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B.Tech. (ECE) (Sixth Semester)

Introduction to Information Theory and Coding

(ECEL-602)

Time : 3 Hours] [*Maximum Marks* : 75

Note : It is compulsory to answer all the questions (1.5 marks each) of Part A in short. Answer any *four* questions from Part B in detail. Different sub-parts of a question are to be attempted adjacent to each other.

Part A

1. (a) How is information related to probability in information theory ? Briefly explain. 1.5

   (b) Define joint entropy and conditional entropy. How do they relate to each other ? 1.5

   (c) State the Channel Coding Theorem and its importance in communication theory. 1.5

   (d) What does a stationary Markov source imply about its probabilities over time ? 1.5

(e) Why is balancing bandwidth and S/N crucial in communication systems ? 1.5

(f) What is Lempel-Ziv coding, and how does it differ from prefix codes like Huffman coding ? 1.5

(g) How does universal coding adapt to unknown probability distributions ? 1.5

(h) Name three coding techniques commonly used in data compression and briefly describe each one. 1.5

(i) What is the Polar Quaternary NRZ format ? How does it differ from other polar formats ? 1.5

(j) How does Split Phase Manchester handle data encoding compared to other formats ? 1.5

Part B

2. (a) Prove that the entropy of a discrete memory less source S is upper bounded by average code word length L for any distortion less source encoding scheme. 6

(b) Consider a source with 8 alphabets, a to h with respective probabilities 0.2, 0.2, 0.18, 0.15, 0.12, 0.08, 0.05 and 0.02. Construct a minimum redundancy code and determine the code efficiency. 9

3. (a) Given a binary source with two symbols x_1 and x_2. Given x_2 is twice as long as x_1 and half as probable. The duration of x_1 is 0.3 seconds. Calculate the information rate of the source. 5

(b) Prove the following expressions : 10

(i) $H(X, Y) = H(X \mid Y) + H(Y)$

(ii) $I(X; Y) = I(Y; X)$.

4. Joint probability matrix of a discrete channel is given by,

$$P(X, Y) = \begin{bmatrix} 0.05 & 0.05 & 0.02 & 0.05 \\ 0.15 & 0.16 & 0.01 & 0.09 \\ 0.12 & 0.03 & 0.02 & 0.05 \\ 0.01 & 0.02 & 0.01 & 0.06 \end{bmatrix}$$

Compute marginal, conditional and joint entropies and verify their relation. 15

5. (a) Given a binary symmetric channel with

$$P(X, Y) = \begin{bmatrix} 3/4 & 1/4 \\ 1/4 & 3/4 \end{bmatrix} \quad \text{and} \quad P(X_1) = \frac{2}{3};$$

$P(X_2) = \frac{1}{3}$. Calculate the mutual information and channel capacity. 9

(b) A communication system employs a continuous source. The channel noise is white and Gaussian. The bandwidth of the source output is 10 MHz and signal to noise power ratio at the receiver is 100. 6

(i) Determine the channel capacity.

(ii) If the signal to noise ratio drops to 10, how much bandwidth is needed to achieve the same channel capacity as in (i) ?

(iii) If the bandwidth is decreased to 1 MHz, what S/N ratio is required to maintain the same channel capacity as in (i) ?

6. (a) How does the Lempel-Ziv algorithm work to compress a sequence by finding repeating patterns and encoding them efficiently using a dictionary-based approach ? 5

(b) Consider a set of variable-length binary codes where the codeword lengths are $l_1 = 2$, $l_2 = 2$, $l_3 = 3$, and $l_4 = 4$. Determine whether this set of codes satisfies Kraft's inequality. 3

(c) List and provide a brief explanation of three commonly used PAM formats in line coding. 7

7. Describe the following : 15

(i) Fixed and Variable Coding

(ii) Bipolar NRZ

(iii) Shanon's Theorem.