Problem 1

(a.) State the protocols for the following random access schemes: unslotted ALOHA, slotted ALOHA, CSMA/CA.

(b.) Consider a communications channel that is shared among 10 stations. The transmission data rate across the channel is 10 Mbps. Each station is noted to transmit (or retransmit) a packet in each slot with probability 0.03. The packet size is equal to 4000 bits, including overhead. The slot duration is equal to the time it takes to transmit a packet.

(i.) Calculate the probability that a given station's packet transmission is successful.

(ii.) Calculate the channel's normalized throughput rate (which is equal to the average number of successful packet transmissions in a slot).

(iii.) Compute the average number of times that a packet is transmitted (and retransmitted) until it is successfully received.

Ans:

(a)

Please reference lecture note.

(i)

The probability that each station transmits (or retransmits) a packet in each slot is equal to 0.03 (i.e., $p = 0.03$). The number of stations is equal to 10 (i.e., $N = 10$). Thus, the probability that a given stationâĂŹs packet transmission is successful is given by

$$P_s = (1-p)^{N-1} = (1-0.03)^9 = 0.76. \tag{1}$$

(ii)

The normalized throughput throughput rate is equal to

$$\rho = Np(1-p)^{N-1} = 10 \times 0.03 \times (1-0.03)^9 = 0.228. \tag{2}$$

(iii)

The average number of times that a packet is successfully transmitted (denoted as N_T) is given by

$$E[N_T] = \sum_{n=0}^{\infty} nP(N_T = n) = \frac{1}{P_s} = 1.3158, \tag{3}$$

where $P(N_T = n) = (1-P_s)^{n-1}P_s, \forall n = 1, 2, \ldots.$

Problem 2

(a.) Define and state key differences between multiplexing and multiple access schemes.

(b.) Define and state key differences between TDMA and demand-assigned TDMA.

(c.) Consider a communications channel that is shared among 10 stations using a TDMA protocol. Each station is allocated a single slot during each TDMA time frame. The transmission data rate across the channel is equal to 2 Mbps. Each time slot is sufficiently wide to allow the transmission of a single packet, including the propagation delay which equals to 1 msec. Each packet contains 5000 information bits and 240 overhead bits.

(i.) Calculate the effective network throughput achieved by a single station, assuming a noiseless channel such that all message transmissions are received correctly.

(ii.) Assume that, for the above described system, the channel bit error rate is equal to 10^{-4}. Assume that a packet that is received incorrectly will be retransmitted by the station in its slot in the next frame. Calculate the net effective throughput achieved by a single station.

Ans:

(a)

Please reference lecture note.

(b)

Please reference lecture note.

(c)

(i)

There are $N = 10$ stations. Propagation delay is equal to $t_p = 1 \times 10^{\text{âĹŠ}3}$ sec. Header size (H) and data length (D) are equal to 240 bits and 5000 bits, respectively. Thus, the time length for a time slot (denoted as T_{slot}) is given by

$$T_{\text{slot}} = t_p + \frac{H + D}{R} = 0.0036 \text{ sec.} \tag{4}$$

As a result, the effective network throughput achieved by a single station is given by

$$\eta = \frac{D}{10 \times T_{\text{slot}}} = 138.12 \text{ Kbps.} \tag{5}$$

(ii)

The bit error rate (BER) (denoted as p_b) is equal to 10^{-4} and, thus, packet error rate (P_E) is given by

$$P_E = 1 - (1 - p_b)^{240+5000} = 0.41. \tag{6}$$

The average number of transmissions for a successful transmitting packet is given as

$$E[N_T] = \frac{1}{1 - P_E} = 1.688. \tag{7}$$

Therefore, the effective throughput rate per station is give by

$$\eta = \frac{5000}{10 \times E[N_T] \times T_{\text{slot}}} = 82.24 \text{ Kbps}. \tag{8}$$

Problem 3

Consider a Half-Duplex communications link which employs a Stop-and-Wait ARQ error-control scheme. The transceiver's equipment has a turn-around time of 3 msec. The link is 2000 Km long, and the propagation rate is 5 microsec/Km. The ACK packet contains 360 bits. Assume ACK messages to be sent as separate frames. The information frame (on which the error control scheme operates) contains a 760 bits header. The link is operated at a data rate of 240 Kbps. The channel's bit error rate is equal to 0.0001.

(a.) Obtain the maximum length of the frame which must be selected to ensure that the frame is retransmitted (at least once) for no more than 30% of the time. Show whether such a maximum length condition can be imposed.

(b.) Under the selected value for the frame, calculate the link's effective throughput and its normalized effective throughput efficiency.

Ans:

(a)

The packet error rate P_E is equal to $1-(1-p_b)^L$, where $p_b = 0.0001$ is bit error rate (BER) and L is the length for a packet. The frame that is retransmitted (at least once) for no more than 30% of the time implies that

$$P_E = 1-(1-0.0001)^L \leq 0.3 \Rightarrow L \leq 3565 \text{ bits.} \tag{9}$$

(b)

With $L = 3565$, we obtain that $P_E = 0.3$. The average number of transmitting a successful packet (denoted as N_T) is given by

$$E[N_T] = \frac{1}{1-P_E} = 1.4286. \tag{10}$$

We also know that propagation delay is equal to $2000 \times 5 \times 10^{-6} = 0.01$ sec (i.e., $t_p = 0.01$) and the line around time is equal to 3×10^{-3} sec (i.e., $t_{ta} = 3 \times 10^{-3}$). Thus, the time between successive packet transmissions is given by

$$T_p = \frac{3656+360}{R} + 2 \times (0.01 + 0.003) = 0.0424 \text{ sec.} \tag{11}$$

As a result, the effective throughput rate is give as

$$\eta = \frac{D}{E[N_T] \times T_p} = \frac{3365-760}{1.4286 \times 0.0424} = 46.3 \text{ Kbps,} \tag{12}$$

where D is the data length. Therefore, the normalized effective throughout rate is given by

$$\rho = \frac{\eta}{R} = \frac{46.3 \text{ Kbps}}{240 \text{ Kbps}} = 19.3\%. \tag{13}$$