Indian Statistical Institute
Mid-Semester Examination: 2019
Course Name: M. Tech in Computer Science
Subject Name: Computer Networks

Date: 21-02-2019 | Maximum Marks: 60 | Duration: 3 hours

Instructions:
You **may** attempt **all** questions which carry a total of **65** marks. However, the maximum marks you can score is only **60**.

1. (a) For the bit stream 101011100, sketch the waveforms for each of the following encoding schemes.
   i. NRZ-L
   ii. Differential Manchester. [3+3=6]

   (b) State three design goals of the scrambling technique? [3]

   (c) If an optical fiber has a bandwidth of 2 GHz and a modem uses 512 signal levels, what is the maximum data rate according to Nyquist? If the average signal power is 405 units and the average noise power is 27 units, what is the maximum channel capacity according to Shannon? [3+3=6]

   (d) Consider a digital telephone system which uses Pulse Code Modulation (PCM) as encoding scheme. Assuming the human voice has a spectrum of frequencies ranging from 200 Hz to 4000 Hz, what sampling rate should be used to retain all necessary information of the original voice signal? Assume that the number of different code levels used for PCM in the said telephone system is 128. If ISI Kolkata has a 1 Mbps dedicated link to ISI Bangalore, how many PCM encoded voice calls can be sent from ISI Kolkata to ISI Bangalore at the same time (ignore other overheads such as headers)? [3+3=6]

   (e) Knowledge of the quantization level (δ) alone is insufficient to make a statement about the possibility of slope overload noise in delta modulation. What else needs to be known? [1]

2. (a) What is a pseudo noise (PN) sequence? State the autocorrelation property of a maximum length PN sequence? [3+3=6]

   (b) Briefly describe the basic principle of direct-sequence spread spectrum. [5]

   (c) Consider an MFSK scheme with carrier frequency f_c equal to 250 KHz, difference frequency f_d equal to 25 KHz, number of different signal elements M equal to 8, and number of bits per signal element L equal to 3.
   Suppose we wish to apply frequency hopping spread spectrum (FHSS) to this MFSK scheme with $k = 2$; that is, the system will hop among 4 different carrier frequencies. Let T_c be the period at which the MFSK carrier frequency changes and T_s is the duration of a signal element. Consider a **fast FHSS** with T_s being $4T_c$. Show the sequence of frequencies used, and the times the frequency changes occur, for transmitting the bit string 011110001. Assume that the PN sequence is 0011 0111 0010 1101 0001 1111. [5]

   (d) A bit string, 01111011111101111110, needs to be transmitted at the data link layer. What is the string actually transmitted after bit-stuffing? [2]

(e) Given the output after byte-stuffing: FLAG A B ESC ESC C ESC ESC ESC FLAG ESC FLAG D FLAG. What is the original data? [2]

3. (a) Consider the use of CRC with generator polynomial $G(x) = x^4 + x^3 + 1$ for error detection. Show the transmitted string for the message string 1 1 0 0 1 1. Construct a burst error of length 5 on the transmitted string in such a way that the error cannot be detected by the CRC with the given $G(x)$. [3+3=6]

(b) Consider a repetition code where each bit b is encoded as n copies of b. Assume that the maximum likelihood decoding rule is employed at the receiver. Assuming binary symmetric channel (BSC) model, compute the probability of decoding error when bit error rate is ϵ and n is an even integer. [3]

(c) Consider a linear block code over $\mathbb{F}_2$ with three data bits D_1, D_2, D_3 and three parity bits P_1, P_2, P_3. The parity bits are defined as follows:

$$P_1 = D_1 + D_2$$
$$P_2 = D_2 + D_3$$
$$P_3 = D_3 + D_1.$$

i. Find the minimum Hamming distance of the code. [3]

ii. What are the error detection and error correction capabilities of the code? [1+1=2]

iii. Suppose the receiver computes three syndrome bits E_1, E_2, E_3 from the (possibly corrupted) received data and parity bits as follows:

$$E_1 = D_1 + D_2 + P_1$$
$$E_2 = D_2 + D_3 + P_2$$
$$E_3 = D_3 + D_1 + P_3.$$

Suppose the receiver performs maximum likelihood decoding using the syndrome bits. Consider the following four combinations of syndrome bits: (i) $E_3 = 0, E_2 = 0, E_1 = 0$, (ii) $E_3 = 0, E_2 = 1, E_1 = 0$, (iii) $E_3 = 1, E_2 = 0, E_1 = 1$, *and* (iv) $E_3 = 1, E_2 = 1, E_1 = 1$. For each combination of syndrome bits, state what the maximum-likelihood decoder believes has occurred: no errors, a single error in a specific bit (state which one), or multiple errors. [4]

(d) Recall that a block code takes a set of k-bit messages and produces n-bit codewords, with a minimum Hamming distance of d between any two codewords. State whether a linear block code with parameters $(n, k, d) = (32, 27, 3)$ exists or not. If such a code exists, give an example; if not, explain why not. [3]

(e) Consider the set of codewords {00000, 01111, 10100, 11011} of a code and state whether the code is a linear block code over $\mathbb{F}_2$ or not. [2]

(b) about 3-5 times lesser storage than the corpus.

(c) about 50-70 times lesser storage than the corpus.

(d) about 3-5 times more storage than the corpus.

(e) may require more, equal, or lesser storage than the corpus.

4. Given a distributed file containing 10 million integers, where every node containing some multiple of 10000 integers, a MapReduce program is defined by the following map and reduce functions:

   map: For every batch of 10,000 integers, emits key value pair $< 1, m >$, where m is the mean of the integers.

   reduce: For each key k, output the mean of the values.

   The program would output

   (a) The median of the integers in the file

   (b) The (arithmetic) mean of the integers in the file

   (c) The harmonic mean of the integers in the file

   (d) The geometric mean of the integers in the file

   (e) None of the other answers is necessarily correct

5. If PageRank is computed without teleporting, and if there are dead ends (nodes with no outlink) in a graph, then

   (a) The PageRank for all nodes become zero.

   (b) The PageRank remains positive for the dead ends, and zero for all other nodes.

   (c) The PageRank becomes zero for the dead ends and remain positive for all other nodes.

   (d) The total PageRank becomes more than 1.

   (e) The PageRank becomes 1 for each of the dead ends, and zero for all other nodes

6. Suppose $\boldsymbol{M} = (m_{ij})_{i,j=1}^{n}$ is an $n \times n$ matrix and $\boldsymbol{v} = (v_k)_{k=1}^{n}$ is a vector of size n. A MapReduce algorithm is defined by the following map and reduce functions.

   map: For every non-zero entry m_{ij} of $\boldsymbol{M}$, emit the key value pair $< j, m_{ij}v_i >$.

   reduce: For every key j, output $\sum_{i=1}^{n} m_{ij}v_i$ as the j-th entry of a vector.

   The above MapReduce algorithm computes

   (a) $\boldsymbol{v}^T\boldsymbol{M}$

   (b) $\boldsymbol{M}\boldsymbol{v}$

   (c) $\boldsymbol{M}^2\boldsymbol{v}$

   (d) $\boldsymbol{M}\boldsymbol{v}^2$

   (e) None of the other answers