Chapter 1
P3

Consider an application that transmits data at a steady rate (for example, the sender generates an N-bit unit of data every k time units, where k is small and fixed). Also, when such an application starts, it will continue running for a relatively long period of time. Answer the following questions, briefly justifying your answer:

a. **Would a packet-switched network or a circuit-switched network be more appropriate for this application? Why?**

b. **b. Suppose that a packet-switched network is used and the only traffic in this network comes from such applications as described above. Furthermore, assume that the sum of the application data rates is less than the capacities of each and every link. Is some form of congestion control needed? Why?**

Answer

a) Since the application will continue to run for a very long period of time **at a predictable steady transmission rate**, I believe a circuit-switched network is more appropriate because once the network establishes a circuit, it also reserves a constant transmission rate in the network links for the duration of the connection and also the sender can transfer the data to the receiver at the guaranteed constant rate.

b) There is no need for congestion control. Since the sum of the application data rates is less than the capacities of each and every link (ie. The band width) .

P10

Consider a packet of length L which begins at end system A and travels over three links to a destination end system. These three links are connected by two packet switches. Let di , si , and Ri denote the length, propagation speed, and the transmission rate of link i, for i = 1, 2, 3. The packet switch delays each packet by d proc. Assuming no queuing delays, in terms of di , si , Ri , (i = 1,2,3), and L, what is the total end-to-end delay for the packet? Suppose now the packet is 1,500 bytes, the propagation speed on all three links is 2.5 · 108 m/s, the transmission rates of all three links are 2 Mbps, the packet switch processing delay is 3 msec, the length of the first link is 5,000 km, the length of the second link is 4,000 km, and the length of the last link is 1,000 km. For these values, what is the end-to-end delay?

Answer

First question

$$d_{end-end} = L/R_1 + L/R_2 + L/R_3 + d_1/s_1 + d_2/s_2 + d_3/s_3 + 2 * d_{proc}$$

Second question

6 +20 +16+4+2*3 = **64 msec.**

P24

Suppose you would like to urgently deliver 40 terabytes data from Boston to Los Angeles. You have available a 100 Mbps dedicated link for data transfer. Would you prefer to transmit the data via this link or instead use FedEx overnight delivery? Explain.

Answer
Since FedEx would takes a day, I would like to know how long it would take via 100 Mbps.

Using L/R;

40 terabytes = $40 * 10^2 * 8 = 3.2 * 10^{14}$ bits
100 megabytes = $1 * 10^8$

Therefore $3.2 * 10^{14} / 1 * 10^8$ = 3200000 seconds

Then Convert to days 3200000/ 60 * 60 * 24 = approximately 37 days

In conclusion I would prefer using FedEx since it would only take a day.

Chapter 2

P9

Consider Figure 2.12, for which there is an institutional network connected to the Internet. Suppose that the average object size is 850,000 bits and that the average request rate from the institution's browsers to the origin servers is 16 requests per second. Also suppose that the amount of time it takes from when the router on the Internet side of the access link forwards an HTTP request until it receives the response is three seconds on average (see Section 2.2.5). Model the total average response time as the sum of the average access delay (that is, the delay from Internet router to institution router) and the average Internet delay. For the average access delay, use Δ/(1 – Δ), where Δ is the average time required to send an object over the access link and is the arrival rate of objects to the access link.

a. Find the total average response time.

b. Now suppose a cache is installed in the institutional LAN. Suppose the miss rate is 0.4. Find the total response time.

Answer

a) The average time is :

Δ = (850,000 bits)/(15,000,000 bits/sec) = 0.057 seconds

The traffic intensity on the link :

$\beta\Delta$ = 16 * 0.057 = 0.907.

Therefore the average access delay :

0.057/(1- 0.907) = 0.61 seconds

The total average response time :

0.61 seconds + 3 seconds = 3.61 seconds

b). The average access delay:

0.057 / [1- (0.4)(0.907)] = 0.089 seconds

The average response time :

0.089 seconds + 3 seconds = 3.089

Since the miss rate is 0.4, therefore the average response time is:

0.4 * 3.089 =. 1.24 seconds

P22
Consider distributing a file of F = 15 Gbits to N peers. The server has an upload rate of us = 30 Mbps, and each peer has a download rate of di = 2 Mbps and an upload rate of u. For N = 10, 100, and 1,000 and u = 300 Kbps, 700 Kbps, and 2 Mbps, prepare a chart giving the minimum distribution time for each of the combinations of N and u for both client-server distribution and P2P distribution

Answer

For minimum distribution time for client-server distribution:

$$D_{cs} = maxNF/u_s, F/d_{min}$$

For minimum distribution time for peer-to-peer distribution:

$$D_{P2P} = max\left\{F/u_s, F/d_{min}, NF/(u_s + \sum_{i=1}^{N} u_i)\right\}$$

$F = 15Gbits = 15 * 1024 = 15360$ Mbits,
u_s = 30 Mbps
$d_{min} = d_i$ = 2 Mbps

where, 300Kbps = 300/ 1024 Mbps.

Client Server

		N		
		10	100	1000
u	**300 Kbps**	7680	51200	512000
	700 Kbps	7680	51200	512000
	2 Mbps	7680	51200	512000

Peer to Peer

		N		
		10	100	1000
u	**300 Kbps**	7680	25904	47559
	700 Kbps	7680	15616	21525
	2 Mbps	7680	7680	7680

Chapter 3

P27

Host A and B are communicating over a TCP connection, and Host B has already received from A all bytes up through byte 126. Suppose Host A then sends two segments to Host B back-to-back. The first and second segments contain 80 and 40 bytes of data, respectively. In the first segment, the sequence number is 127, the source port number is 302, and the destination port number is 80. Host B sends an acknowledgment whenever it receives a segment from Host A.

a. In the second segment sent from Host A to B, what are the sequence number, source port number, and destination port number?
b. If the first segment arrives before the second segment, in the acknowledgment of the first arriving segment, what is the acknowledgment number, the source port number, and the destination port number?
c. If the second segment arrives before the first segment, in the acknowledgment of the first arriving segment, what is the acknowledgment number?
d. Suppose the two segments sent by A arrive in order at B. The first acknowledgment is lost and the second acknowledgment arrives after the first timeout interval. Draw a timing diagram, showing these segments and all other segments and acknowledgments sent. (Assume there is no additional packet loss.) For each segment in your figure, provide the sequence number and the number of bytes of data; for each acknowledgment that you add, provide the acknowledgment number

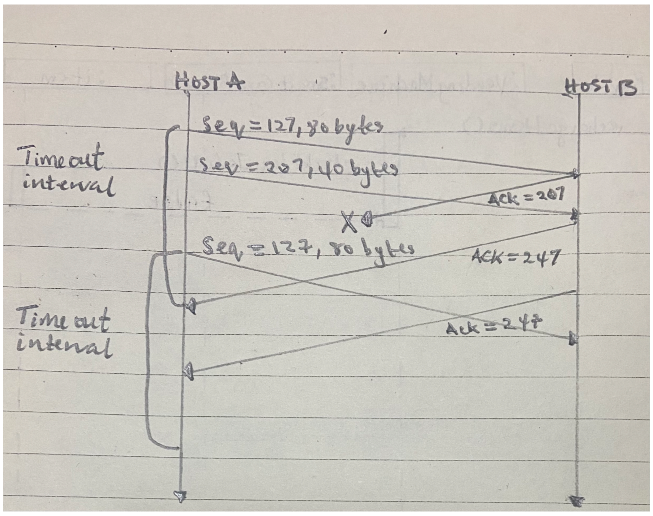
Answer

a) For the second segment, Host A to B, source port number is 302, the destination port number is 80, and the sequence number is 207.

b) If the first segment arrives before the second, in the acknowledgement of the first arriving segment, the acknowledgement number would be 207, the source port number would be 80 and the destination port number would be 302.

c) If the second segment arrives before the first segment, in the acknowledgement of the first arriving segment, the acknowledgement number would be 127, which means it is waiting for bytes 127 and so on.

d)



P28

Host A and B are directly connected with a 100 Mbps link. There is one TCP connection between the two hosts, and Host A is sending to Host B an enormous file over this connection. Host A can send its application data into its TCP socket at a rate as high as 120 Mbps but Host B can read out of its TCP receive buffer at a maximum rate of 50 Mbps. Describe the effect of TCP flow control.

Answer

The link capacity is only 100 Mbps, therefore host A's sending rate can be at most 100Mbps. The fact still holds that host A sends data into the receive buffer faster than Host B can remove data from the buffer. Consequently, the receive buffer fills up at a rate of roughly 40Mbps. When the buffer is full, Host B signals to Host A to stop sending data by setting RcvWindow = 0. Host A then stops sending until it receives a TCP segment with RcvWindow > 0. Host A will thus repeatedly stop and start sending as a function of the RcvWindow values it Ack = 247 Ack = 247 Seq = 127, 80 bytes Seq = 127, 80 bytes Seq = 207, 40 bytes Ack = 207 Host A Host B Timeout interval Timeout interval receives from Host B. On average, the long-term rate at which Host A sends data to Host B as part of this connection is no more than 60Mbps.

P40

Consider Figure 3.58. Assuming TCP Reno is the protocol experiencing the behavior shown above, answer the following questions. In all cases, you should provide a short discussion justifying your answer.

a. Identify the intervals of time when TCP slow start is operating.
b. Identify the intervals of time when TCP congestion avoidance is operating.
c. After the 16th transmission round, is segment loss detected by a triple duplicate ACK or by a timeout?
d. After the 22nd transmission round, is segment loss detected by a triple duplicate ACK or by a timeout?
e. What is the initial value of ssthresh at the first transmission round?
f. What is the value of ssthresh at the 18th transmission round?
g. What is the value of ssthresh at the 24th transmission round?
h. During what transmission round is the 70th segment sent?
i. Assuming a packet loss is detected after the 26th round by the receipt of a triple duplicate ACK, what will be the values of the congestion window size and of ssthresh?
j. Suppose TCP Tahoe is used (instead of TCP Reno), and assume that triple duplicate ACKs are received at the 16th round. What are the ssthresh and the congestion window size at the 19th round?
k. Again suppose TCP Tahoe is used, and there is a timeout event at 22nd round. How many packets have been sent out from 17th round till 22nd round, inclusive?

Answer

a) The TCP slow start operates on the intervals [1,6] and [23,26]

b) The TCP congestion avoidance is operating in the intervals [6,16] and [17,22]

c) After the 16th transmission round, packet loss is recognized by a triple duplicate ACK. If there was a timeout, the congestion window size would have dropped to 1.

d) After the 22nd transmission round, segment loss is detected due to timeout, and hence the congestion window size is set to 1.

e) The threshold is initially 32, since it is at this window size that slow start stops and congestion avoidance begins.

f) The threshold is set to half the value of the congestion window when packet loss is detected. When loss is detected during transmission round 16, the congestion windows size is 42. Hence the threshold is 21 during the 18th transmission round.

g) The threshold is set to half the value of the congestion window when packet loss is detected. When loss is detected during transmission round 22, the congestion windows size is 29. Hence the threshold is 14 (taking lower floor of 14.5) during the 24th transmission round.

h) During the 1st transmission round, packet 1 is sent; packet 2-3 are sent in the 2nd transmission round; packets 4-7 are sent in the 3rd transmission round; packets 8-15 are sent in the 4th transmission round; packets 16-31 are sent in the 5th transmission round; packets 32-63 are sent in the 6th transmission round; packets 64 – 96 are sent in the 7th transmission round. Thus packet 70 is sent in the 7th transmission round.

i) The threshold will be set to half the current value of the congestion window (8) when the loss occurred and congestion window will be set to the new threshold value + 3 MSS . Thus the new values of the threshold and window will be 4 and 7 respectively.

j) threshold is 21, and congestion window size is 1.

k) round 17, 1 packet; round 18, 2 packets; round 19, 4 packets; round 20, 8 packets; round 21, 16 packets; round 22, 21 packets. So, the total number is 52.

Chapter 4

P17

Consider the topology shown in Figure 4.17. Denote the three subnets with hosts (starting clockwise at 12:00) as Networks A, B, and C. Denote the subnets without hosts as Networks D, E, and F.

a. Assign network addresses to each of these six subnets, with the following constraints: All addresses must be allocated from 214.97.254/23; Subnet A should have enough addresses to support 250 interfaces; Subnet B should have enough addresses to support 120 interfaces; and Subnet C should have enough addresses to support 120 interfaces. Of course, subnets D, E and F should each be able to support two interfaces. For each subnet, the assignment should take the form a.b.c.d/x or a.b.c.d/x – e.f.g.h/y.

b. Using your answer to part (a), provide the forwarding tables (using longest prefix matching) for each of the three routers.

Answer

a) For 214.97.254/23, possible assignments are
Subnet A: 214.97.255/24 (256 addresses)
Subnet B: 214.97.254.0/25 - 214.97.254.0/29 (128-8 = 120 addresses)
Subnet C: 214.97.254.128/25 (128 addresses)
Subnet D: 214.97.254.0/31 (2 addresses)
Subnet E: 214.97.254.2/31 (2 addresses)
Subnet F: 214.97.254.4/30 (4 addresses)

b)

1st Router	
Longest Prefix Match	**Outgoing Interface**
11010110 01100001 11111111	Subnet A
11010110 01100001 11111110 0000000	Subnet D
11010110 01100001 11111110 000001	Subnet F

2nd Router	
Longest Prefix Match	**Outgoing Interface**
11010110 01100001 11111111 0000000	Subnet D
11010110 01100001 11111110 0	Subnet B
11010110 01100001 11111110 0000001	Subnet E

3rd Router	
Longest Prefix Match	**Outgoing Interface**
11010110 01100001 11111111 000001	Subnet F
11010110 01100001 11111110 0000001	Subnet E
11010110 01100001 11111110 1	Subnet C

P26
Consider the following network. With the indicated link costs, use Dijkstra's shortest-path algorithm to compute the shortest path from x to all network nodes. Show how the algorithm works by computing a table similar to Table 4.3.

Answer

Step	N'	D(t),p(t)	D(u),p(u)	D(v),p(v)	D(w),p(w)	D(y),p(y)
0	x	∞	∞	3,x	6,x	6,x
1	xv	7,v	6,v	3,x	6,x	6,x
2	xvu	7,v	6,v	3,x	6,x	6,x
3	xvuw	7,v	6,v	3,x	6,x	6,x
4	xvuwy	7,v	6,v	3,x	6,x	6,x
5	xvuwyt	7,v	6,v	3,x	6,x	6,x
6	xvuwytz	7,v	6,v	3,x	6,x	6,x

P28
Consider the network shown below, and assume that each node initially knows the costs to each of its neighbors. Consider the distance-vector algorithm and show the distance table entries at node z.

Answer

		Cost to				
		u	v	x	y	z
	v	∞	∞	∞	∞	∞
From	x	∞	∞	∞	∞	∞
	z	∞	6	2	∞	0

		Cost to				
		u	v	x	y	z
	v	1	0	3	∞	6
From	x	∞	3	0	3	2
	z	7	5	2	5	0

		Cost to				
		u	v	x	y	z
	v	1	0	3	3	5
From	x	4	3	0	3	2
	z	6	5	2	5	0

		Cost to				
		u	v	x	y	z
	v	1	0	3	3	5
From	x	4	3	0	3	2
	z	6	5	2	5	0

Chapter 5

P5

Consider the 7-bit generator, G=10011, and suppose that D has the value 1010101010. What is the value of R?

Answer

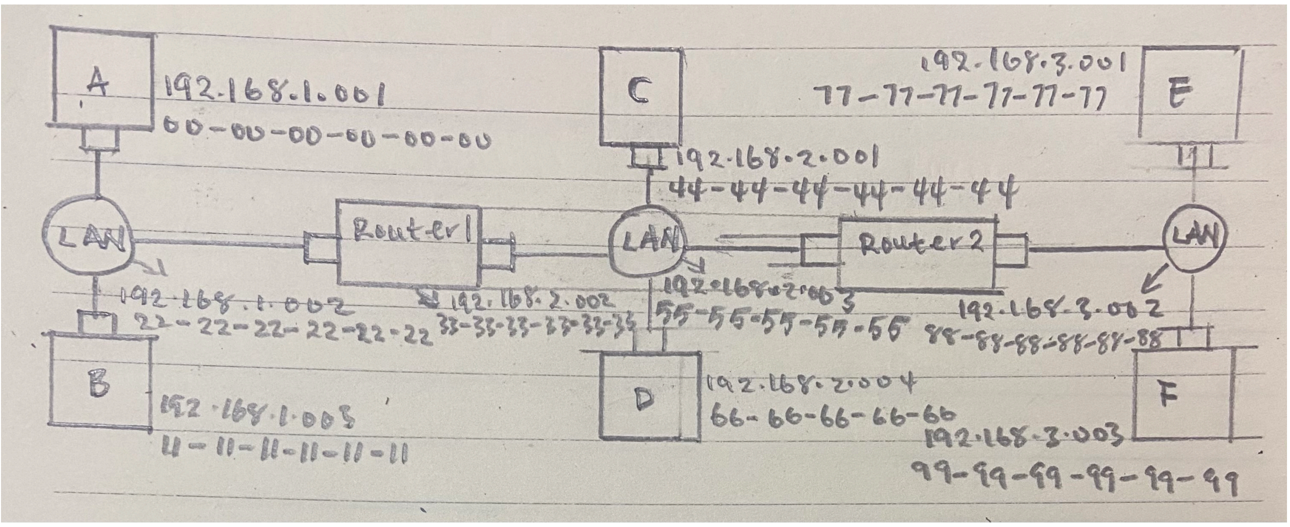
When we divide 10011 into 1010101010 0000, we get 1011011100, with a remainder of R= 0100.

P14
Consider three LANs interconnected by two routers, as shown in Figure 5.33.

a. Assign IP addresses to all of the interfaces. For Subnet 1 use addresses of the form 192.168.1.xxx; for Subnet 2 uses addresses of the form 192.168.2.xxx; and for Subnet 3 use addresses of the form 192.168.3.xxx.
b. Assign MAC addresses to all of the adapters.
c. Consider sending an IP datagram from Host E to Host B. Suppose all of the ARP tables are up to date. Enumerate all the steps, as done for the single-router example in Section 5.4.1. d. Repeat (c), now assuming that the ARP table in the sending host is empty (and the other tables are up to date).

Answer

a), b) See figure below.



c)
1. Forwarding table in E determines that the datagram should be routed to interface 192.168.3.002.
2. The adapter in E creates and Ethernet packet with Ethernet destination address 88-88-88-88-88-88.
3. Router 2 receives the packet and extracts the datagram. The forwarding table in this router indicates that the datagram is to be routed to 198.162.2.002.
4. Router 2 then sends the Ethernet packet with the destination address of 33-33-33- 33-33-33 and source address of 55-55-55-55-55-55 via its interface with IP address of 198.162.2.003.
5. The process continues until the packet has reached Host B. 192.168.3.003 99-99-99-99-99-99 192.168.3.002 88-88-88-88-88-88 192.168.3.001 77-77-77-77-77-77 192.168.2.003 55-55-55-55-55 192.168.2.001 44-44-44-44-44-44 192.168.2.002 33-33-33-33-33-33 A B LAN Router 1 LAN C D F 192.168.1.001 00-00-00-00-00-00 192.168.1.002 22-22-22-22-22-22 192.168.1.003 11-11-11-11-11-11 E Router 2 LAN 192.168.2.004 66-66-66-66-66

d) ARP in E must now determine the MAC address of 198.162.3.002. Host E sends out an ARP query packet within a broadcast Ethernet frame. Router 2 receives the query packet and sends to Host E an ARP response packet. This ARP response packet is carried by an Ethernet frame with Ethernet destination address 77-77-77-77-77-77.

P17

Recall that with the CSMA/CD protocol, the adapter waits K 512 bit times after a collision, where K is drawn randomly. For K = 100, how long does the adapter wait until returning to Step 2 for a 10 Mbps broadcast channel? For a 100 Mbps broadcast channel?

Answer

Wait for 51,200 bit times. For 10 Mbps, this wait is

$51.2 * 10^3 bits / 10 * 10^6 bps = 5.12 msec$

Therefore for 100 Mbps, the wait is 512 μ sec.