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# Problem 1

1. A D
2. D
3. B D
4. C D
5. C
6. C D
7. D E
8. B

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# Problem 2

1. In IPv4, the basic IP header is 20 bytes, but with the options field, the header length of the IP header can vary, so we use the header length field to see what size is the IP header with the options field.

2. No, the Internet cannot always guarantee loop-free routing, so it handles packets on looped routes with the Time-to-live field in the IP header, where the packet's TTL decrements with each hop on its looped route, until it reaches 0 and is dropped.

3. Yes, it includes the IP address of router for the destination subnet being advertised. The Path Vector's purpose in BGP is to inform all ASes that a destination subnet is reachable by the AS path specified in the vector, and the way to identify the destination subnet, is through the IP address of the router that subnet is interfaced with.

4. Yes, BGP is able to detect loops because of the AS-PATH attribute; a router can detect the loop by checking if its ASN was already included in the AS-PATH attribute list of an advertised path.

Problem 2 Cont.

5. Ping uses the two protocols : IP and ICMP. Ping uses ICMP because it leverages the echo messages of the ICMP protocol, wherein ~~ping~~ senders using ping send an ICMP echo request and receivers send ICMP echo replies, so that the sender can calculate the RTT. Inadvertently, Ping uses IP, because ICMP is implemented on top of IP in order to route the ICMP messages to their intended destinations.

6. Yes, the destination address can match multiple entries, because the subnet mask for IP address can be variable, so a destination ~~dest~~ address could be matched to different entries based on the range of the host portion of the address is appropriate. To decide which entry will be used, IP forwarding uses longest-prefix matching to, where the entry used is the one that has the most, significant bits matching the destination address.

7. We can use tunneling. By implementing a functionality in IPv6 routers where the routers can wrap IPv6 datagrams in IPv4 datagrams and unwrap them, this gives IPv6 the ability to be backwards compatible. When IPv6 routers are sending datagrams to IPv4 routers, ~~they can~~ they can put the IPv6 datagram as a payload for an IPv4 datagram that the IPv4 ~~da~~ routers can recognize, which can be transmitted across, until a host or IPv6 router unwraps the IPv4 datagram to ge the IPv6 datagram; this enables IPv6 and IPv4 routers to coexist in the same network to allow for gradual upgrade.

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# Problem 3

1. TCP 4-tuple format: (source IP, source port, dest IP, dest port)

Host 10.1.1.2's SYN: (10.1.1.2, 5000, 128.78.49.7, 80)
Host 10.1.1.3's SYN: (10.1.1.3, 5000, 128.78.49.7, 80)

2. NAT Translation Table

| IP: Port within private net. | IP: port outside private net. |
| --- | --- |
| 10.1.1.2 : 5000 | 158.46.39.3 : 5001 |
| 10.1.1.3 : 5000 | 158.46.39.3 : 5002 |

3. Host 10.1.1.2's SYN sent by NAT: (158.46.39.3, 5001, 128.78.49.7, 80)
Host 10.1.1.3's SYN sent by NAT: (158.46.39.3, 5002, 128.78.49.7, 80)

4. Received by NAT:
Host 10.1.1.2's SYNACK: (128.78.49.7, 80, 158.46.39.3, 5001)
Host 10.1.1.3's SYNACK: (128.78.49.7, 80, 158.46.39.3, 5002)
Sent by NAT:
Host 10.1.1.2's SYNACK: (128.78.49.7, 80, 10.1.1.2, 5000)
Host 10.1.1.3's SYNACK: (128.78.49.7, 80, 10.1.1.3, 5000)

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# Problem 4.

1. a) eBGP, since 1a is a border router learning about x from AS3.

   b) iBGP, since 1c is a border router that learns about x from internal neighbors.

   c) iBGP, since 1i is an internal router that learns from its neighbors.

   d) The path vector 1i learns to reach x is AS3, AS5, AS4, x, using notation from the slides.

   e) I will be equal to s, since the path to x requires going to the gateway router 1a, which is on the path over the router connected to 1i by communication link s.

   f) 1h has 3 neighbors and AS1 runs RIP (dv alg.) so exchange only between neighbors

   2 updates sent by each router per minute

   2 messages/minute × 3 neighbors = $\boxed{\text{6 messages per minute}}$

2. a) Without any special policies, 1i chooses the shortest AS-PATH, so the path vector it uses to reach x is AS2, AS4, x.

   b) I will be set to t, since the path to x it knows goes through router 1c, which is on the route with communication link t.

   c) AS2 is link state and has 9 nodes
   Since 2h must have complete topology, it receives messages from all other routers: 9-1 = 8 ; 2 updates sent by each router per min.

   2 messages/minute × 8 nodes = $\boxed{\text{16 messages per minute}}$

Problem 4 Cont.

2. d) No, 3a will use iBGP to learn its shortest path to x, while 3c will use eBGP to learn its shortest path to x.

e) The path vector 3a uses is ~~AS1, AS2, X~~.
AS1, AS2, AS4, X.

f) The path vector 5a uses is AS3, AS1, AS2, AS4, X.

Problem 5

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1. It takes router E 400 msec to finalize its routing table.
Speed of convergence of OSPF is essentially $O(nE)$, since that's how many messages are sent for Dijkstra's algorithm.
However, assuming that messages are sent simultaneously, there are 14 edges, so we divide $nE$ by $E = 14$, to get 8, meaning it takes 8 rounds for all $nE$ messages to be propagated.
Since it takes 50 msec per round to send 14 simultaneous messages, we have $50 \times 8 = 400$ msec.

2. before fail

| dest | next hop |
|---|---|
| A | D |
| B | D |
| C | E |
| D | D |
| E | E |
| F | F |
| H | H |

after fail

| dest | next hop |
|---|---|
| A | D |
| B | D |
| C | H |
| D | D |
| E | |
| F | F |
| H | H |