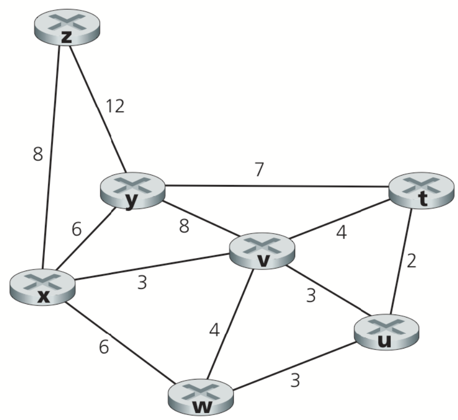
Problem 1

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 Table 5.1 in the textbook.



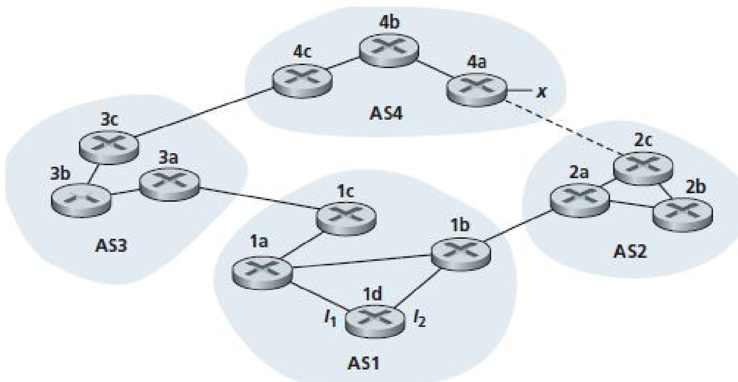
Write your solution to Problem 1 in this box

N'	D(y), P(y)	D(v), P(v)	D(w), P(w)	D(t), P(t)	D(u), P(u)	D(z), P(z)
x	6, x	3, x	6, x	infinity	infinity	8, x
xv	6, x		6, x	7, v	6, v	8, x
xvy			6, x	7, v	6, v	8, x
xvtw				7, v	6, v	8, x
xvtwu				7, v		8, x
xvtwuy						8, x
xvtwuyz						

Shortest path from x to:
-t: xvt (cost=7)
-u: xvu (cost=6)
-v: xv (cost=3)
-w: xw (cost=6)
-y: xy (cost=6)
-z: xz (cost=8)

Problem 2

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?

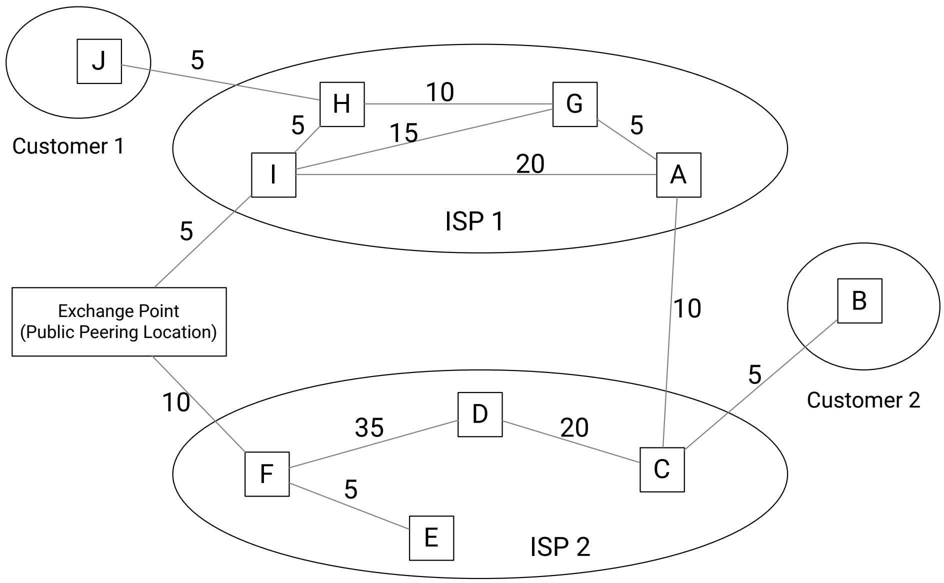
(d) Router 1d learns about prefix x?

Write your solution to Problem 2 in this box

a) eBGP because the path advertisement comes from a different AS
b) iBGP because the path advertisement comes from a gateway router from within the same AS
c) eBGP because the path advertisement comes from a different AS
d) iBGP because the path advertisement comes from a gateway router from within the same AS

Problem 3

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 3 in this box

Hot potato routing claims that we must pick the path to the gateway with the lowest cost, ignoring intra-domain cost.

Dprop from Customer 1 to Customer 2: 5 + 5 + 5 + 10 + 35 + 20 + 5 = 85ms
Dprop from Customer 2 to Customer 1: 5 + 10 + 5 + 10 + 5 = 35ms

Because, the two propagation delays are different, the routing is asymmetric.

Problem 4

Network Address Translation (NAT) is the translation of an IP address used within one network to a different IP address known within another network. A NAT capable router essentially translates private IP address within a network to public IP addresses that can be visited publicly. A simple NAT-capable router will have mappings between the private addresses within the network to the public address(es) that it uses. Suppose that the router has a single public address `131.179.176.1` 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`	`131.179.176.1:8000`
...	...

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 `131.179.176.1:8002`

(8) `204.79.197.200:80` sends a message to `131.179.176.1:8003`

(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 <131.179.176.1:8000, 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.

Problem 4 continued on next page. . .

Write your solution to Problem 4 in this box

a) NAT Translation Table

IP:port within network	IP:port outside
10.0.0.5:5000	131.179.176.1:8000
10.0.0.6:5000	131.179.176.1:8001
10.0.0.10:6000	131.179.176.1:8002
10.0.1.101:6001	131.179.176.1:8003
10.0.0.7:7000	131.179.176.1:8004

b)
1)
Message received from host: MSG<10.0.0.6:5000, 172.217.11.78:80>
Message sent from router: MSG<131.179.176:8001, 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<131.179.176.1:8002, 204.79.197.200:80>

Problem 5

In this problem, you will derive the efficiency of a CSMA/CD like multiple access protocol. In this protocol, time is slotted and all adapters are synchronized to the slots. Unlike slotted ALOHA, however, the length of a slot (in seconds) is much less than a frame time (the time to transmit a frame). Let S be the length of a slot. Suppose all frames are of constant length $L = kRS$, where R is the transmission rate of the channel and k is a large integer. Suppose there are N nodes, each with an infinite number of frames to send. We also assume that $d_{prop} < S$, so that all nodes can detect a collision before the end of a slot time. The protocol is as follows:

- If for a given slot, no node has possession of the channel, all nodes contend for the channel; in particular, each node transmits in the slot with probability p. If exactly one node transmits in the slot, that node takes possession of the channel for the subsequent $k - 1$ slots and transmits its frame.
- If some node has possession of the channel, all other nodes refrain from transmitting until the node that possesses the channel has finished transmitting its frame. Once this node has transmitted its frame, all nodes contend for the channel.

Note that the channel alternates between two states: the productive state, which lasts exactly k slots, and the non-productive state, which lasts for a random number of slots. The channel efficiency is defined as the ratio of $k/(k + x)$, where x is the expected number of consecutive non-productive slots.

(a) For fixed N and p, determine the efficiency of this protocol.

(b) For fixed N, determine the p that maximizes the efficiency.

Problem 5 continued on next page. . .

Write your solution to Problem 5 in this box

a)
probability that any node has successful transmission: NP(1 - P) ^(N - 1)
efficiency of channel: k/(k + x), where x = expected number of consecutive non-productive slots
x = (1 - prob(any node has successful transmission))/(prob(any node has successful trans)
= (1 - NP(1 - P)^(N - 1)) / (NP(1 - P)^(N - 1))
efficiency of channel = k / (k + ((1 - NP(1 - P)^(N - 1)) / (NP(1 - P)^(N - 1))))

b)
For maximum efficiency, we take the first derivative with respect to p, since N is a constant.
The result is when P = 1/N