Homework on basic data networking concepts

Multiple Choice Questions *(12 points)***:**

<u>More than one item may be correct or ALL items may be wrong</u>. **Mark all correct items** for each question. If you think ALL items are wrong, simply do not mark any item. Neatly place a check mark next to the correct answers. For each item, *0.25 points will be awarded based on your marking.*

1. A circuit switch

    a. has large buffers to hold data before forwarding

    X b. can switch data based on the incoming frequency

    X c. can interconnect shared links

    X d. needs to be programmed prior to data transfer

2. A packet switch

    X a. forwards packets received on one link to another based on header information

    X b. could drop packets

    X c. can be programmed with resource reservations prior to data transfer

    d. has only one interface

3. Destination address is

    a. carried in every frame of data carried through a circuit-switched network

    X b. carried in every packet header in a connectionless packet-switched network

    X c. carried in a call setup message in a connection-oriented packet-switched network

    X d. carried in routing protocol messages.

4. If the offered load to a link consisting of 5 circuits is 10 Erlangs, the call blocking probability is:

    a. 0.01

    X b. 56.4%

    c. 3.6%

    d. 56.4%

5. In question 4, what is the utilization:

    a. 0.198

    X b. 0.872

    c. 0.0872

d. unknown

6. Packets arrive at a buffer, which has a capacity to hold 5 packets, and feeds a 100 kbps link. Assume the packet arrival process is Poisson with a rate 50 packets/sec, and packet lengths are exponentially distributed with a mean size of 150 bytes.

    a. The probability of packet loss is 0.33

X b. The mean waiting time in the queue is 12.9 ms

X c. The mean number of packets in the system is 1.2

    d. The mean waiting time in the queue is 0.0249 sec

7. Congestion control

X a. consists of congestion detection and congestion recovery actions

X b. can be prevented during data transfer with a priori resource reservation

    c. is used to correct errors in packets

    d. is used to slow down a transmitter because of a speed mismatch at a receiver.

8. In a priority queueing system

    a. packets are served on a first-come first-serve basis

X b. congestion control schemes that prevent a sender from sending packets at a priority level below some value can be used

    c. the packet requiring the shortest amount of service time is served first

    d. packets are always separated into different queues based on their priority levels

9. Routing protocols are used

    a. by end hosts to request resources

    b. to carry user data

    c. to share resources on a link

    d. to ensure end-to-end reliable transfer

10. Signaling protocols are used

X a. to request resources for a data transfer

    b. to spread topology information

    c. to carry user data

X d. to release resources after a data transfer

11. When *gemini* wants to send an IP datagram to the host *pluto*, what is the IP address
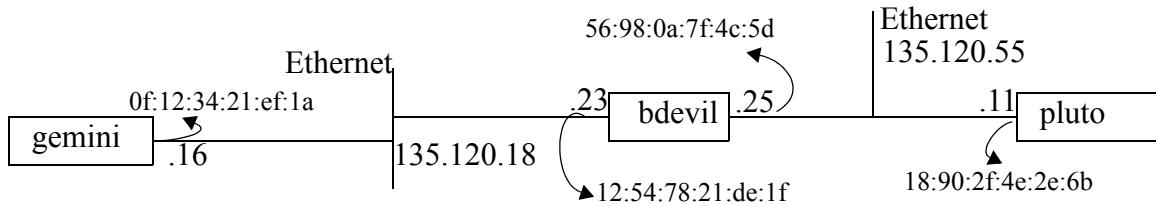
that it tries to resolve in an ARP request, and which node replies?

    a. 135.120.18.16 and bdevil

X b. 135.120.18.23 and bdevil

    c. 135.120.55.11 and bdevil

    d. 135.120.55.11 and pluto

12. Assume that a user data packet is sent from gemini to pluto on the network shown in question 11. What are the destination IP address and destination MAC address values carried in the IP and Ethernet headers, respectively, when the packet traverses the 135.120.18 Ethernet?

    a. 135.120.55.11 and 18:90:2f:4e:2e:6b

    b. 135.120.18.23 and 12:54:78:21:de:1f

X c. 135.120.55.11 and 12:54:78:21:de:1f

    d. 135.120.18.23 and 18:90:2f:4e:2e:6b

Problem 1 *(6 points)*:

    i) If a host attempting to send a frame on an Ethernet LAN has witnessed collisions on 5 attempts, how many time slots does it wait before trying again?

    ii) What is the minimum frame length in a 200m long Ethernet that runs at 1 Gbps? Assume that the speed of light in the medium is 2×10^8 m/s.

    iii) What is the fraction of the time the channel is busy transmitting frames if the frames are 1500 bytes long?
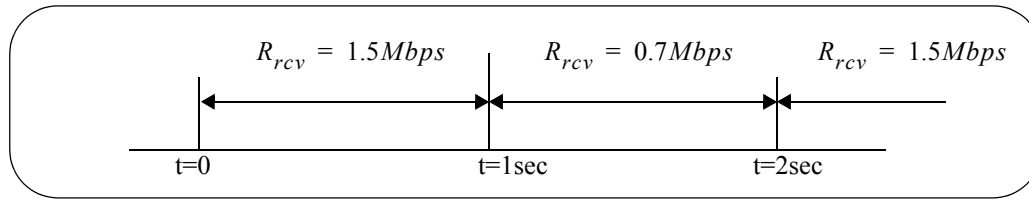
Answer:

    i) It waits between 0 and 31 time slots. The host waits a random amount of time between 0 and $2^i - 1$ after the ith attempt. *(1 point)*

    ii) Round trip propagation delay $= 2 \times \dfrac{200}{200} = 2\mu s$. At a data rate of 1Gb/s, this means minimum frame length should be $1000 \times 2 = 2000 bits = 250 bytes$.
(2 points)

    iii) $\quad f = \dfrac{L/R}{L/R + t_{prop} + 2et_{prop}} = \dfrac{1}{(1 + 6.44a)} \qquad$ where $\qquad a = t_{prop}(R/L)$.

$L = 1500$ bytes, $R = 1\,Gbps$ and $t_{prop} = 1\,\mu s$. Therefore $f = 0.65$ or 65%.
(3 points)

Problem 2 *(6 points)*:

A data-link layer protocol that uses ON/OFF control executes on a 1.5Mbps link. Frames of size 1000 bytes are used. One-way propagation delay is 20ms. The rate at which the receiver empties its buffer, R_{rcv} , is shown in the figure below for different time intervals. Will an OFF signal be sent by the receiver any time between t=0 and t=2 sec? If so, indicate the time instant at which the receiver sends the OFF signal? Assume the receiver buffer size is 10000 bytes.

Answer:

When the buffer at the receiver has only $2t_{prop}(R_{snd} - R_{rcv})$ bytes left, it will send an OFF signal.

This number is $\dfrac{2 \times 20 \times 0.8 \times 10^3}{8} = 4000$ bytes. (3 points)

The sender sends at 1.5Mbps and the receiver empties its buffer at the same rate up to t=1 sec. From 1 sec, the latter rate drops to 0.7Mbps. Therefore it will take $t = \dfrac{(10000 - 4000) \times 8}{(1.5 - 0.7)} = 60000$ µs for the receiver buffer to reach a point when there is only space for 4000 bytes left in the buffer. Therefore at t=1sec+60ms, the receiver will generate an OFF signal. (3 points)

I accepted the answer 1.025 sec because in class I explained that the OFF signal is sent when the receiver has enough space to accept $2t_{prop}R$. Therefore many of you computed this number to be 7500 bytes (60K bits) and correspondingly found the time at which the OFF signal is sent to be 1.025.

Problem 3 *(6 points)*:

Using a CRC generating polynomial $g(x) = x^3 + x^2 + 1$, for the information bit pattern is 110001101110:

      i) Find the codeword polynomial b(x)?

      ii) What is the encoded bit sequence sent by the transmitter?

      iii) If there are no transmission errors, what is the computed remainder at the receiver?

Answers:

The highest degree of $g(x)$ is 3. Hence $n-k = 3$. Multiply $i(x)$ by x^{n-k} (shift bits $n-k$ to the left). Divide this by $g(x)$. The remainder is $r(x)$. The codeword $b(x) = x^{n-k}g(x) + r(x)$. We perform this computation below. $i(x) = x^{11} + x^{10} + x^6 + x^5 + x^3 + x^2 + x$ (corresponding to 110001101110).

$$x^{n-k}i(x) = x^3(x^{11} + x^{10} + x^6 + x^5 + x^3 + x^2 + x) = x^{14} + x^{13} + x^9 + x^8 + x^6 + x5 + x^4$$

$$
\begin{array}{r}
(x^{11} + x^8 + x^7 + x^4 + x^2 + x + 1) \\
x^3 + x^2 + 1 \enclose{longdiv}{x^{14} + x^{13} + x^9 + x^8 + x^6 + x^5 + x^4} \\
x^{14} + x^{13} + x^{11} \\
\hline
x^{11} + x^9 + x^8 \\
x^{11} + x^{10} + x^8 \\
\hline
x^{10} + x^9 + x^6 \\
x^{10} + x^9 + x^7 \\
\hline
x^7 + x^6 + x^5 + x^4 \\
x^7 + x^6 + x^4 \\
\hline
x^5 \\
x^5 + x^4 + x^2 \\
\hline
x^4 + x^2 \\
x^4 + x^3 + x \\
\hline
x^3 + x^2 + x \\
x^3 + x^2 + 1 \qquad \text{Remainder} \\
\hline
x + 1
\end{array}
$$

Therefore the remainder is $r(x) = x + 1$ or 0011.

i) The codeword polynomial $b(x)$ is $x^{14} + x^{13} + x^9 + x^8 + x^6 + x5 + x^4 + x + 1$. *(4 points)*

ii) The encoded bit sequence sent by the transmitter is 110001101110011. *(1 point)*

iii) If no errors occur, the computed remainder at the receiver is 0. *(1 point)*

Problem 4 *(12 points)***:** Suppose that a signal received on a channel has twice the power as the noise signal added to it. The attenuation on the link is 2 dB/km and the dielectric constant of the medium is 1.7. Assume that the length of the link is the maximum possible if an attenuation of 20dB can be tolerated.

i) Find the SNR in decibels.

ii) If the bandwidth of the channel is 600Mhz, what is the maximum data rate at

which information can be transmitted?

iii) How long will it take to send 10 1-minute songs from a conventional CD (assume stereo sound) on this link? CD systems sample music signals at 44 kilosamples/sec at a resolution of 16 bits/sample. A stereo system implies two such channels.

Answers:

i) SNR = 2. $SNR(dB) = 10\log_{10}SNR$. Therefore SNR in decibels = $10\log_{10}2 = 3.01$ *(1 point)*

ii) Use Shannon's channel capacity formula to compute how fast information can be transmitted. W=600Mhz.

$$C = W\log_2(1 + SNR) = 600 \times 10^6 \log_2(1 + 2) = 6 \times 10^8 \frac{\log_{10}(3)}{\log_{10}2} = 950$$

Mb/s

(2 points)

iii) To compute total delay, we need to compute propagation delay and data transmission (emission) delay. We compute propagation delay, we need the length of the channel and speed of light in the channel. Since the dielectric constant is 1.7, the speed of light in this medium is $v = \frac{c}{\sqrt{\varepsilon}}$:

$$v = \frac{c}{\sqrt{\varepsilon}} = \frac{3 \times 10^8}{\sqrt{1.7}} = 2.3 \times 10^8 m/s \quad .$$

The length of the link is 10Km given that the attenuation constant k is 2 dB/km and a 20dB attenuation can be tolerated.

The propagation delay is given by:

$$\text{propagation delay} = \frac{\text{distance}}{\text{speed of light in medium}} = \frac{10 \times 1000\text{m/km}}{2.3 \times 10^8 \text{m/s}} = 43.4 \quad \mu s$$

Next, to compute transmission delay, we need the size of the data to be transmitted. The sampling rate is 44000 samples/sec at a resolution of 16 bits/sample for CD systems. For a stereo system, this results in $44000\text{samples/sec} \times 16\text{bits/sample} \times 2 = 1408000\text{bits/sec}$. Ten 1-minute songs correspond to 600 seconds worth of music. Therefore $1408000\text{bits/sec} \times 600\text{sec} = 845\text{Mbits}$ worth of information.

Therefore the transmission (emission) delay is

$$\text{transmission delay} = \frac{\text{data size}}{\text{bit rate}} = \frac{845\text{Mbits}}{950\text{Mb/s}} = 0.89\text{sec}$$

The total delay is transmission delay + propagation delay = $0.89 + 0.000043 \approx 0.890043$ sec.

(1 point for computing the speed of light in the medium, 2 points for computing the length of the link, 1 point for recognizing need for propagation delay and transmission delay, 1 point for computing the propagation delay, 2 points for computing the data size, 1 point for transmission delay, 1 point for total delay)

Note: The word "channels" in the question was confusing to some students. Stereo means twice as much information, not that the same information was sent half on two different physical links

Problem 5 *(10 points):*

Consider a circuit switch that operates at a crossconnect rate of OC3, and interconnects four OC12 links.

1. Design a 3-stage nonblocking switch in which the input stage has 4 switches. Draw a picture in the space provided below showing the sizes and number of switches in each stage, as well as the connections between the switches in different stages *(6 points)*.

1 point for size of input/output stage; 1 point for number of switches in input/output stage; 1 point

7 center-stage switches
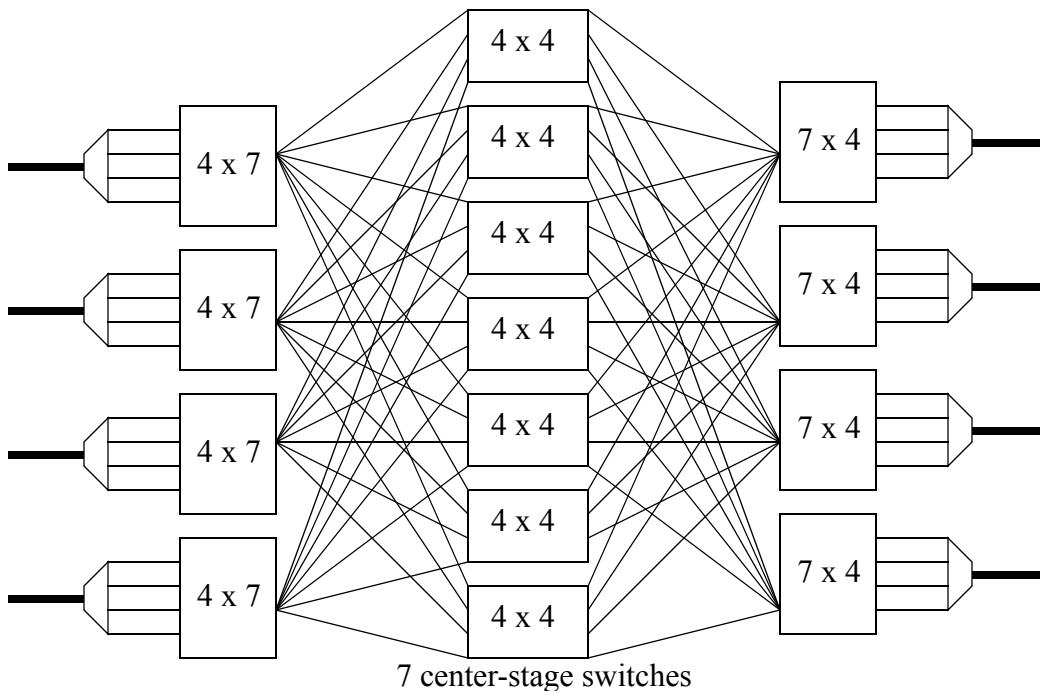
for number of mid-stage switches; 1 for size of mid-stage switches; 2 for connectivity

2. What is the total number of crosspoints in the 3-stage switch? *(2 points)*

The number of crosspoints is $2Nk + k(N/n)^2$. $k = 2n - 1$. $N = 16$ and $n = 4$. Therefore the number of crosspoints is 336. (2 points - 1 for formula; 1 for number)

3. If the switch was a single-stage crossbar switch, how many crosspoints would be required? *(2 points)*

Answer: N^2 which is 256. (1 for formula and 1 for answer)

Problem 6 *(13 points)***:**
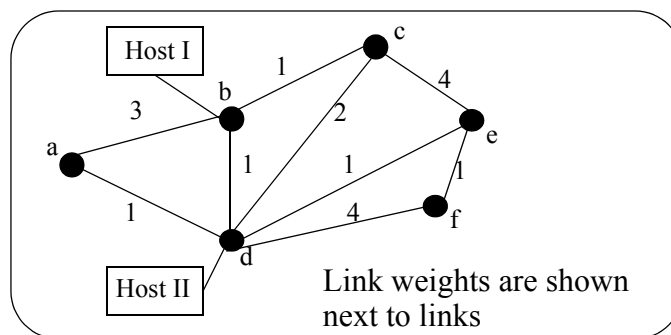
Consider a connectionless packet-switched network as shown below:

Answer the following questions:

1. Show the steps of Dijkstra's shortest path algorithm for the network shown above to obtain the shortest paths from node **b** to all nodes? Show the costs and routes - *5 points*

Answer: (5 points - roughly 1 point per row):

Table 1: Steps of Dijkstra's shortest path algorithm

Iteration	M	D_a; rte. to a	D_c; rte. to c	D_d; rte. to d	D_e; rte. to e	D_f; rte. to f
1	{b}	3; b-a	1; b-c	1; b-d	∞	∞
2	{b,c}	3; b-a	1; b-c	1; b-d	5; b-c-e	∞
3	{b,c,d}	2; b-d-a	1; b-c	1; b-d	2; b-d-e	5; b-d-f
4	{b,c,d,a}	2; b-d-a	1; b-c	1; b-d	2; b-d-e	5; b-d-f
5	{b,c,d,a,e}	2; b-d-a	1; b-c	1; b-d	2; b-d-e	3; b-d-e-f
6	{b,c,d,a,e,f}	2; b-d-a	1; b-c	1; b-d	2; b-d-e	3; b-d-e-f

2. If a 1500-byte packet is sent from Host I to Host II, using the following parameters

compute the end-to-end delay incurred by the packet - *5 points*:

Link	Parameters			
	Propagation delay	Link rate	Size of queue feeding the link	Load ρ of queue
Host I - switch B	100 μsec	56kbps	10 packets	0.2
Switch B - switch D	10ms	45Mbps	10 packets	0.8
Switch D - Host II	100μsec	1.5Mbps	10 packets	0.8

Answer:

Link	Prop. delay (sec)	E[T] (sec)	Delay (sec)
Host I - switch B	0.0001	0.2679	0.268
Switch B - switch D	0.010	0.001	0.011
Switch D - Host II	0.0001	0.0243	0.0304
Total delay			0.268+0.011+0.0304 = 0.3094

1 point for adding prop. delay + E[T]; 3 points for correct numerical answers for E[T]; 1 point for total delay

3. If 1000 packets are sent from host I to host II, on average, how many packets will get through on the first try without requiring retransmissions (make independence assumptions where needed) - *3 points*

A packet will get through if it is not dropped on any of the three links. Therefore probability of a packet being delivered successfully is:

$(1-0.023)^2(1-8.192 \times 10^{-8}) = 0.955$ because loss probability is 0.023 for the two buffers with a ρ

of 0.8 and 8.192×10^{-8} for the buffer with a ρ of 0.2. This means on average 955 packets will get through.

(3 points; 1 point each for two loss probabilities; 1 for final answer)