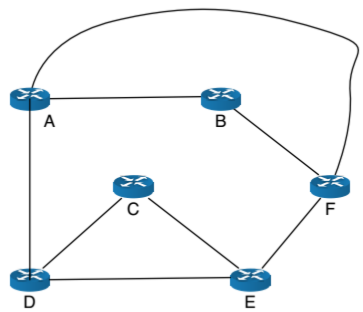
Problem 1

Consider a network of 6 routers shown in the figure below. The network is running OSPF routing protocol and the cost of each link is 10. Each router is announcing a single unique prefix, in total 6 prefixes are announced (prefix A, prefix B, ... prefix F). Propagation delay for each link is 10msec. When a router has to choose between two or more equal cost paths to the same destination, it breaks the tie by picking the path whose next hop has smallest name (A < B < C < D < E < F). The network has been up and running for a long time. However, at time T=100 min, link A-F fails.



1. How do node A and node F discover this link failure?

Each node in this network periodically sends HELLO messages to its neighbors. A, for example, should be periodically receiving HELLO messages from B, D, and F. However, if A does not receive any messages (due to link A-F failing) from F after a certain time, it concludes that there is a link failure and immediately triggers a new Link State Update to its neighbors. Likewise, F does not receive a HELLO from A in time and also concludes that the A-F link failed. F likewise triggers a new Link State Update.

2. Will node C learn about this link failure? If so, does knowing this failure affect C's forwarding table?

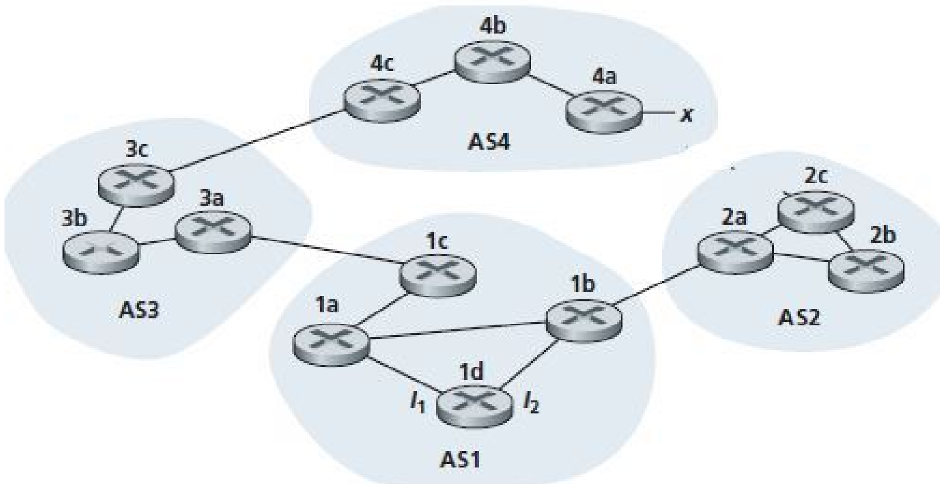
Once node A and node F discover the link failure, they both initiate a Link State Update by sending an updated LSP packet to all neighbors. A no longer considers F a neighbor so F won't show up in A's neighbor list. Likewise, A no longer exists in F's neighbor list. In OSPF, new updates are flooded to the rest of the network, so eventually node C will hear about both node A's update of no longer having a link to F, and node F's update of no longer having a link to A. Thus, node C learns about this link failure. However, this does not affect C's forwarding table. Before the A-F link failure, node C's forwarding table looks like:

Destination	Next Hop
A	D
B	D
C	C
D	D
E	E
F	E

Because none of the original shortest paths from C to each node included the A-F link, C's forwarding table is not affected. Thus, after the failure, the forwarding table remains the same.

Problem 2

Consider the network shown below. Suppose all ASes (AS 1 – AS 4) are running OSPF for their intra-AS routing protocol. Suppose BGP is used for the inter-AS routing protocol (and iBGP is used inside each AS).



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

1. Router 1c learns about prefix x?
2. Router 3b learns about prefix x?
3. Router 4a learns about prefix x?

1. eBGP; because router 1c is an external (gateway) router in AS1, it must have learned about x from router 3a over an eBGP session.
2. iBGP; because router 3b is an internal (non-gateway) router in AS3, the only way for it to learn about prefix x (which exists in a different AS) is through iBGP. Router 3c may use eBGP to learn about x from router 4c, but router 3c creates an iBGP session with router 3b to advertise x.
3. OSPF; the OSPF routing protocol is used to propagate reachability from source (x) to destination (4a) from within the same AS.

Problem 3

1. How does BGP detect loops in paths?
2. Why does a BGP router not always choose routes with the shortest AS-path length?

1. When a router advertises a prefix over a BGP session, certain BGP attributes are also passed. One such attribute is AS-PATH, which contains each AS through which the advertisement for that prefix has passed. If AS4 advertises a prefix x to AS3, and then AS3 advertises x to AS1, then the AS-PATH of this BGP session is AS4 AS3. This is used to detect and prevent loops in paths. If a router sees the AS that it belongs to already in the AS-PATH, it rejects the advertisement, preventing a potential loop.
2. The deciding factor for which routes a BGP router chooses is not the shortest AS-path length but rather the routing policy of that router. Each route has a local preference value set up by the router or learned from another router. This policy decision comes from the AS' network administrator, and a preference value may depend on business decisions. Traffic originating from an AS may not be able to pass through another specific AS. This is intuitive if we picture competing provider networks that do not want to forward traffic in between themselves. Routing traffic through an AS is costly, and a competing AS network has no obligation to help forward traffic from a customer using its competing AS network. There are plenty of other factors that can affect a router's policy, but the main point is that routing policies govern which routes are ultimately chosen by the router. Choosing routes with the shortest AS-path length is only performed once we've filtered out all routes that conflict with the policies set by that AS' network administrator.

Problem 4

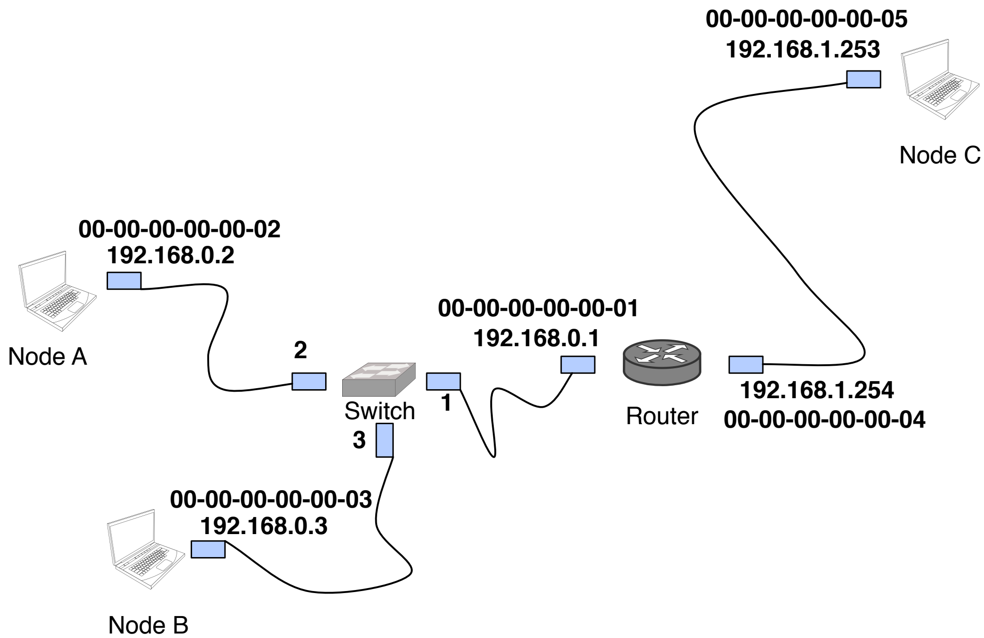
Suppose four active nodes, A, B, C and D, are competing for access to a channel using slotted ALOHA. Assume each node has an infinite number of packets to send. Each node attempts to transmit in each slot with probability p. The first slot is numbered slot 1, the second slot is numbered slot 2, and so on.

1. What is the probability that node A succeeds for the first time in slot 5?
2. What is the probability that any node (either A, B,C or D) succeeds in slot 4?

1. Let $P(A)$ be the probability of node A succeeding in any time slot. This can be calculated with $P(A) = p \times (1-p)^{N-1} = p \times (1-p)^3$.
   Thus, the probability of Node A succeeding for the first time in slot 5 $= (1 - P(A))^4 \times P(A) = (1 - (p \times (1-p)^3))^4 \times (p \times (1-p)^3)$ because this can only be true if Node A fails four times and then succeeds on the fifth.
2. The probability that any node succeeds in slot 4 can be calculated with $N \times p \times (1-p)^{N-1} = 4 \times p \times (1-p)^3$.

Problem 5

Consider the following network topology with specified MAC addresses for network interfaces and the configured IP addresses:



Assume the network mask for both subnetworks is 255.255.255.0.

1. Assume that routing tables are properly configured and the network just started (i.e., all caches are empty), fill the following table to enumerate Ethernet frames (in chronological order) needed for node B to send an IP packet to 192.168.0.2 and receive a response back.

frame #	dst MAC addr	src MAC addr	device(s) that can get the frame, excluding the sender	new entries added into the switch's table (if any)
1	FF-FF-FF-FF-FF-FF	...-03	Node A, Switch, Router	[192.168.0.3:...-03]
2	...-03	...-02	Node B, Switch	[192.168.0.2:...-02]
3	...-02	...-03	Node A, Switch	
4	...-03	...-02	Node B, Switch	

Problem 5 continued on next page. . .

2. Assume that the previous operation is done, fill the following table to enumerate Ethernet frames (in chronological order) for node B to send a packet to 192.168.1.253 and receive a reply.

frame #	dst MAC addr	src MAC addr	device(s) that can get the frame, excluding the sender	new entries added into the switch's table (if any)
1	FF-FF-FF-FF-FF-FF	...-03	Node A, Switch, Router	
2	...-03	...-01	Node B, Switch	[192.168.0.1:...-01]
3	...-01	...-03	Switch, Router	
4	FF-FF-FF-FF-FF-FF	...-04	Node C	
5	...-04	...-05	Router	
6	...-05	...-04	Node C	
7	...-04	...-05	Router	
8	...-03	...-01	Node B, Switch	