

## Problem 1

Suppose that the NAT-capable router has a single public address 128.97.27.37 which it uses for all communication with hosts that are not part of the private network. The private network used is subnet 10.0/16. The router multiplexes its public IP address(es) as needed and keeps track of the multiplexing in a NAT translation table.

Assume that the router multiplexes the public address using ports starting from 8000 and then increments the port number by one for each new entry. For example, if a host behind the router with address and port 10.0.0.5:5000 sends a message to an external server 8.8.8.8:53, then the entry in the NAT table would be filled in as below.

Table 1: NAT Translation Table

IP:port within private network	IP:port outside private network
10.0.0.5:5000	128.97.27.37:8000
...	...

The next time the router will use port 8001 to establish a new connection and so on.

- (a) Draw the resulting NAT Translation Table at the end of the following message exchanges following the format of Table 1 (including the original entry):

- (1) 10.0.0.6:5000 sends a message to 172.217.11.78:80
- (2) 10.0.0.10:6000 sends a message to 204.79.197.200:80
- (3) 10.0.1.101:6001 sends a message to 206.190.36.45:80
- (4) 10.0.0.10:6000 sends a message to 204.79.197.200:80
- (5) 10.0.1.101:6001 sends a message to 172.217.11.78:80
- (6) 10.0.0.7:7000 sends a message to 63.245.215.20:80
- (7) 204.79.197.200:80 sends a message to 128.97.27.37:8002
- (8) 204.79.197.200:80 sends a message to 128.97.27.37:8003

- (b) For simplicity, let us assume that message format is MSG <Sender, Receiver>. In that case, if a host in the private network with IP address and port 10.0.0.5:5000 sends a message to 132.239.8.45:80. Then the message received at the router and leaving at the router would look as follows:

Message Received from Host: MSG <10.0.0.5:5000, 132.239.8.45:80>

Message Sent from Router: MSG <128.97.27.37:8000, 132.239.8.45:80>

List the messages, in the same format shown above, received from the host at the router and the message sent from the router for the following messages:

- (1) 10.0.0.6:5000 sends a message to 172.217.11.78:80
- (2) 10.0.0.10:6000 sends a message to 204.79.197.200:80

Assume the entries from your NAT Translation Table in (a) to do this.

Write your solution to Problem 1 in this box

(a)

Table 1: NAT Translation Table

IP:port within private network	IP:port outside private network
10.0.0.5:5000	128.97.27.37:8000
10.0.0.6:5000	128.97.27.37:8001
10.0.0.10:6000	128.97.27.37:8002
10.0.1.101:6001	128.97.27.37:8003
10.0.0.7:7000	128.97.27.37:8004

(a)

(1)

Message Received from Host: MSG &lt;10.0.0.6:5000, 172.217.11.78:80&gt;

Message Sent from Router: MSG &lt;172.217.11.78:80, 172.217.11.78:80&gt;

(2)

Message Received from Host: MSG &lt;10.0.0.10:6000, 204.79.197.200:80&gt;

Message Sent from Router: MSG &lt;204.79.197.200:80, 204.79.197.200:80&gt;

## Problem 2

Answer the following questions regarding to IP.

- (a) Suppose Host A receives an IP datagram. How does the network layer in Host A know it should pass the segment (that is, the payload of the datagram) to TCP rather than to UDP or to something else?
- (b) Can a host have more than one IP address? Justify your answer briefly.
- (c) How does Skype work between two hosts which are behind two different NAT boxes?
- (d) Do you think NAT is still needed if IPv6 is globally deployed?

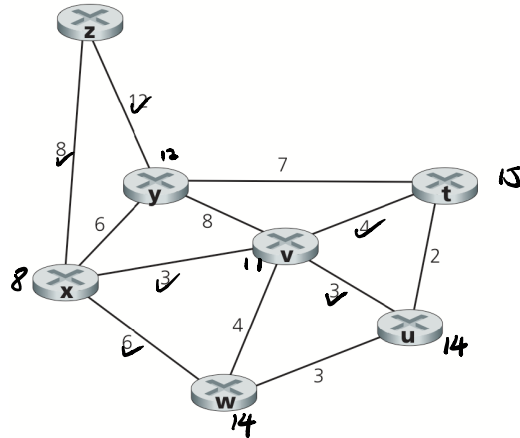
Write your solution to Problem 2 in this box

- (a) The IP header has a field of Upper-layer Protocol to indicates TCP or others. If the field is 6, the payload is a TCP segment, and 17 indicates UDP.
- (b) No. IP address is the ID of a host. If a host has more than one IP, it should be regarded as multiple hosts.
- (c) Skype uses relaying, such that one NATed host initiates a connection to relay, and the other NATed host also reach a connection to relay, then relaying is established.
- (d) Yes, NAT is still needed, because NAT provides security for devices inside the local net, since they are not addressible and visible by outside world. Also, NAT is efficient because it makes devices in local network able to change address without notifying outside world, and ISP can also be efficiently changed.

### Problem 3

Consider the following network. With the indicated link costs, use Dijkstra's shortest-path algorithm to compute the shortest path from **z** to all network nodes. Show how the algorithm works by computing a table similar to the table in chapter 5 lecture slide 12 (Dijkstra's Algorithm: example).

**Note:** When there is a tie, you should select the node with order  $t > u > v > w > x > y$ . For example, when u and w appear to have the same cost, you should add u into  $N'$  in your next iteration.

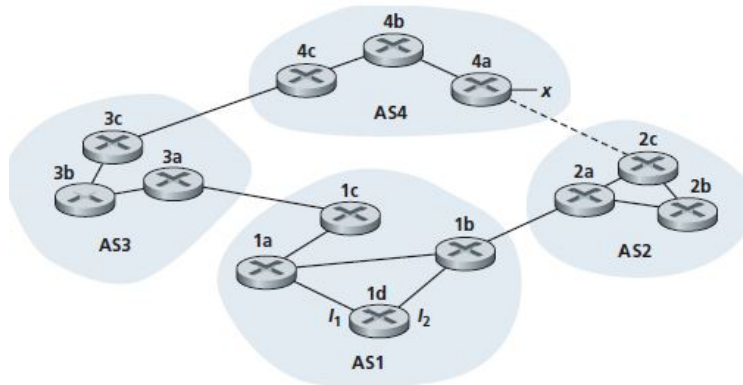


Write your solution to Problem 3 in this table.

Step	$N'$	$D(t), p(t)$	$D(u), p(u)$	$D(v), p(v)$	$D(w), p(w)$	$D(x), p(x)$	$D(y), p(y)$
0	<b>z</b>	0	∞	∞	∞	<b>8, z</b>	12, z
1	<b>zx</b>	0	∞	<b>11, x</b>	14, x		12, z
2	<b>zxv</b>	15, v	14, v		14, x		<b>12, z</b>
3	<b>zxvy</b>	15, v	<b>14, v</b>		14, x		
4	<b>zxvyu</b>	15, v			<b>14, x</b>		
5	<b>zxvyuw</b>	<b>15, v</b>					
6	<b>zxvyuw t</b>						

## Problem 4

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.



At some time T, the prefix  $x$  appears in AS4, adjacent to the router 4a. From which routing protocol (OSPF, RIP, eBGP, or iBGP):

- (a) Router 3c learns about prefix  $x$ ?
- (b) Router 3a learns about prefix  $x$ ?
- (c) Router 1c learns about prefix  $x$ ?
- (d) Router 1d learns about prefix  $x$ ?

Write your solution to Problem 4 in this box

(a) eBGP

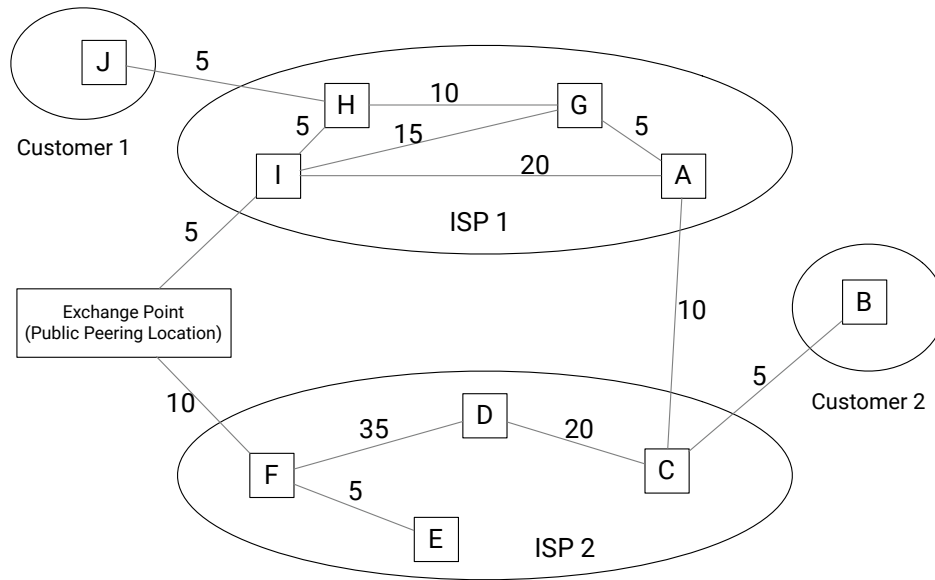
(b) iBGP

(c) eBGP

(d) iBGP

## Problem 5

Consider the following topology. The cost metric of a link denotes the one-way propagation delay on the link in msec (assuming the delays are symmetric). The two ISPs ISP 1 and ISP 2 are peers. CIDR is used for addressing and BGP is used for inter-domain routing. Assume that both ISPs always try to enforce hot-potato routing above all other routing policies. What is the one-way propagation delay between Customer 1 and Customer 2? Is the routing between two customers symmetric or asymmetric?



Write your solution to Problem 5 in this box

Customer 1 to 2 :  $J \rightarrow H \rightarrow I \rightarrow F \rightarrow D \rightarrow C \rightarrow B$   
 $= 5 + 5 + 5 + 10 + 35 + 20 + 5$   
 $= 85 \text{ ms}$

Customer 2 to 1 :  $B \rightarrow C \rightarrow A \rightarrow G \rightarrow H \rightarrow J$   
 $= 5 + 10 + 5 + 10 + 5$   
 $= 35 \text{ ms}$

The routing is asymmetric.