Problems:

- **<u>Problem 1</u>**

  A complex low-pass signal has a bandwidth of 200 kHz. What is the minimum sampling rate for this signal?

- **Answer:**

  The bandwidth of a low-pass signal is between 0 and f, where f is the maximum frequency in the signal. Therefore, we can sample this signal at 2 times the highest frequency (200 kHz). The sampling rate is therefore 400,000 samples per second.

- **Problem 2**

  We want to digitize the human voice. What is the bit rate, assuming 8 bits per sample?

- **<u>Problem 2</u>**

  We want to digitize the human voice. What is the bit rate, assuming 8 bits per sample?

Solution

The human voice normally contains frequencies from 0 to 4000 Hz. So the sampling rate and bit rate are calculated as follows:

$$\boxed{\begin{array}{c}\text{Sampling rate} = 4000 \times 2 = 8000 \text{ samples/s} \\ \text{Bit rate} = 8000 \times 8 = 64{,}000 \text{ bps} = 64 \text{ kbps}\end{array}}$$

- **<u>Problem-3</u>**

3. Suppose that a frequency band W Hz wide is divided into M channels of equal bandwidth.

   a. What bit rate is achievable in each channel? Assume all channels have the same SNR.

   b. What bit rate is available to each of M users if the entire frequency band is used as a single channel and TDM is applied?

   c. How does the comparison of (a) and (b) change if we suppose that FDM requires a guard band between adjacent channels? Assume the guard band is 10% of the channel bandwidth.

- Answer:

Bit rate = BW* $\text{Log}_2(1+\text{SNR})$ bps (Shannons channel capacity theorem)

a. What bit rate is achievable in each channel? Assume all channels have the same SNR.

Each user uses *W/M* bandwidth. Using Shannon's Channel Capacity formula:

$$\text{Bit rate} = \left(\frac{W}{M}\right)\log_2(1+SNR) \text{ bps}$$

b. What bit rate is available to each of *M* users if the entire frequency band is used as a single channel and TDM is applied?

In this case, the total bit rate afforded by the *W* Hz is divided equally among all users:

$$\text{Bit rate} = \frac{W\log_2(1+SNR)}{M} \text{ bps}$$

c. How does the comparison of (a) and (b) change if we suppose that FDM requires a guard band between adjacent channels? Assume the guard band is 10% of the channel bandwidth.

Because of the guard band we expect that the scheme in (b) will be better since the bit rate in (a) will be reduced. In (a), the bandwidth usable by each channel is 0.9*W*/*M*. Thus, we have:

$$\text{Bit rate} = (0.9\frac{W}{M})\log_2(1+SNR) \text{ bps}$$

Problem 4:

Explain where the following fit in the OSI reference model:

a. A 4 kHz analog connection across the telephone network.

b. A 33.6 kbps modem connection across the telephone network.

c. A 64 kbps digital connection across the telephone network.

a. A 4 kHz analog connection across the telephone network.

Physical Layer: the actual 4 kHz analog signal exists only in the physical layer of the OSI reference model.

b. A 33.6 kbps modem connection across the telephone network.

Data-Link Layer: a 33.6 kbps modem uses framing, flow-control, and error correction to connect a user to the switch.

c. A 64 kbps digital connection across the telephone network.

Physical Layer: the digital link across the network is controlled by many higher layer functions, but the 64 kbps signal that carries user information is analogous to the 4 kHz signal used over the twisted pair that runs to the user's premises.

Problem 5:

Give a daily life example for Time Division Multiplexing.
Give a daily life example for Frequency Division Multiplexing.
Give a daily life example for Code Division Multiplexing.

Solution: TDM—appointments for meeting, questioning in lecture based on the instructor's ordering, Doctor's appointments etc.

FDM—AM/FM radio, TV, etc.

CDM—conversations using different languages, party with background music (not exactly orthogonal coding scheme), some cell phones.

Problem 6:

A2: *Give a scenario in which circuit switching is more efficient than the packet switching. Give an example to show that packet switching is better than circuit switching.*

Solution: CS is better than PS—huge data transfer, highly reliable data transfer etc

PS is better than PS—less reliable data transfer, control messages exchanges, best effort data services...etc.

Problem 7:

Assume that a voice channel occupies a bandwidth of 4 kHz. We need to multiplex 10 voice channels with gaurd bands of 500 Hz using FDM. Calculate the required bandwidth.

Answer:

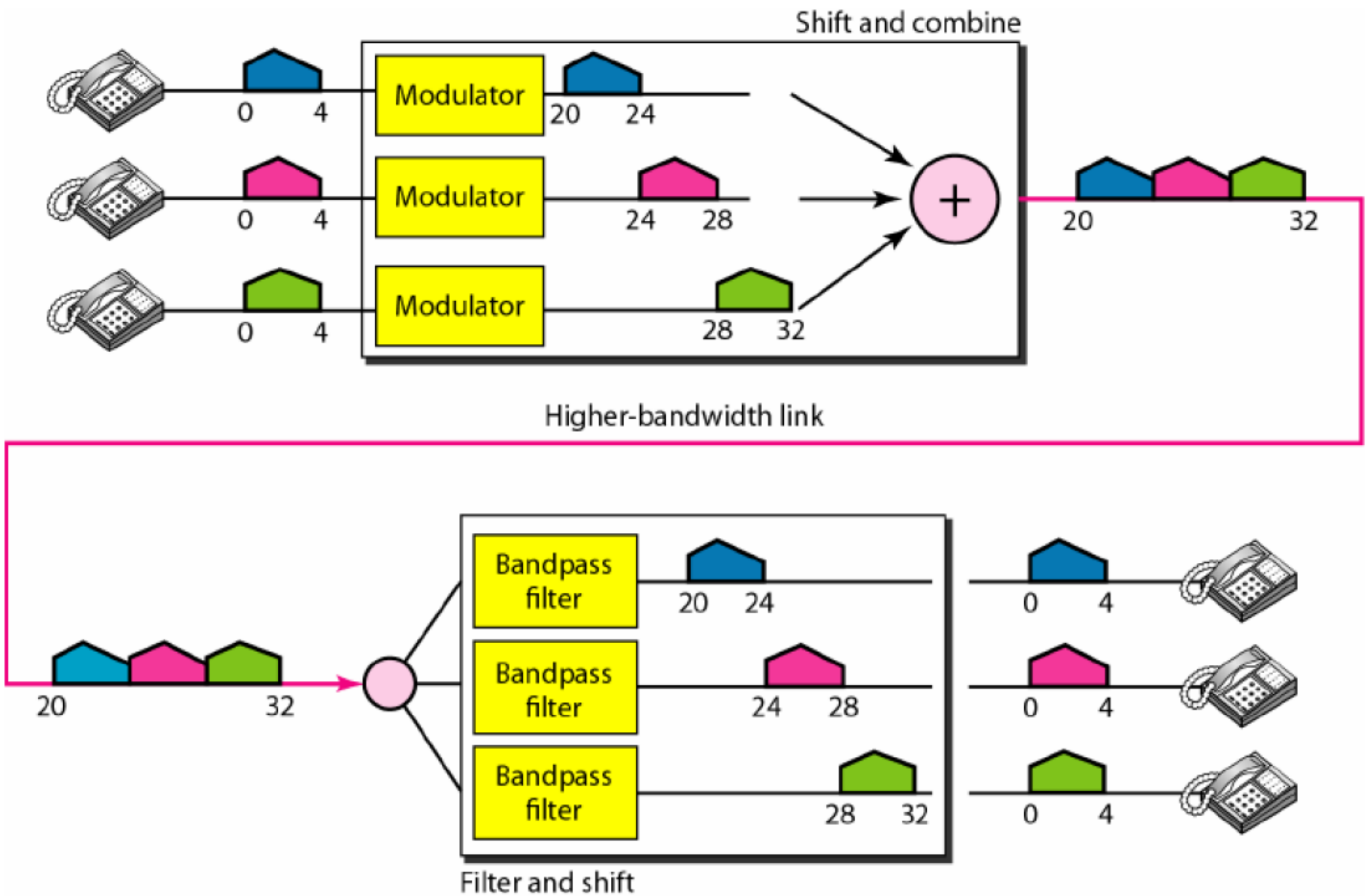
To multiplex 10 voice channels, we need nine guard bands. The required bandwidth is then

$B = (4\ \text{KHz}) \times 10 + (500\ \text{Hz}) \times 9 =$ **44.5 KHz**

Problem 9

Assume that a voice channel occupies a bandwidth of 4 kHz. We need to combine three voice channels into a link with a bandwidth of 12 kHz, from 20 to 32 kHz. Show the configuration, using the frequency domain. Assume there are no guard bands.

Answer:



Shift and combine
Modulator
Modulator
Modulator
0
4
0
4
0
4
20
24
24
28
28
32
+
20
32
Higher-bandwidth link
20
32
Bandpass filter
Bandpass filter
Bandpass filter
20
24
24
28
28
32
0
4
0
4
0
4
Filter and shift

Problem 10

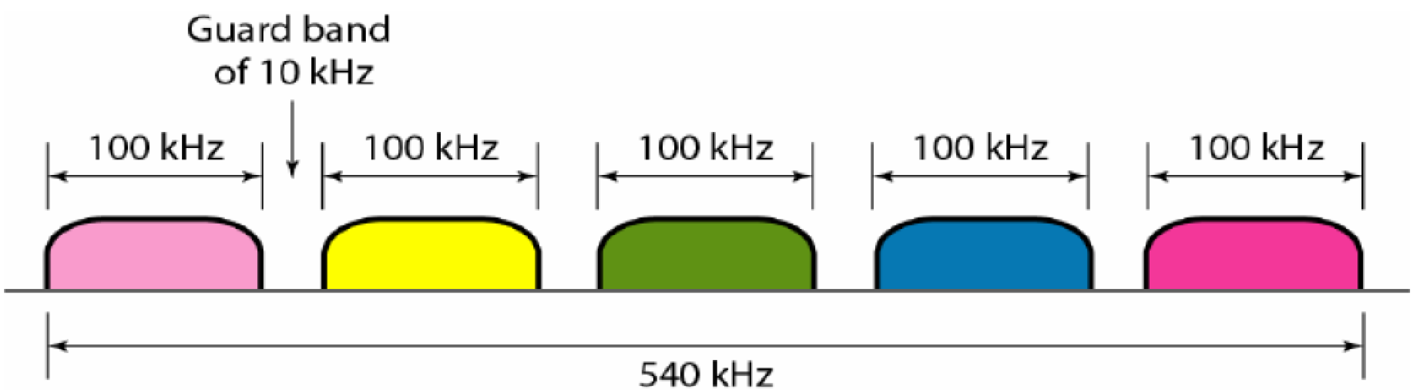
Five channels, each with a 100-kHz bandwidth, are to be multiplexed together. What is the minimum bandwidth of the link if there is a need for a guard band of 10 kHz between the channels to prevent interference?

Solution

For five channels, we need at least four guard bands. This means that the required bandwidth is at least

$$5 \times 100 + 4 \times 10 = 540 \text{ kHz}$$

as shown in the figure below.



Problem 8

Compute the Fourier coefficients for the function $f(t) = t$ $(0 \leq t \leq 1)$.

Answer:

ANS:

$$a_n = \frac{2}{T}\int_0^T g(t)\sin(2\pi nft)dt = 2\int_0^1 t\sin(2\pi nft)dt \Rightarrow \text{ Assume that } 2\pi nt = a \Rightarrow$$

$$2\int_0^1 \frac{a}{2\pi n}\sin(a)\frac{da}{2\pi n} = \frac{1}{2\pi^2 n^2}\int_0^1 a\sin a da = \frac{1}{2\pi^2 n^2}\int_0^1 x\sin x dx$$

$$x = u \Rightarrow dx = du$$

$$\sin x dx = dv \Rightarrow -\cos x = v$$

$$\frac{1}{2\pi^2 n^2}\int_0^1 (x(-\cos x) - \int_0^1 -\cos x dx)dx = \frac{1}{2\pi^2 n^2}\int_0^1 (-\cos x * x + \sin x)dx$$

$$= \frac{1}{2\pi^2 n^2}\int_0^1 (-\cos(2\pi nt) * 2\pi nt + \sin(2\pi nt))dt = \frac{-2\pi n}{2\pi^2 n^2} t \,|_0^1 = -\frac{1}{\pi n}$$

$$b_n = \frac{2}{T}\int_0^T g(t)\cos(2\pi nft)dt = 2\int_0^1 t\cos(2\pi nft)dt = 0$$

$$c = \frac{2}{T}\int_0^T g(t)dt = 2\int_0^1 tdt = 2\frac{t^2}{2}\,|_0^1 = 1$$

1. A noiseless 4-kHz channel is sampled every 1 msec. What is the maximum data rate?

1. A noiseless 4-kHz channel is sampled every 1 msec. What is the maximum data rate?

1. The key word here is “noiseless”. With a normal 4 KHz channel, Shannon limit would not allow this. For the 4 KHz channel we can make 8000 samples/sec. In this case if each sample is 1024 bits this channel can send 8.2 Mbps.

2. Television channels are 6 MHz wide. How many bits/sec can be sent if four-level digital signals are used? Assume a noiseless channel.

2. Television channels are 6 MHz wide. How many bits/sec can be sent if four-level digital signals are used? Assume a noiseless channel.

2. Using the Nyquist theorem, which is "Max. data rate = 2B log_2V bits/sec", we can sample = 2 (6MHz) log_2 (4) = 24 million times/sec. Therefore, using four level signals total data rate will be of 24 Mbps.

4. What signal-to-noise ratio is needed to put a T1 carrier on a 50-kHz line?

4. What signal-to-noise ratio is needed to put a T1 carrier on a 50-kHz line?

4. B = 50,000 Hz.
   Now based on, Shannon's theorem, B log2 (1 + S/N) bits/sec = T1's data-rate.

   50,000 log2(1 + S/N) = 1.544 × 106 log2(1 + S/N) = 30.88

   S/N = (2^30.88) -1

   In dB, S/N = 10 log 10 (S/N) = 10 log 10 ((2^30.88) -1) = 92.95 dB.

   Therefore, the signal-to-noise ratio needs to be 92.95dB.

5. It is desired to send a sequence of computer screen images over an optical fiber. The screen is 480 x 640 pixels, each pixel being 24 bits. There are 60 screen images per second. How much bandwidth is needed, and how many microns of wavelength are needed for this band at 1.30 microns?

5. Bandwidth needed is 480 * 640 * 24 * 60 = 442 368 000 bits

6. Radio antennas often work best when the diameter of the antenna is equal to the wavelength of the radio wave. Reasonable antennas range from 1 cm to 5 meters in diameter. What frequency range does this cover?

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6. Freq = C/W where C: speed of light. W: wavelength. \ Convert 1 cm to m → 1 cm = 0.01 m

For diameter of 1 cm: \ Freq = (3 × sup(10, 8)/0.01 \ Freq = 3 × sup(10, 10) = 30 GHz

For diameter of 5 m: \ Freq = (3 × sup(10, 8)/5 \ Freq = 6 × sup(10, 7) = 60 MHz

The cover range is from 60 MHz to 30 GHz.

7. A modem constellation diagram similar to Fig. 2-25 has data points at the following coordinates: (1, 1), (1, -1), (-1, 1), and (-1, -1). How many bps can a modem with these parameters achieve at 1200 baud?

7. A modem constellation diagram similar to Fig. 2-25 has data points at the following coordinates: (1, 1), (1, -1), (-1, 1), and (-1, -1). How many bps can a modem with these parameters achieve at 1200 baud?

7. QPSK encodes 2 bits/symbol. rate = baud * bits/symbol = 1200 * 2 = 2400bps

8. A modem constellation diagram similar to Fig. 2-25 has data points at (0, 1) and (0, 2). Does the modem use phase modulation or amplitude modulation?

8. A modem constellation diagram similar to Fig. 2-25 has data points at (0, 1) and (0, 2). Does the modem use phase modulation or amplitude modulation?

This is amplitude modulation because both points are the same angle from the positive x axis but are different distances away from origin (0,0).

9. How many frequencies does a full-duplex QAM-64 modem use?

9. How many frequencies does a full-duplex QAM-64 modem use?

9. Two, one for upstream and one for downstream. The modulation scheme itself just uses amplitude and phase. The frequency is not modulated.

10. Ten signals, each requiring 4000 Hz, are multiplexed on to a single channel using FDM. How much minimum bandwidth is required for the multiplexed channel? Assume that the guard bands are 400 Hz wide.

10. Ten signals, each requiring 4000 Hz, are multiplexed on to a single channel using FDM. How much minimum bandwidth is required for the multiplexed channel? Assume that the guard bands are 400 Hz wide.

10. There are ten 4000 Hz signals.

Therefore, we need nine guard bands to avoid any interference.

Altogether, the minimum bandwidth required is $(4000 \times 10 + 400 \times 9)$ or, 43,600 Hz.

11. Why has the PCM sampling time been set at 125 μsec?

11. Why has the PCM sampling time been set at 125 μsec?

11. A sampling time of 125 μsec (micro-sec) corresponds to 8000 samples per second, because, in 1 second (or, in 106μsec) we sample (106/125) or, 8000.According to the Nyquist theorem (which is "Max. data rate = 2B log_2V bits/sec"), this is the

sampling frequency needed to capture all the information in a (B=) 4-kHz channel, such as a telephone channel (Actually the nominal bandwidth is less, but the cutoff is not sharp.). Note:(assuming two signal level or, possible symbol), Max. data rate = 2B log_2V bits/sec = 2 × 4,000 ×log2(2) bits/sec = 2 × 4000 × 1 = 8,000.

12. What is the percent overhead on a T1 carrier; that is, what percent of the 1.544 Mbps are not delivered to the end user?

12. What is the percent overhead on a T1 carrier; that is, what percent of the 1.544 Mbps are not delivered to the end user?

12. With a modern T1 line, the end users get $8 \times 24 = 192$ of the 193 bits in a frame. The overhead is therefore $1 / 193 = 0.5\%$. Therefore, at least 0.5% of the 1.544 Mbps are not delivered to the end user.

13. Compare the maximum data rate of a noiseless 4-kHz channel using

(a) Analog encoding (e.g., QPSK) with 2 bits per sample.

(b) The T1 PCM system.

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(b) The T1 PCM system.

13. In both cases 8000 samples/sec are possible. With dibit encoding, two bits are sent per sample. With T1, 7 bits are sent per period. The respective data rates are 16 kbps and 56 kbps.

14. If a binary signal is sent over a 3kHz bandwidth channel whose signal to noise ratio is 20dB, what is the maximum achievable data rate?

14. If a binary signal is sent over a 3kHz bandwidth channel whose signal to noise ratio is 20dB, what is the maximum achievable data rate?

14. From Shannon's theorem:

Max Data Rate = Wlog2(1+S/N)

Note that the signal to noise ratio (SNR) given here is a power ratio, yet we are given the SNR in decibels. We therefore need to convert back to a power ratio:

SNR in Db = 10log2(1+S/N)

S/N=100

Max Data Rate= Wlog2(1+S/N)=20kbps

The Nyquist limit for binary signalling over a 3kHz channel is

Max Data Rate= 2Wlog2M=6kbps

Therefore, the maximum achievable data rate is 6kbps. (To achieve higher rates than this (up to the Shannon limit), one would have to use a different signalling method.)

15. The loss in a cable is usually defined in decibels per kilometer (dB/km). If the signal at the beginning of a cable with -0.3 dBlkm has a power of 2 mW, what is the power of the signal at 5 km?

15. The loss in a cable is usually defined in decibels per kilometer (dB/km). If the signal at the beginning of a cable with -0.3 dBlkm has a power of 2 mW, what is the power of the signal at 5 km?

15. The loss in the cable in decibels is 5 x (-0.3)::: -1.5 dB.
We can calculate the power as

$$dB = 10log_{10}\frac{P_2}{P_1} = -1.5$$

Thus P_2=1.4mW

16. A TV channel has a bandwidth of 6 MHz. If we send a digital signal using one channel, what are the data rates if we use one harmonic, three harmonics, and five harmonics?

16. A TV channel has a bandwidth of 6 MHz. If we send a digital signal using one channel, what are the data rates if we use one harmonic, three harmonics, and five harmonics?

16. Using the first harmonic, data rate = 2×6 MHz = 12 Mbps

Using three harmonics, data rate = $(2 \times 6 \text{ MHz}) / 3 = 4$ Mbps

Using five harmonics, data rate = $(2 \times 6 \text{ MHz}) / 5 = 2.4$ Mbps

17. A signal travels from point A to point B. At point A, the signal power is 100 W. At point B, the power is 90 W. What is the attenuation in decibels?

17. A signal travels from point A to point B. At point A, the signal power is 100 W. At point B, the power is 90 W. What is the attenuation in decibels?

17. $dB = 10 \log10 (90 / 100) = -0.46$ dB

18. If the bandwidth of the channel is 5 Kbps, how long does it take to send a frame of 100,000 bits out of this device?

18. If the bandwidth of the channel is 5 Kbps, how long does it take to send a frame of 100,000 bits out of this device?

18. 100,000 bits / 5 Kbps = 20s

19. A file contains 2 million bytes. How long does it take to download this file using a 56-Kbps channel? 1-Mbps channel?

19. A file contains 2 million bytes. How long does it take to download this file using a 56-Kbps channel? 1-Mbps channel?

19. The file contains $2{,}000{,}000 \times 8 = 16{,}000{,}000$ bits. With a 56-Kbps channel, it takes $16{,}000{,}000/56{,}000 = 289$ s. With a 1-Mbps channel, it takes 16 s

20. A signal with 200 milliwatts power passes through 10 devices, each with an average noise of 2 microwatts. What is the SNR? What is the SNR_{dB}?

20. A signal with 200 milliwatts power passes through 10 devices, each with an average noise of 2 microwatts. What is the SNR? What is the SNR_{dB}?

20. We have SNR = (200 mW) / (10 × 2 × μW) = 10,000

We then have SNRdB = 10 log10 SNR = 40

21. Calculate the baud rate for the given bit rate and type of modulation.

a. 2000 bps, FSK

b. 4000 bps, ASK

c. 6000 bps, QPSK

d. 36,000 bps, 64-QAM

21. Calculate the baud rate for the given bit rate and type of modulation.

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d. 36,000 bps, 64-QAM

21. We use the formula

$S = (1/r) \times N$, but first we need to calculate the value of r for each case.

a. $r = \log_2 2 = 1 \rightarrow S = (1/1) \times (2000 \text{ bps}) = 2000$ baud

b. $r = \log_2 2 = 1 \rightarrow S = (1/1) \times (4000 \text{ bps}) = 4000$ baud

c. $r = \log_2 4 = 2 \rightarrow S = (1/2) \times (6000 \text{ bps}) = 3000$ baud

d. $r = \log_2 64 = 6 \rightarrow S = (1/6) \times (36{,}000 \text{ bps}) = 6000$ baud

22. Calculate the bit rate for the given baud rate and type of modulation.

a. 1000 baud, FSK

b. 1000 baud, ASK

c. 1000 baud, BPSK

d. 1000 baud, 16-QAM

22. Calculate the bit rate for the given baud rate and type of modulation.

a. 1000 baud, FSK

b. 1000 baud, ASK

c. 1000 baud, BPSK

d. 1000 baud, 16-QAM

22. We use the formula $N = r \times S$, but first we need to calculate the value of r foreach case.

a. $r = \log22 = 1 \rightarrow N = (1) \times (1000 \text{ bps}) = 1000 \text{ bps}$

b. $r = \log22 = 1 \rightarrow N = (1) \times (1000 \text{ bps}) = 1000 \text{ bps}$

c. $r = \log22 = 1 \rightarrow N = (1) \times (1000 \text{ bps}) = 1000 \text{ bps}$

d. $r = \log16 = 4 \rightarrow N = (4) \times (1000 \text{ bps}) = 4000 \text{ bps}$

23. A cable company uses one of the cable TV channels (with a bandwidth of 6 MHz) to provide digital communication for each resident. What is the available data rate for each resident if the company uses a 64-QAM technique?

23. 36Mbps

24. We have 14 sources, each creating 500 8-bit characters per second. Since only some of these sources are active at any moment, we use statistical TDM to combine these sources using character interleaving. Each frame carries 6 slots at a time, but we need to add 4-bit addresses to each slot. Answer the following questions:

a. What is the size of an output frame in bits?

b. What is the output frame rate?

c. What is the duration of an output frame?

d. What is the output data rate?

24. We have 14 sources, each creating 500 8-bit characters per second. Since only some of these sources are active at any moment, we use statistical TDM to combine these sources using character interleaving. Each frame carries 6 slots at a time, but we need to add 4-bit addresses to each slot. Answer the following questions:

a. What is the size of an output frame in bits?
b. What is the output frame rate?
c. What is the duration of an output frame?
d. What is the output data rate?

24. Frame size = (# of slots) x (character size + slot address) = 6 x (8 bits+ 4 bits) =72 bits

We can assume that we have only 6 input lines. Each frame needs to carry one character from each of these lines. This means that the link needs to send500 frames/s

Frame duration = 1 / (frame rate) = 1 / 500 =2ms

Data rate = (500 frames/s) x (72 bits/frame) =36 Kbps

25. Two channels, one with a bit rate of 190 kbps and another with a bit rate of 180 kbps, are to be multiplexed using pulse-stuffing TDM with no synchronization bits. Answer the following questions:

a. What is the size of a frame in bits?

b. What is the frame rate?

c. What is the duration of a frame?

d. What is the data rate?

25. Two channels, one with a bit rate of 190 kbps and another with a bit rate of 180 kbps, are to be multiplexed using pulse-stuffing TDM with no synchronization bits. Answer the following questions:

a. What is the size of a frame in bits?
b. What is the frame rate?
c. What is the duration of a frame?
d. What is the data rate?

25. We need to add extra bits to the second source to make both bit rates = 190Kbps.Now we have two sources, each of 190 Kbps. Since the data unit was not specified, assume that it is one bit. Frame size = 2 bits.

Frame rate =190k frames/s

Frame duration = 1/frame rate = 1/190k = 5.26μs

Data rate = 190k*2 = 380kbps

Chapter 3: Data Link Layer Numericals

Q 1.

The following character encoding is used in a data link protocol:

A: 01000111; B: 11100011; FLAG:01111110; ESC: 11100000

Show the bit sequence transmitted (in binary) for the four-character frame: A B ESC FLAG when each of the following framing methods are used:

a. Character count.

b. Flag bytes with byte stuffing.

c. Starting and ending flag bytes, with bit stuffing.

A.1.

a. 00000100 01000111 11100011 11100000 01111110

b. 01111110 01000111 11100011 11100000 11100000 11100000 01111110 01111110

c. 01111110 01000111 110100011 111000000 011111010 01111110

Q 2.

The following data fragment occurs in the middle of a data stream for which the byte-stuffing algorithm described in the text is used:

A B ESC C ESC FLAG FLAG D. What is the output after stuffing?

A.2.

After stuffing the output is

A B ESC ESC C ESC ESC ESC FLAG ESC FLAG D

Q.3.

What is the maximum overhead in byte-stuffing algorithm?

A.3.

The maximum overhead in byte stuffing algorithm is 100%(i.e. when the payload contains only ESC and Flag bytres).

Q 4.

A bit string, 0111101111101111110, needs to be transmitted at the data link layer. What is the string actually transmitted after bit stuffing?

A.4.

The actual transmitted bit string after bit stuffing is

011110111110011111010

Q.5.

Let us assume that m = 3 and *n* = 4. Find the list of valid datawords and codewords assuming the check bit is used to indicate even parity in the code word.

A.5.

Valid datawords : 000, 001,010, 011,100,101,110,111

Valid codewords : 0000, 0011, 0101, 0110, 1001, 1010, 1100, 1111

Q.6.

What is the Hamming distance for each of the following codewords:

a. (10000, 00000)

b. (10101, 10000)

c. (11111,11111)

d. (000, 000)

A.6.

a. **1**

b. **2**

c. **0**

d. **0**

Q.7.

Given the codeword of size 4 bit. If the size of dataword is 3 bit. What is the value of hamming distance for the codeword?

A. 7.

Hamming distance = 2

Q 8.

To provide more reliability than a single parity bit can give, an error-detecting coding scheme uses one parity bit for checking all the odd-numbered bits and a second parity bit for all the even-numbered bits.

What is the Hamming distance of this code?

A.8.

Making one change to any valid character cannot generate another valid character due to the nature of parity bits. Making two changes to even bits or two changes to odd bits will give another valid character, so the distance is 2.

Q. 9.

Find the minimum Hamming distance to be implemented in codeword for the following cases:

a. Detection of two errors.

b. Correction of two errors.

c. Detection of 3 errors or correction of 2 errors.

d. Detection of 6 errors or correction of 2 errors.

A.9.

a. For error detection → Hamming distance = d + 1 = 2 + 1 = **3**

b. For error correction → Hamming distance = 2d + 1 = 2 × 2 + 1 = **5**

c. For error detection → Hamming distance = d + 1 = 3 + 1 = **4**

For error correction → Hamming distance = 2d + 1 = 2 × 2 + 1 = **5**

Therefore minimum Hamming distance should be **5**.

d. For error detection → Hamming distance = d + 1 = 6 + 1 = **7**

For error correction → Hamming distance = 2d + 1 = 2 × 2 + 1 = **5**

Therefore minimum Hamming distance should be **7**.

Q.10.

Given in the table a set of valid dataword and codeword.

Dataword	Codeword
00	00000
01	01011
10	10101
11	11110

What is the dataword transmitted for the following codewords received assuming there is 1 bit error?

a. 01010

b. 11010

A.10.

a. 01
b. 11

Q 11.

Sixteen-bit messages are transmitted using a Hamming code. How many check bits are needed to ensure that the receiver can detect and correct single bit errors? Show the bit pattern transmitted for the message 1101001100110101. Assume that even parity is used in the Hamming code.

A.11.

5 check bits are needed at positions 1, 2, 4, 8, and 16.

The bit pattern transmitted for the message 1101001100110101 is 011010110011001110101

Q.12.

An 8 bit message using even-parity Hamming code is received as **101001001111**. Find the 8 bit message after getting decoded assuming no error during transmission?

A.12.

The 8 bit message after decoding is 10101111.

Q.13.

A 12-bit Hamming code whose hexadecimal value is 0xE4F arrives at a receiver. What was the original value in hexadecimal? Assume that not more than 1 bit is in error.

A.13.

If we number the bits from left to right starting at bit 1, in this example bit 2 (a parity bit) is incorrect. The 12-bit value transmitted (after Hamming encoding) was 0xA4F. The original 8-bit data value was 0xAF.

Q.14.

Suppose that data are transmitted in blocks of sizes 1000 bits. What is the maximum error rate under which error detection and retransmission mechanism (1 parity bit per block) is better than using Hamming code? Assume that bit errors are independent of one another and no bit error occurs during retransmission.

A.14.

From Eq. $\mathbf{(m+r+1)\leq 2^r}$, we know that 10 check bits are needed for each block in case of using Hamming code. Total bits transmitted per block are 1010 bits. In case of error detection mechanism, one parity bit is transmitted per block (i.e.1001). Suppose error rate is x per bit. Thus, a block may encounter a bit error $1000x$ times. Every time an error is encountered, 1001 bits have to be retransmitted. So, total bits transmitted per block are $1001+1000x \times 1001$ bits. For error detection and retransmission to be better, $1001 + 1000x \times 1001 < 1010$. So, the error rate must be less than 9×10^{-6}.

Q.15.

What is the remainder obtained by dividing x^7+x^5+1 by the generator polynomial x^3+1?

A.15.

The remainder is x^2+x+1.

Q.16.

Given the dataword 101001111 and the divisor 10111. Show the generation of the CRC codeword at the sender site (using binary division).

A.16.

The codeword at the sender site is 1010011110001

Q.17.

A bit stream 10101010 is transmitted using the standard CRC method. The generator polynomial is x^3+x^2+1. Show the actual bit string transmitted. Suppose the second bit from the left is inverted during transmission. Show that this error is detected at the receiver's end.

A.17.

The frame is 10101010. The generator is 1101. We must append 3 zeros to the message (i.e. 10101010000).The remainder after dividing 10101010000 by 1101 is 110. So actual bit string transmitted is 10101010110.Since the second bit from left is inverted during transmission, the bits received are 11101010110. Dividing this by 1101 doesn't give remainder 0. So the received bits contain error.

Q.18.

A bit stream 10011101 is transmitted using the standard CRC method. The generator polynomial is x^3+1. Show the actual bit string transmitted. Suppose that the third bit from the left is inverted during transmission.

A.18.

The frame is 10011101. The generator is 1001. The message after appending three zeros is 10011101000. The remainder on dividing

10011101000 by 1001 is 100. So, the actual bit string transmitted is 10011101100. The received bit stream with an error in the third bit from the left is 10111101100. Dividing this by 1001 produces a remainder 100, not 0. So the received bits contain error and needs retransmission.

Q.19.

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

A.19.

Efficiency will be 50% when the time required to transmit the frame equals the round-trip propagation delay. At a transmission rate of 4 bits/msec, 160 bits takes 40 msec. For frame sizes above 160 bits, stop-and-wait is reasonably efficient.

Q.20.

A 3000-km-long T1 trunk is used to transmit 64-byte frames using protocol 5. If the propagation speed is 6 μsec/km, how many bits should the sequence numbers be?

A.20.

To operate efficiently, the sequence space (actually, the send window size) must be large enough to allow the transmitter to keep transmitting until the first acknowledgement has been received. The propagation time is 18 ms. At T1 speed, which is 1.536 Mbps (excluding the 1 header bit), a 64-byte frame takes 0.300 msec. Therefore, the first frame fully arrives 18.3 msec after its transmission was started. The acknowledgement takes another 18 msec to get back, plus a small (negligible) time for the acknowledgement to arrive fully. In all, this time is 36.3 msec. The transmitter must have enough window space to keep going for 36.3 msec. A frame takes 0.3 ms, so it takes 121 frames to fill the pipe. Seven-bit sequence numbers are needed.

MAC _ Sublayer _ Numericals

Problem 1

A group of *N* stations share a 56-kbps pure ALOHA channel. Each station outputs a 1000-bit frame on an average of once every 100 sec, even if the previous one has not yet been sent (e.g., the stations can buffer outgoing frames). What is the maximum value of *N*?

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Solution:

There are N Stations Sharing 56kbps Pure ALOHA Channel

so with pure ALOHA Usable Bandwidth = 0.184* 56kbps=10.3kbps

1 Station Outputs 1000 bits in every 100sec

so in 1sec One station will ouput at rate 1000/100=10bits/sec

so For N stations in 1 sec Total Output Data is 10*N bits this should be equal to the Channel Capacity in pure ALOHA

N*10=10300

N=1030 it is the maximum value of Number of Station Possible.

Problem 2

Ten thousand airline reservation stations are competing for the use of a single slotted ALOHA channel. The average station makes 18 requests/hour. A slot is 125 µsec. What is the approximate total channel load?

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Solution:

The average station makes $\frac{18}{3600} = \frac{1}{200}$ requests/sec. The total channel load is $10000 \times \frac{1}{200} = 50$ requests/sec. Using slot as the time unit, the total channel load is $50 \times (125 \times 10^{-6}) = \frac{1}{160}$ requests/slot.

Problem 3

A slotted aloha system has packets (both new and retransmissions) arriving at a rate of 50 per second. Packets take 40 ms to transmit.
a) What is G (packets per slot)?
b) What is the probability of success of during a slot?
c) What is the average number of slots per successful transmission?

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a) What is G (packets per slot)?
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Solution:

a) $G = 50 * 0.04 = 2$ packets per slot.
b) $P_s = G e^{-G} = 0.27$
c) $1/P_s = 3.69$

Problem 4

Measurements of a slotted ALOHA channel with an infinite number of users show that 10 percent of the slots are idle.
(a) What is the channel load, *G*?
(b) What is the throughput?
(c) Is the channel underloaded or overloaded?

Problem 4

Measurements of a slotted ALOHA channel with an infinite number of users show that 10 percent of the slots are idle.

(a) What is the channel load, *G*?

(b) What is the throughput?

(c) Is the channel underloaded or overloaded?

Solution:

a) $P(0) = e^{-G} = 0.1 \Rightarrow G = 2.3$

b) $T = G\,e^{-G} = 0.23$

c) Since $G > 1$, the system is overloaded.

Problem 5

Sketch the Manchester encoding for the bit stream: 10000101111

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Solution: