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CS 35201
Final Exam

1. We want to compare the performance of a switch (L2) versus a router (L3) in terms of the average packet delay. In both, we use the same hardware that consists of a processor that runs at 1 Gbps (2^{30} bps). The switch accepts 1 KB ($2^{10}B$) fixed size packets. The router accepts variable size packets with an average 1 KB. In both scenarios, packets arrive at a rate λ=64 packets/s.

(a) What is the service rate (μ), in terms of packets/s, at each port for the switch and the router? 4 pts

2^{30}=1,073,741,824 bits per second 2^{10}= 1024 Bytes*8 =8192bits

Assuming that the router's packets maintain at the average of 1KB:

The router can process 1,073,741,824 bits per second and each packet is 8192bits.

So, the router can process 1,073,741,824/8192= 131,072 packets per second= μ

The switch can process 1,073,741,824 bits per second and each packet is 8192bits.

So, the switch can process 1,073,741,824/8192= 131,072 packets per second= μ

(b) What is the traffic intensity (service utilization, ρ) at each port for the switch and the router? 4 pts

Since both the switch and the router have the same λ and μ,

$\rho=\lambda/\mu$

where λ=64 and μ=131,072

So, in both cases p=64/131,072=0.005780346821

(c) What is the average queuing delay for the switching port? 4 pts

The switch accepts fixed sized packets so we'll use the equation: $D = \frac{2-\rho}{2\mu(1-\rho)}$

D=(2-0.005780346821)/(2(131,072)(1-0.005780346821))=1.994219653/(262,144*.9942196532)= 1.994219653/260,628.7168=.000007651573

D=.000007651573sec

(d) What is the average queuing delay for the router port? 4 pts

The router accepts variable sized packets so we'll use the equation: $D = \frac{1}{\mu-\lambda}$

D=1/(131,072-64)=.00000763312164sec

(e) Which one is faster and by how much? 4 pts

So, the router is faster by .00000001845136 sec

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Note that: The delay in a buffer with variable size packets is, $D = \frac{1}{\mu - \lambda}$
The delay in a buffer with fixed size packets, $D = \frac{2-\rho}{2\mu(1-\rho)}$ where $\rho = \lambda/\mu$.

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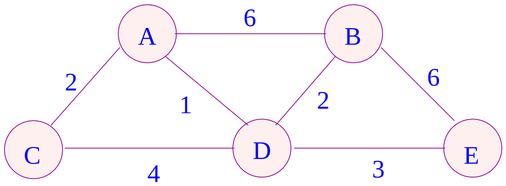
2. Consider the following network of 5 routers, with edge weights labeled.

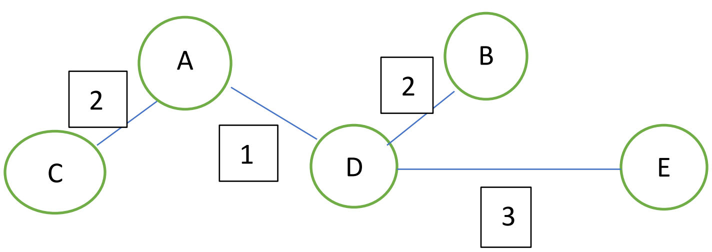


(a) Use Link State routing algorithm to derive the routing table for node A. Show the step-by-step operation.

i. Draw the spanning tree. 7 pts

Step:	Confirmed:	Tentative:
1	(A,0,-)	(C,2,C)
		(D,1,D)
		(B,6,B)
2	(A,0,-)	(C,2,C)
	(D,1,D)	(B,6,B)
3	(A,0,-)	(B,3,D)
	(D,1,D)	(E,4,D)
	(C,2,C)	
4	(A,0.-)	
	(D,1,D)	
	(C,2,C)	
	(B,3,D)	
	(E,4,D)	

Resulting in the spanning tree:



ii. What happens where there is a tie in choosing the next hops between to or more nodes? 3 pts

The path that has the least distance for each node would be chosen.

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(b) Now consider a Bellman-Ford-based distance-vector protocol. Assume that the protocol has converged, and then router E fails. 10 pts

i. Will the protocol converge? If yes, show the sequence of updates that result (after each update, show the next hop and cost for E as seen by each of the remaining routers. If not, explain why not.

No, because slowly the other routers would count up to infinity as they each realize that there is no link to E anymore.

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3. An Internet Service Provider (ISP) deploys a leaky bucket followed by a token bucket to regulate the traffic and control the data rate with the following parameters.

Leaky bucket departure rate:	2 packet per second.
Leaky bucket size:	5, initially empty.
Token bucket size:	20, initially full. Each token is good for one packet (1 KB = $2^{13} bps$)
Token arrival rate:	1 every 4 seconds. 1 at time 4, 8, 12, etc.

(a) Determine the content of the buckets and the number of packets dropped by each bucket for the following time interval. Note: operations are performed at the end of each cycle (i.e., if the leaky bucket is full, 2 packets arrive, and two packets depart, ther is no overflow). 10 pts

Time(t)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Packet arrival	6	0	3	5	0	1	1	8	0	3	2	6	0	0	4	8
Leaky bucket length	4	2	3	5	3	2	1	5	3	4	4	5	3	1	3	5
Token bucket length	19	17	15	13	12	10	8	6	5	3	1	0	0	0	0	0
# of packets dropped from leaky bucket	0	0	0	1	0	0	0	2	0	0	0	3	0	0	0	4
# of packets dropped from token bucket	0	0	0	0	0	0	0	0	0	0	0	1	1	2	2	2

(b) What is the effective rate (Packets/sec) of the leaky bucket for this packet stream? 5 pts

32packets/16sec=

2 packets per sec

(c) What is the effective rate (Packets/sec) of the entire system? 5 pts

24packets/16sec=

1.5 packets per sec

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4. Suppose you are using TCP over a 1-Gbps (2^{30} bps) link with a latency 100 ms to transfer a 10 MB (10×2^{20}B) file. The TCP receiving window is 1 MB. If TCP sends 1 KB (2^{10} B) packets (assuming no congestion):

- How many RTTs does it take until Slow Start opens the send window to 1 MB? 5 pts

Starting at second 0: 1KB sent

second 1: 2KB Sent

second 2: 4KB sent

second 3: 8KB sent

second 4: 16KB sent

second 5: 32KB sent

second 6: 64KB sent

second 7: 128KB sent

second 8: 256KB sent

second 9: 512KB sent

second 10: 1024KB sent= 1 MB sent

Assuming that we start at second 0 the send window will be 1MB at second 10

- How many RTTs does it take to send the file? 5 pts

10MB= 10*1024KB= 10240KB

RTT:	Amount sent this RTT:	Total amount sent thus far:
1	1KB	1KB
2	2KB	3KB
3	4KB	7KB
4	8KB	15KB
5	16KB	31KB
6	32KB	63KB
7	64KB	127KB
8	128KB	255KB
9	256KB	511KB
10	512KB	1023KB
11	1024KB	2047KB

From here we will send 1536KB every two RTT. So,

(((10240KB-511KB)/1536KB)*2)=12.66796875 RTTs

Thus, it will take 22RTTs to send the 10MB file if the receiver has a window size of 1MB

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- Given the receiving window is 1 MB, and the Slow Start starts with 1 KB, what is the effective throughput (bps)? 5 pts

Window size: 1MB= 1024KB*1024=1,048,576*8=8,388,608 bits

RTT= 2*100ms=.2sec

8,388,608/.2=41,943,040 bits per sec

- How many RTTs does it take to send the file if TCP runs into a congestion when the window size is 8KB? 5 pts

10MB= 10*1024KB= 10240KB need to be sent

RTT 1 --> 1KB sent

RTT 2 --> 2KB sent Total sent: 3KB

RTT 3 --> 4KB sent Total sent: 7KB

RTT 4 --> 8KB sent Total sent: 15KB

From here we send 12KB every two RTT. So,

(((10240KB-3KB)/12KB)*2)= 1706.166667 RTTs

Thus, it will take 1709 RTTs to send the 10MB file if the receiver window size is 8KB

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5. TCP has a 32-bit sequence number field and 16-bit advertised window field. Assume that RTT is 512 (2^9) ms, transmission speed is 1 Gbps (2^{30} bps) and each segment transmitted is 1B byte. Note that Since not two identical sequence numbers can be unacknowledged in the pipe, half of the sequence numbers can used (2^{31}).

(a) How long does it take for the sequence numbers to warp around? 5 pts

Number of sequence numbers= 2^{31}=2,147,486,350

Transmission speed=2^{30}=1,073,741,820 bits per sec

Segment transmitted= 1B=8bits

So,

2,147,486,350/1,073,741,820/8=16.00000007sec

(b) Now, instead of sending 1 B segment, let's send a 16 B segment. How long does it take for the sequence numbers to warp around? 5 pts

Number of sequence numbers= 2^{31}=2,147,486,350

Transmission speed=2^{30}=1,073,741,820 bits per sec

Segment transmitted= 16B=128bits

So,

2,147,486,350/1,073,741,820/128=256.0003231sec

(c) What is the drawback in using large segments? 5 pts

A greater transmission speed is needed to send the larger segments to the receiver without packets being dropped.

(d) What is the maximum achievable throughput? 5 pts

Assuming 1B window size:
One window takes 512 ms
1sec/512ms=1.953125 windows per second
1.953125windows*1byte*8bits=15.625 bits per second

Assuming 16B window size:
One window takes 512 ms
1sec/512ms=1.953125 windows per second
1.953125windows*16bytes*8bits=250 bits per second