Chapter 5 Review Questions

1. The transportation mode, e.g., car, bus, train, car.

2. Although each link guarantees that an IP datagram sent over the link will be received at the other end of the link without errors, it is not guaranteed that IP datagrams will arrive at the ultimate destination in the proper order. With IP, datagrams in the same TCP connection can take different routes in the network, and therefore arrive out of order. TCP is still needed to provide the receiving end of the application the byte stream in the correct order. Also, IP can lose packets due to routing loops or equipment failures.

3. Framing: there is also framing in IP and TCP; link access; reliable delivery: there is also reliable delivery in TCP; flow control: there is also flow control in TCP; error detection: there is also error detection in IP and TCP; error correction; full duplex: TCP is also full duplex.

4. There will be a collision in the sense that while a node is transmitting it will start to receive a packet from the other node.

5. Slotted Aloha: 1, 2 and 4 (slotted ALOHA is only partially decentralized, since it requires the clocks in all nodes to be synchronized). Token ring: 1, 2, 3, 4.

6. In polling, a discussion leader allows only one participant to talk at a time, with each participant getting a chance to talk in a round-robin fashion. For token ring, there isn't a discussion leader, but there is wine glass that the participants take turns holding. A participant is only allowed to talk if the participant is holding the wine glass.

7. When a node transmits a frame, the node has to wait for the frame to propagate around the entire ring before the node can release the token. Thus, if L/R is small as compared to t_{prop}, then the protocol will be inefficient.

8. 2^{48} MAC addresses; 2^{32} IPv4 addresses; 2^{128} IPv6 addresses.

9. C's adapter will process the frames, but the adapter will not pass the datagrams up the protocol stack. If the LAN broadcast address is used, then C's adapter will both process the frames and pass the datagrams up the protocol stack.

10. An ARP query is sent in a broadcast frame because the querying host does not which adapter address corresponds to the IP address in question. For the response, the sending node knows the adapter address to which the response should be sent, so there is no need to send a broadcast frame (which would have to be processed by all the other nodes on the LAN).

11. No it is not possible. Each LAN has its own distinct set of adapters attached to it, with each adapter having a unique LAN address.

12. The three Ethernet technologies have identical frame structures.

13. 20 million transitions per second.

14. After the 5^{th} collision, the adapter chooses from {0, 1, 2,…, 31}. The probability that it chooses 4 is 1/32. It waits 204.8 microseconds.

15. 2 (the internal subnet and the external internet)

16. In 802.1Q there is a 12- bit VLAN identifier. Thus 2^{12} = 4,096 VLANs can be supported.

17. We can string the N switches together. The first and last switch would use one port for trunking; the middle N-2 switches would use two ports. So the total number of ports is 2+ 2(N-2) = 2N-2 ports.

Chapter 5 Problems

Problem 1

1 1 1 0 1
1 0 1 1 1
1 0 0 1 0
1 1 0 1 1
0 0 0 1 1

Problem 2

Suppose we begin with the initial two-dimensional parity matrix:

0 0 0 0
1 1 1 1
0 1 0 1
1 0 1 0

With a bit error in row 2, column 3, the parity of row 2 and column 3 is now wrong in the matrix below:

0 0 0 0
1 1 0 1
0 1 0 1
1 0 1 0

Now suppose there is a bit error in row 2, column 2 and column 3. The parity of row 2 is now correct! The parity of columns 2 and 3 is wrong, but we can't detect in which rows the error occurred!

0 0 0 0
1 0 0 1
0 1 0 1
1 0 1 0

The above example shows that a double bit error can be detected (if not corrected).

Problem 3

```
  01001100  01101001
+ 01101110  01101011
------------------------------
  10111010  11010100
+ 00100000  01001100
------------------------------
```

```
  11011011  00100000
+ 01100001  01111001
-----------------------------
  00111100  10011010  (overflow, then wrap around)
+ 01100101  01110010
------------------------------
```

10100010 00001100

The one's complement of the sum is 01011101 11110011

Problem 4

a) To compute the Internet checksum, we add up the values at 16-bit quantities:

```
00000001  00000010
00000011  00000100
00000101  00000110
00000111  00001000
00001001  00001010
-------------------------
00011001  00011110
```

The one's complement of the sum is 11100110 11100001.

b) To compute the Internet checksum, we add up the values at 16-bit quantities:

```
01000001  01000010
01000011  01000100
01000101  01000110
01000111  01001000
01001001  01001010
-------------------------
01011000  01011111
```

The one's complement of the sum is 10100111 10100000

c) To compute the Internet checksum, we add up the values at 16-bit quantities:

```
01100001  01100010
01100011  01100100
01100101  01100110
01100111  01100111
01101000  01101001
-------------------------
11111001 11111101
```

The one's complement of the sum is 00000110 00000010.

Problem 5

If we divide 10011 into 1010101010 0000, we get 1011011100, with a remainder of R=0100. Note that, G=10011 is CRC-4-ITU standard.

Problem 6

a) we get 1000100011, with a remainder of R=0101.
b) we get 1011111111, with a remainder of R=0001.
c) we get 0101101110, with a remainder of R=0010.

Problem 7

a. Without loss of generality, suppose i^{th} bit is flipped, where 0<= i <= d+r-1 and assume that the least significant bit is 0^{th} bit.
A single bit error means that the received data is $K=D*2^r$ XOR $R + 2^i$. It is clear that if we divide K by G, then the reminder is not zero. In general, if G contains at least two 1's, then a single bit error can always be detected.
b. The key insight here is that G can be divided by 11 (binary number), but any number of odd-number of 1's cannot be divided by 11. Thus, a sequence (not necessarily contiguous) of odd-number bit errors cannot be divided by 11, thus it cannot be divided by G.

Problem 8

a)

$$
\begin{aligned}
E(p) &= Np(1-p)^{N-1} \\
E'(p) &= N(1-p)^{N-1} - Np(N-1)(1-p)^{N-2} \\
&= N(1-p)^{N-2}((1-p) - p(N-1))
\end{aligned}
$$

$$E'(p) = 0 \Rightarrow p^* = \frac{1}{N}$$

b)

$$E(p^*) = N\frac{1}{N}(1-\frac{1}{N})^{N-1} = (1-\frac{1}{N})^{N-1} = \frac{(1-\frac{1}{N})^{N}}{1-\frac{1}{N}}$$

$$\lim_{N\to\infty}(1-\frac{1}{N}) = 1 \qquad \lim_{N\to\infty}(1-\frac{1}{N})^N = \frac{1}{e}$$

Thus

$$\lim_{N\to\infty} E(p^*) = \frac{1}{e}$$

Problem 9

$$\begin{aligned} E(p) &= Np(1-p)^{2(N-1)} \\ E'(p) &= N(1-p)^{2(N-2)} - Np2(N-1)(1-p)^{2(N-3)} \\ &= N(1-p)^{2(N-3)}((1-p) - p2(N-1)) \end{aligned}$$

$$E'(p) = 0 \Rightarrow p^* = \frac{1}{2N-1}$$

$$E(p^*) = \frac{N}{2N-1}(1-\frac{1}{2N-1})^{2(N-1)}$$

$$\lim_{N\to\infty} E(p^*) = \frac{1}{2}\cdot\frac{1}{e} = \frac{1}{2e}$$

Problem 10

a). A's average throughput is given by $p_A(1\text{-}p_B)$.
Total efficiency is $p_A(1\text{-}p_B) + p_B(1\text{-}p_A)$.

b). A's throughput is $p_A(1\text{-}p_B)=2p_B(1\text{-}p_B)= 2p_B\text{-}\ 2(p_B)^2$.
B's throughput is $p_B(1\text{-}p_A)=p_B(1\text{-}2p_B)= p_B\text{-}\ 2(p_B)^2$.
Clearly, A's throughput is not twice as large as B's.
In order to make $p_A(1\text{-}p_B)= 2\ p_B(1\text{-}p_A)$, we need that $p_A= 2 - (p_A / p_B)$.

c). A's throughput is $2p(1\text{-}p)^{N\text{-}1}$, and any other node has throughput $p(1\text{-}p)^{N\text{-}2}(1\text{-}2p)$.

Problem 11

a) $(1 - p(A))^4\ p(A)$
where,
$p(A)$ = probability that A succeeds in a slot

$p(A) = p(A \text{ transmits and } B \text{ does not and } C \text{ does not and } D \text{ does not})$
$= p(A \text{ transmits})\, p(B \text{ does not transmit})\, p(C \text{ does not transmit})\, p(D \text{ does not transmit})$
$= p(1 - p)\,(1 - p)(1-p) = p(1 - p)^3$

Hence, $p(A \text{ succeeds for first time in slot } 5)$
$= (1 - p(A))^4\, p(A) = (1 - p(1 - p)^3)^4\, p(1 - p)^3$

b) $p(A \text{ succeeds in slot } 4) = p(1-p)^3$
$p(B \text{ succeeds in slot } 4) = p(1-p)^3$
$p(C \text{ succeeds in slot } 4) = p(1-p)^3$
$p(D \text{ succeeds in slot } 4) = p(1-p)^3$

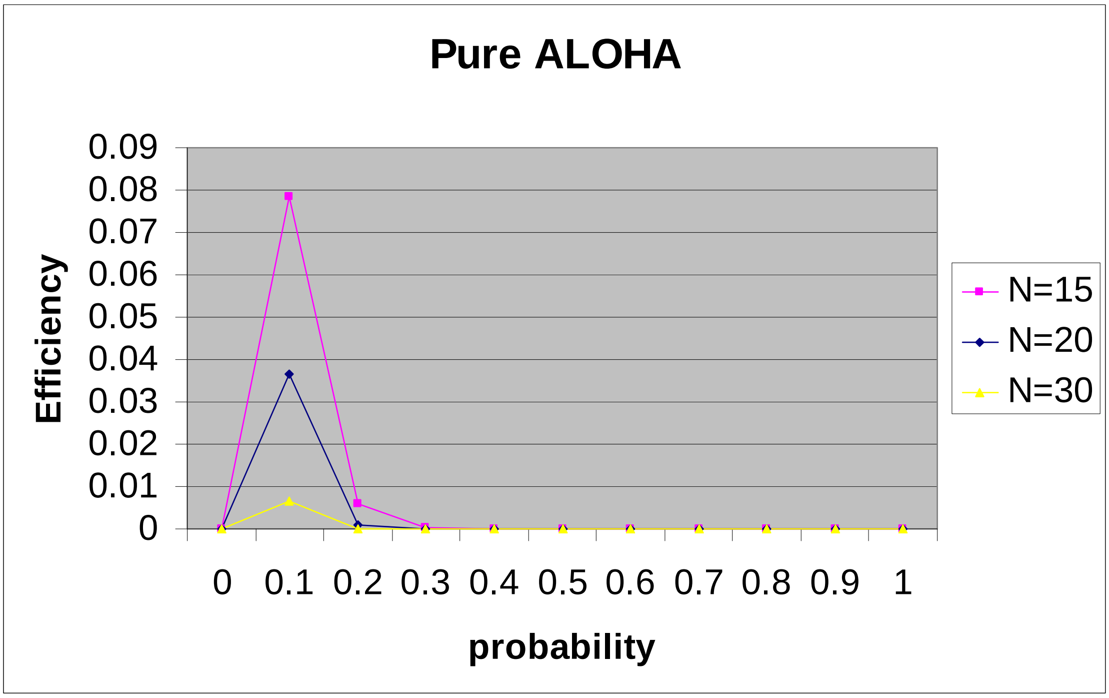
$p(\text{either } A \text{ or } B \text{ or } C \text{ or } D \text{ succeeds in slot } 4) = 4\, p(1-p)^3$
(because these events are mutually exclusive)

c) $p(\text{some node succeeds in a slot}) = 4\, p(1-p)^3$
$p(\text{no node succeeds in a slot}) = 1 - 4\, p(1-p)^3$

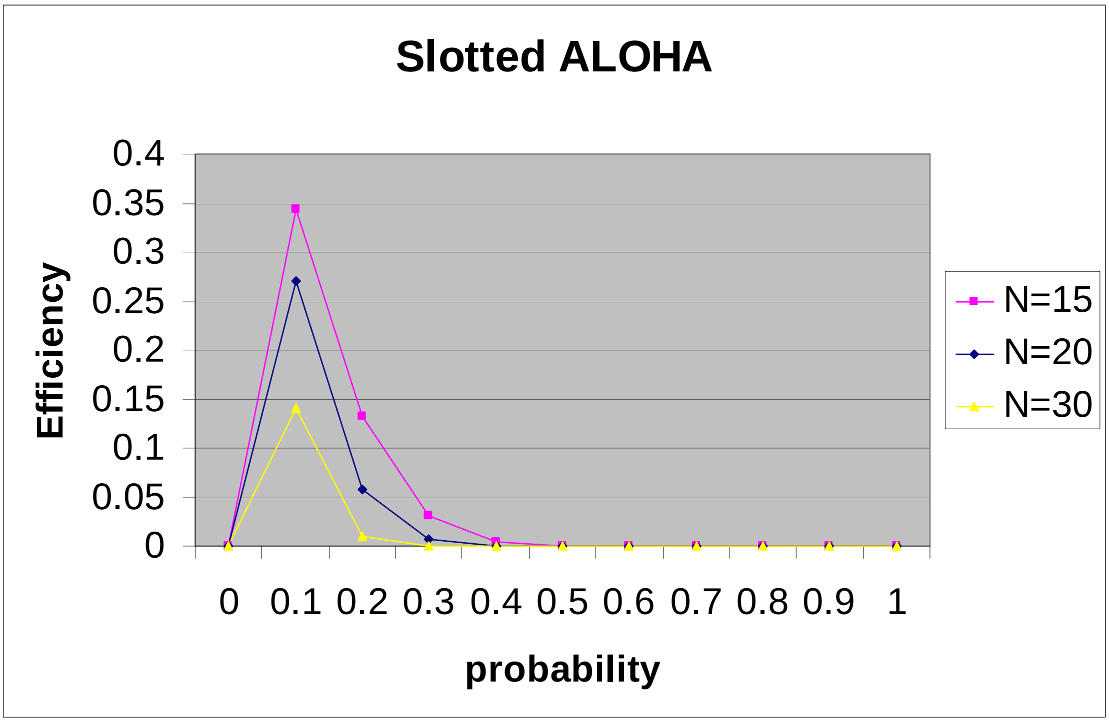
Hence, $p(\text{first success occurs in slot } 3) = p(\text{no node succeeds in first 2 slots})\, p(\text{some node succeeds in } 3^{rd} \text{ slot}) = (1 - 4\, p(1-p)^3)^2\, 4\, p(1-p)^3$

d) efficiency = $p(\text{success in a slot}) = 4\, p(1-p)^3$

Problem 12



Pure ALOHA
Efficiency
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
probability
N=15
N=20
N=30



Slotted ALOHA
Efficiency
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
probability
N=15
N=20
N=30

Problem 13

The length of a polling round is

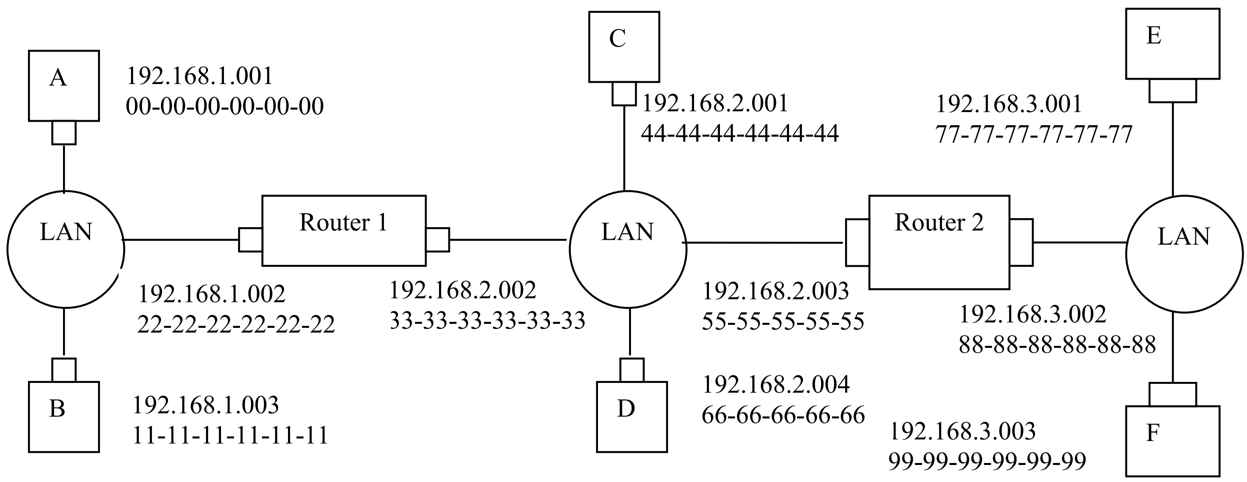
$$N(Q/R + d_{poll}).$$

The number of bits transmitted in a polling round is NQ. The maximum throughput therefore is

$$\frac{NQ}{N(Q/R + d_{poll})} = \frac{R}{1 + \frac{d_{poll} R}{Q}}$$

Problem 14

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.

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.

Problem 15

a). No. E can check the subnet prefix of Host F's IP address, and then learn that F is on the same LAN. Thus, E will not send the packet to the default router R1.
Ethernet frame from E to F:
Source IP = E's IP address
Destination IP = F's IP address
Source MAC = E's MAC address
Destination MAC = F's MAC address

b). No, because they are not on the same LAN. E can find this out by checking B's IP address.
Ethernet frame from E to R1:
Source IP = E's IP address
Destination IP = B's IP address
Source MAC = E's MAC address
Destination MAC = The MAC address of R1's interface connecting to Subnet 3.

c).
Switch S1 will broadcast the Ethernet frame via both its interfaces as the received ARP frame's destination address is a broadcast address. And it learns that A resides on Subnet 1 which is connected to S1 at the interface connecting to Subnet 1. And, S1 will update its forwarding table to include an entry for Host A.

Yes, router R1 also receives this ARP request message, but R1 won't forward the message to Subnet 3.

B won't send ARP query message asking for A's MAC address, as this address can be obtained from A's query message.

Once switch S1 receives B's response message, it will add an entry for host B in its forwarding table, and then drop the received frame as destination host A is on the same interface as host B (i.e., A and B are on the same LAN segment).

Problem 16

Lets call the switch between subnets 2 and 3 S2. That is, *router R1 between subnets 2 and 3 is now replaced with switch S2.*

a). No. E can check the subnet prefix of Host F's IP address, and then learn that F is on the same LAN segment. Thus, E will not send the packet to S2.
Ethernet frame from E to F:
Source IP = E's IP address
Destination IP = F's IP address
Source MAC = E's MAC address
Destination MAC = F's MAC address

b). Yes, because E would like to find B's MAC address. In this case, E will send an ARP query packet with destination MAC address being the broadcast address.
This query packet will be re-broadcast by switch 1, and eventually received by Host B.
Ethernet frame from E to S2:
Source IP = E's IP address
Destination IP = B's IP address
Source MAC = E's MAC address
Destination MAC = broadcast MAC address: FF-FF-FF-FF-FF-FF.

c).
Switch S1 will broadcast the Ethernet frame via both its interfaces as the received ARP frame's destination address is a broadcast address. And it learns that A resides on Subnet 1 which is connected to S1 at the interface connecting to Subnet 1. And, S1 will update its forwarding table to include an entry for Host A.

Yes, router S2 also receives this ARP request message, and S2 will broadcast this query packet to all its interfaces.

B won't send ARP query message asking for A's MAC address, as this address can be obtained from A's query message.

Once switch S1 receives B's response message, it will add an entry for host B in its forwarding table, and then drop the received frame as destination host A is on the same interface as host B (i.e., A and B are on the same LAN segment).

Problem 17

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

$$\frac{51.2 \times 10^3 bits}{10 \times 10^6 bps} = 5.12 \, \text{msec}$$

For 100 Mbps, the wait is 512 μsec.

Problem 18

At $t = 0$ A transmits. At $t = 576$, A would finish transmitting. In the worst case, B begins transmitting at time t=324, which is the time right before the first bit of A's frame arrives at B. At time t=324+325=649 B's first bit arrives at A. Because 649> 576, A finishes transmitting before it detects that B has transmitted. So A incorrectly thinks that its frame was successfully transmitted without a collision.

Problem 19

Following the same reasoning as in last problem, we need to make sure that one end of the Ethernet is able to detect the collision before it completes its transmission of a frame. Thus, a minimum frame size is required.

Let BW denote the bandwidth of the Ethernet. Consider the worst case for Ethernet's collision detection:
1. At t=0 (bit times): A sends a frame
2. At t=d_{prop}-1 (bit times): B sends a frame right before it can sense A's first bit.
3. At t=2d_{prop}-2 (bit times): If A finishes its transmission of its last bit just before B's frame arrives at A, then, A won't be able to detect a collision before finishing its transmission of a frame. Thus, in order for A to detect collision before finishing transmission, the minimum required frame size should be >= 2d_{prop}-1 (bit times).

Assume that the signal propagation speed in 10BASE-T Ethernet is $1.8*10^8$m/sec.
As d_{prop}=d/($1.8*10^8$)*BW(here, we need to convert the propagation delay in seconds to bit times for the specific Ethernet link), we find the minimum required frame size is 2*d/($1.8*10^8$)*BW-1 (bits). Or approximately we choose 2*d/($1.8*10^8$)*BW (bits).
If d=2km, then minimum required frame size is: 222 bits.

Problem 20

Based on the solution of last problem, you know that a higher link speed requires a larger minimum required packet size. If you cannot change packet size, then you can add switches or routers to segment your LAN, in order to make sure each LAN segment's size is sufficiently small for small frame size.

Problem 21

Time, t	Event
0	A and B begin transmission
245	A and B detect collision
293	A and B finish transmitting jam signal
293+245 = 538	B's last bit arrives at A; A detects an idle channel
538+96=634	A starts transmitting
293+512 = 805	B returns to Step2 B must sense idle channel for 96 bit times before it transmits
634+245=879	A's transmission reaches B

Because A 's retransmission reaches B before B 's scheduled retransmission time (805+96), B refrains from transmitting while A retransmits. Thus A and B do not collide. Thus the factor 512 appearing in the exponential backoff algorithm is sufficiently large.

Problem 22

A frame size is 1000*8+64 = 8064 bits, as 64-bit preamble is added into the frame.
We want $1/(1+5a) = .5$ or, equivalently, $a = .2 = t_{prop} / t_{trans}$. $t_{prop} = d/(1.8\times 10^8)$ m/sec and $t_{trans} = (8064 \text{ bits})/(10^8 \text{ bits/sec}) = 80.64\mu$ sec. Solving for d we obtain $d = 2903$ meters.

For transmitting station A to detect whether any other station transmitted during A's interval, t_{trans} must be greater than $2t_{prop} = 2\cdot 2903 \text{ m} / 1.8\times 10^8 \text{ m/sec} = 32.26\mu$ sec. Because $32.26 < 80.64$, A will detect B's signal before the end of its transmission.

Problem 23

a). minimum required frame length is given by
$2*d_{prop}* BW=2*(500+700)/(2 \cdot 10^8) * 10 * 10^6=120$ bits.
There is no maximum required packet length.

b). Efficiency is given by
$1/(1+5* d_{prop}/ d_{trans}) =1/(1+5*120/2/1500)=0.83$

Problem 24

a)
Let Y be a random variable denoting the number of slots until a success:

$$P(Y = m) = \beta(1-\beta)^{m-1},$$

where β is the probability of a success.

This is a geometric distribution, which has mean $1/\beta$. The number of consecutive wasted slots is $X = Y - 1$ that

$$x = E[X] = E[Y] - 1 = \frac{1-\beta}{\beta}$$

$$\beta = Np(1-p)^{N-1}$$

$$x = \frac{1 - Np(1-p)^{N-1}}{Np(1-p)^{N-1}}$$

$$\text{efficiency} = \frac{k}{k+x} = \frac{k}{k + \frac{1 - Np(1-p)^{N-1}}{Np(1-p)^{N-1}}}$$

b)

Maximizing efficiency is equivalent to minimizing x, which is equivalent to maximizing β. We know from the text that β is maximized at $p = \frac{1}{N}$.

c)

$$\text{efficiency} = \frac{k}{k + \frac{1 - (1 - \frac{1}{N})^{N-1}}{(1 - \frac{1}{N})^{N-1}}}$$

$$\lim_{N\to\infty} \text{efficiency} = \frac{k}{k + \frac{1 - 1/e}{1/e}} = \frac{k}{k+e-1}$$

d) Clearly, $\frac{k}{k+e-1}$ approaches 1 as $k \to \infty$.

Problem 25

a)

$$\frac{800m}{2 \cdot 10^8 m/\sec} + 4 \cdot \frac{20bits}{100 \times 10^6 bps}$$

$$= (4 \times 10^{-6} + 0.8 \times 10^{-6})\sec$$
$$= 4.8 \mu \sec$$

b)
First note, the transmission time of a single frame is give by 1500/(100Mbps)=15 micro sec, longer than the propagation delay of a bit.

- At time $t = 0$, both A and B transmit.

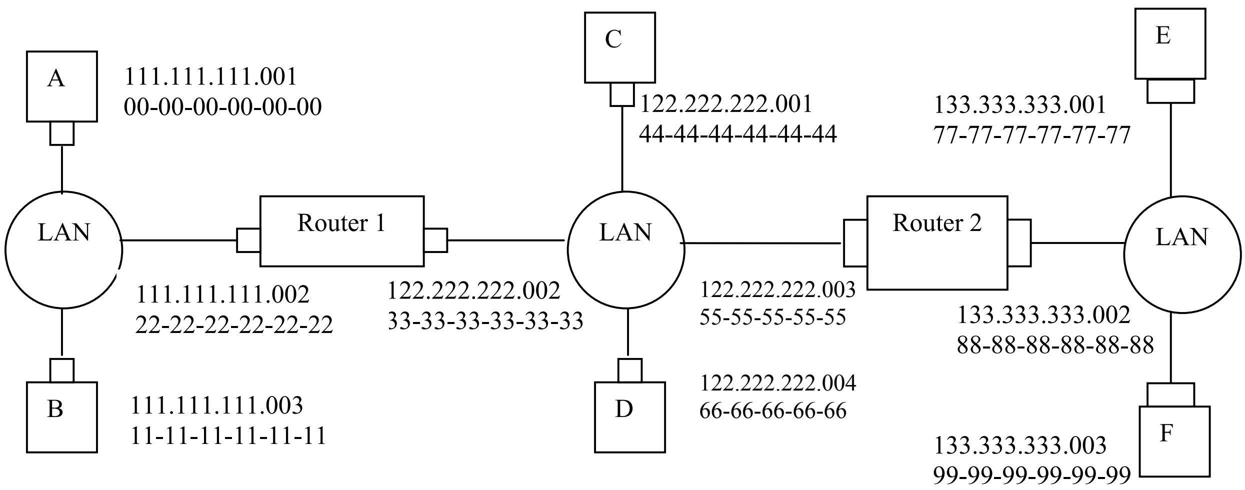
- At time $t = 4.8\mu\sec$, both A and B detect a collision, and then abort.
- At time $t = 9.6\mu\sec$ last bit of B's aborted transmission arrives at A.
- At time $t = 14.4\mu\sec$ first bit of A's retransmission frame arrives at B.
- At time $t = 14.4\mu\sec + \dfrac{1500bits}{100\times10^6 bps} = 29.4\mu\sec$ A's packet is completely delivered at B.

c) The line is divided into 5 segments by the switches, so the propagation delay between switches or between a switch and a host is given by $\dfrac{800m/5}{2\cdot10^8 m/\sec} = 0.8 micro\sec$.
The delay from Host A to the first switch is give by 15micosec (transmission delay), longer than propagation delay. Thus, the first switch will wait 16=15+0.8+0.2 (note, 0.2 is processing delay) till it is ready to send the frame to the second switch. Note that the store-and-forward delay at a switch is 15 microsec. Similarly each of the other 3 switches will wait for 16 microsec before ready for transmitting the frame.
The total delay is:
16*4 + 15+0.8=79.8 micro sec.

Problem 26

Higher speed of processor and memory implies that the inter-frame gap can be shortened, since it takes less time to complete the processing of a received frame. However, higher speed of Ethernet cable implies that the inter-frame gap should be increased.

Problem 27



i) from A to left router: Source MAC address: 00-00-00-00-00-00
Destination MAC address: 22-22-22-22-22-22
Source IP: 111.111.111.001

Destination IP: 133.333.333.003

ii) from the left router to the right router: Source MAC address: 33-33-33-33-33-33
Destination MAC address: 55-55-55-55-55-55
Source IP: 111.111.111.001
Destination IP: 133.333.333.003

iii) from the right router to F: Source MAC address: 88-88-88-88-88-88
Destination MAC address: 99-99-99-99-99-99
Source IP: 111.111.111.001
Destination IP: 133.333.333.003

Problem 28

i) from A to switch: Source MAC address: 00-00-00-00-00-00
Destination MAC address: 55-55-55-55-55-55
Source IP: 111.111.111.001
Destination IP: 133.333.333.003

ii) from switch to right router: Source MAC address: 00-00-00-00-00-00
Destination MAC address: 55-55-55-55-55-55
Source IP: 111.111.111.001
Destination IP: 133.333.333.003

iii) from right router to F: Source MAC address: 88-88-88-88-88-88
Destination MAC address: 99-99-99-99-99-99
Source IP: 111.111.111.001
Destination IP: 133.333.333.003

Problem 29

If all the 11=9+2 nodes send out data at the maximum possible rate of 100 Mbps, a total aggregate throughput of 11*100 = 1100 Mbps is possible.

Problem 30

Each departmental hub is a single collision domain that can have a maximum throughput of 100 Mbps. The links connecting the web server and the mail server has a maximum throughput of 100 Mbps. Hence, if the three collision domains and the web server and mail server send out data at their maximum possible rates of 100 Mbps each, a maximum total aggregate throughput of 500 Mbps can be achieved among the 11 end systems.

Problem 31

All of the 11 end systems will lie in the same collision domain. In this case, the maximum total aggregate throughput of 100 Mbps is possible among the 11 end sytems.

Problem 32

Action	Switch Table State	Link(s) packet is forwarded to	Explanation
B sends a frame to E	Switch learns interface corresponding to MAC address of B	A, C, D, E, and F	Since switch table is empty, so switch does not know the interface corresponding to MAC address of E
E replies with a frame to B	Switch learns interface corresponding to MAC address of E	B	Since switch already knows interface corresponding to MAC address of B
A sends a frame to B	Switch learns the interface corresponding to MAC address of A	B	Since switch already knows the interface corresponding to MAC address of B
B replies with a frame to A	Switch table state remains the same as before	A	Since switch already knows the interface corresponding to MAC address of A

Problem 33

The time required to fill $L \cdot 8$ bits is

$$\frac{L \cdot 8}{128 \times 10^3} \sec = \frac{L}{16} m\sec.$$

b) For $L = 1{,}500,$ the packetization delay is

$$\frac{1500}{16} m\sec = 93.75 m\sec.$$

For $L = 50,$ the packetization delay is

$$\frac{50}{16} m\sec = 3.125 m\sec.$$

c)

$$\text{Store-and-forward delay } = \frac{L \cdot 8 + 40}{R}$$

For $L = 1{,}500$, the delay is

$$\frac{1500 \cdot 8 + 40}{622 \times 10^6} \sec \approx 19.4 \mu \sec$$

For $L = 50$, store-and-forward delay $< 1 \mu \sec$.

d) Store-and-forward delay is small for both cases for typical link speeds. However, packetization delay for $L = 1500$ is too large for real-time voice applications.

Problem 34

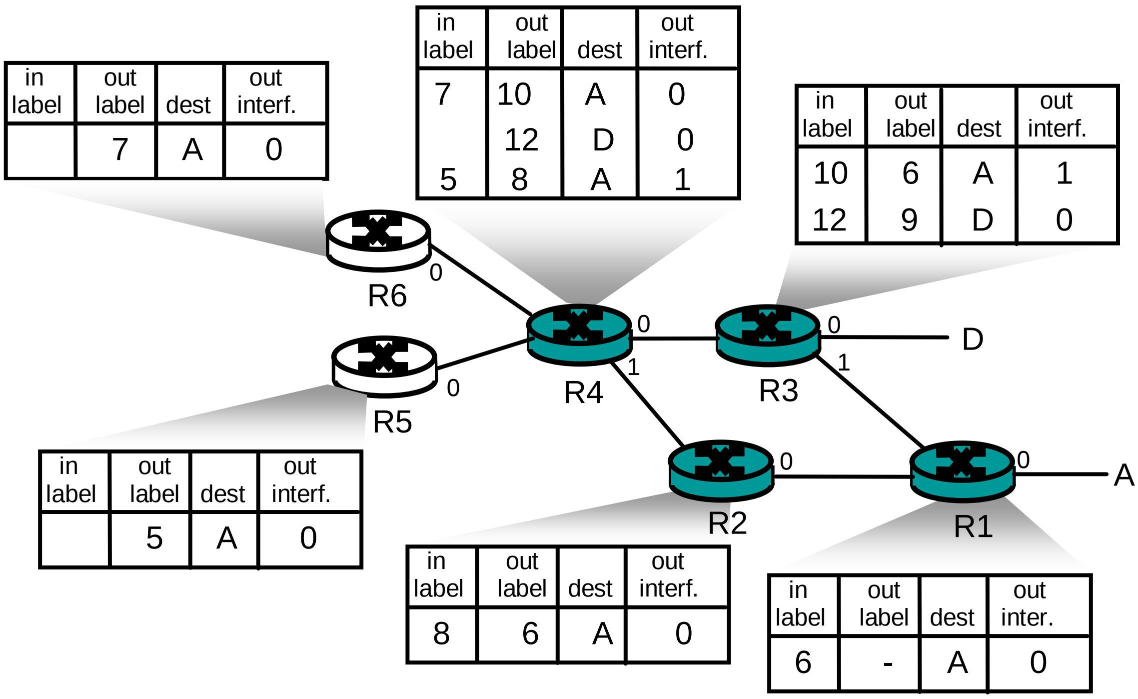
The IP addresses for those three computers (from left to right) in EE department are: 111.111.1.1, 111.111.1.2, 111.111.1.3. The subnet mask is 111.111.1/24.

The IP addresses for those three computers (from left to right) in CS department are: 111.111.2.1, 111.111.2.2, 111.111.2.3. The subnet mask is 111.111.2/24.

The router's interface card that connects to port 1 can be configured to contain two sub-interface IP addresses: 111.111.1.0 and 111.111.2.0. The first one is for the subnet of EE department, and the second one is for the subnet of CS department. Each IP address is associated with a VLAN ID. Suppose 111.111.1.0 is associated with VLAN 11, and 111.111.2.0 is associated with VLAN 12. This means that each frame that comes from subnet 111.111.1/24 will be added an 802.1q tag with VLAN ID 11, and each frame that comes from 111.111.2/24 will be added an 802.1q tag with VLAN ID 12.

Suppose that host A in EE department with IP address 111.111.1.1 would like to send an IP datagram to host B (111.111.2.1) in CS department. Host A first encapsulates the IP datagram (destined to 111.111.2.1) into a frame with a destination MAC address equal to the MAC address of the router's interface card that connects to port 1 of the switch. Once the router receives the frame, then it passes it up to IP layer, which decides that the IP datagram should be forwarded to subnet 111.111.2/24 via sub-interface 111.111.2.0. Then the router encapsulates the IP datagram into a frame and sends it to port 1. Note that this frame has an 802.1q tag VLAN ID 12. Once the switch receives the frame port 1, it knows that this frame is destined to VLAN with ID 12, so the switch will send the frame to Host B which is in CS department. Once Host B receives this frame, it will remove the 802.1q tag.

Problem 35



R6:

in label	out label	dest	out interf.
	7	A	0

R4:

in label	out label	dest	out interf.
7	10	A	0
	12	D	0
5	8	A	1

R3:

in label	out label	dest	out interf.
10	6	A	1
12	9	D	0

R5:

in label	out label	dest	out interf.
	5	A	0

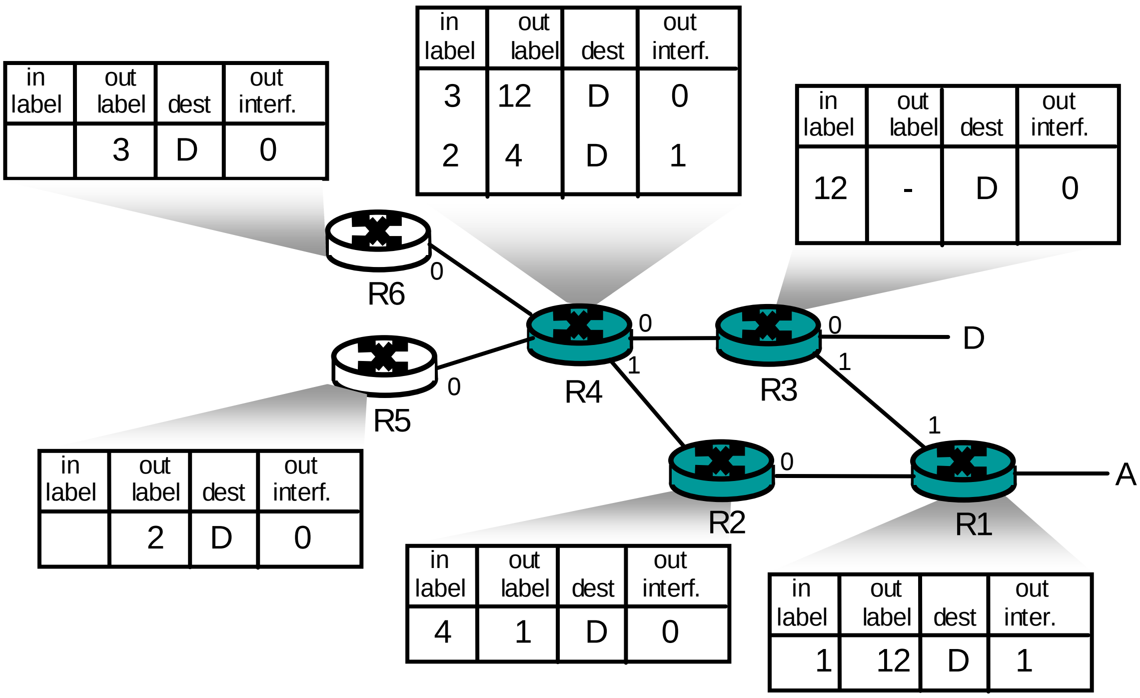
R2:

in label	out label	dest	out interf.
8	6	A	0

R1:

in label	out label	dest	out inter.
6	-	A	0

Problem 36



R6:

in label	out label	dest	out interf.
	3	D	0

R4:

in label	out label	dest	out interf.
3	12	D	0
2	4	D	1

R3:

in label	out label	dest	out interf.
12	-	D	0

R5:

in label	out label	dest	out interf.
	2	D	0

R2:

in label	out label	dest	out interf.
4	1	D	0

R1:

in label	out label	dest	out inter.
1	12	D	1

Problem 37

(The following description is short, but contains all major key steps and key protocols involved.)

Your computer first uses DHCP to obtain an IP address. You computer first creates a special IP datagram destined to 255.255.255.255 in the DHCP server discovery step, and puts it in a Ethernet frame and broadcast it in the Ethernet. Then following the steps in the DHCP protocol, you computer is able to get an IP address with a given lease time.

A DHCP server on the Ethernet also gives your computer a list of IP addresses of first-hop routers, the subnet mask of the subnet where your computer resides, and the addresses of local DNS servers (if they exist).

Since your computer's ARP cache is initially empty, your computer will use ARP protocol to get the MAC addresses of the first-hop router and the local DNS server.

Your computer first will get the IP address of the Web page you would like to download. If the local DNS server does not have the IP address, then your computer will use DNS protocol to find the IP address of the Web page.

Once your computer has the IP address of the Web page, then it will send out the HTTP request via the first-hop router if the Web page does not reside in a local Web server. The HTTP request message will be segmented and encapsulated into TCP packets, and then further encapsulated into IP packets, and finally encapsulated into Ethernet frames. Your computer sends the Ethernet frames destined to the first-hop router. Once the router receives the frames, it passes them up into IP layer, checks its routing table, and then sends the packets to the right interface out of all of its interfaces.

Then your IP packets will be routed through the Internet until they reach the Web server.

The server hosting the Web page will send back the Web page to your computer via HTTP response messages. Those messages will be encapsulated into TCP packets and then further into IP packets. Those IP packets follow IP routes and finally reach your first-hop router, and then the router will forward those IP packets to your computer by encapsulating them into Ethernet frames.