1. True or False

F a. It takes a single bit ten times to propagate over a 10 Mbps link than over a 100 Mbps link

F b. In continuous sliding window ARQ, when a frame is lost, the sender can't keep the pipe full.

F c. In persistent TCP connections with pipelining, clients can send requests, back-to-back, without waiting for responses from the server. The server will then respond by sending all objects simultaneously.

F d. TCP connections are uniquely identified by the NOS using the local and remote IP addresses

T e. In SR ARQ, the sender window size can be no more than half the number of available sequence numbers 2^{m-1}

F f. HTTP is the communications protocol between an HTTP client and an HTTP server. It determines how a web page is displayed on the client screen.

T g. When changing ISPs, your IP address must change, but your host name remain the same.

T h. Theoretically, A single client can have up to ~ 64K connections to the server for the same destination port

T i. Multiple client sockets can be bound to the same local IP/port pair at the same time if they are connected to different servers.

F j. Two distinct Web pages www.usc.edu/research.html and www.mit.edu/grades.html can be sent over the same persistent connection

T k. The DNS server and the DHCP server could be installed in the same device

-5

F ✓ l. In sliding window ARQ, there can never be more unacknowledged frames than the receiver window size.

F ✓ m. Protocols define how a layer of the networking stack interacts with adjacent layers.

F X n. In UDP socket, data being read from the server-side socket can been sent by more than one client.

T X o. A client located outside the usc.edu domain needs to contact three name servers to resolve the address www.usc.edu (Assume no entries are cached anywhere)

T ✓ p. ARP is a protocol used to resolve the "next hop IP address" to its MAC address

T ✓ q. Routers only process frames that are specifically addressed to them or frames that are broadcasted.

T X r. TCP is a transport layer protocol that provides guarantees on Reliability, Delay and Throughput

T X s. SMTP and IMAP are two protocols used to send electronic messages.

T ✓ t. Web caching can reduce the delay for all objects, even objects that are not cached.

T ✓ u. If a computer has multiple Network Interface Cards, The DHCP process must occur separately over each interface to obtain a separate dynamically assigned IP address for each interface.

Part 2: Quickies (every blank is worth 2 points)

1. Consider a transmission link that uses the stop and wait protocol. The ratio of the transmission time to the propagation delay is 1/3. Frames are transmitted at a rate of 10 Mbps and each frame is 1k bits long. Bits propagate at a speed of 2×10^8 m/sec.

$1\times10^3/(10\times10^6)\times3\times2\times10^8$

- The length of the link is 60000 meter.
- The link utilization is 14.3 %

$\frac{1}{3+3+1} = 14.3\%$

2. Ten sources are multiplexed using FDM on a link that has a total bandwidth of 10K Hz. The maximum bandwidth for each source if there must be a 200 Hz guard band between the channels is 820 Hz.

$10000 - 9\times200 = 8200$

3. The following sequence of bits were delivered to the DLC layer at the receiver.

flag

10 0111 1110 0101 1111 0110 1111 0101 0011 1111 0111

flag

The payload of the frame is 0101 1111 110 1111 0101 0

P2P

4. Suppose a movie studio wants to distribute a new movie as a digital file to 1,000 movie theaters across country using peer-to-peer file distribution. Assume that the studio and all the theaters have DSL connections with an 8 Mb/s downstream rate and a 4Mb/s upstream rate and that the file is 10 GB long. Ignore all delay components that are not specified in question. The time it takes to distribute the file to all the theaters under ideal conditions is 20000 seconds. Now suppose the studio wanted to use a client-server model. The smallest link rate that is required at the studio (server) that would allow distribution of the file in under 40,000 seconds is 2×10^9 bps (2Gbps) bps.

$$\frac{F}{d_i} = \frac{10\times8\times10^9}{8\times10^6} = 1000s$$

$$\frac{1000\times8\times10\times10^9}{2\times10^6\times10^3} = 20000$$

$$\frac{8\times10^4}{4}$$

$$\frac{1000\times8\times10\times10^9}{4\times10^4}$$

2×10^9

49

5. We have 3 information sources, generating traffic at rates 350bps, 500bps and 750bps respectively. The sources are active 25%, 75% and 60% respectively. They are to be multiplexed using multiple slot (each slot supporting 5 bits), synchronous TDM. Ignore any synchronization bits.

   a. The minimum length of the TDM frame is = 50 bits.

   b. The multiplexor bit rate is 1600 bps. $350+500+750=1600$

   c. The TDM frame rate is 10 frames/sec. $50/5=10$

   d. The slot rate is 0.1 slots/sec. $1/10=0.1$

6. The same information sources as above are to be multiplexed using a Statistical TDM. With 10% of the link capacity to used to support headers, the required MUX rate at the is 1013.9 bps. -912.5

   $\underbrace{350 \times 0.25}_{87.5} + \underbrace{500\times0.75}_{375} + \underbrace{750\times0.6}_{450}$

   $912.5/0.9$

7. The maximum throughput over a channel with a bandwidth of 1 MHz and a signal to noise ratio of 15:1 is 7.82×10^9 bps

   $SNR = 15^2/1 = 225$

   $\log(226)/\log(2)$ $7.82\times1\times10^9$ $\log_2(226)$ 1×10^9

8. Suppose you are using Go-back-N sliding window protocol over a 1Gbps link. The length of the link is 10Km and the speed of propagation is $2x10^8$ m/sec. It is desired to keep the pipe full and achieve maximum utilization. The length of each frame is 1000 bits. The "minimum" number of bits needed to sequence the frames is m = 50 bits

   $dp = 5\times10^{-5}$

   $\times1\times10^9 = 5\times10^4/1000 = 50$

9. Consider transmitting a packet from host A to host B via a router (i.e. hosts A and B are located on different networks). All ARP tables (in hosts and router) are empty. Let x denote the time (in seconds) to transmit the packet. Let y denotes the time (in seconds) elapsed from the beginning of transmitting an ARP query until receiving an ARP response. Ignoring propagation delay, the total time it takes to forward the packet from A to B is (2x+y) sec.

   1x

   A → router → B

$150 KB = 150 \times 8 \times 10^3$

10×10^6

10. A user in Los Angeles, connected to the internet via a 10 Mb/s (b=bits) connection retrieves a 150 KB (B=bytes) web page from a server in New York, where the page references 3 images of 1 MB each. Assume that the one-way propagation delay is 20 ms.

$dt = 2.52s$ $\quad 3 \times MB = 1 \times 8 \times 10^6 \times 3$ $\quad RTT = 40ms$

a. Approximately how long does it take for the page (including images) to appear on the user's screen, assuming non-persistent HTTP using a single connection at a time? Answer: 2.84 sec $\quad 8RTT + dt = 2.84$

b. Repeat part "a" assuming persistent HTTP. Answer: 2.72 sec

$(2+3)RTT + dt$ $\quad 5RTT$

c. Repeat part "a" assuming persistent HTTP with pipelining. Answer: 2.64 sec $\quad (2+1) \times 40 + dt.$ $\quad 3RTT$

d. Repeat part "a" assuming non-persistent HTTP with 2 parallel connections. Answer: 2.76 sec $\quad (2+2+2)$ $\quad 6RTT$

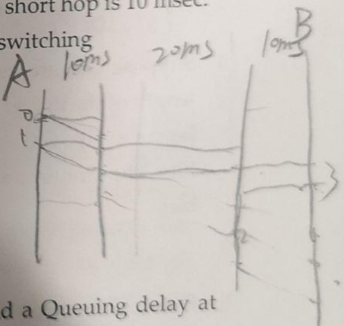
1,2 $\quad$ 3

11. The number of hops separating two end hosts A and B is 3 with the middle hop twice as long as the other two. A message of 10 Kbits long is to be transmitted. The data rate on each link is 10 Kbps. The propagation delay over a short hop is 10 msec. It is desired to compare the end-to-end delay for two different switching technologies.

?

$(1+10ms)$ $\quad 40 ms = 0.04ms$

$dt =$ $\quad 3+0.2+0.04$

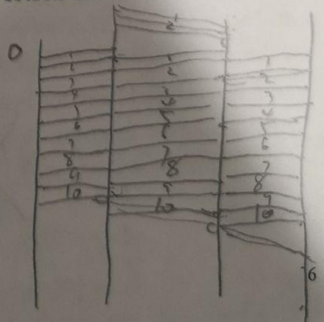


a. Circuit Switching: Assume the call set-up delay is 0.2 sec.

Answer: 3.24 sec

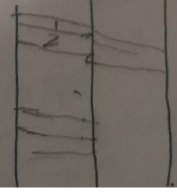
b. Packet Switching: Assume each Packet length is 1Kbits and a Queuing delay at each intermediate node of 5 msec

Answer: 1.25 sec



$1 + 0.04 + 0.9 + 0.2.$

2s

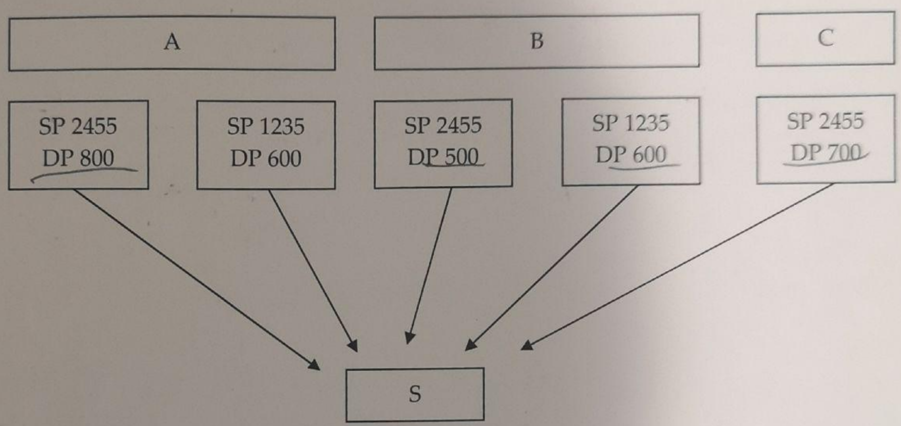


−11

13. Three nodes A, B, C are communicating with a server node S. with the indicated Source and Destination Port numbers. From this diagram determine, what is the "total" number of sockets does "S" have to open assuming:

a. UDP Sockets: 4

b. TCP Sockets: 9



Part 3: Error Detection (10 points)

$x^{10}+x^{7}+x^{6}+x^{4}$

3. An FCS error detection mechanism is used over a communications link. The message bit sequence is 1001101. An FCS generator pattern of 11001 is used to generate the FCS sequence. $(x^6+x^3+x^2+x^0)\,x^4$ $\quad x^4+x^3+x^0$

   a) How many FCS bits are generated? What are they? What is the transmitted bit sequence? Identify the FCS bits in that sequence. Show details of your work.

   b) Now suppose the received sequence is 01000101110. Did errors occur, if yes, how many? Will the receiver accept the frame? if yes, what will he decide the message sequence bits are? If no, why not?

   c) Now suppose the channel introduces the following error sequence 01000101000. Will the receiver be able to detect the error? Prove your answer analytically. Remember, neither the transmitter nor the receiver knows about the error sequence.

a) 4 FCS bits

$$x^6+x^5+x^4+x+1$$
$$x^4+x^3+x^0 \;\big)\; x^{10}+x^7+x^6+x^4$$
$$x^{10}+x^9+x^6$$
$$x^9+x^7+x^4$$
$$x^9+x^8+x^5$$
$$x^8+x^7+x^5+x^4$$
$$x^8+x^7+x^4$$
$$x^5$$
$$x^5+x^4+x^1$$
$$x^4+x^1$$
$$x^4+x^3+x^0$$
$$x^3+x^1+x^0=1011$$

The FCS is 1011

Transmitted bit sequence is 10011011011

FCS bits

b)

T 10011011011

R 01000101110

yes, errors occur

8 errors

$$(x^4+x^3+x^0) \;\big)\; x^9+x^5+x^3+x^2+x^1$$
$$x^9+x^8+x^5$$
$$x^8+x^3+x^2+x^1$$
$$x^8+x^7+x^4$$
$$x^7+x^4+x^3+x^2+x^1$$
$$x^7+x^6+x^3$$
$$x^6+x^4+x^2+x$$
$$x^6+x^5+x^2$$
$$x^5+x^4+x^1$$
$$x^5+x^4+x^1$$
$$0$$

∴ It will accept the frame because the reminder is 0,

he decide the message are 0100010

C) Transmit 100110101011

error sequence 010001010000

Transmit Sequence ⊕ error sequence = 110111100011

$$
\begin{array}{r}
x^6 \\
x^4+x^3+x^0 \overline{\big) \cancel{x^{10}}+\cancel{x^9}+x^7+\cancel{x^6}+x^5+x^4+x^1+x^0} \\
\cancel{x^{10}}+\cancel{x^9}+\cancel{x^6} \\
\hline
\cancel{x^7}+x^5+x^4+x^1+x^0 \\
\cancel{x^7}+x^6+x^3 \\
\hline
\cancel{x^6}+\cancel{x^5}+x^4+x^3+x^1+x^0 \\
\cancel{x^6}+\cancel{x^5}+x^2 \\
\hline
\cancel{x^4}+\cancel{x^3}+x^2+x^1+\cancel{x^0} \\
\cancel{x^4}+\cancel{x^3}+\cancel{x^0} \\
\hline
x^2+x
\end{array}
$$

$= 110$

Yes, the receiver will be able to detect the error because there is a reminder.

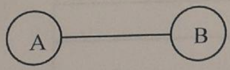
Part #4: Error & Flow Control

You are given the following parameters of a Point-to-Point Data Link

- Transmission Time of a Data Frame = 1 sec
- One way Propagation Delay = 1 sec
- Transmission Time of ACK frames = 0sec
- Processing Delay at either side is = 0sec
- Timeout = 3 sec. The Timer, for any frame, starts immediately after the sender finishes transmitting that frame.
- # of bits for frame sequencing m = 2. Start the sequencing with F_0. Acknowledgements are sequenced as follows: ACK_n means receiver is acknowledging frame F_n (i.e., not accumulative acknowledgements). Frames received out of order are acknowledged. When receiver receives a frame in error, it drops it and does nothing. Frames are 1000 bits long. The sender has only 5 frames to send F_0 through F_4.
- Frame Length = 1000 bits
- No accumulative Acknowledgements

$SWS = RWS = 2^{m-1} = 2$

A Selective Repeat ARQ is used with SWS = RWS = Maximum allowable. You are asked to show a detailed timing diagram until F_4 is acknowledged. You are also asked to calculate the Throughput and the Link Utilization for this following scenario: Frame F_1 is received in error and frame F_3 is lost in the channel.



Total time 13s

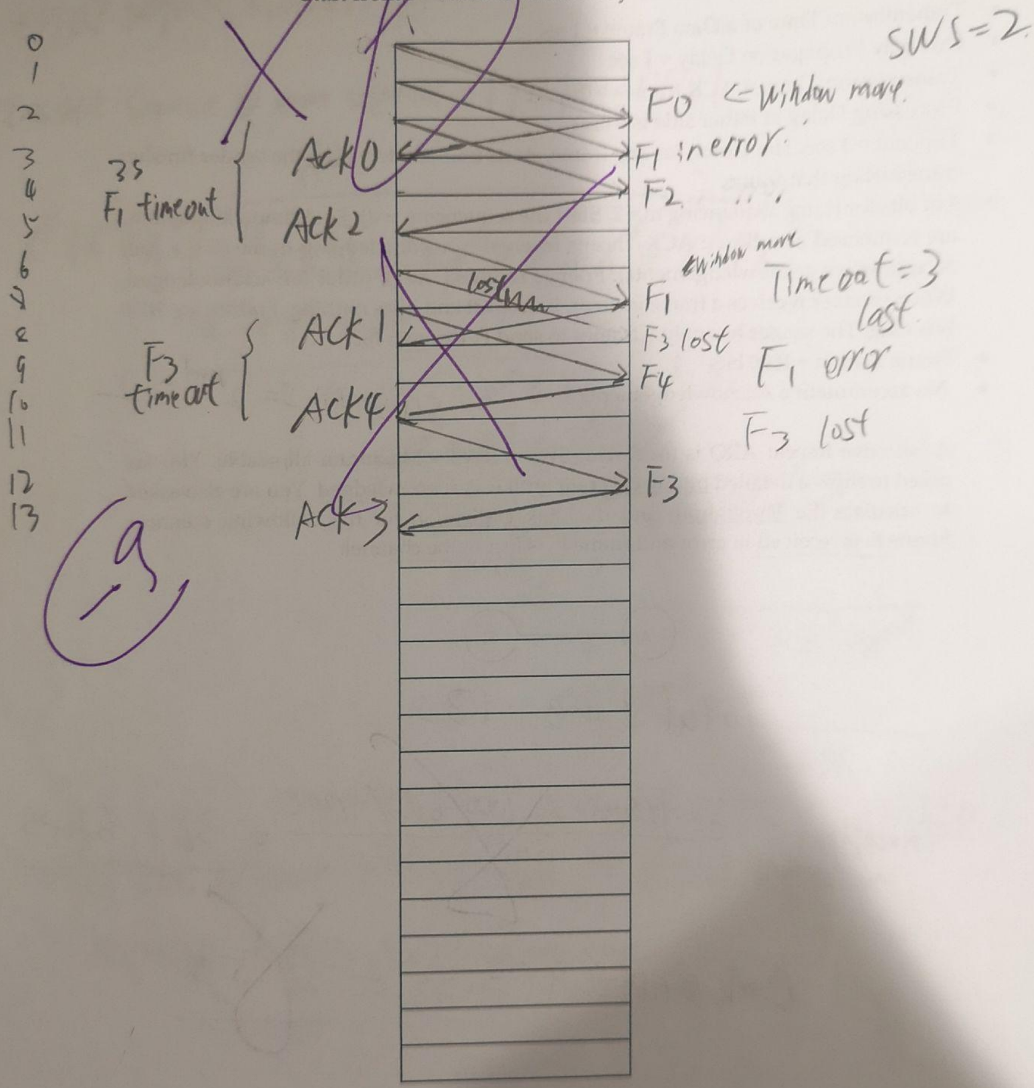
$$\text{Throughput} = \frac{5 \text{ frames} \times 1000 \text{ bits/frame}}{13} = 384.6\text{BPS}$$

$$\text{Link utilization} = \frac{5}{13} = 38.5\%$$

dt = 1
one dp = 1

Work Sheet #5

Start from t = 0 and assume every division is 1 sec



-9

5. Part 5: Name Resolution and Web Browsing

Consider the following configuration. Host A is located on LAN_1. A web Server X (www.cnn.com) is located on LAN_2. Suppose that the user at host "A" types the URL of server X to download a given 1G-bit HTML file. Host A does **NOT** know the IP address of Server X (and neither does the local DNS server). Host A is configured with the IP address of the local DNS server. Assume the following:

- DNS commands and HTTP commands are too short compared to the file such that you can ignore their transmission times (**ONLY**)
- The propagation delay within either LAN is negligible. The propagation delay from R_1 to R_2 is 200 msec. The propagation delay from the local DNS server and the root name server is 400 msec. The propagation delay from the local DNS server and the TLD (in this problem assume the TLD knows the IP address of the web server X) server is 300 msec. The propagation delay from the client to the local DNS server is 100 msec
- Each LAN operates at 1 Gbps. The link between R_1 and R_2 is 1 Mbps (in each direction)
- The local DNS server is configured with the IP address of the root name server.
- Local DNS server will cache the IP address of the web server when he gets it
- DNS runs over UDP whereas HTTP runs over TCP.
- Ignore any other delay component such as processing and Queuing

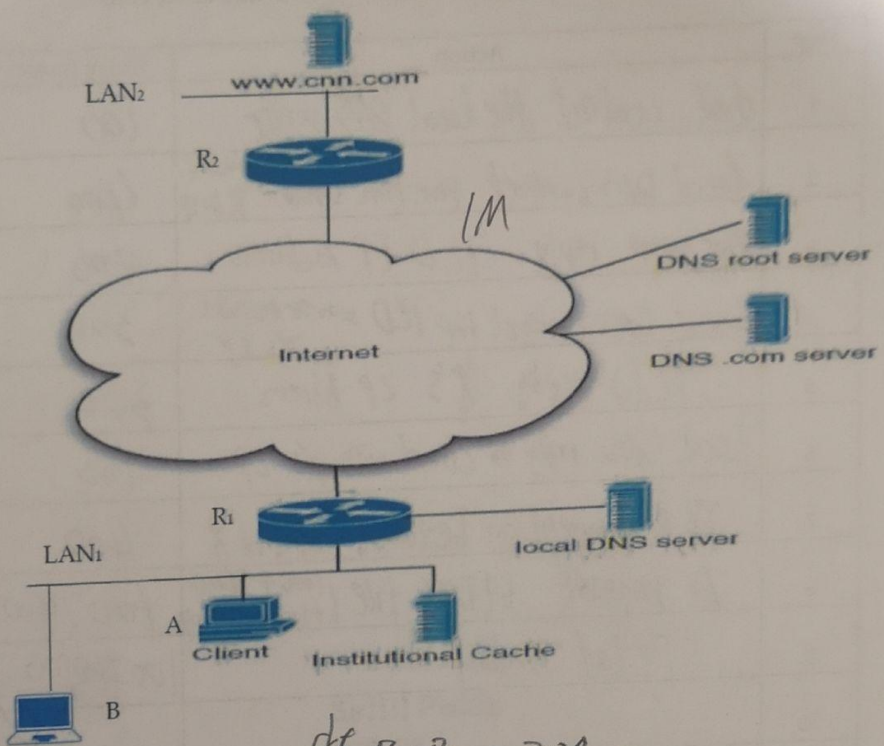
a. Calculate the time elapsed from the moment Client A enters the URL till the time the file is completely downloaded. You need to list the steps involved clearly in the table provided. The order is IMPORTANT.

b. Now suppose that **immediately after** the first client, there is another client B located on the same network as A, who wants to access the same web server X. How long does it take him to get the IP address of the web server?

200msec.

C. $0.5 \times 1\,Gbps + 0.5 \times 1\,Mbps$
$= \underline{0.5005\ Gbps}$

c. Now assume that LAN₁ has a web cache (i.e., HTTP cache). Assume client A is the only active client and assume that 50% of his requests can be satisfied by the local cache. What is the average rate at which the client can receive data in this case?



de R_1-R_2 = 200 ms
local-T = 400 ms
L-TLD = 300 ms
Client-Local = 100 ms

a. $\underline{1004.4\ s}$

b. 100 msec × 2 = $\underline{200\ msec}$
(contact local, local reply)

C. 50% × 1Gbps + 50% × 1Mbps
$= 5.005 \times 10^8$ bps
$= \underline{0.5005\ Gbps}$

Work Sheet #7

Table maybe longer or shorter than what you need. Do NOT accumulate each delay component, just list the delays, and then add at the end!

Step	Action	Delay (msec)
1	client contact the local DNS server	100
2	local DNS contact the root server request TLD IP	400
3	Root server reply TLD IP Address	400
4	Local DNS contact the TLD server request X's IP	300
5	TLD reply X's IP Adress	300
6	Local DNS reply to client with X's IP	100
7	TCP connection between A and X	400
8	A request HTML file (1000 + 400 + 1000000 + 1000)	1002400
9	Total delay	1004400
10		
11		
12		
13		
14		
15		

msec

=

1004.4s