

CS 655 Homework 3

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1. Suppose that you are using an extended version of TCP Reno that allows window sizes much larger than 64K bytes (A 16-bit receiver's advertised window in the TCP segment means that $2^{16} = 64K$ bytes is traditionally a maximum limit on the send window.). Suppose you are using it over a 1Gbps link with a round-trip time (RTT) of 200ms to transfer 16M-byte file, and the TCP receiver's advertised window is 2M bytes. If TCP sends 1K-byte segments, and assuming no congestion and no lost segments:

- (a) How many RTTs does it take until the sender's congestion window reaches 2M bytes? Recall that the congestion window is initialized to the size of a single segment, and assume that the slow-start threshold is initialized to a value higher than the receiver's advertised window.

The sender window will change as follows.

1 KB \rightarrow 2 KB \rightarrow 4 KB \rightarrow 8 KB $\rightarrow \dots \rightarrow$ 1024 KB \rightarrow 2MB

2^{11} KB $>$ 2 MB

It takes 11 RTTs until the sender's congestion window reaches 2M bytes.

- (b) How many RTTs does it take to send the file?

When the sender's congestion window reaches 2M bytes, the sender has sent

$$1 \times (1 - 2^{-11}) / (1 - 2) = 2047 \text{ KB}$$

Then, the sender will send 2M bytes at a time. Thus, it needs

$$\lceil (16\text{M} - 2047 \text{ KB}) / 2\text{M} \rceil = 7 \text{ RTTs}$$

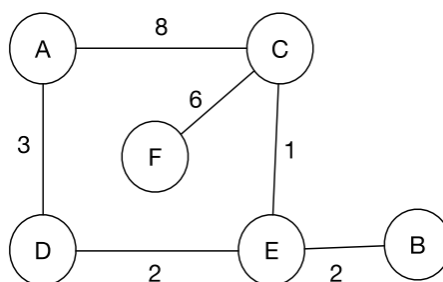
Therefore, it takes $11 + 7 = 18$ RTTs to send the file.

- (c) If the time to send the file is given by the number of required RTTs times the RTT value, what is the effective throughput for the transfer? What percentage of the link capacity is utilized?

$$\text{Effective throughput} = 16\text{MB} / (18 \times 200\text{ms}) = 4.4 \text{ MB/s}$$

$$\text{Utilization} = \text{throughput} / \text{Capacity} = 4.4 \times 8 \text{ Mbps} / 1 \text{ Gbps} = 3.52 \%$$

2. Consider the network given in Figure below with link costs indicated. Give the datagram-forwarding (next-hop routing) table for routers (nodes) A, B, and C. Assume that a shortest-path-first algorithm is used to select the (least cost) route to each destination.



Router A Dijkstra algorithm:

Iteration	N'	D(B), p(B)	D(C), p(C)	D(D), p(D)	D(E), p(E)	D(F), p(F)
Initialization	A	Infinity	8, A	3, A	Infinity	Infinity
1	AD	Infinity	8, A		5, D	Infinity
2	ADE	7, E	6, E			Infinity
3	ADEC	7, E				12, C
4	ADECB					12, C
5	ADECBF					

Router A forwarding table:

Destination	Next hop
B	D
C	D
D	D
E	D
F	D

Router B Dijkstra algorithm:

Iteration	N'	D(A), p(A)	D(C), p(C)	D(D), p(D)	D(E), p(E)	D(F), p(F)
Initialization	B	Infinity	Infinity	Infinity	2, B	Infinity
1	BE	Infinity	3, E	4, E		Infinity
2	BEC	11, C		4, E		9, C
3	BECD	7, D				9, C
4	BECD A					9, C
5	BECD A F					

Router B forwarding table:

Destination	Next hop
A	E
C	E
D	E
E	E
F	E

Router C Dijkstra algorithm:

Iteration	N'	D(A), p(A)	D(B), p(B)	D(D), p(D)	D(E), p(E)	D(F), p(F)
Initialization	C	8, C	Infinity	Infinity	1, C	6, C
1	CE	8, C	3, E	3, E		6, C
2	CED	6, D	3, E			6, C
3	CEDB	6, D				6, C
4	CEDBA					6, C
5	CEDBAF					

Router C forwarding table:

Destination	Next hop
A	E
C	E
D	E
E	E
F	F

3. Consider a campus-area network that runs the distance-vector routing protocol RIP (Routing Information Protocol), where router K has the following routing table.

Destination	Distance	Next-Hop
Net 1	0	direct
Net 2	0	direct
Net 5	8	Router L
Net 17	6	Router M
Net 24	6	Router J
Net 30	2	Router Q
Net 42	2	Router J

Suppose router K receives the following routing update from router J.

Destination	Distance
Net 1	2
Net 5	4
Net 17	7
Net 22	8
Net 24	5
Net 30	10
Net 42	3

Give router K's routing table after it incorporates this update from router J. Note that RIP assumes that the distance over each network (i.e., between two neighbor routers) is 1.

Router K's routing table:

Destination	Distance	Next-Hop
Net 1	0	Direct
Net 2	0	Direct
Net 5	5	Router J
Net 17	6	Router M
Net 22	9	Router J
Net 24	6	Router J
Net 30	2	Router Q
Net 42	4	Router J

4. Assume a distance-vector routing algorithm is used in a WAN of 60 switches (nodes). If costs are recorded as 8-bit numbers and cost vectors are exchanged twice a second, how much capacity per (full-duplex) link is chewed up by the distributed routing algorithm? Assume that each node has three links to other nodes.

At each node, the size of cost vectors is $(60 - 1) * 8 = 472$ bits

$C = 472 * 2 * 2 = 1888$ bps

Thus, 1888 bps capacity is chewed up.

5. A TCP segment of 2000 bytes is to be transmitted over a network with MTU of 262 bytes. Assuming the header in each IP datagram requires 20 bytes, would fragmentation take place? Explain why or why not? If fragmentation takes place, derive the number of datagrams (fragments) required. Also, show how many bytes are in each fragment, and how many of those bytes correspond to headers and data (payload) fields. [Hint: in IPv4, the fragmentation-offset field is expressed in multiple of 8 bytes (see Section 4.3.2 on IP Datagram Fragmentation in textbook), i.e. the amount of original payload data from the original datagram that each fragment carries (except the last fragment) must be multiple of 8 bytes.]

Fragmentation would take place, because the TCP segment is bigger than MTU.

The maximum payload is $262 - 20 = 242$ bytes.

The IPv4 fragmentation-offset field is expressed in multiple of 8 bytes. Thus, the maximum payload will become 240 bytes.

The number of datagrams will be $\lceil 2000 / 240 \rceil = 9$ where the first 8 datagrams have a size of 260 bytes and a payload of 240 bytes and the last one has a size of 100 bytes and a payload of 80 bytes. All datagrams have a header of 20 bytes.

6. What are the CIDR addresses for a network if all its addresses start with 145.98? And if this network has exactly two subnets, what are the CIDR addresses for each of its subnets?

The CIDR addresses are 145.98.0.0/16 ~ 145.98.255.255/16.

The subnets are 145.98.0.0/17 and 145.98.128.0/17.

7. How many addresses are spanned by the CIDR address 214.13.192.0/21, and what range do they span?

1101 0110 0000 1101 1100 0000 0000 0000

$2^{11} = 2048$ addresses are span by the address 214.13.192.0/21.

The range is 214.13.192.0 ~ 214.13.199.255

8. Suppose P, Q, and R, are network service providers, with respective CIDR address allocations C1.0.0.0/8, C2.0.0.0/8, and C3.0.0.0/8 (using hexadecimal dotted notation with mask). Each provider's customers initially receive address allocations that are a subset of the provider's address space.

P has the following customers:

- PA, with allocation C1.B3.0.0/16, and
- PB, with allocation C1.A0.0.0/12.

Q has the following customers:

- QA, with allocation C2.0B.10.0/20, and
- QB, with allocation C2.0A.0.0/16.

- (a) Assume there are no other providers or customers, and that each provider connects to both of the others. Give the routing table for a router in provider P and indicate, for each destination entry, the next hop using the name of the domain (provider or customer). Also assume that we want to be able to send a datagram to any destination address, i.e. we have routing entries for the address range/subrange that contains that destination. Also, you may assume that the path selection is based on the shortest AS path criterion. (Please make any other assumptions clear in your answer.)

Assumption: use CIDR longest prefix match rule.

P routing table

Destination	Next Hop
C1.0.0.0/8	P
C1.B3.0.0/16	PA
C1.A0.0.0/12	PB
C2.0.0.0/8	Q
C3.0.0.0/8	R

- (b) Now suppose customer PB switches to provider Q and customer QA switches to provider R. Use the CIDR longest prefix match rule to give the routing table for a router in P that allows PB and QA to switch without renumbering (i.e., keeping their initial address allocations).

Destination	Next Hop
C1.0.0.0/8	P
C1.B3.0.0/16	PA
C1.A0.0.0/12	Q
C2.0.0.0/8	Q
C3.0.0.0/8	R
C2.0B.10.0/20	R