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Sirindhorn International Institute of Technology
Thammasat University

Midterm Examination: Semester 1/2007

Course Title : ITS 323 – Introduction to Data Communications

Instructor : Dr Steven Gordon

Date/Time : Thursday 19 July 2007, 9:00 – 12:00

Instructions:

- This examination paper has __ pages (including this page).
- Condition of Examination
  Closed book (No dictionary, **Non-programmable calculator allowed**)
- Students are not allowed to be out of the exam room during examination. Going to the restroom may result in score deduction.
- Turn off all communication devices (mobile phone etc.) and leave them under your seat.
- Write your name, student ID, section, and seat number clearly on the answer sheet.
- The space on the back of each page can be used if necessary.
- Unless stated in the question, you can assume the speed of transmission is 3×10^8 m/s

Part A - Multiple Choice Questions [30 marks]

Select the most accurate answer (only select one answer). Each correct answer is worth 2 marks.

1. Computer A sends 8 bits of data plus a single even parity bit (as the first bit) to Computer B. A single bit error occurs during the transmission. Computer B receives the bits 000011010. Which of the following is *true*?
   a) The original 8 bits of data was 00011010
   b) The original 8 bits of data had an even number of 1's
   c) The original 8 bits of data had an odd number of 1's
   d) The transmitted parity bit had a value of 1
   e) The transmitted parity bit had a value of 0
   f) The receiver cannot detect the error
   g) The receiver cannot determine the original 8 bits of data

2. The data link layer in the Internet layered model:
   a) Defines user friendly addresses like URLs and email addresses
   b) Converts digital data into electromagnetic energy for transmission
   c) Selects paths across multiple networks
   d) Aims to provide error-free transmission across links
   e) Does not include an addressing scheme

3. According to the free-space propagation model, increasing the size of the transmit antenna (while maintaining all other parameters at the transmitter) will:
   a) Increase the power lost between transmitter and receiver
   b) Increase the received power
   c) Increase the frequency used in transmission
   d) Reduce the distance that can be transmitted
   e) Reduce the gain of the transmit antenna
   f) Reduce the gain of the receive antenna

4. Unshielded twisted pair:
   a) Can be used to transmit over longer distance than optical fibre
   b) Provides higher data rates than coaxial cable
   c) Is easier to install than coaxial cable
   d) Is affected less by interference from other twisted pairs, than optical fibre
   e) Is no longer used because of the low data rates
   f) Carries light waves across glass fibres

5. A transmission system that provides half-duplex communications between A and B:
   a) Only allows A to send to B
   b) Only allows B to send to A
   c) If A is sending to B, then B cannot send to A at the same time
   d) If A is sending to B, then B can send to A at the same time
   e) Allows both A and B to transmit to each at the same time

6. If a signal has a period of 5 milliseconds (ms), then its wavelength is:
   a) 200 m
   b) 1500 m
   c) 200 Hz
   d) 1.5 MHz
   e) 1500 km
   f) 200 km
   g) 1500 Hz

7. You use Skype (a voice over Internet program) on your computer to talk to a friend. Your computer is connected to your friend's computer via the fixed, land-based telephone network. The transmission is an example of:
   a) Sending digital data on a digital signal
   b) Sending analog data on a digital signal
   c) Converting analog data to digital data, and sending digital data on an analog signal
   d) Converting analog data to digital data, and sending digital data on a digital signal
   e) Converting digital data to analog data, and sending analog data on an analog signal
   f) Converting digital data to analog data, and sending analog data on a digital signal

8. TCP (the Transmission Control Protocol) is a common transport layer protocol used in the Internet. It would normally be implemented:
   a) As part of the operating system
   b) In an Ethernet or Wireless LAN card
   c) As part of web browser (e.g. Firefox, Internet Explorer)
   d) As part of a new application (such as file sharing or instant messaging)
   e) In hardware to perform transmission of bits as analog or digital signals

9. TCP uses which of the following address types:
   a) Application specific addresses (e.g. an Instant Messing addresses)
   b) Physical addresses
   c) URLs such as www.google.com
   d) Data link layer addresses
   e) Port numbers, such as port 80 for a web server
   f) Hardware addresses

10. What is the maximum data rate of a 4MHz channel if the signal to noise ratio is 18dB? (The answer is in the nearest Mb/s)
   a) 48 Mb/s
   b) 24 Mb/s
   c) 17 Mb/s
   d) 4Mb/s
   e) 2Mb/s
   f) 19Mb/s

11. If a transmission system uses 8 voltage levels to transmit a digital signal, then how many bits does each signal level represent?
    a) 1
    b) 2
    c) 3
    d) 4
    e) 8
    f) 16
    g) 128
    h) 256

12. What layers are in the OSI layered model, but not in the Internet layered model:
    a) Hardware, Transport
    b) Hardware, Session
    c) Transport, Session
    d) Hardware, Presentation
    e) MAC, Presentation
    f) Presentation, Session
    g) MAC, Session
    h) MAC, Transport
    i) Hardware, MAC

13. If ten packets sent in a computer network experience the delays as given below, then the jitter is:

Packet	1	2	3	4	5	6	7	8	9	10
Delay (ms)	13	6	4	11	10	9	5	8	8	6

    a) 3 ms
    b) 4 ms
    c) 8 ms
    d) 9 ms
    e) 10 ms
    f) 13 ms

14. A simple internet router:
    a) Implements only the physical layer in the Internet layered model
    b) Implements only the physical layer and data link layer in the Internet layered model
    c) Implements only the application layer in the Internet layered model
    d) Will have more than one physical layer interface
    e) None of the above

15. Which of the following is an example of a logical address:
    a) www.siit.tu.ac.th
    b) steve@siit.tu.ac.th
    c) 00:17:31:7E:50:7D
    d) 125.61.3.28
    e) None of the above

Part B – General Questions [90 marks]

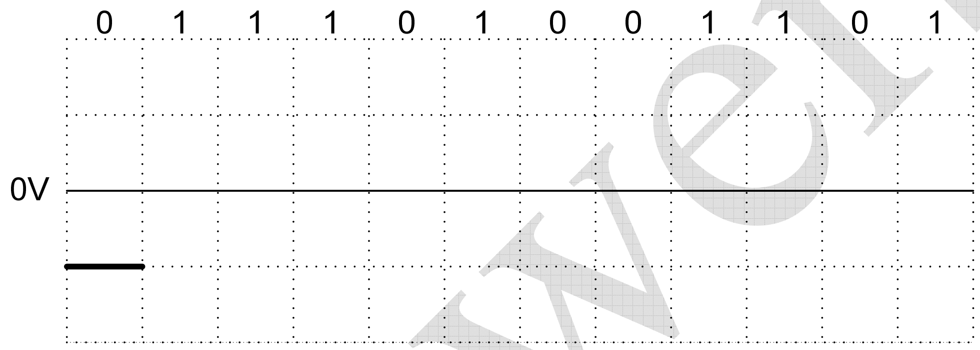
Question 1 [18 marks]

The following sequence of bits are to be transmitted across a link.

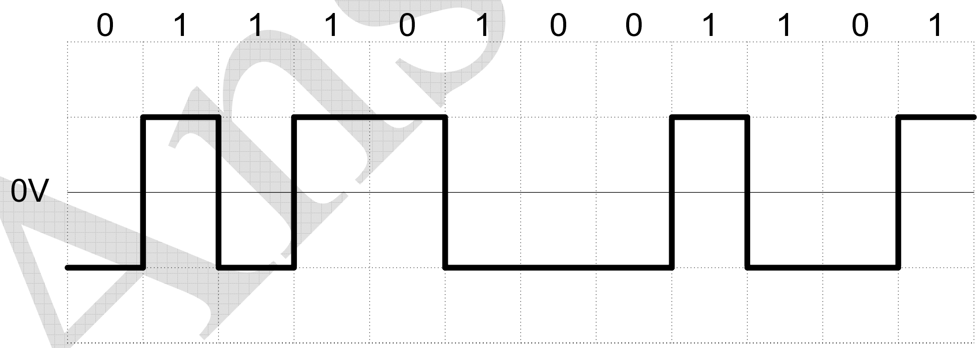
0 1 1 1 0 1 0 0 1 1 0 1

Consider the following options for transmitting the bits.

a) The bits are to be sent over a digital signal using Non-Return to Zero Invert on Ones (NRZI) encoding. Complete the digital waveform below. The value of the first bit is shown. [3 marks]



Answer

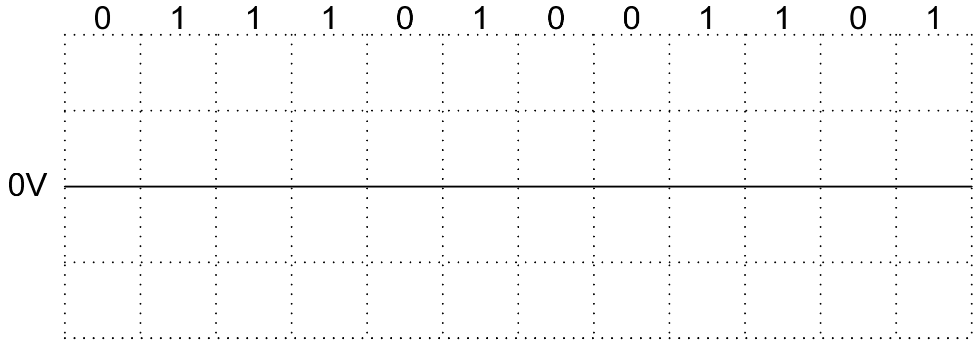


b) The bits are to be sent over a digital signal using Bipolar Alternative Mark Inversion (AMI) encoding. Bipolar AMI has the following rules:

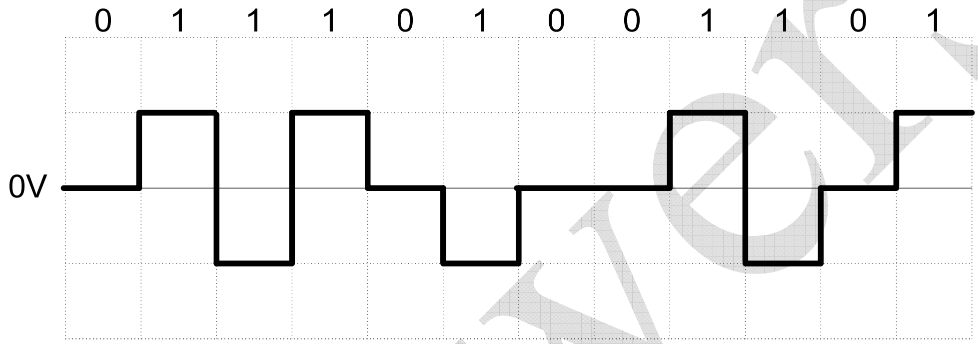
0 = no line signal

1 = positive or negative level, alternating for successive ones

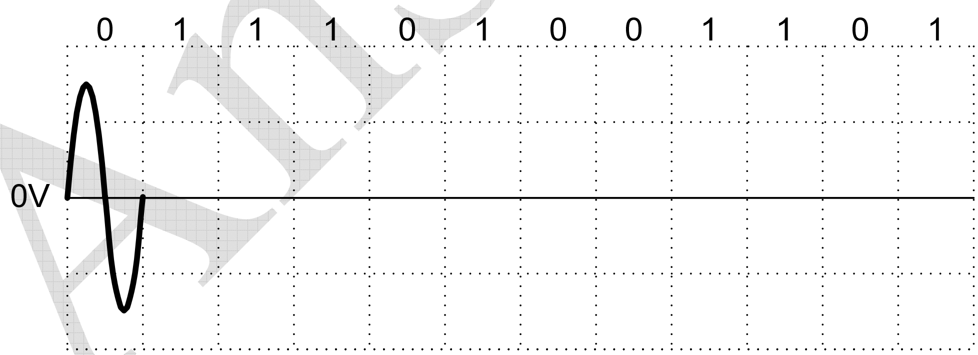
Complete the digital waveform below. Assume that the previous 1 bit has negative voltage. [5 marks]



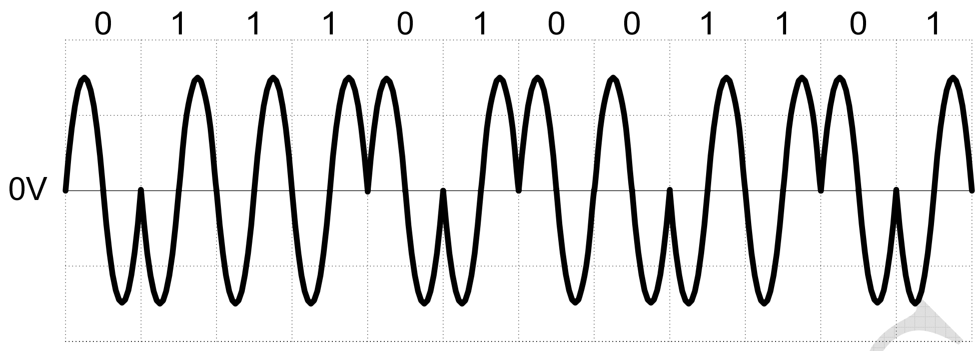
Answer



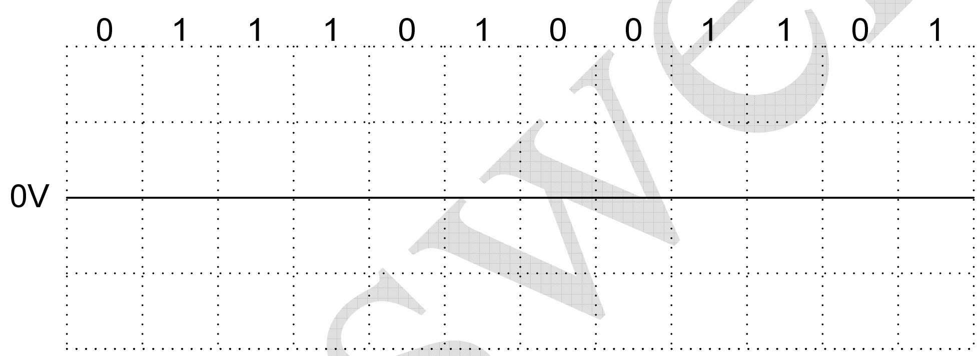
c) The bits are to be transmitted over an analog signal using Binary Phase Shift Keying (BPSK). Complete the analog waveform below. The value of the first bit is shown. [3 marks]



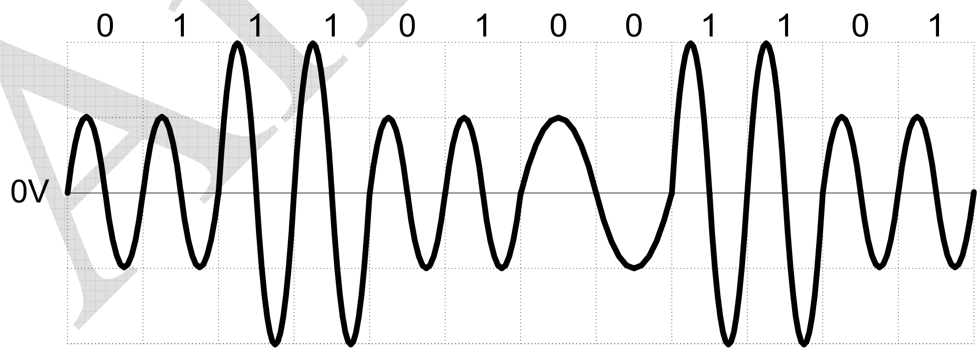
Answer



d) The bits are to be transmitted over an analog signal using a combination of Binary Amplitude Shift Keying and Binary Frequency Shift Keying. Complete the analog waveform below. [5 marks]



Answer



e) Explain the encoding scheme you used in part (d). [2 marks]

Answer

Binary ASK gives two different signal levels. So does Binary FSK. Therefore combining them provides for 4 different signal levels:

Low amplitude, slow frequency
Low amplitude, fast frequency
High amplitude, slow frequency
High amplitude fast frequency

We can therefore assign 2 bits to one of the four combinations. You can do so in any pattern. My answer in part (d) uses the pattern:

Low amplitude, slow frequency: 00
Low amplitude, fast frequency: 01
High amplitude, slow frequency: 10
High amplitude fast frequency: 11

Question 2 [16 marks]

Consider a forward error correcting (FEC) coder that maps 3 bits of data to the codewords in Table 1.

Data	*Codeword*
000	000000
001	001011
010	010010
011	011001
100	100001
101	101011
110	110011
111	111100

Table 1: Forward error correcting coder

The decoder uses the minimum Hamming distance to perform error correction.

Consider the following cases:

a) The transmitter uses the FEC coder to send the data 010. If a single bit error occurs on the final bit of the transmitted data, explain the steps the receiver takes on receiving the data, and give the result at the receiver. [5 marks]

Answer

The transmitted codeword is 010010. The received codeword is 010011. The receiver notes that this is not a valid codeword (and hence detects an error) and so finds the nearest codeword based on minimum unique Hamming distance.

Codeword	000000	001011	010010	011001	100001	101011	110011	111100
Received	010011	010011	010011	010011	010011	010011	010011	010011
Distance	3	2	1	2	3	3	1	5

Since there are two valid codewords with minimum distance 1 (010010 and 110011) the receiver cannot determine the transmitted codeword, that is, the error is not corrected (and no data is received).

b) The transmitter uses the FEC coder to send the data 010. If two bit errors occur, one on the first bit and one on the final bit of the transmitted data, explain the steps the receiver takes on receiving the data, and give the result at the receiver. [4 marks]

Answer

The received codeword is 110011. The receiver notes that this is a valid codeword 110011 and hence determines the transmitted data to be 110. This is in fact an error – this is a case of the error not being detected (or corrected).

c) If a 54Mb/s data rate link is used with this FEC codec, what is the maximum throughput that can be achieved? [2 marks]

Answer

To send 3 bits of real data, you must send a 6 bit codeword. Therefore 50% efficiency, giving a maximum throughput of 27Mb/s.

d) Explain how the FEC codec could be change to increase the efficiency of the transmissions. [2 marks]

Answer

To increase efficiency (or throughput), increase the number of data bits per codeword. That is, increase from 3-bit data to 4 or 5, or decrease 6-bit codeword to 4 or 5.

e) What is the advantage of increasing the codeword length for the FEC from 6 to 8 bits (while keeping the data length to 3 bits)? Explain why. [3 marks]

Answer

Increases the chance we can detect and correct errors. Why? We will have 256 possible receive codewords (compared to 64 with 6-bits). If we choose the correct 8 valid codewords, then more received codewords will have a *unique* minimum Hamming distance to a valid codeword. Therefore we can detect and correct more errors.

Question 3 [12 marks]

Analog data represented by Figure 1 is to be sent as a digital signal using Pulse Code Modulation (PCM). The analog waveform can be shown in the frequency domain as Figure 2.

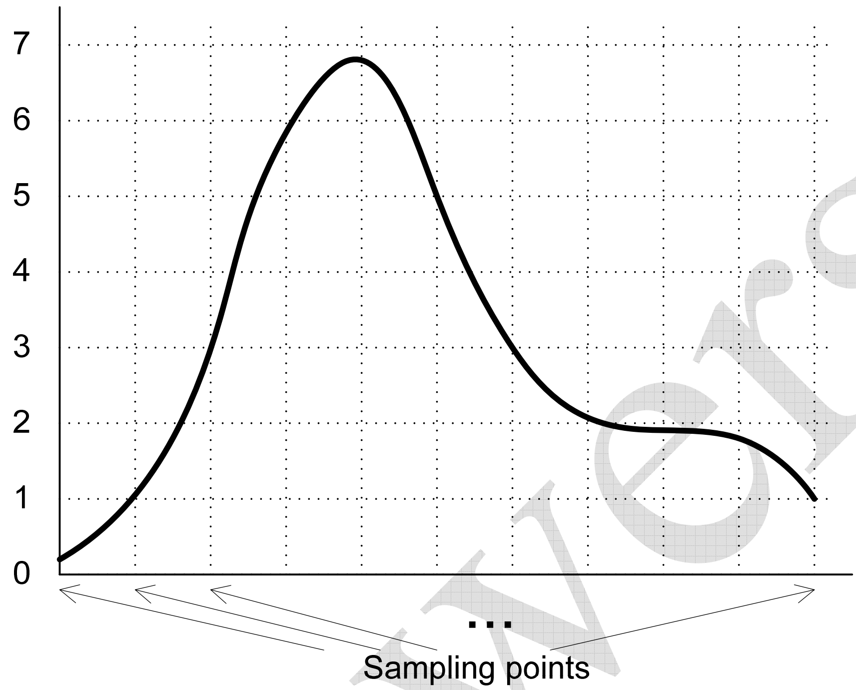


Figure 1: Analog signal

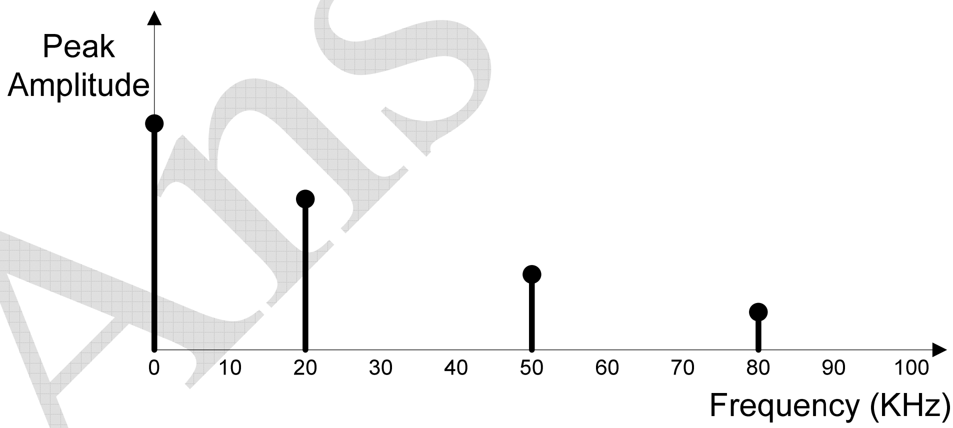


Figure 2: Analog signal in frequency domain

a) What is the bandwidth of the analog data? [2 marks]

Answer

From Figure 2 the spectrum ranges from 0 KHz to 80KHz, and hence the bandwidth is 80KHz.

b) What minimum sampling rate should be used to convert the analog data into discrete values? [2 marks]

Answer

The minimum sampling rate should be at least 2 times the bandwidth. Therefore 160,000 samples per second.

c) Assume the analog data is sampled at the 11 vertical lines shown in Figure X. The signal is sampled at integer levels, from 0 to 7. Each level is converted to its corresponding 3 bit number. What is the digital (binary) data to be sent on the digital signal after sampling? [5 marks]

Answer

First map the signal level to the nearest integer value at each sampling point, and then represent that value as binary, so we get 11 binary numbers:

Sample	*Value*	*Binary*
1	0	000
2	1	001
3	3	011
4	6	110
5	7	111
6	5	101
7	3	011
8	2	010
9	2	010
10	2	010
11	1	001

Table 2: Sampled data

Hence the digital data sent is: 000 001 011 110 111 101 011 010 010 010 001

d) After sampling, what is the data rate required to send the digital data? [3 marks]

Answer

Each sample is 3 bits, and there are 160,000 samples per second, so the data rate required is 480,000 bits per second, that is 480kb/s.

Question 4 [8 marks]

Consider the network in Figure 3 where computer A is to send a 2000 byte message to computer B via optical fibres and satellite links. Assume the following:

- A geostationary satellite orbits the Earth at an altitude of 36,000km.
- The transmission speed from Earth to satellite is 3×10^8 m/s
- The transmission speed over optical fibre is 2×10^8 m/s
- There is a processing delay at each gateway of 10μsec. There is also a processing delay of 5 μsec at the satellite. There is no processing delay at the end computers.
- There is a queuing delay at each gateway of 5μsec. There is no queuing delay at the end computers or on the satellite.

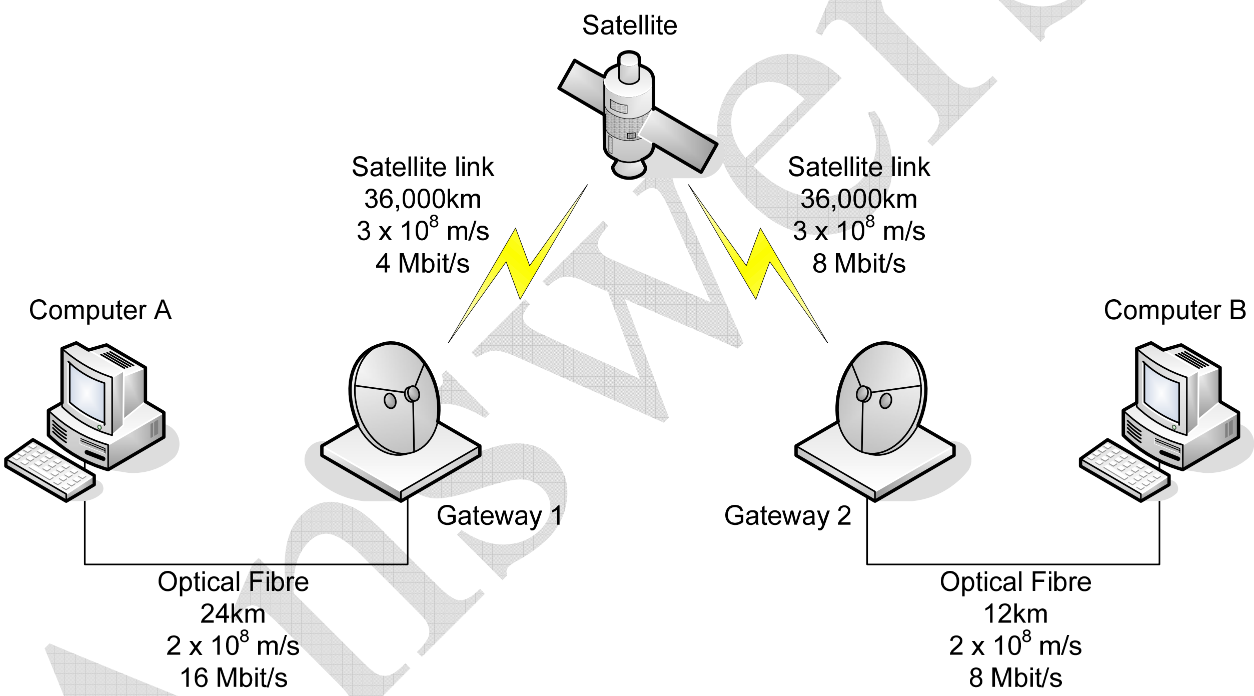


Figure 3: Satellite network

a) What is the total delay for sending the message from Computer A to Computer B? Give your answer in microseconds (μs). [5 marks]

Answer

Transmission delay is (2000 bytes / datarate).
Computer A – GW1: 16000 bits / 16000000 = 1ms = 1000μs
GW1 – Sat: 250μs (one quarter the data rate of 16Mb/s, so one quarter the transmission time for same message size)
Sat – GW2: 500μs
GW2 – B: 500μs

Total transmission delay: 2250μs

Propagation delay is (distance / speed).
A – GW1: 24000/200000000 = 120μs
GW1 – Sat: 36000000/300000000 = 120,000μs
Sat – GW2: 120,000μs
GW2 – B: 60μs

Total propagation delay: 240,180μs

Processing delay: 25μs

Queuing delay: 10μs

Total delay: 242,465μs

b) If Stop and Wait flow control protocol was used by the transport layer between A and B, would it be efficient? Explain your answer. [3 marks]

Answer

We know the efficiency of Stop and Wait flow control depends on the ratio of Propagation Delay to Transmission Delay. If propagation delay is larger, then inefficient. In this case the propagation delay is *much larger* than the transmission delay, therefore **inefficient**.

Another argument is that we know that Stop and Wait is generally inefficient with small frames (2000 bytes is small, when the propagation delay is very large).

Question 5 [13 marks]

Consider the network in Figure 4 where frames are generated at node A and sent to node C through node B. Assume the following:

- The data rate between A and B is 100Kb/s
- The propagation delay is 5μs/km for both lines
- There are full duplex lines between the nodes
- All data frames are 1000 bits long; ACK frames are separate frames of negligible length (that is, you can assume the transmission time of an ACK is 0)
- Between A and B, a sliding window flow control protocol with window size W=3 is used.
- In the sliding window protocol, the receiver s*ends an ACK for every frame received* (and there is no processing delay)
- Between B and C, stop and wait flow control is used.
- There are no errors.

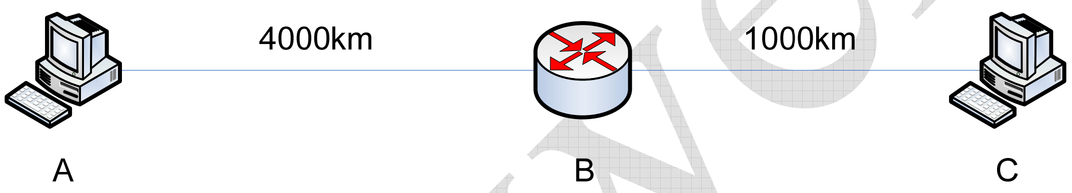


Figure 4: A to C via B

Figure 5 gives an example of a single frame being sent from B to C using Stop and Wait flow control.

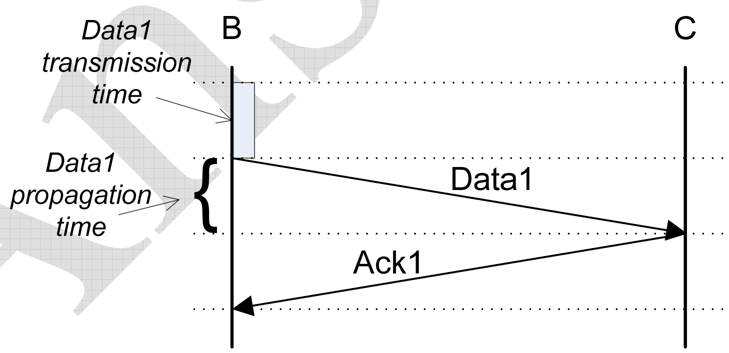


Figure 5: B to C using Stop and Wait

a) Complete the diagram in Figure 6 that illustrates the maximum transmission rate using the sliding window when sending 6 data frames from A to B. Use the same format as Figure 5. Draw the diagram to scale – the horizontal vertical lines are in 10ms intervals. [6 marks]

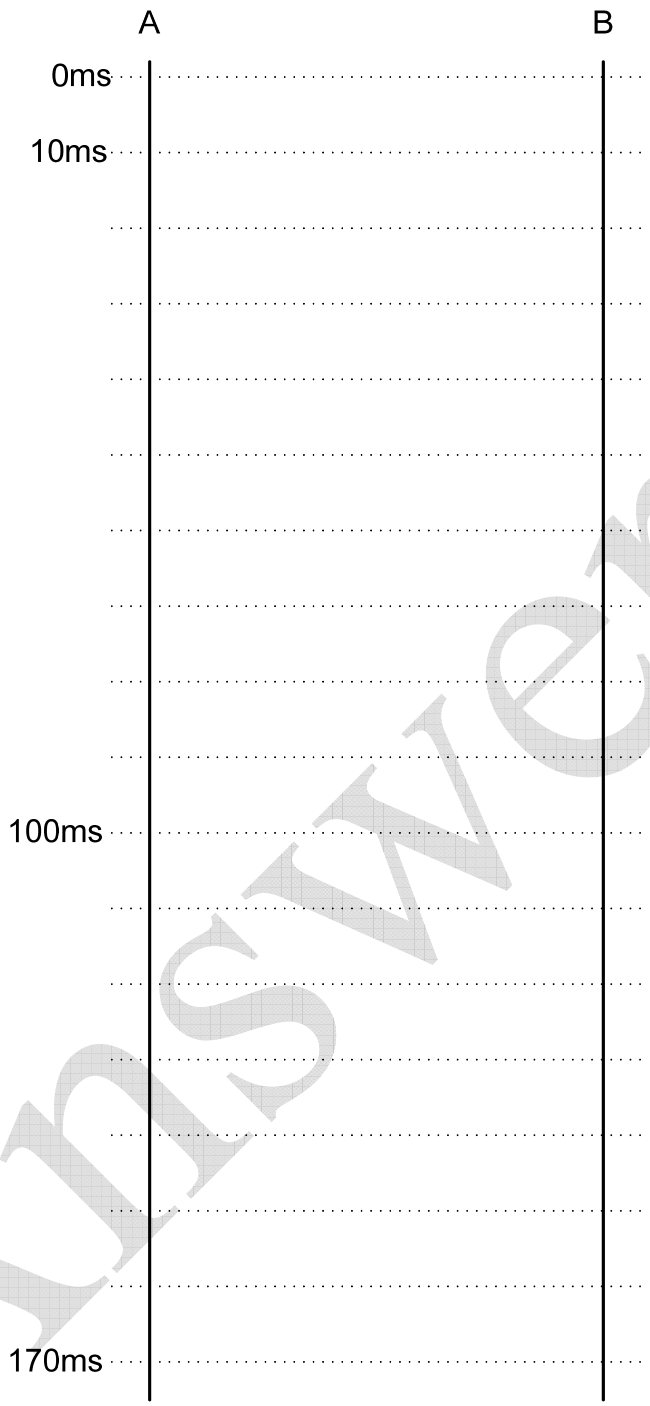
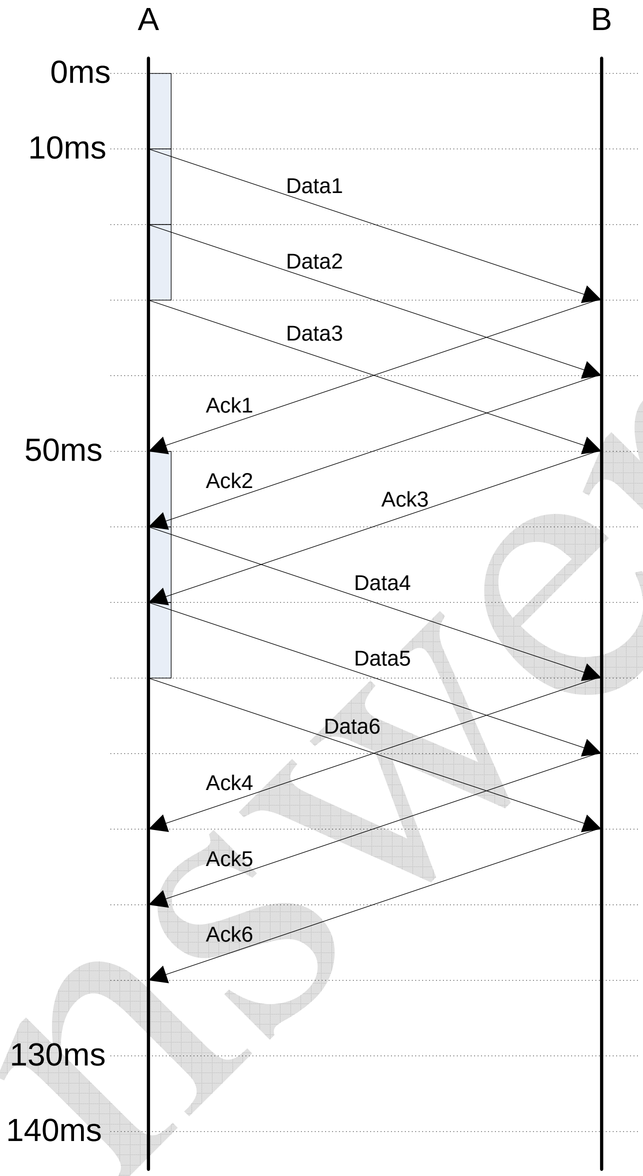


Figure 6: A to B using Sliding Window

Answer



b) Determine the minimum data rate required between nodes B and C so that the buffers at node B are not flooded. [Hint: In order to not flood the buffers of B, the average number of frames entering and leaving B must be the same over a long interval. Use your answer from part (a) to work out the rate of frames entering B.] [7 marks]

Answer

It takes A 50ms to send 3 frames (if you see the answer for part (a), three new frames can be sent after 50ms). So B must be able to send 3 frames to C using Stop and Wait in 50ms (otherwise the frames coming into B will be faster than the frames leaving, creating buffer overflow).

For stop and wait, the time for transmitting one frame is:

DataTransmision + 2 x Propagation (since Ack transmission is ignored)

We know the propagation time is 5ms (1000km at 5us per km) and the data transmission is 1000 bits / Rate. So we need to find the Rate, X.

So we need:

$$3(t_{Data} + 2t_{prop}) < 50ms$$

$$3(\frac{1000}{X} + 2 \times 5) < 50$$

$$\frac{3000}{X} < 20$$

$$X > 150kb/s$$

The answer is 150kb/s – the data rate must be more than 150kb/s in order to avoid overflow at B.

Question 6 [10 marks]

Figure 7 and Figure 8 show a portion of the signals $s_1(t)$ and $s_2(t)$, respectively.

a) For each signal, calculate the maximum data that can be achieved if the system bandwidth is limited to 24MHz. You can assume only 2 signaling levels are used. [8 marks]

$$s_1(t) = \sin(2\pi f t) + \tfrac{1}{3}\sin(2\pi 3 f t) + \tfrac{1}{5}\sin(2\pi 5 f t)$$

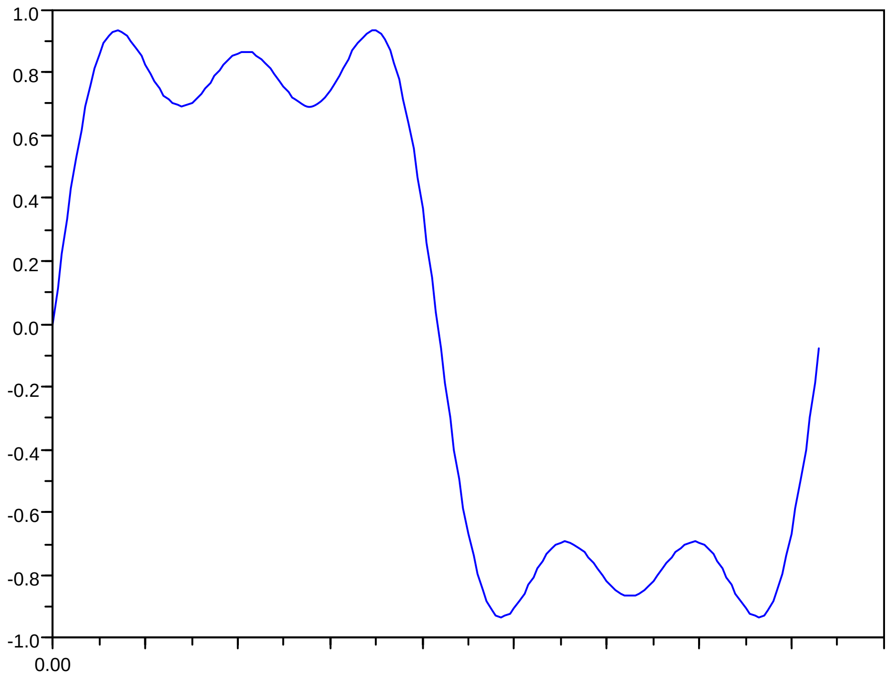


Figure 7

Answer

The bandwidth of s_1 is 4f = 24MHz, and hence the frequency must be 6MHz. Therefore the period of the signal is 1/6μs. Assuming a high level is 1 bit and a low level is another bit, there can be two bits sent per period. That is, 2 bits per 1/6μs. Therefore maximum data rate is 12Mb/s.

$$s_2(t) = \sin(2\pi ft) + \tfrac{1}{3}\sin(2\pi 3\,ft) + \tfrac{1}{5}\sin(2\pi 5\,ft) + \tfrac{1}{7}\sin(2\pi 7\,ft) + \tfrac{1}{9}\sin(2\pi 9\,ft)$$

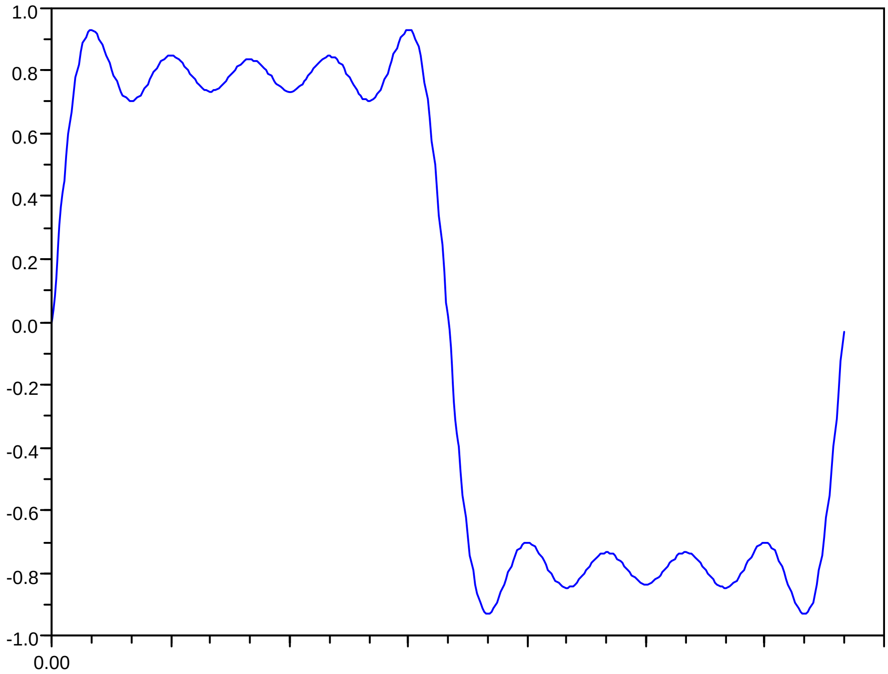


Figure 8

Answer

The bandwidth of s_2 = 8f = 24MHz, hence frequency is 3MHz. Following same calculations as previous signal, the data rate is 6Mb/s.

b) What is an advantage of $s_2(t)$ compared to $s_1(t)$? [2 marks]

Answer

Although offering a lower data rate, less errors are likely to occur if $s_2(t)$ is used.

Question 7 [6 marks]

You want to design a home network to connect several High Definition Television (HDTV) devices together (e.g. TVs, receiver, digital recorders, computer). The specifications of HDTV are:

- The image resolution is 1920 x 1080 pixels
- Screen refresh rate is 30 images per second
- 24-bit colour is used; each pixel is represented by 24-bits.

a) What is the data rate required to transmit the HDTV data between devices? Give your answer to the nearest Mb/s. [3 marks]

Answer

Data rate = 1920 x 1080 pixels x 24bits per pixel x 30 images per second
= 1493Mb/s

b) What is the minimum number of signaling levels required if the HDTV is to be transmitted over a 75 MHz noise-free channel? [3 marks]

Answer

Nyquist: $C = 2B\log_2(M)$

$1493M = 2 \times 75M \log_2(M)$

$9.95 = \log_2(M)$

M = 990 (or without approximating data rate, 991.3 or 992)

Question 8 [7 marks]

You design a new, simple layered protocol architecture for connecting two computers that uses only 3 layers, called (from bottom to top): Physical, Network, Application. The main role of each layer is (from the sender's point of view):

- Application layer receives the user data (e.g. files, web page requests and responses) and adds a 5 byte header to indicate the destination.
- Network layer receives data from the Application layer, and breaks it into packets no larger than 100 bytes. It then adds a 10 byte header for addressing and other control information.
- Physical layer takes each Network layer packet, breaks it into 80-bit frames, adds a 16-bit Cyclic Redundancy Check (CRC) code and transmits the signal to the receiver. If a packet does not contain an integral number of 80-bit frames, then the Physical expands the last frame to 80-bits (for example, by padding it with 0's).

If the user wishes to send a 100KB file using the protocol stack, what is the throughput if the Physical layer data rate is 1Mb/s?

Answer

User data: 100KB

Application layer adds 5 bytes: 100,005Bytes

Network layer creates 1001 packets (the first 1000 are 100 bytes in length, and the last is 5 bytes in length). Then it adds a 10 byte header to each.

So far: 1000 x 110B + 1 x 15B.

Physical layer takes each 110B packet and creates 11x10 byte frames. Each of these frames has another 16 bits added. The Physical layer takes the 15B packet and creates 2x10B frames and adds 16 bits to each.

So we transmit: 1000 x (11 x (10B + 16b)) + 1 x (2 x (10B + 16b))

= 1000 x 11 x 96bits + 1 x 2 x 96 bits
= 11002 x 96 bits
= 1056192 bits

Useful data was 800000 bits.

Throughput = (800000/1056192) x 1Mb/s = 757kb/s