4.

a) Explain briefly what distinguishes CSMA from other multiple access schemes.

[3 marks]

A simple model of a multiple access scheme, which neglects retransmission, is as follows. Packets arrive as a Poisson process of rate λ, and are transmitted as soon as they arrive. It takes time Δ to transmit a single packet. If several packets are being transmitted at the same time, all those packets are lost.

b) Explain why the probability that a packet is successfully transmitted is $e^{-2\lambda\Delta}$. Show that the maximum possible efficiency is $1/2e$.

[5 marks]

c) One way to model CSMA is to say: while the channel is in use, any newly arriving packets are dropped immediately without attempting transmission. Calculate the maximum possible efficiency of this system.

[5 marks]

We can model retransmissions, in a slotted time system, using a Markov chain. Let $\Delta = 1$ for simplicity. Let N_t be the number of new packets which arrived in $[t-1, t]$ and which will attempt transmission in $[t, t+1]$. Let B_t be the backlog, i.e. the number of packets which at time t have attempted transmission in the past but not succeeded. Let R_t be the number of these that attempt retransmission in $[t, t+1]$; suppose that each of the B_t backlogged packets attempts retransmission with probability p, independently of the others.

d) Explain the equation

$$B_{t+1} = B_t + N_t - 1_{X_t=1} \tag{1}$$

and specify the term X_t in it. Calculate the probability that $B_{t+1} - B_t = i$ for each i, given $B_t = b$. *(Hint. You may find it helpful to draw up a grid listing the values of X_t and of $B_{t+1} - B_t$ for each possible value of N_t and of R_t.)*

[9 marks]

e) In an idealized CSMA system, no matter how many packets are scheduled to attempt transmission in $[t, t+1]$, no more than one will actually be transmitted—the other packets will sense that the link is busy and will back off. Modify equation (1) to model this, and recalculate the probability that $B_{t+1} - B_t = i$ for each value of i, given $B_t = b$.

[11 marks]

[Total 33 marks]

5.

a) State the TCP throughput equation, which relates throughput x to drop probability p and round trip time RTT, and give a sketch proof.

[8 marks]

TCP's windowed flow control algorithm increases window size w by $1/w$ for each acknowledgement it receives, and cuts w by $w/2$ for each drop it detects. We can generalize this: suppose instead that it increases w by A/w^α for each acknowledgement, and cuts it by Bw^β for each drop. Thus, for TCP, $A = 1$, $\alpha = 1$, $B = 1/2$, $\beta = 1$.

A crude way to heuristically estimate the average window size is as follows. There are $1/p$ successful acknowledgements for every 1 drop. Since window increases and window decreases must balance out, the average window size $\hat{w}$ must satisfy

$$\frac{1}{p} A/\hat{w}^\alpha = B\hat{w}^\beta.$$

b) Use this equation to estimate the average window size for TCP. How does your answer relate to the TCP throughput formula?

[3 marks]

c) In TCP, throughput depends on RTT. How might you choose alternative window increase and decrease parameters so as to remove this dependence? *(Hint. You will find the algebra easiest if you keep $\alpha = \beta = 1$.)*

[8 marks]

d) For fairness, it is desirable that your modified TCP should achieve the same throughput that standard TCP achieves when $RTT = 20$ms. How does this affect your choice of window increase and decrease parameters?

[6 marks]

e) Suppose that TCP has reached throughput x_{max} and then it detects a drop and cuts its window. In the absence of drops, how long does it take for throughput to return to x_{max}? how long does your modified TCP take to return to x_{max}? how long does your modified TCP take to reach x_{max} starting from near-nothing?

[8 marks]

[Total 33 marks]