Name ….....ID …..... Section ….....Seat No.....

Sirindhorn International Institute of Technology
Thammasat University

Midterm Examination: Semester 1/2009

Course Title : ITS323 Introduction to Data Communications

Instructor : Dr Steven Gordon

Date/Time : Monday 27 July 2009; 13:30 – 16:30

Instructions:

- This examination paper has 18 pages (including this page).
- Condition of Examination
  Closed book (No dictionary; Non-programmable calculator is 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.
- Assume bits are ordered from left to right: 1st bit, 2nd bit, 3rd bit, …, nth bit
- Unless otherwise stated in the question, assume the speed of transmission is 3×10^8m/s
- Free space propagation path loss:

$$\frac{P_t}{P_r} = \frac{(4\pi d)^2}{G_t G_r \lambda^2}$$

- Antenna gain for parabolic antenna with area A:

$$G = \frac{4\pi A}{\lambda^2}$$

Part A – Multiple Choice Questions [22 marks]

Select the most accurate answer (only select one answer). Each correct answer is worth 2 marks. Incorrect answer is 0 marks. No answer is 0 marks.

1. Which technique is used for transmitting analog data as digital signals?
   a) Frequency Modulation
   b) Pulse Code Modulation
   c) Quadrature Amplitude Modulation
   d) Binary Frequency Shift Keying
   e) Manchester Encoding
   f) None of the above

2. Which of the following is an example of a network layer address?
   a) 00:17:31:7e:50:7d
   b) its323@ict.siit.tu.ac.th
   c) www.siit.tu.ac.th
   d) 72.103.16.5
   e) Port 22
   f) None of the above

3. What is the absolute bandwidth of the signal:

$$s(t) = 15\sin(2000\pi t) + 5\sin(6000\pi t) + 3\sin(10000\pi t) + 2\frac{1}{7}\sin(14000\pi t)$$

   a) 1000 Hz
   b) 2000 Hz
   c) 3000 Hz
   d) 6000 Hz
   e) 10000 Hz
   f) 12000 Hz
   g) 14000 Hz
   h) 28000 Hz

4. Which technique can be described as “vary the frequency of the output carrier signal as the amplitude of the input data changes”:
   a) Frequency Modulation
   b) Frequency Shift Keying
   c) Quadrature Amplitude Modulation
   d) Bipolar AMI Encoding
   e) Phase Modulation
   f) Delta Modulation

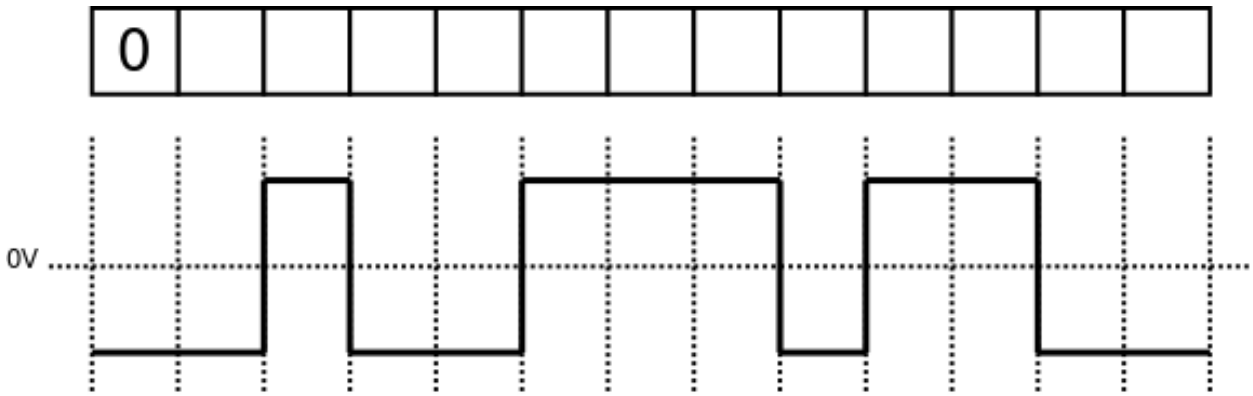
5. Which of the following is incorrect?
   a) Optical fibre provides higher data rates than electrical cabling technologies
   b) With coaxial cable signals can be transmitted over a large distance than with twister pair.
   c) Unshielded twister pair is easier to install than shielded twisted pair
   d) Electrical cable technologies are designed to minimise the effects of interference from other sources on the transmitted signal
   e) The most common technology used in home telephone lines and in-building LANs is coaxial cable
   f) Optical fibre can be used over larger distances the twisted pair.

6. Quadrature PSK uses the phases: 45°, 135°, 225°, 315°. If the duration of each signal element (that is, signal at one phase) is 200ns, then the data rate is:
   a) 1 Mb/s
   b) 2.5 Mb/s
   c) 5 Mb/s
   d) 10 Mb/s
   e) 25 Mb/s
   f) 50 Mb/s
   g) 100 Mb/s
7. A transmission systems 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
8. If a signal has a period of 4us, then the wavelength of the signal is:
   a) 1200 m
   b) 2500 m
   c) 2.5 KHz
   d) 120000 m
   e) 120000 Hz
   f) 250000 Hz
   g) 2.5 MHz
9. A link with data rate of 3Mb/s has a received signal power of 6.3W and received noise level of 20dBm. What is the minimum bandwidth required?
   a) 20 KHz
   b) 300 KHz
   c) 500 KHz
   d) 600 KHz
   e) 1.5 MHz
   f) 3 MHz
   g) 6 MHz
10. The User Datagram Protocol (UDP) is an example transport layer protocol. Normally it would be implemented as:
   a) Software in the operating system
   b) Part of a user application, such as web browser, email client or audio/video streaming application.
   c) Device drivers that control the LAN/WAN interface cards
   d) hardware on the LAN/WAN interface cards
   e) An application installed by users that want to use UDP
11. Which layer in the Internet stack has the role of delivering packets from source node to intermediate nodes and eventually to destination node when there are multiple links between source and destination?
   a) Physical
   b) Transport
   c) Application
   d) Hardware
   e) Data Link
   f) Network

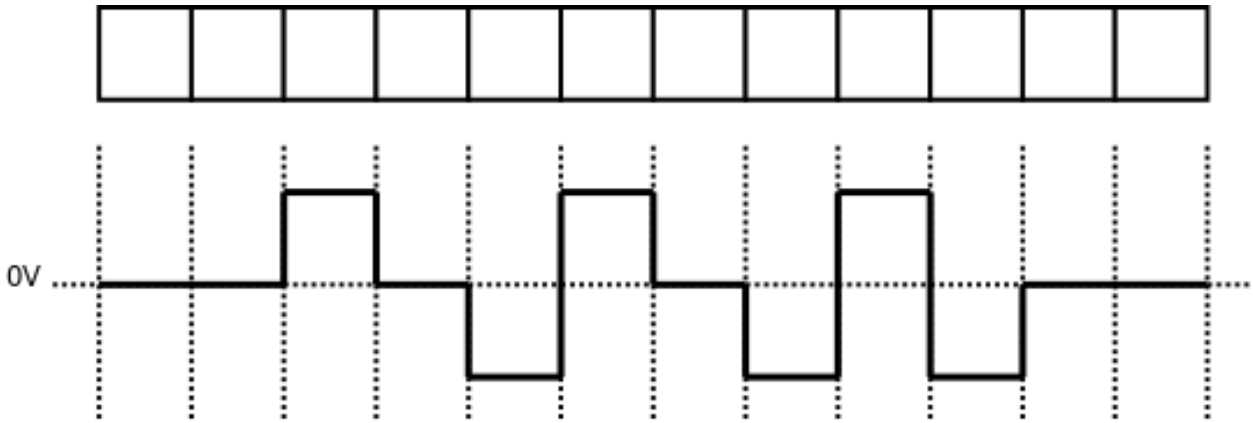
Part B – General Questions [78 marks]

Question 1 [12 marks]

a) The following digital signal was encoded using NRZ-Invert. What is the digital data? (Fill in the boxes). [3 marks]



b) The Pseudoternary digital encoding scheme alternates between positive and negative voltage levels between successive bit 0's, and uses zero voltage for bit 1. Write the received bits in the boxes for the following received digital signal. [3 marks]



The following data is to be sent using a combination of FSK and ASK. There are 2 possible frequencies and 4 possible amplitudes.

010101001001010110110111

c) Select and describe a mapping of bits to signals (sinusoids) that uses all possible combinations of frequencies and amplitudes. [3 marks]

d) Using the mapping you selected in part (c), draw the analog signal to be transmitted. [3 marks]

Question 2 [11 marks]

Consider a point-to-point wireless communications system using two parabolic antennas:

- Transmit antenna diameter: 1 metre
- Receive antenna gain: 20dBi
- Signal frequency: 3GHz
- Distance between transmitter and receiver: 10km
- Receive power threshold: -80dBm

a) Assuming free space path loss, what is the minimum transmit power required? [6 marks]

In the free space path loss model, the absolute path loss (L) between the two antenna's can be written as:

$$L = \frac{(4\pi d)^2}{\lambda^2}$$

However, the free space path loss model does not consider obstructions or other environmental factors. Assume you have measured the real path loss between the two antennas to be L_{dB} = 130dB

b) Using the measured path loss (instead of free space path loss), what is the minimum transmit power required? [5 marks]

Question 3 [9 marks]

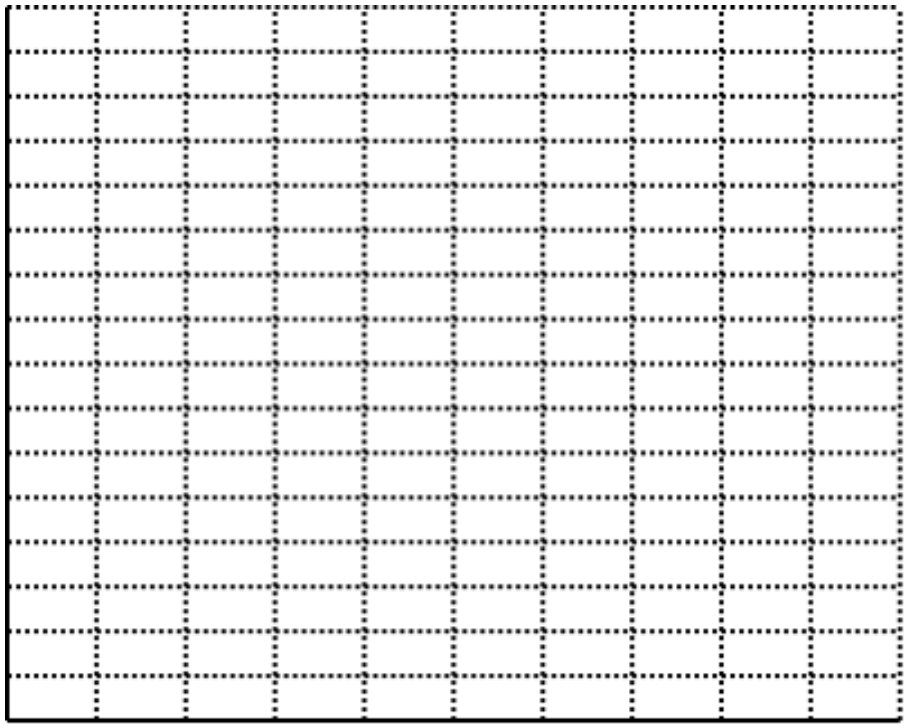
A standard encoding format for digital telephony is Pulse Code Modulation.

a) Assuming the human voice has a spectrum of frequencies ranging from 200Hz to 4000Hz, what sampling rate should be used to retain all necessary information in the digital data? [1 mark]

Assume that the number of code levels used for PCM in a telephone system is 16. The following sequence of bits are the PCM encoded digital data received by a destination telephone (assume no errors).

0101001100110010010001111010101010111100

b) On the figure below draw the output analog audio signal at the destination telephone. The horizontal dotted lines should be used as the levels, and the vertical dashed lines as the sample points. [3 marks]



In practice, the number of code levels used in telephone systems is normally 128 (instead of 16). Assume this is the case in the following parts.

c) If SIIT Bangkadi has a 1Mb/s link to SIIT Rangsit, how many PCM encoded voice calls can be sent from Bangkadi to Rangsit at the same time (ignore other overheads such as headers)? [3 marks]

d) Some applications that transmit voice over the Internet (such as Skype, MSN) may use lower sampling rates and less code levels than above. Referring to part (c), that is the number of voice calls, explain an advantage and disadvantage of changing these values for voice applications [2 marks]

Advantage of lower sampling rates, less code levels

Disadvantage of lower sampling rates, less code levels

Question 4 [16 marks]

Table 1 shows the list of codewords for a Hamming-distance based Forward Error Correction (FEC) scheme.

Data	Codeword
000	011011
001	100110
010	100111
011	010000
100	111100
101	001010
110	100101
111	001011

Table 1: Hamming-based FEC

a) For the following cases, explain the steps taken by the receiver (showing any calculations where necessary), and summarise the outcome by answering the 4 questions. [9 marks]

i. The data 010 is to be sent from transmitter to receiver. The 1st bit transmitted is in error (that is, the 1st bit transmitted is different from the 1st bit received).

Steps taken by receiver:

Codeword received by receiver: ___ ___ ___ ___ ___ ___

Error detected by receiver? YES NO

Data received: ___ ___ ___ (if applicable)

Is the correct data received? YES NO

ii. The data 100 is to be sent from transmitter to receiver. The 1st and 2nd bits transmitted are in error.

Steps taken by receiver:

Codeword received by receiver: ___ ___ ___ ___ ___ ___

Error detected by receiver? YES NO

Data received: ___ ___ ___ (if applicable)

Is the correct data received? YES NO

iii. The data 001 is to be sent from transmitter to receiver. The last bit transmitted is in error.

Steps taken by receiver:

Codeword received by receiver: ___ ___ ___ ___ ___ ___

Error detected by receiver? YES NO

Data received: ___ ___ ___ (if applicable)

Is the correct data received? YES NO

b) Assuming you must use a FEC with 3 bits of data and 6-bit codeword, explain how the scheme in Table 1 could be changed to reduce the possibility of single-bit errors being undetected. [3 marks]

c) If using a link with data rate of 12Mb/s, what is the maximum possible throughput using the encoding scheme in Table 1? [2 marks]

d) Explain one advantage and one disadvantage of using an 8-bit codeword (instead of 6-bit codeword as in Table 1). [2 marks]

Advantage

Disadvantage

Question 5 [14 marks]

Consider a network with two links: A --- B --- C.

First consider the link from A to B with the following characteristics.

- DATA frame consists of 100 bits of header plus 9900 bits of data (total size 10,000 bits)
- ACK frame consists only of 100 bits of header
- Link data rate is 100Mb/s
- Link distance is 120km
- Link signal speed is $3x10^8$ m/s

The Sliding Window flow control protocol is used on this link. The receiver (B) sends an ACK frame immediately after receiving a DATA frame (there is no processing delay). A 3-bit sequence number is used within the header of the DATA frame (and ACK frame).

a) What is the maximum number of DATA frames node A can send before having to wait for an ACK? [1 mark]

b) Assuming node A always has data ready to send, and it starts transmission of its 1st DATA frame at time 0s, at what time can node A start transmitting the 2nd DATA frame? [2 marks]

c) At what time can node A start transmitting the 8th DATA frame? (You may draw a diagram to help in the calculation) [4 marks]

d) What is the maximum throughput that can be achieved across the link from A to B? [3 marks]

Now consider the link from B to C with the following characteristics:

- DATA frame consists of 100 bits of header plus 9900 bits of data (total size 10,000 bits)
- ACK frame consists only of 100 bits of header
- Link distance is 1200m
- Link signal speed is $3x10^8$ m/s

The Stop and Wait flow control protocol is used in this link.

e) What is the minimum data rate necessary for Link B to C such that the throughput from A to C is the same as calculated in part (d)? [4 marks]

Question 6 [7 marks]

High Definition TV consists of a 1920 x 1080 pixel image, refreshed at a rate of 30 images per second. 24-bit colour is used – that is, each pixel is a 24-bit colour value.

a) What is the data rate required to transmit an uncompressed HDTV movie in real-time? [3 marks]

b) Compression is often used to reduce the data rate necessary for sending video. Under some circumstances, HDTV can be compressed to 5% of its original size. What is the data rate required to transmit a compressed HDTV movie in real-time? [1 mark]

c) In a noise-free channel, what is the minimum number of signal levels necessary to transmit the compressed HDTV within 6MHz of bandwidth? (Note the number of signal levels must be a power of 2) [3 marks]

Question 7 [9 marks]

Table 2 shows a set of frames received by the Data Link layer of a computer (including the time when it is received). Each frame contains a header plus data. The amount of data in each frame is shown in the Data column. The Data Link layer header contains five fields:

1. A 16-bit timestamp, which indicates the time when the frame was sent
2. Address of the source, in the format of a 48-bit IEEE address
3. Address of the destination, in the format of a 48-bit IEEE address
4. A 32-bit sequence number
5. A 2 byte field to indicate the type of protocol used.

Time received [ms]	*Sequence number*	*Timestamp [ms]*	*Data [Bytes]*
7	0	0	100
11	1	3	120
14	2	6	150
16	3	9	125
22	4	12	100
23	5	15	125

Table 2: Frames Received

Answer the following questions considering only the frames in the table.

a) What is the average delay from source to destination? [2 marks]

b) What is the jitter between source and destination? [2 marks]

c) What is the throughput for the received data? [2 marks]

d) Consider the source sending the frames. Assume the Physical layer at the source adds an additional 80 bits to each frame. What is the average rate at which bits are sent by the source Physical layer? [3 marks]