Homework Solution 5

1. (10%) What is the difference between routing and forwarding?
   "Forwarding" is about moving a packet from a router's input link to the appropriate output link. "Routing" is about determining the end-to-routes between sources and destinations.

2. (20%) Consider a virtual circuit (VC) network with a 2-bit field for the VC number. Suppose that the network wants to set up a virtual circuit over four links: link A, link B, link C, and link D. Suppose that each of these links is currently carrying two other virtual circuits, and the VC numbers of these other VCs are as follows:

Link A	Link B	Link C	Link D
00	01	10	11
01	10	11	00

   In answering the following questions, keep in mind that each of the existing VCs may only be traversing one of the four links.

   a. (10%) If each VC is required to use the same VC number on all links along its path, what VC number could be assigned to the new VC?
      No VC number can be assigned to the new VC; thus the new VC cannot be established in the network.

   b. (10%) If each VC is permitted to have different VC numbers in the different links along its path (so that forwarding tables must perform VC number translation), how many different combinations of four VC numbers (one for each of the four links) could be used?
      Each link has two available VC numbers. There are four links. So the number of combinations is $2^4 = 16$. One example combination is (10, 00, 00, 10).

3. (20%) Consider a datagram network 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:

Destination Address Range	Link Interface
11100000 00000000 00000000 00000000 through 11100000 00111111 11111111 11111111	0

11100000 01000000 00000000 00000000 through 11100000 01000000 11111111 11111111	1
11100000 01000001 00000000 00000000 through 11100001 01111111 11111111 11111111	2
otherwise	3

a. (10%) Provide a forwarding table that has four entries, uses longest prefix matching, and forwards packets to the correct link interfaces.

Prefix Match	Link Interface
11100000 00	0
11100000 01000000	1
1110000	2
11100001 1	3
otherwise	3

or

Prefix Match	Link Interface
11100000 00	0
11100000 01000000	1
11100000	2
11100001 0	2
otherwise	3

b. (10%) Describe how your forwarding table determines the appropriate link interface for datagrams with destination addresses:

11001000 10010001 01010001 01010101
11100001 01000000 11000011 00111100
11100001 10000000 00010001 01110111

Prefix match for first address is 5th entry: link interface 3
Prefix match for second address is 3nd entry: link interface 2
Prefix match for third address is 4th entry: link interface 3

4. (10%) Consider a subnet with prefix 128.119.40.128/26.

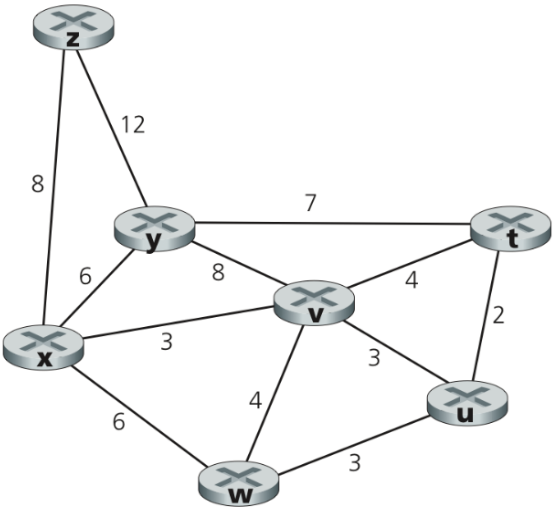
a. (5%) Give an example of one IP address (of form xxx.xxx.xxx.xxx) that can be assigned to this network.

Any IP address in range 128.119.40.128 to 128.119.40.191.

b. (5%) Suppose an ISP owns the block of addresses of the form 128.119.40.64/25. Suppose it wants to create four subnets from this block, with each block having the same number of IP addresses. What are the prefixes (of form a.b.c.d/x) for the four subnets?

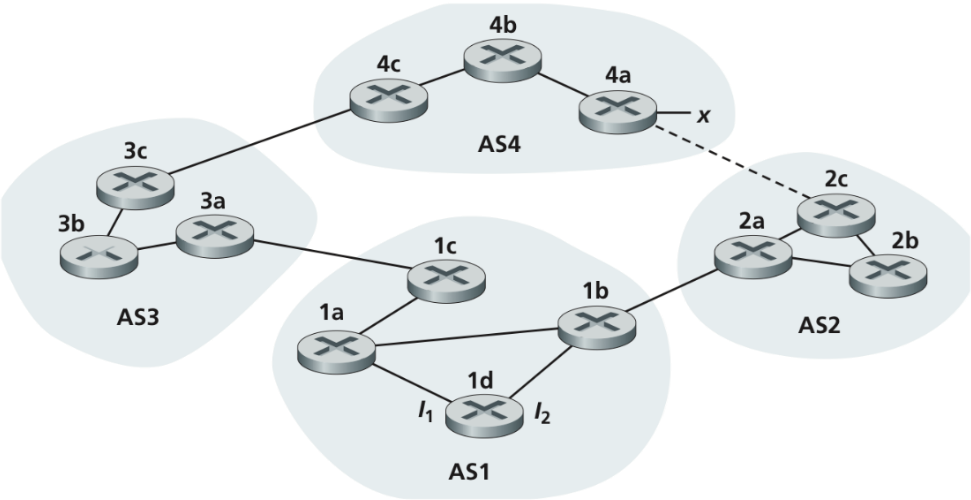
Four equal size subnets: 128.119.40.64/28, 128.119.40.80/28, 128.119.40.96/28, 128.119.40.112/28.

5. (20%) Consider the following network. With the indicated link costs, use Dijkstra's shortest-path algorithm to compute the shortest path from x to all network nodes. Show how the algorithm works by computing a table similar to the table in lecture slide 4-81.



Step	***N'***	***D(t), p(t)***	***D(u), p(u)***	***D(v), p(v)***	***D(w), p(w)***	***D(y), p(y)***	***D(z), p(z)***
0	x	∞	∞	3, x	6, x	6, x	8, x
1	xv	7, v	6,v	3, x	6, x	6, x	8, x
2	xvu	7, v	6,v	3, x	6, x	6, x	8, x
3	xvuw	7, v	6,v	3, x	6, x	6, x	8, x
4	xvuwy	7, v	6,v	3, x	6, x	6, x	8, x
5	xvuwyt	7, v	6,v	3, x	6, x	6, x	8, x
6	xvuwytz	7, v	6,v	3, x	6, x	6, x	8, x

6. (20%) Consider the network shown below. Suppose AS3 and AS2 are running OSPF for their intra-AS routing protocol. Suppose AS1 and AS4 are running RIP for their intra-AS routing protocol. Suppose eBGP and iBGP are used for the inter-AS routing protocol. Initially suppose there is no physical link between AS2 and AS4.



a. (5%) Router 3c learns about prefix x from which routing protocol: OSPF, RIP, eBGP, or iBGP?
eBGP

b. (5%) Router 3a learns about x from which routing protocol?
iBGP

c. (5%) Router 1c learns about x from which routing protocol?
eBGP

d. (5%) Router 1d learns about x from which routing protocol?
iBGP

7. (15%)

a. (5%) What is the size of the multicast address space?
32 – 4 = 28 bits are available for multicast addresses. Thus, the size of the multicast address space is $N = 2^{28}$.

b. (5%) Suppose now that two multicast groups randomly choose a multicast address. What is the probability that they choose the same address
The probability that two groups choose the same address is

$$\frac{1}{N} = 2^{-28} = 3.73 * 10^{-9}$$

c. (5%) Suppose now that 1,000 multicast groups are ongoing at the same time and choose their multicast group addresses at random. What is the probability that they interfere with each other?
The probability that 1000 groups all have different addresses is

$$\frac{N * (N-1) * (N-2) \ldots (N-999)}{N^{1000}} = \left(1 - \frac{1}{N}\right)\left(1 - \frac{2}{N}\right) \ldots \left(1 - \frac{999}{N}\right)$$

Ignoring cross-product terms, this is approximately equal to

$$1 - \left(\frac{1 + 2 + \cdots + 999}{N}\right) = 1 - \frac{999 * 1000}{2N} = 0.998$$

Therefore, the probability that they interfere with each other is $1 - 0.998 = 0.002$.