Solutions for Homework #7

1. Why do LANs tend to use broadcast networks? Why not use networks consisting of multiplexers and switches?

Solution:

The computers in a LAN are separated by a short distance (typically < 100m) so high speed and reliable communication is possible using a shared broadcast medium. The cost of the medium is negligible and the overall cost is dominated by the cost of the network interface cards in each computer. In addition, the LAN users usually belong to the same group where all users are generally trusted, so broadcast does not pose much security danger.

The original reason for avoiding a multiplexer and switch approach to LANs is that a centralized, expensive "box" is required. The availability of Application Specific Integrated Circuits (ASICs) has reduced the cost of switching boxes and made switch-based LANs feasible, and in some environments the dominant approach.

4. Suppose that the ALOHA protocol is used to share a 56 kbps satellite channel. Suppose that frames are 1000 bits long. Find the maximum throughput of the system in frames/second.

Solution:

Maximum throughput for ALOHA = 0.184
Maximum throughput in frames/sec = (56000 bits/sec) x (1 frame/1000 bits) x 0.184 = 10.304
The maximum throughput is approximately 10 frames/sec.

5. Let G be the total rate at which frames are transmitted in a slotted ALOHA system. What proportion of slots goes empty in this system? What proportion of slots go empty when the system is operating at its maximum throughput? Can observations about channel activity be used to determine when stations should transmit?

Solution:

Proportion of empty slots = P[0 transmission] = $[G^0/0!]e^{-G} = e^{-G}$

Maximum throughput = 0.368; $G_{mt} = 1$
Proportion of empty slots at maximum throughput = $e^{-1} = 0.368$

Any attempt to decrease the proportion of empty slots below e^{-1} is counterproductive as this action will push the throughput below its maximum value.

8. Consider four stations that are all attached to two different bus cables. The stations exchange fixed-size frames of length 1 second. Time is divided into slots of 1 second. When a station has a frame to transmit, the station chooses either bus with equal probability and transmits at the beginning of the next slot with probability p. Find the value of p that maximizes the rate at which frames are successfully transmitted.

Solution:

To maximize the successful transmission rate is to maximize the probability of successful transmission.

P(success) = (number of stations) × *P*(one station transmits on one bus) × *P*(no other station transmit on the same bus)

$$= 4(\frac{1}{2}p)(1-\frac{1}{2}p)^3 = 2p(1-\frac{1}{2}p)^3$$

Take the derivative with respect to p,

$$\frac{\partial P(success)}{\partial p} = 2(1-\frac{1}{2}p)^3 - (3p)(1-\frac{1}{2}p)^2$$

set it to 0 and find the value of p that maximizes P(success).

$$p = \frac{1}{2}$$

9. In a LAN, which MAC protocol has a higher efficiency: ALOHA or CSMA-CD? What about in a WAN?

Solution:

The maximum efficiency achieved by the Slotted ALOHA is 0.368. The efficiency of CSMA-CD is given by $1/(1 + 6.4a)$, and is sensitive to $a = t_{prop}R/L$, the ratio between delay-bandwidth product and frame length.

In a LAN environment, the end-to-end distance is around 100m and the transmission rates are typically 10Mbps, 100Mbps and 1Gbps (See Table 6.1). An Ethernet frame has a maximum length of 1500 bytes = 12,000 bits.

The table shows the efficiency of CSMA-CD at various transmission rate. Assume L = 12,000 bits and propagation speed of 3×10^8.

	a	Efficiency
10 Mbps	3×10^{-4}	0.998
100 Mbps	3×10^{-3}	0.981
1 Gbps	3×10^{-2}	0.839

Note however that if shorter frame sizes predominate, e.g. 64 byte frames, then a increases by a factor of about 20. According to the above formula the efficiency of CSMA-CD at 1 Gbps then drops to about 0.7. The situation however is worse in that the minimum frame size at 1 Gbps needs to be extended to 512 bytes, as discussed in page 436 of the text.

In a WAN environment d is larger. Assuming 100 Km, a is larger by a factor of 10^3 resulting in an efficiency of 0.36, 0.05, and 0.005 respectively for 10 Mbps, 100 Mbps, and 1 Gbps transmission rates. In the case of 10 Mbps transmission rate the efficiency of CSMA-CD is close to the efficiency of ALOHA but in the other two cases it is much less than ALOHA.

17. Suppose that a LAN is to carry voice and packet data traffic. Discuss what provisions if any are required to handle the voice traffic in the reservation, polling, token ring, ALOHA and CSMA-CD environments. What changes if any are required for the packet data traffic?

Solution:

Voice traffic is delay sensitive, so the MAC protocols must ensure the delays experienced by voice data packets are sufficiently low.

The reservation, polling and token ring systems use scheduling approach to medium access control and so are better able to provide predictable delay performance. Random access approaches on the other hand have greater variability in delay.

Reservation: Reservation schemes can provide performance close to time-division multiplexing and hence can support voice traffic.

Polling: Polling schemes can be configured to provide a bound on the value on the cycle time. This provides a guaranteed delay bound for voice traffic.

Token Ring: Limit the transmission time per token to place a maximum value on the token rotation time. Avoid single-token or single-frame operation if ring latency is large. Priority token operation can also be used if there is non-voice traffic in the network.

The ALOHA and CSMA-CD systems use random access approach to medium access control. The system throughput and delay performance are affected by traffic load. At a high load, the collision rate is high, and the packets experience long delays. To meet the delay requirement of voice traffic, the maximum traffic load should be kept very low for Aloha and relatively low for CSMA-CD. The CSMA-CD systems can be modified to provide different levels of access priority. Lower delay performance can be provided by giving voice traffic higher priority.

Packet data traffic is usually not delay sensitive, but does require low loss. In carrying both voice and data, the MAC protocol must provide voice traffic with low delay and data with low loss. In general, this requires giving voice priority access over data. Otherwise surges in data traffic can introduce unacceptable delay for voice traffic.

38. Provide a brief explanation for each of the following questions:

a. Under a light load, which LAN has a smaller delay: Ethernet or token ring?

Ethernet has smaller delay under a light load. In Ethernet under a light load, there is little or no contention for the channel, the delay incurred is close to the frame transmission time. In token ring, however, there is always the additional delay incurred from circulating the token around the ring.

b. Under a high load, which LAN has a smaller delay: Ethernet or token ring?

Token ring has smaller delay under a high load. In Ethernet there is more contention for the channel, much of the time is spent in collision and backoff, so on average the frames experience longer delay and higher delay variability. In comparison, token ring provides each station with an orderly and round-robin access to the channel by passing the token around. When the number of frames transmitted per token is limited, and frames are kept at a fixed length, token ring can guarantee a maximum delay for each station.