)

```
          1011000101011101
100000111)101100100100101100000000
          100000111
            110001110
            100000111
             100010010
             100000111
                 101011011
                 100000111
                   101110000
                   100000111
                     111011100
                     100000111
                      110110110
                      100000111
                       101100010
                       100000111
                         110010100
                         100000111
                          10010011
```

So the remainder is 10010011, so we will subtract that from the message using logical XOR:

$$\begin{array}{rr} & 101100100100101100000000 \\ \oplus & 10010011 \\ \hline & 101100100100101110010011 \end{array}$$

So the final message to send is: 101100100100101110010011

(b)

If the left most bit is inverted due to noise, then the new message will be: 0011001001001011110010011
In that case, the long division will give us:

```
            11001011010111
100000111)0011001001001011110010011
            100000111
             100101010
             100000111
                101101101
                100000111
                  110101011
                  100000111
                   101011000
                   100000111
                     101111101
                     100000111
                       111101000
                       100000111
                        111011111
                        100000111
                         110110001
                         100000111
                           10110110
```

Which isn't a remainder of 0. This means that an error has occurred because the remainder of the message must be 0

Question 6.

(1)

00111100
10110101

So the hamming distance is 3

(2)

10110101
00001111 = Hamming distance 5

10110101
01010101 = Hamming distance 3

10110101
00111100 = Hamming distance 3

10110101
10000000 = Hamming distance 4

10110101
11110111 = Hamming distance 2

10110101
11111111 = Hamming distance 3

So the most likely transmitted codeword is 11110111

(3)

1, 10, 11, 100, 101, 110, 111, 1000, 1001, 1010, 1011
bit number 1, 2, 4, and 8 are parity bits
the rest are all data bits.

So we have 4 parity bits.

(4)

Total bits is 4 parity + 7 bits = 11 bits.

(5)

let R be a redundant parity bit. Then the message would look like:

`1 0 1 R 1 0 0 R 1 R R`

(6)

$$\underset{0001}{R1}\quad \underset{0010}{R2}\quad \underset{0011}{1}\quad \underset{0100}{R3}\quad \underset{0101}{0}\quad \underset{0110}{0}\quad \underset{0111}{1}\quad \underset{1000}{R4}\quad \underset{1001}{1}\quad \underset{1010}{0}\quad \underset{1011}{1}$$

$R1 = 0$

$$\underset{0001}{0}\quad \underset{0010}{R2}\quad \underset{0011}{1}\quad \underset{0100}{R3}\quad \underset{0101}{0}\quad \underset{0110}{0}\quad \underset{0111}{1}\quad \underset{1000}{R4}\quad \underset{1001}{1}\quad \underset{1010}{0}\quad \underset{1011}{1}$$

$R2 = 1$

$$\underset{0001}{0}\quad \underset{0010}{1}\quad \underset{0011}{1}\quad \underset{0100}{R3}\quad \underset{0101}{0}\quad \underset{0110}{0}\quad \underset{0111}{1}\quad \underset{1000}{R4}\quad \underset{1001}{1}\quad \underset{1010}{0}\quad \underset{1011}{1}$$

$R3 = 1$

$$\underset{0001}{0}\quad \underset{0010}{1}\quad \underset{0011}{1}\quad \underset{0100}{1}\quad \underset{0101}{0}\quad \underset{0110}{0}\quad \underset{0111}{1}\quad \underset{1000}{R4}\quad \underset{1001}{1}\quad \underset{1010}{0}\quad \underset{1011}{1}$$

$R4 = 0$

$$\underset{0001}{0}\quad \underset{0010}{1}\quad \underset{0011}{1}\quad \underset{0100}{1}\quad \underset{0101}{0}\quad \underset{0110}{0}\quad \underset{0111}{1}\quad \underset{1000}{0}\quad \underset{1001}{1}\quad \underset{1010}{0}\quad \underset{1011}{1}$$

(7)

`1 0 1 0 1 0 0 1 1 1 0`

after tramsmission:

`1 0 1 0 1 1 0 1 1 1 0`

(8)

$$\underset{0001}{R1}\quad \underset{0010}{R2}\quad \underset{0011}{1}\quad \underset{0100}{R3}\quad \underset{0101}{0}\quad \underset{0110}{0}\quad \underset{0111}{1}\quad \underset{1000}{R4}\quad \underset{1001}{1}\quad \underset{1010}{0}\quad \underset{1011}{1}$$

turns to:

$$\underset{0001}{0} \quad \underset{0010}{1} \quad \underset{0011}{1} \quad \underset{0100}{1} \quad \underset{0101}{0} \quad \underset{0110}{0} \quad \underset{0111}{1} \quad \underset{1000}{0} \quad \underset{1001}{1} \quad \underset{1010}{0} \quad \underset{1011}{1}$$

(9)

The redundant bits sequence is 0110, which is 6. It matches my expectations since that's the bit that has been flipped.

Question 7.

(a)

$$\text{dB} = 10 \times \log_{10}\left(\frac{S}{N}\right)$$

$$20 = 10 \times \log_{10}\left(\frac{S}{N}\right)$$

$$\log_{10}\left(\frac{S}{N}\right) = 2$$

$$\frac{S}{N} = 100$$

$$\begin{aligned} C &= B \times \log_2\left(1 + \frac{S}{N}\right) \\ &= 16\ 000 \times \log_2(1 + 100) \\ &= 16\ 000 \times \log_2(101) \\ &\approx 106\ 531.3837 \text{ bits/second} \end{aligned}$$

(b)

$$
\begin{aligned}
C &= B \times \log_2\left(1 + \frac{S}{N}\right) \\
50\ 000 &= 1\ 000\ 000 \times \log_2\left(1 + \frac{S}{N}\right) \\
\log_2\left(1 + \frac{S}{N}\right) &= \frac{1}{20} \\
1 + \frac{S}{N} &= 2^{\frac{1}{20}} \\
\frac{S}{N} &= 2^{\frac{1}{20}} - 1 \\
&\approx 0.035265
\end{aligned}
$$

For the minimum signal-to-noise ratio, there is significantly more noise than signal.

Question 8.

Band	Range (Hz)	10dB Capacity	20dB Capacity	30dB Capacity
Narrowband	300-3400	10724.238018	20640.455597	30898.40140
Wideband	50-7000	24043.04975	46274.56981	69272.22250
Super-wideband	50-14000	48259.07108	92882.05018	139042.80631
Fullband	20-20000	69119.44374	133031.065425	199145.18065

10dB

$$10\text{dB} = 10 \times \log_{10}\left(\frac{S}{N}\right)$$
$$\log_{10}\left(\frac{S}{N}\right) = 1$$
$$\frac{S}{N} = 10$$

for Narrowband

$B = 3400 - 300 = 3100$

$$C = 3100 \times \log_2(1 + 10)$$
$$\approx 10724.238018 \text{ bits/second}$$

for Wideband

$B = 7000 - 50 = 6950$

$$C = 6950 \times \log_2(1 + 10)$$
$$\approx 24043.04975 \text{ bits/second}$$

for Super-wideband

$B = 14000 - 50 = 13950$

$$C = 13950 \times \log_2(1 + 10)$$
$$\approx 48259.07108 \text{ bits/second}$$

for Fullband

$B = 20000 - 20 = 19980$

$$C = 19980 \times \log_2(1 + 10)$$
$$\approx 69119.44374 \text{ bits/second}$$

20dB

$$20\text{dB} = 10 \times \log_{10}\left(\frac{S}{N}\right)$$
$$\log_{10}\left(\frac{S}{N}\right) = 2$$
$$\frac{S}{N} = 100$$

for Narrowband

$$B = 3400 - 300 = 3100$$

$$\begin{aligned} C &= 3100 \times \log_2(1 + 100) \\ &\approx 20640.455597 \text{ bits/second} \end{aligned}$$

for Wideband

$$B = 7000 - 50 = 6950$$

$$\begin{aligned} C &= 6950 \times \log_2(1 + 100) \\ &\approx 46274.56981 \text{ bits/second} \end{aligned}$$

for Super-wideband

$$B = 14000 - 50 = 13950$$

$$\begin{aligned} C &= 13950 \times \log_2(1 + 100) \\ &\approx 92882.05018 \text{ bits/second} \end{aligned}$$

for Fullband

$$B = 20000 - 20 = 19980$$

$$\begin{aligned} C &= 19980 \times \log_2(1 + 100) \\ &\approx 133031.065425 \text{ bits/second} \end{aligned}$$

30dB

$$30\text{dB} = 10 \times \log_{10}\left(\frac{S}{N}\right)$$
$$\log_{10}\left(\frac{S}{N}\right) = 3$$
$$\frac{S}{N} = 1000$$

for Narrowband

$$B = 3400 - 300 = 3100$$

$$\begin{aligned} C &= 3100 \times \log_2(1 + 1000) \\ &\approx 30898.40140 \text{ bits/second} \end{aligned}$$

for Wideband

$$B = 7000 - 50 = 6950$$

$$\begin{aligned} C &= 6950 \times \log_2(1 + 1000) \\ &\approx 69272.22250 \text{ bits/second} \end{aligned}$$

for Super-wideband

$$B = 14000 - 50 = 13950$$

$$\begin{aligned} C &= 13950 \times \log_2(1 + 1000) \\ &\approx 139042.80631 \text{ bits/second} \end{aligned}$$

for Fullband

$$B = 20000 - 20 = 19980$$

$$\begin{aligned} C &= 19980 \times \log_2(1 + 1000) \\ &\approx 199145.18065 \text{ bits/second} \end{aligned}$$

Question 9.

Let blank cell = distance ∞

	A	B	C	D	E	F
A	0	2		5		
B	2	0	2		1	
C		2	0	2		3
D	5		2	0		
E		1			0	3
F			3		3	0

A:

Destination	Cost	NextHop
B	2	B
C		
D	5	D
E		
F		

Destination	Cost	NextHop
B	2	B
C	4	B
D	5	D
E	3	B
F		

Destination	Cost	NextHop
B	2	B
C	4	B
D	5	D
E	3	B
F	6	E

B:

Destination	Cost	NextHop
A	2	A
C	2	C
D		
E	1	E
F		

Destination	Cost	NextHop
A	2	A
C	2	C
D	4	C
E	1	E
F	4	E

Destination	Cost	NextHop
A	2	A
C	2	C
D	4	C
E	1	E
F	4	E

C:

Destination	Cost	NextHop
A		
B	2	B
D	2	D
E		
F	3	F

Destination	Cost	NextHop
A	4	B
B	2	B
D	2	D
E	3	B
F	3	F

Destination	Cost	NextHop
A	4	B
B	2	B
D	2	D
E	3	B
F	3	F

D:

Destination	Cost	NextHop
A	5	A
B		
C	2	C
E		
F		

Destination	Cost	NextHop
A	5	A
B	4	C
C	2	C
E		
F	5	C

Destination	Cost	NextHop
A	5	A
B	4	C
C	2	C
E	5	C
F	5	C

E:

Destination	Cost	NextHop
A		
B	1	B
C		
D		
F	3	F

Destination	Cost	NextHop
A	3	B
B	1	B
C	3	B
D		
F	3	F

Destination	Cost	NextHop
A	3	B
B	1	B
C	3	B
D	5	C
F	3	F

F:

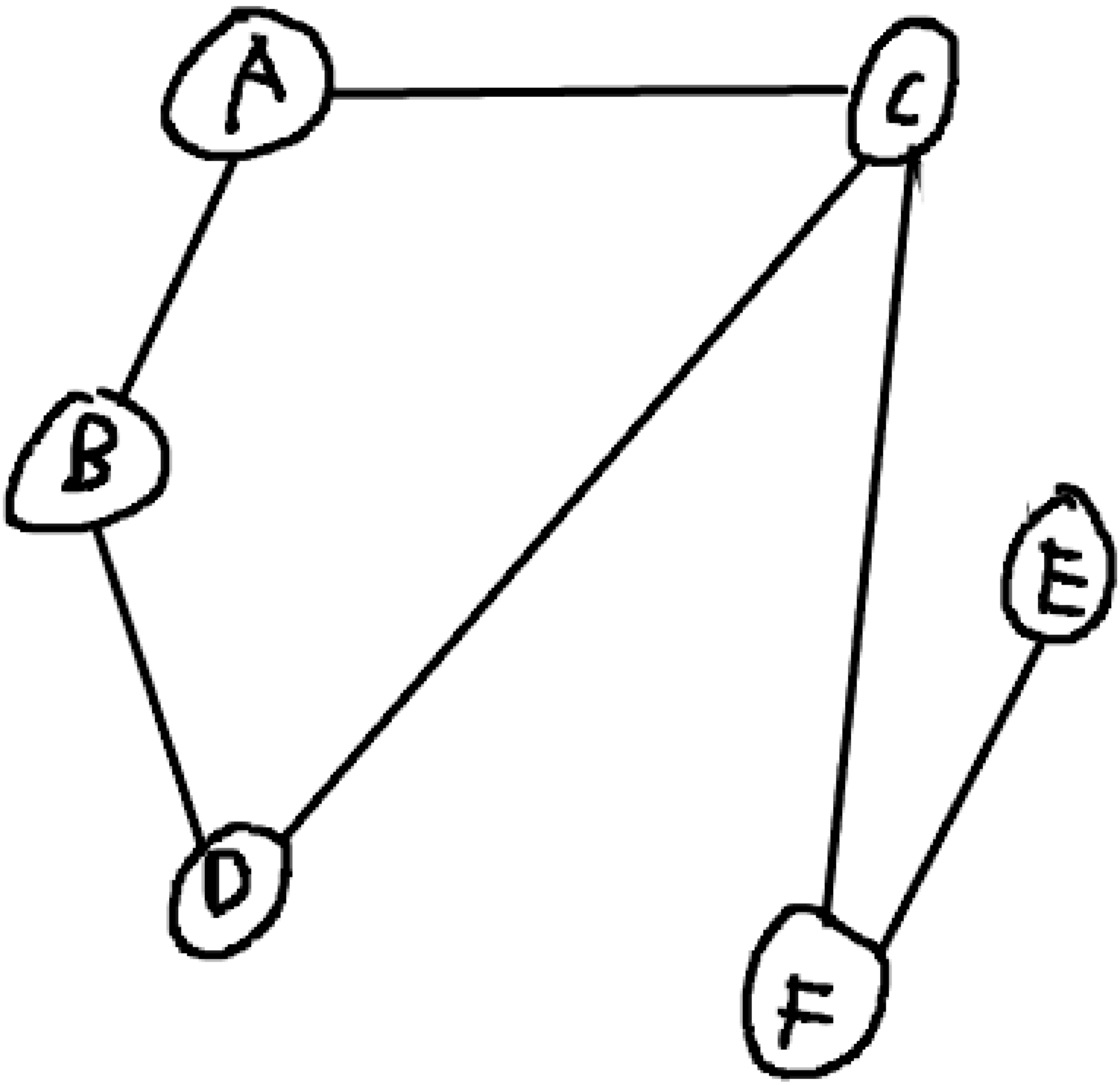
Destination	Cost	NextHop
A		
B		
C	3	C
D		
E	3	E

Destination	Cost	NextHop
A		
B	4	E
C	3	C
D	5	C
E	3	E

Destination	Cost	NextHop
A	6	B
B	4	E
C	3	C
D	5	C
E	3	E

	A	B	C	D	E	F
A	0	2	4	5	3	6
B	2	0	2	4	1	4
C	4	2	0	2	3	3
D	5	4	2	0	5	5
E	3	1	3	5	0	3
F	6	4	3	5	3	0

Question 10.



Question 11.

(a)

`128.96.171.92 AND 255.255.254.0 = 128.96.170.0`

`128.96.171.92 AND 255.255.252.0 = 128.96.168.0`

So it sends the packet to Interface 0

(b)

`128.96.167.151 AND 255.255.254.0 = 128.96.166.0`

`128.96.167.151 AND 255.255.252.0 = 128.96.164.0`

So it sends the packet to R2

(c)

`128.96.163.151 AND 255.255.254.0 = 128.96.162.0`

`128.96.163.151 AND 255.255.252.0 = 128.96.160.0`

So it sends the packet to R4 (no match)

(d)

`128.96.169.192 AND 255.255.254.0 = 128.96.168.0`

`128.96.169.192 AND 255.255.252.0 = 128.96.168.0`

So it sends the packet to Interface 1

(e)

`128.96.165.121 AND 255.255.254.0 = 128.96.164.0`

`128.96.165.121 AND 255.255.252.0 = 128.96.164.0`

So it sends the packet to R3

Question 12.

Step	Confirmed	Tentative
1	(A,0,-)	
2	(A,0,-)	(B,1,B) (D,5,D)
3	(A,0,-) (B,1,B)	(D,5,D)
4	(A,0,-) (B,1,B)	(D,4,B) (C,5,D)
5	(A,0,-) (B,1,B) (D,4,B)	(C,5,D)
6	(A,0,-) (B,1,B) (D,4,B) (C,5,D)	(C,5,D) (E,6,C)
7	(A,0,-) (B,1,B) (D,4,B) (C,5,D)	(E,6,C)
8	(A,0,-) (B,1,B) (D,4,B) (C,5,D) (E,6,C)	