Instructions

You are required to work on the homework on your own. Please be legible and state all assumptions clearly. Show all work in order to receive partial credit.

Problems

3.1 Virtual Circuits and Datagram Networks

3.1.1 Problem 1 (Kurose p. 404, 5 pts.)
Consider a virtual-circuit network. Suppose the VC number is a 16-bit field.

a) What is the maximum number of virtual circuits that can be carried over the link?

b) Suppose a central node determines paths and VC numbers at connection setup. Suppose the same VC number is used on each link along the VC's path. Describe how the central node might determine the VC number at connection setup. Is it possible that there are fewer VCs in progress than the maximum as determined in part (a) yet there is no common free VC number?

c) Suppose that different VC numbers are permitted in each link along a VC's path. During connection setup, after an end-to-end path is determined, describe how the links can choose their VC numbers and configure their forwarding tables in a decentralized manner, without reliance on a central node.

3.1.2 Problem 2 (Kurose p. 405, 5 pts.)
Consider a datagram networking using 32-bit host addresses. Suppose a router has four links, numbered 0 through 3, and packets are to be forwarded to the link interfaces as follows:

<table>
<thead>
<tr>
<th>Destination Address Range</th>
<th>Link Interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>11100000 00000000 00000000 00000000 through 11100000 11111111 11111111 11111111 11100001 00000000 00000000 00000000 through 11100001 00000000 11111111 11111111 11100001 00000001 00000000 00000000 through 11100000 11111111 11111111 11111111 otherwise</td>
<td>0</td>
</tr>
<tr>
<td>11100000 11111111 11111111 11111111 11100001 00000000 00000000 00000000 through 11100001 00000000 11111111 11111111 11100001 00000001 00000000 00000000 through 11100000 11111111 11111111 11111111 otherwise</td>
<td>1</td>
</tr>
<tr>
<td>11100000 11111111 11111111 11111111 11100000 11111111 11111111 11111111 otherwise</td>
<td>2</td>
</tr>
<tr>
<td>11100000 11111111 11111111 11111111 11100000 11111111 11111111 11111111 otherwise</td>
<td>3</td>
</tr>
</tbody>
</table>
a) Provide a forwarding table that has four entries, uses longest-prefix matching, and forwards packets to the correct link interfaces.

b) Describe how your forwarding table determines the appropriate link interface for datagrams with destination addresses:

<table>
<thead>
<tr>
<th>Destination Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>11001000 10010001 01010001 01010101</td>
</tr>
<tr>
<td>11100001 00000000 11000011 00111100</td>
</tr>
<tr>
<td>11100001 10000000 00010001 01110111</td>
</tr>
</tbody>
</table>

3.2 Subnets

3.2.1 Problem 3 (Kurose p. 406, 3 pts.)

Consider a router that interconnects three subnets: Subnet 1, Subnet 2, and Subnet 3. Suppose all of the interfaces in each of these three subnets are required to have the prefix 223.1.17/24. Also suppose that Subnet 1 is required to support up to 125 interfaces, and Subnets 2 and 3 are each required to support up to 60 interfaces. Provide three network addresses (of the form a.b.c.d/x) that satisfy these constraints.

3.2.2 Problem 4 (Kurose p. 406, 7 pts.)

Consider the topology shown in Figure 4.17 (Kurose p. 334). Denote the three subnets with hosts (starting clockwise at 12:00) as Networks A, B, and C. Denote the subnets without hosts as Networks D, E, and F. To simplify the solution, assume that no datagrams have router interfaces as ultimate destinations.

a) Assign network addresses to each of these six subnets, with the following constraints: All addresses must be allocated from 214.97.254/17; Subnet A should have enough addresses to support 250 interfaces; Subnet B should have enough addresses to support 120 interfaces; and Subnet C should have enough addresses to support 120 interfaces. Of course, subnets D, E, and F should each be able to support two interfaces. For each subnet, the assignment should take the form a.b.c.d/x or a.b.c.d/x-e.f.g.h/y.

b) Using your answer to part (a), provide the forwarding tables (using the longest prefix matching) for each of the three routers.

3.3 Fragmentation and NAT translation table

3.3.1 Problem 5 (Kurose p. 407, 4 pts.)

Consider sending a 3,000 byte datagram into a link that has an MTU of 500 bytes. Suppose the original datagram is stamped with the identification number 422. How many fragments are generated? What are their characteristics?

3.3.2 Problem 6 (Kurose p. 407, 4 pts.)

Suppose datagrams are limited to 1,500 bytes (including header) between source Host A and destination Host B. Assuming a 20-byte IP header, how many datagrams would be required to send an MP3 consisting of 4 million bytes?

3.3.3 Problem 7 (Kurose p. 407, 2 pts.)

Consider the network setup in Figure 4.20 (Kurose p. 340). Suppose that the ISP instead assigns the router the address 126.13.89.67 and that the network address of the home network is 192.168/16.
a) Assign addresses to all interfaces in the home network.
b) Suppose each host has two ongoing TCP connections, all to port 80 at host 128.119.40.86. Provide the six corresponding entries in the NAT translation table.

3.4 Routing Algorithms

3.4.1 Problem 8 (Kurose p. 408, 6 pts.)
Consider the network shown in Kurose on page 408 at the bottom. Assume each node initially knows the costs to each of its neighbors. Consider the distance vector algorithm and show the distance table entries at node z. Consider writing a program.

3.4.2 Problem 9 (Kurose p. 409, 4 pts.)
Consider a general topology (that is, not the specific network shown in Problem 8) and a synchronous version of the distance vector algorithm. Suppose that at each iteration, a node exchanges its distance vectors with its neighbors and receives their distance vectors. Assuming that the algorithm begins with each node knowing only the costs to its immediate neighbors, what is the maximum number of iterations required before the distributed algorithm converges? Justify your answer. This may be a bit ambiguous; this refers to the number of iterations from when the algorithm is run for the first time, i.e., assuming the only information the nodes initially have is the cost to their nearest neighbors.

3.5 Link Layer

3.5.1 Problem 10 (Kurose p. 494, 2 pts.)
Consider the 4-bit generator, G, shown in Figure 5.8 (Kurose p. 430), and suppose that D has the value 10101010. What is the value of R?

3.5.2 Problem 11 (Kurose p. 494, 4 pts.)
Show that the maximum efficiency of pure ALOHA is 1/(2e). Note: This problem may be easy if you also complete problem 5 for chapter 5 in Kurose.

3.5.3 Problem 12 (Kurose p. 495, 4 pts.)
Consider a broadcast channel with \( N \) nodes and a transmission rate of \( R \) bps. Suppose the broadcast channel uses polling (with an additional polling node) for multiple access. Suppose the amount of time from when a node completes transmission until the subsequent node is permitted to transmit (that is, the polling delay) is \( t_{\text{poli}} \). Suppose that within a polling round, a given node is allowed to transmit at most \( Q \) bits. What is the maximum throughput of the broadcast channel?