University College Dublin
An Coláiste Ollscoile, Baile Átha Cliath

SEMESTER II EXAMINATIONS - 2012-2013

School of Electrical, Electronic and Communications Engineering

EEEN 20060

Communication Systems

External Examiner:	Professor S. McLaughlin
Head of School:	Professor T. Brazil
Module Coordinator:	Brian Mulkeen*

Time Allowed: 2 Hours

Instructions for Candidates

Answer any **three** questions. All questions carry equal marks.
The percentages in the right margin give an approximate indication of the relative importance of each part of the question.

You may consult one textbook and one folder of notes during the examination.
You must keep these items on or under your desk during the examination, and you must use them quietly, without causing inconvenience to others.

All rough work should be entered in your answer books.

Instructions for Invigilators

This is an **open-book** examination – candidates are allowed to bring one textbook and one folder of notes to the examination, and to consult these during the examination.

Calculators are permitted, but no rough-work paper is to be provided for candidates.

Question 1

Answer any **four** parts of this question. All parts carry equal marks.

a) A device transmits text, encoded using ASCII, using an asynchronous serial protocol. The line idles at logic 1, which is represented by a negative voltage. Each character group has 1 start bit; 7 data bits, sent least-significant bit first; 1 parity bit, giving odd parity; and 1 stop bit. Figure 1 shows an example of the received signal. Identify the characters and any parity errors.

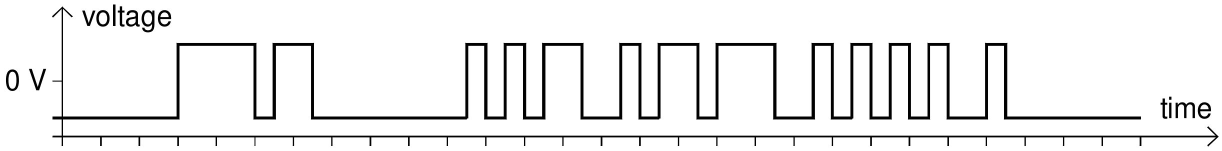

Figure 1: Received Signal

b) Figure 2 shows a small packet-switched network that uses simple fixed routing tables. The number beside each link represents the cost of using that link. Draw up the routing table at node E, showing, for each destination, the preferred next node and an alternative (for use if the preferred link is broken). Consider what happens if node F fails, so that all links leading to F appear to be broken. Is there any risk of packets circulating in a loop?

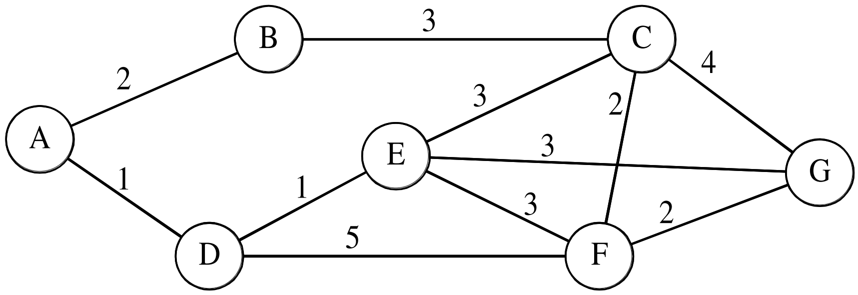

Figure 2: Network Diagram

c) When a packet arrives at a node in the network in Figure 2, a routing decision is made and the packet is placed in a first-in-first-out queue for the appropriate link. Packets arriving at node D can be modelled as a Poisson random process, with parameter $\lambda = 2000\ \text{s}^{-1}$. Of these, 25% need to travel on link D-E, which operates at 1 Mbit/s. The packet size has exponential probability density function, with average 1500 bits. The link layer protocol adds an overhead of 64 bits. Find the average waiting time in the queue for link D-E at node D. Also find the probability of finding the queue empty.

d) A byte-oriented link-layer protocol uses a separate checksum to detect errors in the header, which contains 10 bytes, including one header checksum byte. The checksum is such that when all 10 header bytes are added at the receiver, modulo 256, the result should be 0. Calculate the checksum byte that should be appended to the 9 header bytes below. Explain what is meant by failure of an error detection system, and give examples of error combinations that could cause this error detection system to fail.

1 198 18 157 23 165 49 0 82 ???

e) Explain briefly why a hierarchical addressing scheme is needed in a network of networks, such as the worldwide telephone network or the Internet. A PC is configured with IP Address: 137.43.68.29, Subnet Mask: 255.255.224.0 , Gateway: 137.43.66.1. What range of IP addresses is in its subnet? What will it do with packets destined for IP addresses outside this range?

Question 2

You are to design a link-layer protocol to provide reliable transmission of arbitrary binary data over a 60 km radio link. The physical layer delivers 1.2 Mbit/s in either direction, with each bit having probability of error 2×10^{-5}. The hardware at each end of the link can be switched to transmit mode or to receive mode, but cannot do both at the same time. Each change of mode takes 20 μs, and it is not possible to transmit or to receive during this time. You may assume that the speed of light is 3×10^{8} m/s.

Other devices use the radio channel, so every transmission must include the address of the intended receiver, which is an 8-bit number. The blocks of data to be transmitted can vary in size from 64 bits to 3200 bits, always a multiple of 16 bits, with an average size of 2000 bits.

a) Decide how your protocol will operate. Explain how it will recognise the start and end of each frame, and how it will detect errors in the frame. Specify the size of the sending and receiving windows (if any). Specify what responses the receiver should send, and what the sender should do if it receives no response. Give reasons for your design decisions. (30%)

b) Design the frame structure. Specify what information is in the header of a data frame, and in the trailer, and the number of bits allocated to each item. Similarly, specify the structure of any non-data frames that you use. Give reasons for your design decisions. (30%)

c) Consider a cycle starting as the sender switches to transmit mode after receiving an acknowledgement, and ending when the next acknowledgement is received. Hence calculate the throughput that your protocol can deliver, using the average size of data block and assuming that there is always data waiting to be transmitted. Show clearly how you arrive at your answers, and explain any additional assumptions that you make. (40%)

Question 3

In a robot soccer competition, each team has 5 robots, playing in an arena which is 10 m wide and 20 m long. The robots communicate using infra-red light, transmitted using a special prism at the top of each robot, which directs light in all directions in the horizontal plane and also allows light to be received from all directions. Transmission is at 50 kbit/s, using Manchester coding, with the light either on or off.

The aim is to have each robot broadcast a message every 2 or 3 seconds, giving information such as its position, velocity, intentions, etc. Messages will be about 200 bits long, and will be encrypted so that they can only be interpreted by robots on the same team. It is accepted that transmissions will sometimes be blocked when there is another robot in the path, but as the robots are moving most of the time, it is expected that enough messages will get through to make the system work.

Each team has a leader, and this robot could take on additional communication responsibilities if necessary. The rules also allow a communication node to be installed at one corner of the arena, if required. You may make reasonable assumptions about the other details of this system, but you must state these assumptions clearly in your answers.

a) Suggest some options that could be considered in the design of the medium-access control protocol for this system, and outline the advantages and disadvantages of each, in the context of this system. Make it clear which of your suggestions would require a fixed communication node, and which would give extra work to the team leader. (60%)

b) Choose one of your suggestions as the medium-access control protocol to be used, and give reasons for your choice. Specify the details of your proposed protocol, and estimate the throughput that it could provide, in terms of messages per second. (40%)

Question 4

A physical-layer protocol uses a set of 4 signals to send binary data along a cable of length 30 km. Each of the four signals is represented by a different voltage, which is transmitted for 400 ns. The next signal follows immediately. The cable has attenuation 2.2 dB/km at frequencies up to 4 MHz. From the viewpoint of the transmitter, the cable looks like a resistance of 200 Ω. The average transmitter output power is limited to 100 mW.

a) What voltage would you use to represent each of the signals? Give reasons for your proposal. You may assume that all bit sequences are equally likely to occur. (30%)

b) Explain briefly how the receiver would make decisions on the received signals, which will have been distorted by the channel, and will have some random noise added. Sketch an eye diagram, and mark the position of the thresholds that the receiver should use. (30%)

c) The signal-to-noise power ratio (S/N) at the receiver is 45 dB. Figure 3 shows part of the relationship between the probability of bit error and S/N, assuming a sensible choice in part a. Explain why this protocol would not work with a cable length of 100 km. Suggest a method of achieving a reasonable probability of error at 100 km, by adding extra equipment at a point or points along the cable. (40%)

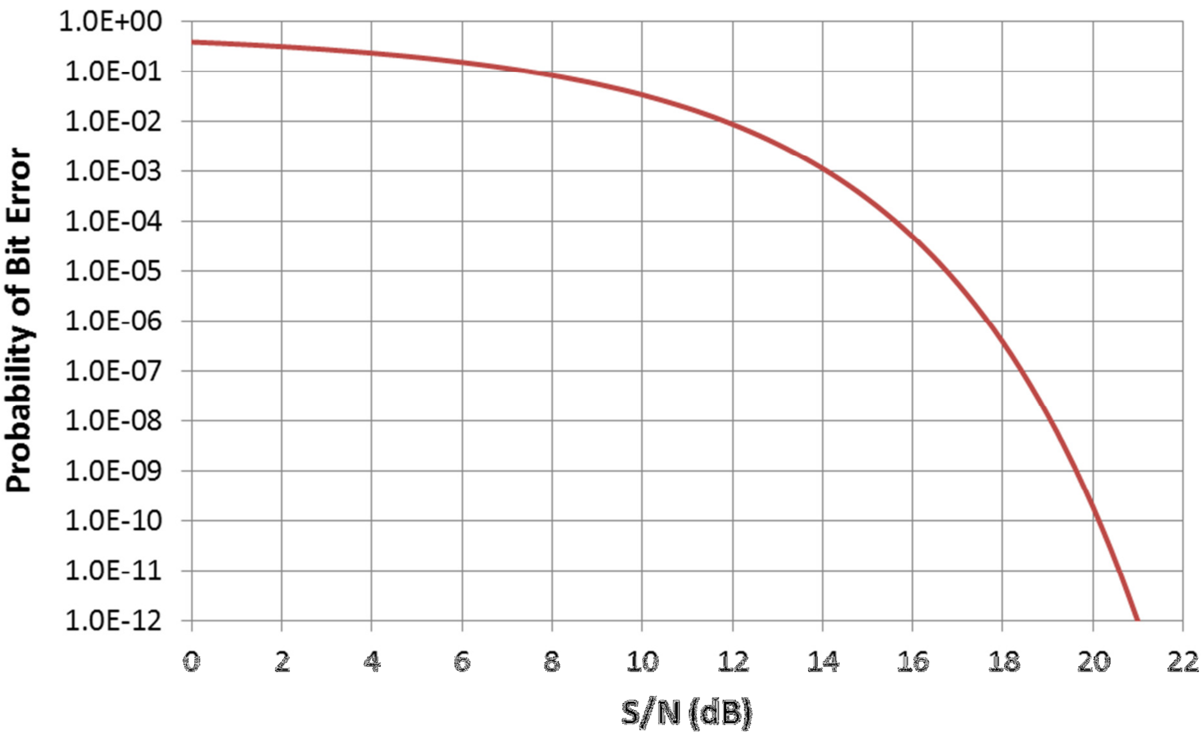

Figure 3: Probability of bit error as a function of signal-to-noise power ratio.

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