Question 1. In class, we examined how the time required to deliver a message in a switched network depended on the switching scheme used. In particular, under the following assumptions:

M is the total number of data bits being sent,

R is the rate at which bits are transmitted (assumed uniform throughout the network in our analysis),

D_i is the distance between the ith and $i+1$th switch/computer along the path through which the data travels,

c is the speed at which the signal travels in the network cables,

S is the number of steps along the path (i.e., the number of distinct cables through which the message will be transmitted), and

P is the amount of data carried in a single packet in bits (in the case of packet switching)

We concluded that the formula

$$\frac{D_1 + D_2 + ... + D_S}{c} + S\frac{M}{R}$$

described the time required to deliver the message using message switching and that the formula

$$\frac{D_1 + D_2 + ... + D_S}{c} + (S-1)\frac{P}{R} + \frac{M}{R}$$

described the time required if packet switching was used instead.

Unfortunately, these formulae ignore one cost associated with packet switching. As we have seen, each frame transmitted in a network contains "overhead" including information such as addresses, length fields, and error checking fields in addition to the actual data being transmitted. Since packet switching requires sending more frames, it would involve more overhead. We have not accounted for this overhead in our analysis. We would like you to revise our formulae to take this factor into account.

Assuming O is the number of overhead bits required in each frame transmitted and that the total amount of data being sent, M, conveniently divides up evenly into packets containing P bits of data (i.e., that P divides M evenly):

a) Give a formula for the total time required to deliver the message using message switching, and

b) Give a formula for the total time required to deliver the message using packet switching.

Question 2. Consider the imaginary IP network fragment show in Figure 1. The network is composed of three physical networks connected to one another by the internal router shown in the center of the diagram. To make it clear that they are distinct physical networks, the diagram shows that each network uses a very distinct networking technology: the two laptops are shown as part of a wireless network, the two cartoon computers are attached to an Ethernet, and the connection between the internal router in the center of the diagram and the external router that connects to the rest of the Internet is drawn as a ring network. The details of ring, wireless and Ethernet technologies, however, are irrelevant to the problem. All that matters is that there are three distinct physical networks involved. Since the internal router has connections to all three physical networks, it has three distinct IP addresses — one for each of the interfaces through which it connects to the three physical networks. The IP addresses associated with router interfaces and with the computers connected to the Ethernet and wireless networks are shown in Figure 1. The physical addresses associated with all of the IP addresses shown in the figure are given in the following table:

(a) Suppose that 200.134.73.19 wants to send an IP packet to 200.134.73.6. How would 200.134.73.19 figure out whether the IP packet should be sent to 200.134.73.6 directly or whether it must go through the router? Once it realized it should send the packet directly, how would 200.134.73.19 determine 200.134.73.19's Ethernet address (i.e. physical address)?

(b) Suppose 200.134.73.19 wants to send an IP packet to 200.134.172.9. How would 200.134.73.19 determine whether the IP packet should be sent to 200.134.172.9 directly or via the router? Once it determined it should send the packet to the router, how would 200.134.73.19 determine the router's IP address? How would Station 200.134.73.19 determine the router's physical address?

IP Address	Physical Address
200.134.172.12	02:4F:30:A5:00:1F
200.134.172.9	39:22:0D:10:3B:33
200.134.172.1	01:3F:22:9B:6C:99
137.165.2.1	22:31:FF:21:4B:18
137.165.4.201	02:4F:30:03:F2:11
200.134.73.1	39:22:0D:93:83:AA
200.134.73.19	20:90:33:D0:D6:41
200.134.73.6	50:57:30:28:01:9B

(c) Suppose that a packet originally sent from IP address 202.34.190.4 to 200.134.73.6 was delivered to 200.134.73.6. What would be the IP source and destination addresses and the Ethernet source and destination addresses in the packet?

(d) Suppose that a packet originally sent from IP address 202.34.190.4 to 200.134.73.6 was observed while traveling through the ring network between the two routers shown. What would be the IP source and destination addresses and the physical source and destination addresses in the packet?

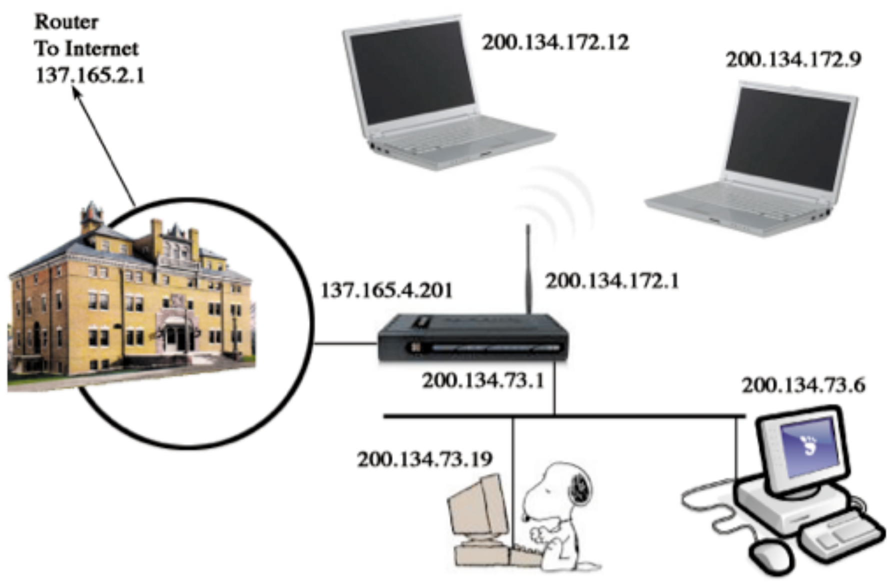

Figure 1: An IP Network.