Final — May 11, 2010

Name (Last, First):
SID:

Problem 1. (10%)

Consider the Ethernet network shown in Figure 1. Each rectangle is an Ethernet switch.
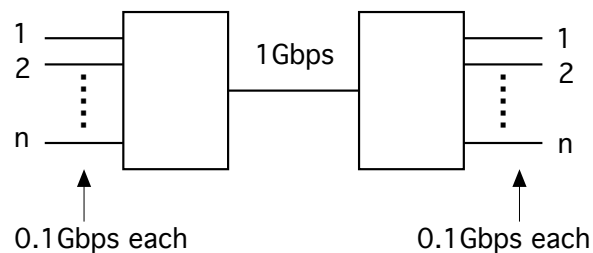

Figure 1. Ethernet Network for Problem 1.

The links are full-duplex with the rates shown. Assume that one host is attached to each 0.1Gbps link and that each host sends data at an average rate of Rbps, with equal fractions to all the other $2n-1$ hosts. (Thus, host i sends data to host j at an average rate $R/(2n-1)$ for all $j \neq i$.)

(a) Find the maximum value of R.

(b) For what values of n does the 1Gbps link become the bottleneck?

Problem 2. (12%)

This problem studies the throughput of a Reservation ALOHA network that works as follows (see Figure 2). There are N stations (not shown in the figure). Time is divided into alternating reservation and transmission phases. A reservation phase has K slots. The N stations transmit independently with probability p during each reservation slot, to make a reservation for later transmission. A reservation is successful when exactly one station sends a reservation during a reservation slot. After the reservation phase, the stations (if any) that were successful in making a reservation transmit their packets in turn, one after the other. After these transmissions, a new reservation phase starts, and so on. Assume that the average transmission time of a packet lasts the same as M reservation slots.
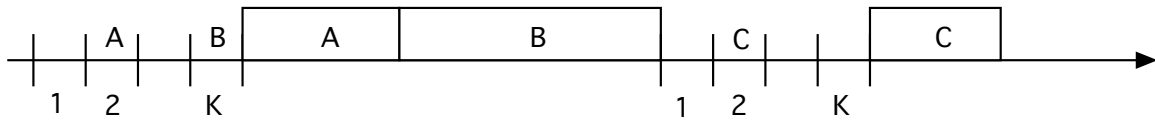

Figure 2. Reservation ALOHA Network for Problem 2.

(a) What is the fraction of time η that the stations transmit packets (not reservation messages).

(b) Assume that N is fixed. What is the values of p that maximizes the above fraction of time? What is the corresponding value of η when N is large?

(c) Assume that N and p are fixed. What is the average number A of slots between transmissions of packets by one given station?

Problem 3. (12%) *In this problem, we investigate the effect of packet losses due to wireless transmission errors on the throughput of a TCP connection. The model is as follows. A source of a TCP connection increases its transmission rate by ρbps every RTT. The source multiplies its rate by $\alpha < 1$ every time that it notices that a packet is lost.*

(a) We assume that a packet is lost exactly every T seconds, independently of the transmission rate (for simplicity of analysis). Say that the source starts with rate $R(0) = 0$. Plot the rate of the source as a function of time. Thus, the rate increases with rate ρ/RTT for T seconds, then gets multiplied by α, then increases with rate ρ/RTT for T seconds, and so on.

(b) Does the average rate of the source converge to some limit? If so, what is the limit when $\rho = 10^4, RTT = 0.1, T = 1, \alpha = 0.5$?

Problem 4. (10%)

Consider a TCP connection that is in congestion-avoidance phase for a long time. Its rate increases from $R/2$ to R, then drops to $R/2$, and this cycle repeats. [R is in packets/second.] The rate increases at rate $1/T^2$ where $T = RTT$ (in packets/second^2). Assume that one packet is lost in each cycle.

(a) What is the duration S of a cycle, in terms of R and T?

(b) What is the average throughput λ of the connection, in terms of R?

(c) What is the number N of packets sent in a cycle, in terms of R and T?

(d) What is the loss rate ρ of the connection, in terms of R and T?

(e) Express λ in terms of T and ρ.

(f) Assume two TCP connections with different RTTs share a single bottleneck link. Do you think they have the same loss rate? Explain.

Problem 5. (12%) *Consider a wireless LAN (WLAN) operating at 11 Mbps that follows the 802.11 MAC protocol with the parameters given below. There is only one user present in this WLAN who wants to transmit a file with 10^6 bytes of data using UDP.*

The drawings in Figure 3 (not drawn to scale) show the sequence of channel activities for a successful transmission and for a transmission with channel errors.
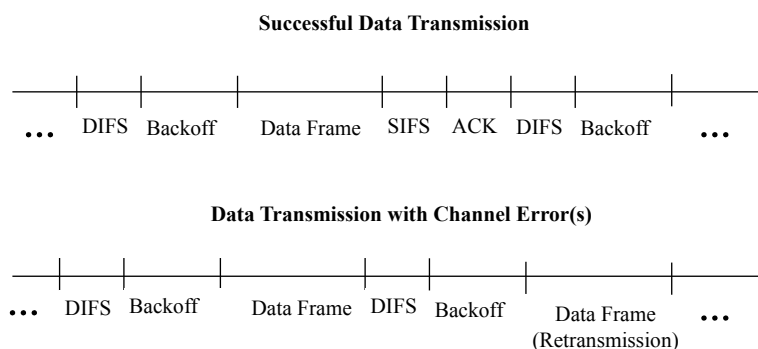
Successful Data Transmission

... DIFS Backoff   Data Frame   SIFS   ACK   DIFS   Backoff   ...

Data Transmission with Channel Error(s)

... DIFS Backoff   Data Frame   DIFS   Backoff   Data Frame (Retransmission) ...

Figure 3. Plot for Problem 5.

Recall that transmission of each data or acknowledgement frame incurs the Physical Layer overhead as indicated below.

The parameters for the WLAN are as follows:

$$Slot = 20\mu s$$
$$DIFS = 2.5\ Slots$$
$$SIFS = 0.5\ Slots$$
$$ACK = 10.5\ Slots\ (including\ Physical\ Layer\ overhead)$$
$$Physical\ Layer\ overhead\ for\ data\ frames = 10\ Slots$$
$$Collision\ Windows\ grow\ as\ 31,\ 63,\ 127,\ ...\ Slots.$$

Assume the following:

- All data frames are 1100 byte long which includes 100 byes of overhead for MAC and upper layers;

- Propagation delay is negligible;

- An acknowledgement is always received without any errors.

With the above parameters and assumptions, answer the following questions:

(1) How long will it take transmit the file if data frames are always transmitted without errors?

(2) How long will it take to transmit the file on average if each new data frame is received correctly either after the original transmission or after one retransmission with probabilities 0.9 and 0.1, respectively?

(3) If each data frame transmission (an original transmission or a retransmission) has the probability 0.9 of being received correctly, how will the time to transmit the file compare to the estimate in (2) above? Explain your answer. (Only a qualitative answer is needed for this part.)

Problem 6. (12%)

Suppose a router has built up the routing table shown in the following table. The router can deliver packets directly over interfaces 0 and 1, or it can forward packets to routers R2, R3, or R4. Assume the router does the longest prefix match. Describe which subnet mask the router uses with a packet addressed to each of the following destinations and which interface or router does it forward the packet to:

Subnet Number	Subnet Mask	Next Hop
128.96.170.0	255.255.254.0	Interface 0
128.96.168.0	255.255.254.0	Interface 1
128.96.166.0	255.255.254.0	R2
128.96.164.0	255.255.252.0	R3
Default		R4

a 128.96.171.92

b 128.96.167.151

c 128.96.163.151

d 128.96.169.192

e 128.96.165.121

Problem 7. (12%)

Suppose we have the forwarding tables shown in the following table for nodes A and F, in a network where all links have cost 1. Give a diagram of the smallest network consistent with these tables.

A

Node	Cost	NextHop
B	1	B
C	1	C
D	2	B
E	3	C
F	2	C

F

Node	Cost	NextHop
A	2	C
B	3	C
C	1	C
D	2	C
E	1	E

Problem 8. (20%)

1 Let A be the number of autonomous systems on the Internet, and let D (for diameter) be the maximum AS path length.

     a Give a connectivity model for which D is of order $\log A$.

     b Give one for which D is of order $\sqrt{A}$.

2 The reason(s) that routing is decomposed into two levels is/are: [Mark the correct answer(s) with an X]

     a Scalability

     b The design of IP

     c Historic

     d Economic/Business

     e All of the above

3 State the key difference in path advertisements between transit and peering agreements between ISPs.

4 Consider a token bucket of bucket size B bits and rate of tokens α bits/s that is full at time $t = 0$. A source starts transmitting data at r bits/s at time t=0 and is regulated by this token bucket. Let t be the time until the output rate of data from the token bucket regulator is r bits/s. Then [Mark the correct answer(s) with an X]

     a $t = B/(\alpha - r)$ if $\alpha > r$

     b $t = \infty$ if $\alpha > r$

    c $t = B/(r - \alpha)$ if $r > \alpha$

    d $t = B/r$ irrespective of α

5 Suppose a switch performs processor sharing on 3 queues. Let packets of sizes 3, 6 and 5 units respectively arrive at the three queues at time t=0. What are the finish times of the respective packets if the outgoing link rate is 1 unit/s? [Mark the correct answer with an X]

    a 3s, 6s, 5s

    b 7s, 14s, 13s

    c 3s, 9s, 14s

    d 8s, 9s, 5s

    e 9s, 14s, 13s

6 Assume a TCP connection starts in slow start (an later stays in that phase) with an initial window size equal to 10KBytes and with an RTT equal to 0.2s. Assume also that no packet gets lost. Approximately how long does it take for a 1MByte file to reach the destination? [Circle the best answer.]

$$19s, 1.9s, 2.6s, 1.3s, 0.6s.$$

7 To minimize interference with neighboring cells in networks based on OFDMA, one can deploy [Mark the correct answer(s) with an X]

    a Fractional frequency reuse.

    b Interference averaging using pseudo-random mapping of subcarriers to subchannels.

    c Coordinated use of subchannels in neighboring cells.

    d Careful spectrum planning to avoid neighboring cells using the identical frequency channels.

8 LTE allows for the signaling plane prioritization (e.g., for preemption) based on [Mark the correct answer(s) with an X]

    a Maximum Bit Rate.

    b Allocation and Retention Priority.

    c Guaranteed Bit Rate.

    d Aggregate Maximum Bit Rate.

9 LTE has chosen to use SC-FDMA in the UL direction mainly to reduce [Mark the correct answer(s) with an X]

    a *Delay Jitter.*

    b *Interference.*

    c *Peak-to-Average Power Ratio.*

    d *Inter-Symbol Interference.*

10 *Base Station in WiMAX can provide UL opportunity for transmitting [Mark the correct answer(s) with an X]*

    a *Bandwidth Request.*

    b *Data.*

    c *HARQ Feedback.*

    d *End-to-End Performance Indication.*

11 *The key feature that makes the subcarriers in OFDM orthogonal is [Mark the correct answer(s) with an X]*

    a *Number of subcarriers is equal to the number of symbol times in a frame.*

    b *Symbol time is reciprocal of the subcarrier spacing.*

    c *Number of subcarriers in a subchannel is fixed.*

    d *Multiplexing is allowed both in frequency and time dimensions.*

12 *In WiMAX, Bandwidth Request can be sent [Mark the correct answer(s) with an X]*

    a *On contention basis.*

    b *Piggybacked with data.*

    c *Upon receiving appropriate allocation from the Base Station.*

    d *Out of band.*

13 *In LTE, handovers based on the principle of make-before-break is [Mark the correct answer(s) with an X]*

    a *Done away with.*

    b *A key requirement.*

    c *Allowed per Base Stations discretion.*

    d *Negotiated at the time of setting up the bearer.*

14 *The primary duplex modes for LTE and WiMAX are [Mark the correct answer(s) with an X]*

    a *FDD for both.*

b TDD for both.

c FDD and TDD, respectively.

d TDD and FDD, respectively.