Indian Statistical Institute
Semestral Examination: 2025
Course Name: M. Tech. in Computer Science
Subject Name: Mobile Computing

Date: 17-11-2025 Maximum Marks: 100 Duration: 3 hours

Instructions: You **may** attempt **all** questions which carry a total of **110** marks. The maximum marks you can score is only **100**.

1. (a) State the differences between *simple* and *hybrid* channel borrowing schemes. [3]

   (b) What is *channel locking* in the context of channel borrowing? [3]

   (c) Briefly describe the *borrowing with channel ordering (BCO)* hybrid channel borrowing scheme. [4]

   (d) Briefly describe the *mean square* based channel reuse optimization scheme. [4]

   (e) How is *local oscillator detection* used for *direct* spectrum sensing in cognitive radio networks? [4]

   (f) In a cognitive radio network, suppose a secondary user detects the primary user's existence periodically at every $T = \tau_s + \tau_d$ time, where τ_s and τ_d are the sensing and data transmission times, respectively. Let P_0 and P_1 be the probabilities of primary user being absent and present, respectively. Let P_d and P_f be the probabilities of detection of the primary user and false alarm, respectively. Let P_s and P_t be the sensing and transmission powers, respectively. Assuming C as the channel capacity, derive the expression for the *energy efficiency* η obtained by a secondary user during sensing and transmission process. [12]

2. (a) In low-energy adaptive clustering hierarchy (LEACH) protocol, how does the rotation of cluster heads contribute to balancing energy consumption across the sensor network? [10]

   (b) Briefly describe a method for computing a *steinerized graph* (r, R, X) for a given set of sensor nodes $X = \{x_1, x_2, \cdots, x_n\}$ where R and r ($R \geq r \geq 0$) are the communication ranges of relay nodes and sensor nodes, respectively. [5]

   (c) Given a heterogeneous wireless sensor network with M supernodes and N energy-constrained sensors that can adjust their transmission ranges up to a maximum value R_{max}, present an algorithm for determining the transmission range r_i ($0 \leq r_i \leq R_{max}$) of each sensor n_i such that

      - there exist k-vertex disjoint communication paths from every sensor to the set of supernodes, that is, the k-vertex supernode connectivity, and
      - the total power consumed over all sensor nodes is minimized, that is, $\sum_{i=1}^{N} p_i$ is minimum, where $p_i = r_i^{\alpha}$ is the transmission power of node n_i for a transmission range r_i and α is the power attenuation exponent.

   Assume that when each sensor is using a maximum transmission range R_{max}, there exist at least k paths from any sensor node to the set of supernodes. [15]

(d) Let N_i be the number of neighbours of a sensor node i. Define the binary variables T_i and S_i as follows:

- $T_i = 0$ if the node is in a *normal region* and $T_i = 1$ if the node is in an *event region*.
- $S_i = 0$ if the sensor measurement indicates a *normal reading* and $S_i = 1$ if the sensor measurement indicates an *event reading*.

Let $E_i(a, k)$ be the evidence such that k of its neighbouring sensors report the same binary reading a as node i itself. Assuming that the sensor fault probability p is independent and same for all the sensors, determine the probability with which node i can make a decision to accept its own reading S_i as correct in the face of the evidence $E_i(a, k)$. Using this probability, present an event detection algorithm in the presence of sensor faults where each node accepts its own reading if at least half of its neighbors have the same reading. [5+5=10]

(e) Briefly explain how the size of the *request zone* in location aided routing (LAR) varies with the average speed of movement v and time elapsed since the last known location of the destination was recorded. [5]

3. (a) Consider a millimeter wave cellular network with full-duplex relay-assisted device to device (D2D) communication, where source device s_i communicates with destination device d_i via relay r_j. Let P_{s_i,r_j} be the transmit power of source device s_i to relay r_j, P_{r_j,d_i} be the transmit power of relay r_j to destination device d_i, B be the channel bandwidth, N_0 be the noise power, h_{LI} be the loop-interference channel gain and $h_{a,b}$ be the total gain (including channel and antenna gains) between two devices a and b. Derive expressions for the 1) SINR from source s_i to relay r_j, 2) SINR from relay r_j to destination d_i, 3) throughput obtained by the user pair $l_i = (s_i, d_i)$ assisted by r_j, and 4) P_{r_j,d_i} in terms of P_{s_i,r_j}, h_{s_i,r_j}, h_{r_j,d_i}, h_{s_i,d_i}, h_{LI} and N under the condition that the source-to-relay throughput is equal to the relay-to-destination throughput. [3+3+3+6=15]

(b) Consider a reconfigurable intelligent surface (RIS) assisted cellular network where ψ_{BS} and ψ_R are the sets of base stations (BSs) and RISs, respectively. Let $\delta_L^{a,b} = 1$ if the path between locations a and b is free of blockages, and 0 otherwise. Let $\mathcal{K}_z^{a,b} = 1$ if locations a and b are facing the same side of the RIS z, and 0 otherwise. Derive an expression for the average ratio of blind-spot areas where blind-spots are the areas that have neither direct nor indirect line of sight (LoS) links to any BS. [5]

(c) Consider the three-dimensional unmanned aerial vehicle (UAV) deployment problem for millimeter wave communications. Briefly describe the *BT-K-Means* algorithm to achieve initial user-UAV association and the *coordinate search* based oscillation aware trajectory design mechanism to achieve minimum sum path loss. You can use the path loss model: $PL(d) = \alpha + 10\beta \log_{10}(d)$, where d is the distance between the user and the UAV and α and β are the parameters of the line of sight (LoS) and non-LoS models, respectively. [5+ 10=15]