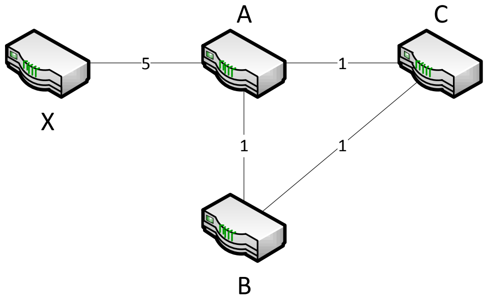
Homework 4

1 Distance Vector

Consider the network shown in the figure. Assume the network uses split horizon/poisoned reverse.



a) Fill in the following distance vector tables after the nodes converge.

D^A	B	C	X
B			
C			
X			

D^B	A	C
A		
C		
X		

D^C	A	B
A		
B		
X		

b) Suppose the link between X and A fails. Show how the distance vector table entries for X evolve for nodes A, B and C. Show the changes that occur during the first 6 iterations of routing update exchanges. The first update should consist of A updating its cost to destination X via X to ∞. Explicitly note when updates are sent, when updates are received, and when nodes poison each other. Assume that:

- Routing information exchanges and table updates are synchronous (meaning that they occur at the same time)

- Updates produced from the prior iteration are sent before processing updates received during the current iteration.
- Assume that if a node has two next hops of equal cost to the same destination, it will chose the node that occurs first in the alphabet.

Answer

a)

D^A	B	C	X
B	1	2	∞
C	2	1	∞
X	∞	∞	5

D^B	A	C
A	1	2
C	2	1
X	6	7

D^C	A	B
A	1	2
B	2	1
X	6	7

b)

Iteration 1: A updates its distance vector entry for X.

D^A	B	C	X
X	∞	∞	∞

Iteration 2: B and C both receive A's update.

D^B	A	C
X	∞	7

D^C	A	B
X	∞	7

Iteration 3: B and C send their updated distance vectors to A. Meanwhile, they send poisoned updates to each other.

D^A	B	C	X
X	8	8	∞

D^B	A	C
X	∞	∞

D^C	A	B
X	∞	∞

Iteration 4: A chooses B as the next hop; A sends updates to B and C, but the update sent to B is poisoned (no effect). A receives the updates from B and C, causing A to update its entries for destination X to ∞.

D^A	B	C	X
X	∞	∞	∞

D^C	A	B
X	9	∞

Iteration 5: C updates B with the new routing information to reach X; C sends a poisoned update back to A (no effect). A updates B and C with a cost of ∞ to reach X.

D^B	A	C
X	∞	10

D^C	A	B
X	∞	∞

Iteration 6: B sends an update to A and sends a poisoned update back to C (no effect). C sends its updated distance vector to B. The rows for destination X after the 6^{th} iteration are shown.

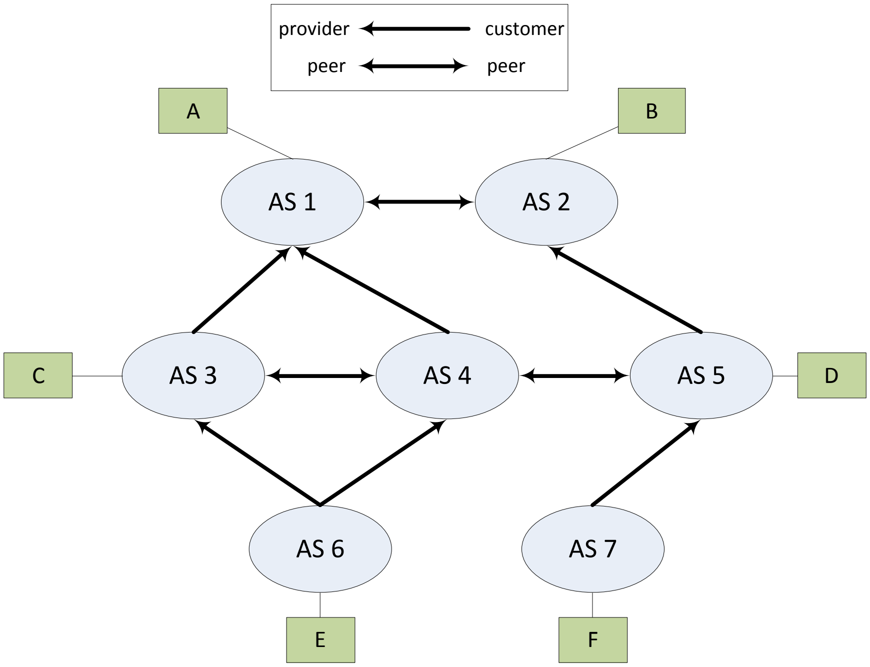
D^A	B	C	X
X	11	∞	∞

D^B	A	C
X	∞	∞

D^C	A	B
X	∞	∞

2 BGP

Consider the network shown in the following figure. For parts a) and b), assume that if a customer has an equally good choice of providers to send outbound traffic through, the customer will pick the provider with the lowest AS number. Assume the nodes evaluate path choices using the shortest hop count metric.



a) What path would E take to reach B?
b) What path would F take to reach C?
c) Network operators typically like to equalize the amount of traffic coming from multiple providers. Suppose AS 6 owns prefix 123.4.0.0/16, and all IP addresses in this prefix receive approximately the same amount of traffic. AS 6 has two options for announcing this prefix. In the first option, AS 6 sends the same announcement to both AS 3 and AS 4. In the second option, AS 6 announces 123.4.0.0/17 to AS 3 and 123.4.128.0/17 to AS 4. Discuss the pros and cons of both approaches.
d) Suppose AS 3 and AS 4 become engaged in a bitter corporate rivalry. AS 3 wishes to implement a policy where any of its outbound traffic will avoid traversing AS 4. Using only your knowledge of BGP, what would you advise AS 3 to do?

Answer

a) E → AS 6 → AS 3 → AS 1 → AS 2 → B

b) F → AS 7 → AS 5 → AS 2 → AS 1 → AS 3 → C
Note: Many people missed this question; it was worth 2 points. If the packet from F to C traversed AS 4, it would be traversing two peering hops; AS 4 gains nothing by providing this transit service.

c) The first option does nothing to equalize the traffic coming from either provider. A portion of the Internet will route to AS 6 via AS 3, and the rest will route through AS 4. There is no guarantee that the amount of traffic is balanced through either provider.
The second option equalizes the traffic, but has an adverse effect on BGP scalability. Suppose every AS subdivides the prefixes they announce into two parts; each BGP router would need to double the amount of space used in its forwarding table. Also, suppose that the link between AS 3 and AS 6 (or AS 4 and AS 6) is of poor quality (lossy, low capacity, high latency, etc.). Half the hosts behind AS 6 will be subject to bad service, even though an alternate path to reach them exists.

d) AS 3 should choose routes that do not include AS 4 in their AS PATH attributes.
Note: I wanted you to specifically mention the AS PATH attribute. I was looking for a solution where outbound traffic would not cross AS 4, meaning that you should eliminate all routes that go through AS 4.

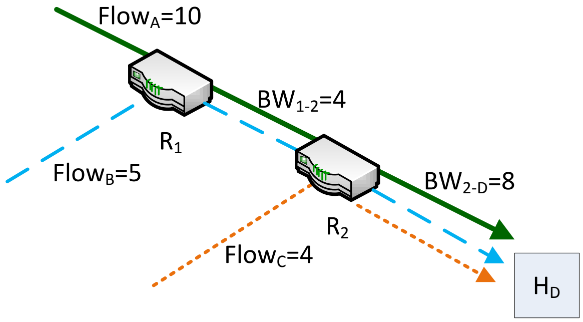
3 Fair Queuing

For parts a) and b), assume that the four flows are traversing a router that implements fair queuing. They are competing for a link with a bandwidth of 16 Kbps.

a) Flow A transmits at a rate of 1 Kbps, flow B at 1 Kbps, flow C at 4 Kbps, and flow D at 10 Kbps. How much bandwidth will each flow get under fair queuing?

b) Flow A transmits at a rate of 4.5 Kbps, flow B at 1 Kbps, flow C at 5.25 Kbps, and flow D at 8 Kbps. How much bandwidth will each flow get under fair queuing?

c) Consider the network depicted in the following figure.



$Flow_A$ transmits at a rate of 10 Kbps at router R_1. $Flow_B$ transmits at a rate of 5 Kbps at R_1. Both are competing for the same outgoing link at R_1 and that link has 4 Kbps of available bandwidth (represented by BW_{1-2} in the figure). At R_2, Flow$_A$ is competing with Flow$_B$ and Flow$_C$. How much bandwidth will each flow be allocated at R_2?

Answer

a)

i. Iteration 1: Each flow receives $1/4$ of the 16 Kbps bandwidth. Flow A is satisfied with 1 Kbps, flow B is satisfied with 1 Kbps, and flow C is satisfied with 4 Kbps.
ii. Iteration 2: Flow D is satisfied with 10 Kbps.

b)

i. Iteration 1: Each flow receives $1/4$ of the 16 Kbps bandwidth. Flow B is satisfied with 1 Kbps.
ii. Iteration 2: Each flow receives $1/3$ of the remaining 15 Kbps bandwidth. Flow A is satisfied with 4.5 Kbps.
iii. Iteration 3: Each flow receives $1/2$ of the remaining 10.5 Kbps bandwidth. Flow C is satisfied with 5.25 Kbps, and flow D gets 5.25 Kbps.

c) At R$_1$, Flow A will be allocated 2 Kbps, and Flow B will be allocated 2 Kbps. At R_2, each flow will receive $1/3$ of the 8 Kbps bandwidth, meaning Flow A will receive 2 Kbps, Flow B will receive 2 Kbps, and the remaining 4 Kbps will be allocated to Flow C.

4 RED

Suppose a router implements RED for congestion avoidance, with maxP=0.02. The router is currently processing two flows, A and B. Suppose the average queue length is 12 packets, while the minimum and maximum thresholds are 8 and 16 packets, respectively. For the purposes of this problem, assume the average queue length has stabilized, meaning perturbations in the queue length do not affect its value.

a) Compute the drop probability for an incoming packet if the number of packets queued since the average length crossed the minimum threshold is 10.
b) Suppose flow A and flow B are about to send 8 packets each, with flow A's packets arriving at the router before flow B's do. Prior to the arrival of flow A's first packet, the number of packets queued since the average length crossed the minimum threshold is 6. All 8 of flow A's packets are enqueued at the router. What is the probability that none of flow B's packets are dropped?

Answer

a) $\text{TempP} = \text{maxP} * (\text{AvgLen} - \text{MinThreshold})/(\text{MaxThreshold} - \text{MinThreshold})$
$\text{TempP} = 0.02 * (12 - 8)/(16 - 8) = 0.01$
$\text{P} = \text{TempP}/(1 - \text{count} * \text{TempP})$
$\text{P} = .01/(1 - 10 * 0.01) = .01/.90 = 1/90$

b) `count` will be 14 when the first packet from flow B arrives (6 from before flow A sent its packets and 8 from flow A). Let $P_{\mathrm{B,i}}$ denote the probability that flow B's i$^{\mathrm{th}}$ packet is dropped if B's prior i-1 packets are successfully enqueued.
The first packet from B will be dropped with probability:
$P_{\mathrm{B,1}} = .01/(1 - 14 * 0.01) = .01/.86 = 1/86$
If B's first packet is successfully enqueued, then the second packet from B will be dropped with probability:
$P_{\mathrm{B,2}} = .01/(1 - (14 + 1) * 0.01) = .01/.85 = 1/85$
Thus, the probability that all 8 of flow B's packets are successfully enqueued is:
$\prod_{i=1}^{8} (1 - P_{B,i}) = (1 - 1/86) * (1 - 1/85) \ldots (1 - 1/79) = 78/86$

5 Token Bucket

Consider the arrival traffic characterized by a token bucket with the following parameters: r (average rate) = 5 Mbps, R (maximum rate) = 10 Mbps, and b (token depth) = 100 Kb.

a) Compute the duration of time for which a flow can send at rate R before exhausting its tokens.
b) Using your previous answer, compute the number of bits transmitted before the flow depletes its tokens.
c) Suppose the router allocates 50 Kb of buffer space for the flow discussed in parts a) and b) of this problem. The allocated buffer must be drained at some rate to ensure that no packets are lost, given the value computed in part b) of this problem. What is the minimum sustained rate r_a that must be allocated by the router to ensure that no packets from this flow are dropped during the time period computed in part a)?

Answer

a) The flow starts with a bucket containing b tokens. Those tokens are drained at a rate R and replenished at a rate r. Thus, we solve the equation $b - R * t + r * t = 0$ for t, where t represents time. This simplifies to $t = b/(R - r)$. Using the numbers above, this gives us $102,400b/(10,000,000bps - 5,000,000bps) = 1,024/50,000sec$ or $10/500sec$ or $10/512sec$, depending on what size conventions you use.
b) The flow sends at a rate R, and we know the duration from a). If we use the general equation from the previous part, we have $R * b/(R - r)$. Using the numbers above, $10,000Kbps * (10/500sec) = 200Kb$.
c) We can only buffer 50 Kb. However, we know that the flow can send up to 200 Kb before depleting its token bucket. Thus, we need to make sure that we empty the queue at a rate that makes up for the discrepancy, over the period of time before the flow depletes its tokens. Let M denote the value computed in part b), B_a denote the buffer size, and T denote the value computed in part

a). $r_a = (M - B_a)/T = (200Kb - 50Kb)/(10/500sec) = 7,500Kbps$ or $7,680kbps$.