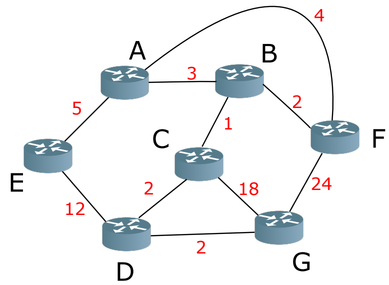
# Problem 1

Consider the network graph shown below to answer the following questions. The number beside each link indicates the cost of the link.




1. If each router runs the link-state routing algorithm, detail one run of the algorithm at router E.

| N' | A | B | C | D | F | G | |
|---|---|---|---|---|---|---|---|
| E | 5,E | $\infty$ | $\infty$ | 12,E | $\infty$ | $\infty$ | |
| E,A | 5,E | 8,A | $\infty$ | 12,E | 9,A | $\infty$ | |
| E,A,B | 5,E | 8,A | 9,B | 12,E | | $\infty$ | |
| E,A,B,C | 5,E | 8,A | 9,B | 11,C | | 27,C | |
| E,A,B,C, | 5,E | 8,A | 9,B | | | 27,C | |
| E,A,B,C,F,D | 5,E | 8,A | | | | 13,D | |
| E,A,C,F,D | 5,E | 8,A | | | | 13,D | |

2. What path will packets from E take to reach G?

E → A → B → C → D → G

3. Suppose the cost of each link is determined by amount of traffic that the link is carrying in Mbps (higher utilization = higher cost), and the cost at each link is updated every 10 seconds. At $t = 0$, the costs are the values shown in the figure. If E now opens a TCP connection to G and starts sending a very large file at 4 Mbps, what will happen during the next 25 seconds? Assume that the cost was last updated just before $t = 0s$, and everything else remains static.

Link costs will update every 10s:

$t=0$ : costs as displayed

$t=10$ : link costs ↑ → costs increase based on complexity of the algorithm

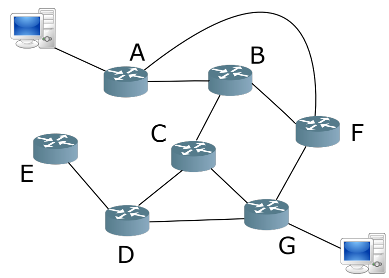
$t=20$ : link costs ↑

$t=25$ : link costs are same as $t=20$

# Problem 2

Consider the network shown below. Assume each router in the network runs the OSPF routing protocol and announces a unique prefix. Each link has a propagation delay of 100ms and a cost of 10. Neglect any routing update processing delays. If a router has to choose between two or more equal cost paths to the same destination, assume it chooses the next hop with the smaller name (i.e. $A < B < C$ ...).

Assume the network has already been operational for a long time at $t = 0$. At $t = 10s$, the link A-F fails.




1. How will A and F detect the failure? How long will it take?

OSPF routers send Hello packets to each neighbor — when F doesn't receive one from A, and vice versa, for a long enough time (40 seconds), they both will detect an error.

2. How will the routing and forwarding tables at C be affected due to the failure?

Routing table would no longer have route C→G→F→A because F now fails. It would now only contain a route through B (C→B→A)

Forwarding table will be updated to have all packets destined to A are forwarded to B.

3. Suppose an LSP about the link failure sent from D to E gets lost. What happens next?

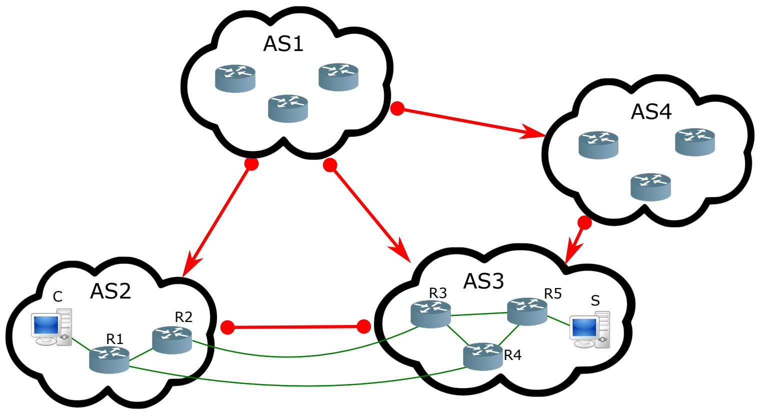
OSPF uses acknowledgements, so if there is a link failure and D doesn't receive an ACK, it will retransmit the LSA until it receives an acknowledgement or the relationship between D and E is determined to be down

4. At $t = 5s$, a host connected to router A established a TCP connection to a host connected to router G and started transferring a very large file. How will the failure affect the file transfer?

The failure will lead to a stoppage in data flow — as a result, the OSPF would search for a new path to G if there exists and continue transferring the file. This will inevitably cause a delay in the execution of the transfer.

# Problem 3

Consider four autonomous systems connected with BGP. The red arrows represent prover-customer relationships (refer to lecture 13), while the green lines represent physical links between routers. Assume each AS owns a single unique IPv4 prefix block not overlapping with any other AS's block.




1. Router R2 (AS2) sends an UPDATE message to R3 (AS3), but the packet carrying the message gets lost. What happens next? What does the BGP daemon at R2 do?

R2's BGP daemon will not get a response from R3, setting their connection to an idle state. It will then continue to set up a connection regularly until a response has been given.

2. If a host in **AS2** sends an IP packet to a host in **AS3**, enlist all the valid AS paths that the packet may take.

AS2 → AS3

AS2 → AS1 → AS4 → AS3

AS2 → AS1 → AS3

3. Host C (AS2) wants to send a packet to host S (AS3), and one of the peering links is used. Assume AS3 uses iBGP for internal routing. What paths can the packet take (enlist the routers, not just AS paths).

AS2(R2) → AS3(R3) → AS3(R4)

AS2(R2) → AS3(R3) → AS3(R5)

AS2(R2) → AS3(R3)

AS2(R1) → AS3(R4)

AS2(R1) → AS3(R4) → AS3(R3)

AS2(R1) → AS3(R4) → AS3(R5)

4. If a host in **AS2** sends an IP packet to a host in **AS4**, enlist all the valid AS paths that the packet may take. Explain your answer. What will happen if the link between AS1 and AS2 fails?

AS2 → AS3 → AS4

AS2 → AS3 → AS1 → AS4

AS2 → AS1 → AS4

AS2 → AS1 → AS3 → AS4

If link fails, the routing tables update by exchanging information and calculating alternative costs. Routers AS1 and AS2 will remove the link, and re-route through other routes to restore connectivity.

# Problem 4

Assume two nodes A and B are connected with a 8Mbps Ethernet link. The propagation delay between the nodes is 200$\mu$s. Suppose A and B both send frames of 1000 bytes size, and both detect the first collision at $t = 0$ and stop transmitting. Ignore the time spent transmitting the jam signal.

At this stage, A and B choose a random value for K for scheduling the frame retransmission. Assume A chooses $K_A = 0$ and B chooses $K_B = 1$.

1. At what times do A and B schedule the retransmission of their frames $F_A$ and $F_B$ respectively.

Ethernet slot time = 51.2 µ for 10 MBps ethernet link

$K_A = 0$ $K_B = 1$

$F_A = 0 \cdot \left(\frac{10}{8}\right) 51.2 = 0$ ⇒ schedule retransmission 0µs after collision

$F_B = 1 \cdot \left(\frac{10}{8}\right) 51.2 = 64\ \mu s$ ⇒ schedule retransmission 64µs after collision

2. How much time does it take to transmit one frame of 1000 bytes?

1000 bytes = 8000 bits over 8 Mbps link ⇒ $\frac{8000 \text{ bits}}{8 \text{ Mbps}} = 1\text{ ms}$

1ms

3. Will there be another collision in the retransmitted frame? Explain your answer.

No –

Node A takes 0µs, Node B takes 64µs.

The propogation delay is 200 µs, so Node A's retransmission will reach B after B has transmitted its frame, so there will be no collision

4. Now assume the propagation delay between A and B is 20$\mu$s instead, everything else remaining the same. In this case, will there be another collision in the retransmitted frame? Explain your answer.

Yes,

Since propogation delay will result in Node A's retransmission reaching B in the midst of its frame, so there will be a collision

## Problem 5

1. You are downloading a file over a TCP connection while connected to UCLA's WiFi network. As you walk around campus, the download continues without getting disconnnected, even while you switch wireless access points. Can you suggest two distinct mechanisms through which such a "roaming" enabled wireless network could be realized? How will packets be forwarded inside the UCLA network for each?

1. Wireless controller routing —
Centralized wireless LAN controller can be used to manage multiple access points. WLC facilitates the switch when a device moves from one network to another. Packets are sent to original access point, but is forwarded to the new access point associated with the device.

2. Mobile IP —
give each device its own IP "home" address. When a mobile moves across networks, a new IP is given separately for the home address to interpret. When a packet is sent, the home IP forwards it to the new IPs depending on its access points.

2. Based on what you learned in the course, can you identify two issues in the current internet architecture (e.g. TCP/IP stack or routing)? This question is open-ended.

1. Security of routing — no end-to-end encryption is used for routing so the current architecture would be subject to spoofing attacks where an attacker route hijacks a network for eavesdropping

2. Current architecture for TCP assumes a static end-to-end path which isn't ideal for mobile devices that move through networks. There exist patches for this use case, but the architecture itself doesn't resolve it.