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.

(a) NAT Translation Table

Table 2: NAT Translation Table Solution

`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

(b) (1) Message Received from Host: `MSG <10.0.0.6:5000, 172.217.11.78:80>`
Message Sent from Router: `MSG <128.97.27.37:8001, 172.217.11.78:80>`

(2) Message Received from Host: `MSG <10.0.0.10:6000, 204.79.197.200:80>`
Message Sent from Router: `MSG <128.97.27.37:8002, 204.79.197.200:80>`

Problem 2

Answer the following questions regrading 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?

(a) 'Protocol' field in the IP header is used to find out the protocol of the next layer.

(b) Yes, if a host has multiple NICs (network interface cards) then the host can have more than one IP address.

(c) The hosts behind NAT boxes can be found by each other since they are first connected to the Skype server. The server then helps each user make a connection to the other users by providing connection information.

(d) Open question. The answer is correct if it is reasonable.

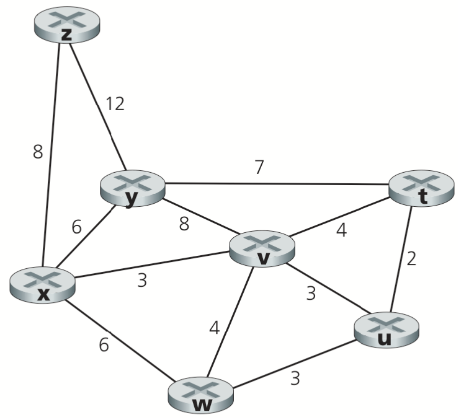
Yes answer example: We still need NAT in IPv6 because NAT can also protect the hosts within the network from malicious attacks from external network.

No answer example: We don't need NAT anymore because we have enough IP addresses to assign to hosts.

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.

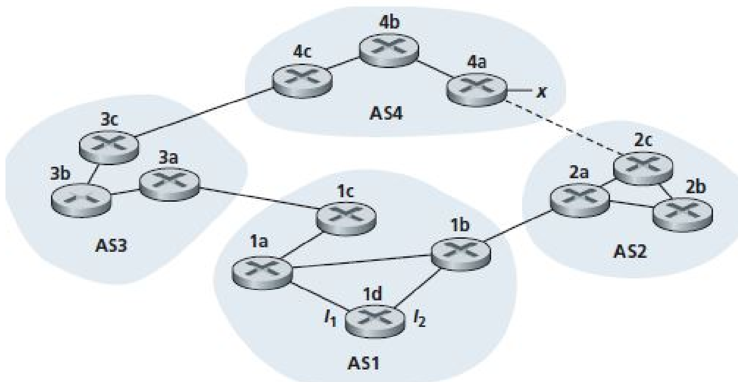


Write your solution to Problem 3 in this table.

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	z	∞	∞	∞	∞	**8,z**	12,z
1	zx	∞	∞	**11,x**	14,x		12,z
2	zxv	15,v	14,v		14,x		**12,z**
3	zxvy	15,v	**14,v**		14,x		
4	zxvyu	15,v			14,x		
5	zxvyuw	15,v			**14,x**		
6	zxvyuwt	**15,v**					

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?

(a) Router 3c receives from AS4: eBGP

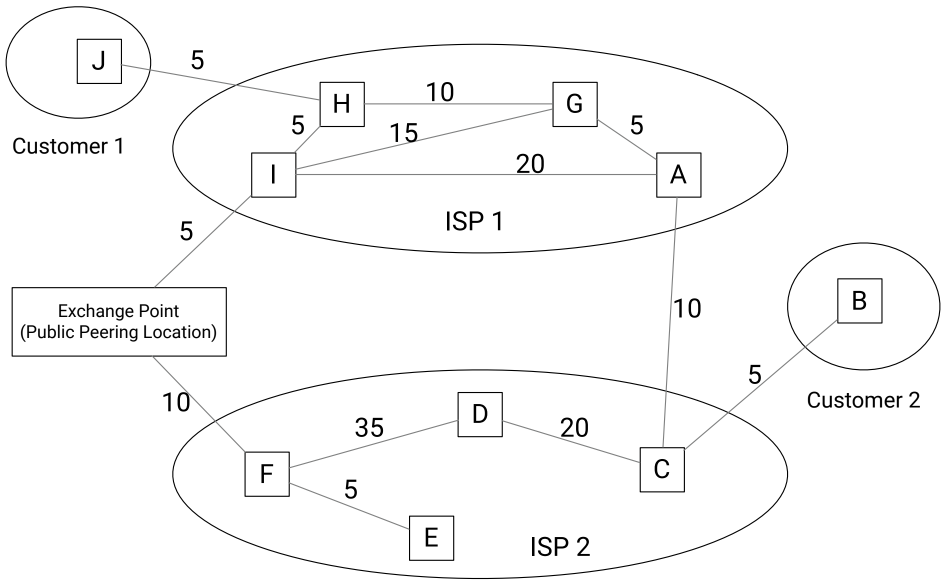
(b) Router 3a receives from AS3: iBGP

(c) Router 1c receives from AS3: eBGP

(d) Router 1d receives from AS1: 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?



Hot potato routing means that traffic is handed off to the next hop network as soon as possible.
From Customer 1 to Customer 2: J-H-I-F-D-C-B: 5 + 5 + 5 + 10 + 35 + 20 + 5 = 85 msec.
From Customer 2 to Customer 1: B-C-A-G-H-J: 5 + 10 + 5 + 10 + 5 = 35 msec.
Routing here is asymmetric.