ECE 438/638: Computer Communications **Spring 2013**
Problem Set 7 solutions

1. **Multiple subnets on a LAN.**
   (a) DHCP will have considerable difficulty sorting out to which subnet various hosts belonged; subnet assignments would depend on which server answered first. For you information, the full DHCP implementation deals with this by allowing servers to be manually configured to ignore address-assignment requests from certain physical addresses on the other subnet. Note that subnet assignment in this situation may matter for consistent naming, performance reasons, certain security access rules, and for broadcast protocols. However, this significantly increases the work for system administrators.
   (b) ARP will not be affected. Hosts will only broadcast ARP queries for other hosts on the same subnet; hosts on the other subnet will hear these but will not answer. A host on one subnet would answer an ARP query from the other subnet, if it were ever issued, but such an ARP query will never be issued.

2. **IP forwarding**.
   (a) H2 uses subnet mask 255.255.255.128 and ANDs this with the destination IP address 128.96.33.14 to get 128.96.33.0. Since H2's subnet number is 128.96.34.128, H2 determines that H3 is not on H2's local LAN. So, H2 needs to forward the IP packets to its default router, R1. The following sequence of Ethernet frames are initiated:
      1. broadcast ARP query from H2 looking for R1's MAC address
      2. ARP reply (not broadcast) from R1 to H2 with R1's MAC address
      3. Ethernet frame containing IP packet from H2 with R1 as the destination
      4. R1 transmits broadcast ARP query looking for R2's MAC address
      5. ARP reply from R2 to R1 with R2's MAC address
      6. Ethernet frame containing IP packet from R1 to R2
      7. R2 transmits broadcast ARP query looking for H3's MAC address (notice that the bridge 1 will forward this ARP query onto LAN D, since the Ethernet frame has a broadcast address, and bridges always forward all broadcast messages.
      8. ARP reply from H3 to R2 with H3's MAC address (notice this Ethernet frame will not be forwarded onto LAN D, because the bridge has learned the port number for R2's MAC address during step 7)
      9. Ethernet frame containing IP packet from R2 to H3. This frame will not be relayed by the bridge onto LAN D because the bridge learned the port for H3 during step 8.

   (b) R1 will send an ICMP redirect message to H2 forcing H2 to add a host-specific entry into its forwarding table. Future IP packets from H2 to H3 will be forwarded directly to R2 instead of R1.

3. **Subnet design**.

No changes are made to LAN A, and there are 128 addresses assigned to this LAN. Of the 128 addresses assigned to LAN B, split them into two groups. The new addresses for LAN B must include 129 to avoid having to change the IP addresses of the existing hosts. The table shows the address assignments.

	LAN A	LAN B	LAN E
Subnet number	128.96.34.0	128.96.34.128	128.96.34.192
Mask	255.255.255.128	255.255.255.192	255.255.255.192

4. **IP Forwarding**, **LAN Forwarding, ARP, and Subnet Masks.**

(a). Yes. H5 does not use subnets and its network address is 128.96.0.0. H5 believes that H3 has the same network address (H5 AND's H3's address with 255.255.0.0 and gets 128.96.0.0). Thus, H5 concludes that H3 is on the same LAN. H5 generates an ARP query which is broadcast on LAN D. The bridge relays the broadcast transmission to LAN C and H3 receives the ARP query and replies to H5 with its LAN address. H5 can now send the IP packet to H3

(b). No. H5 AND's H2's address with 255.255.0.0 and gets 128.96.0.0. Again H5 concludes that H2 is on the same network. However, now the broadcast ARP query is not received by H2. The query is related onto LAN C by the bridge but the message is not relayed by R2. The ARP message is not an IP packet, and the router does not relay it.

(c). Yes. When H5 AND's the destination address with 255.255.0.0 the result is not equal to 128.96.0.0 (because this class B address is assigned to this organization). So, H5 must forward the IP packet to its default router (R2). H5 broadcasts an ARP query to get R2's LAN address and R2 replies. H5 can the forward the IP packet to R2 and the packet proceeds normally. Note that the bridge is transparent to H5. The bridge does not consider IP addresses or subnet masks.

5. **Forwarding tables with CIDR,** Chapter 4, number 45.

(a): B (b): A (c): E (d): F (e): C (f): D

(for the last one, note that the first 14 bits of C4.6B and C4.68 match, since B = 1011)

6. **Forwarding tables with CIDR** (variation on 47 and 48)

(a) Note, the ISP's do not need to distribute any information about how they assign addresses to customers

ISP-1	
Address	Next hop
D2.0.0.0/8	ISP-2
D3.0.0.0/8	ISP-3
D1.A3.0.0/16	Cust1
D1.B0.0.0/12	Cust2

ISP-2	
Address	Next hop
D1.0.0.0/8	ISP-1
D3.0.0.0/8	ISP-3
D2.0A.10.0/20	cust3
D2.0B.0.0/16	cust4

ISP-3	
Address	Next hop
D1.0.0.0/8	ISP-1
D2.0.0.0/8	ISP-2

(b) The longest match rule allows the ISP's to use the new links. Only the bold entries are changed.

ISP-1	
Address	Next hop
D2.0.0.0/8	ISP-2
D3.0.0.0/8	ISP-3
D1.A3.0.0/16	Cust1
D1.B0.0.0/12	Cust2
D2.0A.10.0/20	**cust3**

ISP-2	
Address	Next hop
D1.0.0.0/8	ISP-1
D3.0.0.0/8	ISP-3
D2.0A.10.0/20	cust3
D2.0B.0.0/16	cust4
D1.A3.0.0/16	**cust1**

ISP-3	
Address	Next hop
D1.0.0.0/8	ISP-1
D2.0.0.0/8	ISP-2

(c) Customers 1 and 3 have changed to new ISP's and some of the aggregation has been lost. However, this allows the customers to keep their original IP addresses. Note that the two entries marked with a "*" are needed. In this particular network if there are omitted, the network is able to forward the packets. However, BGP minimizes the number of inter-domain relays and does not try and optimize aggregation.

ISP-1	
Address	Next hop
D2.0.0.0/8	ISP-2
D3.0.0.0/8	ISP-3
D1.A3.0.0/16	**ISP-2**
D1.B0.0.0/12	Cust2
D2.0A.10.0/20	**ISP-3 ***

ISP-2	
Address	Next hop
D1.0.0.0/8	ISP-1
D3.0.0.0/8	ISP-3
D2.0A.10.0/20	**ISP-3**
D2.0B.0.0/16	cust4
D1.A3.0.0/16	cust1

ISP-3	
Address	Next hop
D1.0.0.0/8	ISP-1
D2.0.0.0/8	ISP-2
D2.0A.10.0/20	**cust3**
D1.A3.0.0/16	**ISP-2 ***

7. CIDR, and IP Forwarding

By inspection, the routing table at F to the routes A – G is

Destination	Next	Cost
A	E	4
B	B	4
C	G	5
D	G	4
E	E	3
G	G	3

Notes on table:

1) Notice that destinations A and E are both reachable with E as the next hop.
2) Since C is the border router, we make a default route to C. We can eliminate the entries for routers D and G, since they will also use F's default forwarding table entry.

If we do not consider CIDR, then we just list all networks in the forwarding table. However we can substantially reduce the size of the forwarding table by using super-nets and taking advantage of the CIDR longest match rule. We also use the default route for networks located at routers D and G

Consider the next hop to router E. We can reduce the networks listed because there is significant overlap between the addresses assigned to routers E and A. Here are the networks assigned to A and E:

1) 141.126.134.0/25
2) 141.126.132.128/25
3) 141.126.134.128/25
4) 141.126.132.0/24
5) 141.126.135.0/24

Observe that we can combine numbers 1 and 3 to get 141.126.134.0/24, and numbers 2 and 4 to get 141.126.132.0/24.

So we have reduced the networks F reaches via E to

1) 141.126.132.0/24
2) 141.126.134.0/24
3) 141.126.135.0/24

Notice that 141.126.133.0/24 is assigned to router B. Here is where we can use the longest match rule. We combine the entries 1 through 3 into a single super-net, but also list the longer match to router B.

We also observe that

132 = 128 + 4 = 1000 0100
133 = 128 + 5 = 1000 0101
134 = 128 + 6 = 1000 0110
135 = 128 + 7 = 1000 0111

Notice how the first 6 bits are all the same for 132, 133, 134, and 135. So, we can represent this as a super-net with 141.126.132.0/22, where 22 = 16 + 6. That is, we take the first 6 bits of the number 132.

Next check the IP addresses assigned to router G: 141.126.136.0/21. Since 21 = 16 + 5, we take the first 5 bits of the number 136. But,

136 = 128 + 8 = 1000 1000
132 = 128 + 4 = 1000 0100

So, the first 5 bits of 136 does not overlap with the first 6 bits of 132, and the addresses at router G do not overlap with the addresses at routers A and E. A similar argument shows that there is no overlap between the addresses at router D with the addresses at A and E (141.126.128.0/23 means take the left 7 bits of 128 = 1000 0000). Combining the above we have the following forwarding table for router F:

Network number/mask length	next hop
141.126.132.0/22	E
141.126.134.64/26	B
141.126.133.0/24	B
128.32.0.0/16	E
default	G

Router F's forwarding table only lists 4 CIDR address blocks instead of the 12 blocks shown in the figure for the problem, a substantial reduction in the size of F's forwarding table.

8. **Networking utilities** `ifconfig` and `arp`

(a) Typing ifconfig –a on host unixlab1.ces.clemson.edu shows that the machine has a single physical network interface (the loopback interface to itself does not count) to subnetwork (130.127.220.151 netmask ffffff00 or 255.255.255.0). The broadcast address is 130.127.220.255.

For the PC in my office, my IP address is 130.127.199.51, and the netmask is 255.255.254.0 (notice that only 7 bits are used for the subnet number, and the subnet number is 130.127.198 – and not 130.127.199). Setting the 9 last bits to 1's gives the broadcast address of 130.127.199.255.)

(b) Typing arp –a only produced a few Ethernet addresses. But after executing ping to the broadcast address, the arp –a command produced a list of approximately 100 machines, some of which are listed below. Repeating the arp command a few minutes later showed that all of the additional addresses had timed out of the arp table.

```
unixlab1% ping 130.127.220.255
unixlab1% arp -a
Net to Media Table: IPv4
Device   IP Address               Mask      Flags   Phys Addr
------ -------------------- --------------- ----- ---------------
bge0   130.127.220.2        255.255.255.255       00:0c:85:72:79:ff
bge0   nisboot220           255.255.255.255       00:03:ba:2d:6c:26
bge0   bigultra1            255.255.255.255       08:00:20:9a:09:ea
bge0   curiosity            255.255.255.255       08:00:20:a7:7c:e7
bge0   camus                255.255.255.255       08:00:20:f0:c0:ee
bge0   unixlab1             255.255.255.255 SP    00:03:ba:27:0d:dc
bge0   unixlab3             255.255.255.255       00:03:ba:27:0d:b7
bge0   unixlab2             255.255.255.255       00:03:ba:27:0d:cd
bge0   unixlab5             255.255.255.255       00:03:ba:27:10:13
```

pinging the broadcast address on my office windows PC, resulted in this ARP table. Notice the range of IP address is from 198.2 to 199.253, confirming that this local LAN has 510 possible IP addresses.

```
Interface: 130.127.199.51 --- 0x2
  Internet Address      Physical Address      Type
  130.127.198.2         00-1b-54-a0-65-c2     dynamic
  130.127.198.8         00-80-67-80-00-fe     dynamic
  130.127.198.9         00-90-e8-10-6d-bf     dynamic
  130.127.198.17        00-e0-81-21-4f-60     dynamic
  130.127.198.35        00-1a-92-2b-6d-cf     dynamic
  130.127.198.39        08-00-20-b4-11-24     dynamic
  130.127.198.40        08-00-20-c6-29-b5     dynamic
  130.127.198.41        08-00-20-c3-46-63     dynamic
  130.127.198.42        00-03-ba-3a-2a-54     dynamic
  130.127.198.43        00-03-ba-3a-2a-ee     dynamic
  130.127.198.45        00-03-ba-3a-2a-e4     dynamic
  130.127.198.47        08-00-20-c3-45-45     dynamic
  130.127.198.48        00-03-ba-3a-2a-3d     dynamic
  130.127.198.49        08-00-20-c4-c6-9a     dynamic
  130.127.199.23        00-13-72-a5-e4-84     dynamic
  130.127.199.74        00-17-f2-2e-6e-af     dynamic
  130.127.199.80        00-a0-cc-56-a4-3c     dynamic
  130.127.199.101       00-01-e6-32-bf-3a     dynamic
  130.127.199.116       00-17-08-8c-cb-9b     dynamic
  130.127.199.161       00-12-3f-4c-ff-9e     dynamic
  130.127.199.198       00-a0-cc-d3-1f-a5     dynamic
  130.127.199.205       00-30-65-f5-36-16     dynamic
  130.127.199.253       00-a0-cc-57-3f-21     dynamic
```