1. Create an infographic to explain "Comparison of fixed assignment and random access MAC protocols for multimedia IoT applications". The infographic will explain basic properties of the considered MAC protocols and their suitability to support multimedia IoT applications.

   (20 marks)

(See Attached Question_1_Infographic.pdf)

2. Consider a transmitter located at distance of 0km transmitting signals to a receiver (Figure Q2). The transmit power of the transmitter is varied between 5 and 15 watts uniformly. The receiver can be at any location on a straight line from 2km to 12km. The receive power is denoted by $P_R = P_T/D^3$, where P_T is the transmit power and D is the distance in kilometer. Calculate the average receive power of the receiver. Assume that the heights of the transmitter and the receiver are the same.

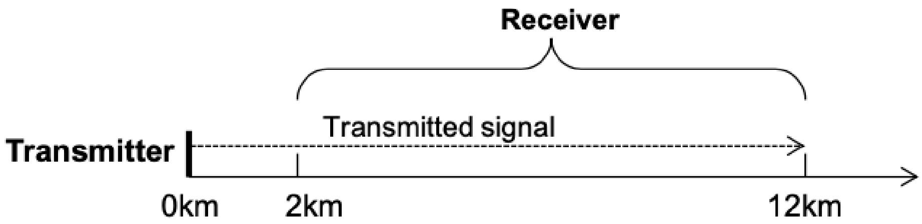

Figure Q2

(20 marks)

$$P_{Av} = \frac{\int\int P_R dP_T dD}{\int\int dP_T dD} = \frac{\int_5^{15}\int_2^{12} \frac{P_T}{D^3} dP_T dD}{\int_5^{15}\int_2^{12} dP_T dD}$$

$$P_{Av} = \frac{\int_5^{15} \left(\frac{-P_T}{2D^2}\Big|_2^{12} \right) dP_T}{\int_5^{15} (12-2) dP_T} = \frac{\frac{35}{288} \times \frac{P_T^2}{2}\Big|_5^{15}}{10 P_T\Big|_5^{15}} = \frac{35}{288}\ W = 0.123\ W$$

3. Consider a relay transmission as shown in Figure Q3. Node A transmits one packet to node B in a time slot fashion. Node B then transmits the received packet to node C. Node B and node C can be in one of two modes, i.e., active and sleep modes. Node B can receive the packet from node A if node B is in an active mode. Likewise, node B can transmit the packet to node C only when both node B and node C are in the active mode. Node B and node C are in the active mode with probabilities P_B and P_C, respectively. Although node B has received a packet from node A, node B can switch to the sleep mode with the probability $1-P_B$. Assume that there is no transmission error, and node A is always in the active mode. Derive the probability that node C will receive a packet from node A within 4 time slots.

$$\boxed{A} \longrightarrow \boxed{B} \longrightarrow \boxed{C}$$

Figure Q3

(20 marks)

Date No.

Probability that node b receive packet from node a $= P_b$ (case 1)

given case 1 occur in time slot 1,

probability that node c receive packed from node b in slot 2 $= P_c$

probability that node c receive packet from node b in slot 3 $= (1-P_c) \times P_c$

probability that node c receive packed from node b in slot 4 $= (1-P_c)^2 \times P_c$

$\therefore$ total probability $= P_b \times (P_c + (1-P_c) \times P_c + (1-P_c)^2 \times P_c)$ — let this be P_1

given case 1 occur in time slot 2 (probability will be $(1-P_b)(P_b)$)

probability that node c receive packet from node b in slot 3 $= P_c$

probability that node c receive packet from node b in slot 4 $= (1-P_c)P_c$

$\therefore$ total probability $= P_b(1-P_b) \times [P_c + P_c(1-P_c)]$ — let this be P_2

given case 1 occur in time slot 3 (probability will be $(1-P_b)^2(P_b)$)

probability that node c receive packet from node b in slot 4 $= P_c$

$\therefore$ total probability $= P_c \times P_b \times (1-P_b)^2$ — let this be P_3

$\therefore$ answer $= P_1 + P_2 + P_3$

$= \cancel{P_bP_c + P_bP_c + P_bP_c^2 + P_c(1-P_c)^2 + P_bP_c - P_b^2P_c + P_bP_c(1-P_b)(1-P_c) + P_cP_b(1-P_b)^2}$

$= \cancel{X + X + P_cX + P_c(1-2P_c+P_c^2) + X + XP_b + X(1-P_c-P_b+X) + X(1-P_b)^2}$ where $X = P_bP_c$

$= \cancel{X\left(3 + P_c + \frac{1}{P_b}(1-2P_c+P_c^2) + P_b + 1 - P_c - P_b + X + 1 - 2b + P_b^2\right)}$

$= \cancel{X\left(5 + X - 2b + 2b^2 + \frac{1}{P_b}(1-2P_c+P_c^2)\right)}$

$= P_bP_c(1 + (1-P_c) + (1-P_c)^2) +$
$P_bP_c(1-P_b)(1+1-P_c) +$
$P_bP_c(1-P_b)^2$

$= P_bP_c(2-P_c+1-2P_c+P_c^2) +$
$P_bP_c(1-P_b)(2-P_c) +$
$P_bP_c(1-2P_b+P_b^2)$

$= P_bP_c(3-3P_c+P_c^2) +$
$P_bP_c(2-P_c-2P_b+P_cP_b) +$
$P_bP_c(1-2P_b+P_b^2)$

$= P_bP_c(6-4P_c-4P_b+P_c^2+P_b^2+P_cP_b)$

4. Consider a circle service area with user A and user B transmitting packets to the base station, i.e., uplink. The base station is located in the middle of the circle service area while user A is fixed and located 3 km away from the base station as shown in Figure Q4. User B can move in the service area randomly and uniformly in which the radius of the circle service area is 20 km. Time division multiple access (TDMA) is employed in which user A and user B transmit packets in a time slot alternatingly. There is the guard time in a time slot with the length of 50 microseconds. The packet period is 1 millisecond, and hence the length of a time slot is 1.050 milliseconds. Assume that user A and user B start their data transmissions immediately at the beginning of the time slot, i.e., perfect time synchronization. Figure Q4 shows the time slot structure defined by the base station. The signal travels at the speed of light, i.e., 300,000 km/second. Calculate the probability that the transmissions of users A and B are unsuccessful due to collision.
   Hint: The collision happens because of the overlap between the packets of user A and user B at the base station. The overlap can happen due to propagation delay.

(20 marks)

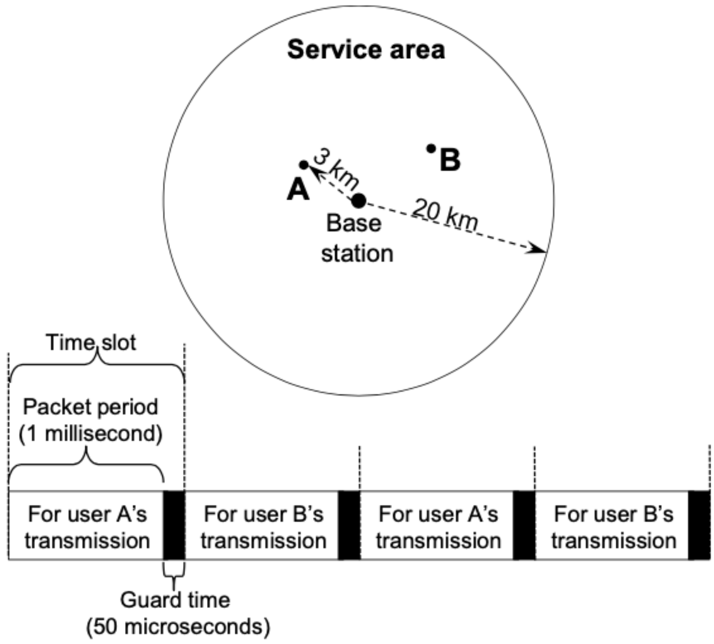

Figure Q4

5. Consider time slot data transmission from a base station to a node. In each time slot, the base station transmits a packet with probability 0.4. The node can be in the active mode and can receive the packet, the power consumption of which is 30 mW. Alternatively, the node can be in the sleep mode and cannot receive the packet, the power consumption of which is 10 mW. The node can decide to be in the receive mode or sleep mode with probability p. Calculate an optimal value of probability p such that the average power consumption of the node is minimized, and the base station achieves the throughput of 0.3 packets/time slot. Compute the average power consumption at the optimal value of probability p.

(20 marks)

Assume probability for node to be in sleep mode = p
Assume probability for node to be in receive mode = 1 – p

Average power consumption per timeslot = p * 10 + (1 – p) * 30 = 30 – 20p

Given that throughput needs to be at 0.3, and that for a packet to be successful transmitted from base station to node, there needs to be a transmission AND station must be in receive mode.

Hence, 0.4 * (1 – p) = 0.3
p = 0.25

Average power consumption = 30 – 20 * 0.25 = 25mW