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

Sirindhorn International Institute of Technology
Thammasat University

Midterm Exam: Semester 1, 2014

Course Title: ITS323 Introduction to Data Communications

Instructor: Steven Gordon

Date/Time: Monday 6 October 2014; 13:30–16:30

Instructions:

- This examination paper has 17 pages (including this page).
- Conditions 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 at the front of the examination room.
- The examination paper is not allowed to be taken out of the examination room. A violation may result in score deduction.
- Write your name, student ID, section, and seat number clearly on the front page of the exam, and on any separate sheets (if they exist).
- Assume bits are ordered from left to right. For example, for the data 00001111, the first (1st) bit is 0 and the last (8th) bit is 1.
- Assume the speed of transmission is 3×10^8 m/s
- Nyquist capacity: $C = 2B \log_2 (M)$
- Shannon capacity: $C = B \log_2 (1 + SNR)$
- Antenna gain:
$$G = \frac{4\pi A_e}{\lambda^2}$$
- Path loss model:
$$P_r = \frac{P_t G_t G_r}{L_p}$$
- Free space path loss:
$$L_p = \frac{(4\pi d)^2}{\lambda^2}$$

Question 1 [18 marks]

For each question fill in the blank space with the most appropriate term from Table 1. For each blank space you must give only one answer. However, there may be more than one correct answer. You may use a term from the table in more than one question. You must not use terms that are not in the table. Each correct answer is worth 1.5 marks.

accuracy	fundamental	point-to-point
analog data	gain	processing
analog signal	guided	propagation
attenuation	half-duplex	queuing
carrier	harmonic	simplex
center	header	spectrum
coaxial cable	HTTP	timeliness
delivery	isotropic	trailer
digital data	LAN	transmission
digital signal	multipoint	twisted pair
directional	network	unguided
frequency	noise	WAN
full	omnidirectional	wavelength
full-duplex	optical fibre	-

Table 1: Possible answers for Question 1

SG: I forgot to add "transmitter" and "receiver" to the table, so question (a) was marked correct for everyone, no matter what your answer was

(a) A model of a communication system consists of a source and _____ in the source system, a transmission system, and a _____ and destination in the destination system. **SG: Marked correct for everyone**

(b) Most applications require delivery of data for effective communications. Of the other requirements for effective communications, for multimedia (or real-time applications) usually _____ is more important than _____.

(c) The protocol used for web browsing is _____.

(d) When all components in a signal have a frequency which is an integer multiple of one frequency, then that one frequency is called the _____ frequency.

(e) As the _____ received at a receiver increases (compared to the received signal), the increased chance of errors.

(f) For a device that has data arriving from multiple different sources, and then sends that data onto a single destination, as the data arriving increases, the _____ delay increases.

(g) TV broadcasts are an example of simplex communications using an unguided media and in a _____ configuration.

(h) _____ is a guided media that provides higher data rates and allows for transmission across larger distances than coaxial cable.

(i) As the distance a signal needs to propagate increases, the _____ of that signal increases.

(j) _____ is the most common guided media used within home LANs.

(k) A common measure of an antenna characteristic is to consider the gain of its signal strength in one direction compared to when using a/an _____ antenna.

(l) A LAN cable has multiple pairs of wires, with one pair used for transmission of signals in one direction, and another pair used for transmission of signals on the opposite direction. With respect to direction of communications, a LAN cable is considered to be _____.

Question 2 [12 marks]

Consider a transmission system for which you have measured different characteristics. Figure 1 shows the received signal in the frequency domain. Figure 2 shows the measured signal power and noise power at the receiver.

Figure 1: Signal in frequency domain

Figure 2: Receive signal and noise power

(a) What is the bandwidth of the transmission system? [3 marks]

(b) What is the SNR of the transmission system? [3 marks]

(c) If the signal uses 8 bits per level, then what is the maximum theoretical data rate that can be achieved in this transmission system? (Show all calculations) [6 marks]

Question 3 [11 marks]

Consider the network in Figure 3 where computer A has data to send to computer B. Link distances and data rates are shown for each link, and the processing delay for each device is shown below the device (e.g. the processing delay for each message at the satellite is 7 ms). The distance to the satellite from A is the same as the distance from the satellite to the gateway (GW): 36,000 km. Assume computer A has a 12,500 B message to send to computer B.

Figure 3: Satellite network

(a) What is the transmission delay of the message from computer A up to the satellite? [2 marks]

(b) What is the propagation delay of a signal from the satellite down to the gateway? [2 marks]

(c) What is the total delay to deliver the message from computer A to computer B? [4 marks]

(d) If computer A has many messages of the same size to send to computer B (e.g. millions of messages ready to send from A, with each message 12,500 B in length), then if you ignore protocol overheads, what is the maximum throughput that can be achieved? Explain your answer. [3 marks]

Question 4 [16 marks]

Consider a communications signal, $s(t)$, given by the following general equation:

$$s(t) = A\left(\sin(2\pi ft) + \frac{1}{3}\sin(2\pi 3ft) + \ldots \frac{1}{2N-1}\sin(2\pi(2N-1)ft)\right)$$

where N is the number of components in the signal.

As an example, Figure 4 shows the signal in the time domain and Figure 5 shows the corresponding signal in the frequency domain when N=2. (T is the signal period).

Figure 4: Signal in time domain, $N = 2$

Figure 5: Signal in frequency domain, $N = 2$

Answer the following questions assuming the general signal equation.

(a) If the frequency of a signal with 3 components is 1 kHz, then what is the signal period? [1 mark]

(b) If the frequency of a signal with 3 components is 1 kHz, and 2 bits can be transmitted per period, then what is the data rate? [1 mark]

(c) If the bandwidth of a signal with 3 components is 24 MHz, and 2 bits can be transmitted per period, then what is the data rate? [2 marks]

(d) If the bandwidth of a signal with 4 components is 24 MHz, and 2 bits can be transmitted per period, then what is the data rate? [2 marks]

(e) Consider a signal with 5 components that occupies a bandwidth of 40 kHz. Draw a plot of the signal in the frequency domain. [2 marks]

When the signal frequency is fixed, the relationship between the number of components and the data rate can be described as:

"increasing the number of components does not increase or decrease the data rate"

Use a similar statement to describe the relationship in the following questions.

(f) When the number of components is fixed, describe the relationship between the signal bandwidth and data rate. [2 marks]

(g) When the bandwidth is fixed, describe the relationship between the number of components and the signal accuracy. [2 marks]

(h) When the data rate is fixed, describe the relationship between the number of components and the signal bandwidth. [2 marks]

(i) Explain two disadvantages of increasing the bandwidth used by a signal or transmission system. [2 marks]

Question 5 [14 marks]

You have a wireless system with the following components:

- Transmitter with adjustable transmit power
- Transmit antenna with gain of 15 dBi
- Receive antenna is a parabolic antenna with radius of 0.4 m. Assume the effective area is 0.5 times the physical area (of a circle).
- Receiver with receive sensitivity of -60 dBm
- Distance between transmitter and receiver is 4500 m
- Signal frequency is 3 GHz

(a) What is the wavelength of the signal? [1 mark]

(b) What is the gain of the receive antenna in dBi? [3 marks]

(c) What is the free space path loss, in dB, between the transmit antenna and receive antenna? [3 marks]

(d) What is the minimum transmit power, in dBm, needed to be able to successfully communicate between transmitter and receiver? [4 marks]

Now consider the same wireless system, but using long cables: a 30 metre cable between transmitter and transmit antenna, as well as a 10 metre cable between receive antenna and receiver. With longer cables, the loss across those cables can become significant. Assume now the loss for each cable is 0.2 dB per metre.

(e) What should the transmit power be adjusted to, in dBm, so that the cable loss is also considered? [3 marks]

Question 6 [8 marks]

Computer A is connected to computer B by a link with data rate 50 Mb/s. The user on computer A has 12.5 GB of data to send to B. The protocol used for sending the data splits the data into packets: each packet contains 1000 B of data plus 75 B of overhead information.

(a) What is the maximum throughput that can be achieved in the data transfer? [4 marks]

(b) What is the efficiency of the protocol? [2 marks]

(c) If, due to errors in the link, 5,000 packets that arrived at the receiver contained unrecoverable errors (i.e. the receiver cannot use the data), then what is the average packet error rate of the link? [2 marks]

Question 7 [8 marks]

Assume Binary Frequency Shift Keying is used to transmit the data 01100101 across a link.

(a) Draw the transmitted signal on Figure 6. [2 marks]

Figure 6: Draw the transmitted signal data

Often PSK is combined with ASK. When used together they are called *Quadrature Amplitude Modulation*. The combination of amplitudes and phases is often drawn in a constellation diagram, as shown in Figure 7 for 16-QAM. The length of the line from centre to the dot indicates the amplitude to use in a signal element for a sequence of bits, while the angle indicates the phase.

Figure 7: Constellation for 16-QAM

(b) If each signal element contains a signal constructed of a simple sine wave (i.e. single frequency component) with frequency 200 kHz, then write an equation for the signal element that produces data 1000. (Hint: $s(t) = \ldots$ and the only variable in the equation is t. You may write the angle in either radians or degrees). [2 marks]

(c) What signalling rate is needed to achieve a data rate of 20 Mb/s when using 16-QAM? [1 mark]

(d) Given a constant signalling rate, if 256-QAM was used, the data rate would be how many more times faster than if using BPSK? [1 mark]

(e) Explain two disadvantages of using 256-QAM compared to 16-QAM. [2 marks]

Question 8 [8 marks]

Consider two example AM radio channels; each channel uses a bandwidth of 10 kHz. Channel 1 uses a carrier signal with center frequency of 905 kHz, while channel 2 uses a carrier signal with center frequency of 920 kHz. Also consider an example FM radio channel with bandwidth 40 kHz and center frequency of 105.5 MHz.

(a) NRZ is used to transmit digital data as a digital signal. What is AM (and FM) used for? [1 mark]

(b) Draw a single plot showing both AM radio channel signals in the frequency domain. [3 marks]

(c) Explain how an AM signal is generated. [2 marks]

Both AM and FM radio normally is used for voice and music. The spectrum of voice ranges from 100 Hz to 4 kHz, while the spectrum for music ranges from 10 Hz to 20 kHz.

(d) Assuming the same music is being played on both AM radio and on FM radio, which one would sound better? Explain why. [2 marks]

Question 9 [5 marks]

Consider a transmitter with an attached antenna. Explain the direction in which a signal propagates, and at what strength, if using a:

(a) Isotropic antenna [1 mark]

(b) Omni-directional antenna [1 mark]

Assume if the antenna attached to the transmitter was isotropic, then the power received at a distance of 100 m away is 100 mW.

(c) If instead the antenna is a parabolic dish antenna with a gain of 20 dBi, then what would the highest receive power be at a distance of 100 m away. [3 marks]