Exam #2 for *Computer Networks* <u>>>> *SOLUTION* <<<</u> ***Spring 1999***

Name: ______________________________ **SSN:** ________________________

Welcome to exam #2 in *Computer Networks.* Read each problem carefully. There are eight required problems (each worth 12.5 points) and one extra credit problem worth 5 points. Please write your answers on a separate sheet of paper and start each problem on a new page. For problems asking for a derivation or numerical solution, the majority of "points" are in the set-up and derivation, the least in the statement of the final answer. You may have one 8.5 x 11 inch sheet of paper with you. On this sheet you may have anything you want (definitions, formulas, etc.) in handwriting only, you may use both sides of the sheet. You have 80 minutes to complete this exam. This exam covers traffic analysis, LANs, sockets programming, TCP/IP, IP routing, bridging, ISDN and frame relay, and ATM. "Fair game" for this exam are lecture content, class handouts, anything posted on the class web pages, and the textbook chapters as listed in the class outline (subsequent to exam #1). The emphasis is on lecture content. **Good luck!!!**

<u>Problem #1:</u> (traffic analysis)

a) What is self-similarity? What is the significance of self-similar traffic to computer networks?

Self-similarity of a time series means that it "looks the same" at all time scales. If network traffic is self-similar and bursty (i.e., CoV > 1), the significance is that multiplexed traffic streams will not approach a Poisson process. This means that the expected (given Poisson assumption) SMG cannot be obtained and the network will be under-capacity (and more losses and delays will occur than expected).

b) Give the formula for autocorrelation. If the sum of autocorrelations (for an infinite time series) for all lags is infinite, what property exists in the time series? If the sum is finite, what property exists?

$\rho_k = \frac{E[(x_i - \mu)\cdot(x_{i+k} - \mu)]}{\sigma^2}$. An infinite sum value means that the time series is LRD, otherwise it is SRD.

c) What is the Hurst parameter? Briefly describe one way of estimating the Hurst parameter.

The Hurst parameter (H) is a measure of self-similarity ($0.50 \leq H \leq 1.00$). An H = 0.50 means that the time series is independent, 1.0 means fully dependent. R/S analysis is one way of estimate the H paramter where S is the sample variance and R is the rescaled range statistic. On a plot of Log(M) vs Log(R/S) (M is the aggregation level), H will be the slope of the line.

d) Briefly (3 or 4 sentences) summarize the Leland et al. *IEEE/ACM Transactions on Networking* paper studied in class. Identify what was studied, how it was studied, and where and when the study occurred.

In W. Leland, M. Taqqu, W. Willinger, and D. Wilson, "On the Self-Similar Nature of Ethernet Traffic (extended version)," *IEEE/ACM Transactions on Networking*, Vol. 2, No. 1, pp. 1 - 15, February 1994 the self-similarity of Ethernet traffic from a Bellcore Ethernet network was studied. This study to place in the late 1980's and early 1990's. This paper is considered to be the most significant paper in the area of networking in the 1990's by being the first paper to show that network traffic is not SRD.

<u>Problem #2:</u> (LANs)

a) Assume CSMA/CD protocol. Find the minimum frame length for a 1-Mbps bit rate and maximum network span of 10 kilometers with no repeaters. Assume a medium propagation delay of 4.5 nanoseconds per meter. Is CSMA/CD a reasonable protocol for a network of this span and bit-rate?

Minimum frame size for CSMA/CD is 2 * Tpr. Tpr = (4.5 * 10^-9)*(10 * 10^3) = 4.5 * 10^-5 sec. Thus, (1.0 * 10^6) * (9.0 * 10^-5) = 11.25 bytes. CSMA/CD would be a very reasonable protocol for a network of this span and speed since the minimum frame size is not “excessive” (e.g., larger than 64 bytes).

b) Assume unslotted ALOHA protocol. Derive the maximum channel throughput. State any simplifying assumptions (you will need to make such assumptions for a tractable analysis).

G = S + G(1 - e^-(2*G)) => S = G*e^-(2*G) from a channel with input from a Poisson source (assume infinite users and Poisson arrivals), and a feedback with probability p from collided packets. Where,p = 1 - e^-(2*G) from 2 packet length vulnerability period (fixed length packets are assumed) and the previous Poisson assumption. Taking the first derivative of the expression for S and setting it to zero yields a maximum throughput (Smax) of 18.4%.

<u>Problem #3:</u> (bridging)

a) Give the transparent bridging (learning and filtering) algorithm.

```
At each bridge port:
  (1) receive a frame
  (2) If (DA in table) and (DA local) then do not forward, else forward
  (3) If (SA in table) check/update direction
  (4) If (SA not in table) add to table
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b) What is the purpose of the spanning tree algorithm (stating that its purpose is to “make a spanning tree” or the equivalent “prevent loops” is NOT sufficient)?

The TB algorithm requires that a station only appear on “one side” of a bridge (i.e., for steps (3) and (4)). If the are parallel bridges, a frame can loop forever creating multiple (infinite in theory) copies to be received at the destination station. A spanning tree eliminates such parallel conditions.

c) Give one good argument for routers being “better” than bridges.

Bridges forward broadcast frames, routers do not. Excessive amounts of broadcast frames can waste expensive network bandwidth and host CPU cycles.

<u>Problem #4</u> (sockets programming)

a) Sketch the flow chart for TCP/IP client-server. You will have two flowcharts - one for client and another for the server. Show the appropriate sockets function names in the flowchart (e.g., bind(), etc.).

```
SERVER                     CLIENT
------                     ------
socket()                   socket()
bind()
listen() <---------------- connect()
accept()
send()/recv() <----------> send()/recv()
close()                    close()
```

b) From what you know about UDP/IP, identify the necessary changes to the flowchart of (a) for UPD/IP client/server.

Remove the listen() and accept() in the server and remove the connect() in the client. Use sendto() and recvfrom() instead of send() and recv().

Problem #5: (TCP/IP)

How is the time-out value determined for a TCP/IP connection? Explain why the time-out value is determined in this way. Be as precise as possible. Just writing down the “formulas” is insufficient.

Van Jacobson’s method computes a smoothed RTT estimate (SRTT), a smoothed error estimate (SERR), and a smoothed deviation estimate (SDEV). From this RTO is directly computed as SRTT + (f * SDEV). The time-out is computed this way to determine a “good” time-out for both short/low-delay-variance and long/large-delay-variance connections. It would be impossible to fix a single time-out value for all possible TCP/IP connections. A time-out that is too short causes duplicate packet sends, one that is too long causes excessive waiting when a recovery should be taking place.

Problem #6: (IP routing)

a) Describe the purpose of ARP and how it works.

ARP is use to resolve IP and MAC addresses and does so by a sender MAC broadcasting to a known IP address, the known IP address (or its proxy - e.g., a router port) responds directly and the sender now learns the MAC address of the target IP address.

b) In a connection-oriented network (e.g., in an ATM network), how can the ARP function be implemented?

Since broadcasting is effectively impossible, a well known “ARP server” containing registered IP and MAC addresses could be used. New hosts register with the ARP server. Hosts needing to resolve an address communicate directly with the ARP server.

Problem #7: (ISDN and frame relay)

a) What was the original goal (or motivation) for ISDN? Briefly describe ISDN.

The original goal of ISDN was to have end-to-end digital telephony (replacing the still current analog subscriber loop). ISDN is a synchronous full-duplex technology that supplies bandwidth in 64-kbps increments (B channels). Out-of-band signaling is used (e.g., via the D channel).

b) What was the original goal (or motivation) for frame relay?

The original goal of frame relay was end-to-end frame-based (e.g., LAN-to-LAN) communications with charge by usage.

Problem #8: (ATM)

a) What are the attributes of a “perfect transport”?

Distance scalable, speed scalable, suitable for real-time traffic (low mean and variance of delay), and easy to switch.

b) Why is an ATM cell small and fixed in size? What would benefit it its size were even smaller?

An ATM cell is small in size to minimize delay and delay variance. A sending station has to wait, at most, for one cell time. The fixed size is intended to simplify switching. The benefit of an even smaller cell size would be to reduce the packetization delay for real-time applications. For voice applications, the need for an echo canceller would be reduced.

c) What do we mean by the "ATM cell tax" and why was/is this a non-issue with the original proposers of ATM?

```
The ATM cell header is approximately 10% of the overall cell.  Thus, 10% of the channel
bit-rate is overhead for the cell header.  This is a non-issue with high-capacity fiber
channels (fiber has an effectively "infinite" bandwidth).
```

d) Describe ATM switching in terms of VPI and VCI.

```
ATM switching is in terms of virtual circuits which are divided into VP and VC.  VP =
virtual physical and VC = virtual channel.  A VP is a physical bundle of VC's.  This
division allows for VP-only switches, VC-only switches, and VP/VC switches.
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Extra Credit:

a) What is the primary problem that IPv6 is intended to solve?

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IPv6 addresses the limited address space of IPv4 (IPv4 has 32-bit IP addresses).
```

b) How does IPv6 solve the problem from (a)?

```
IPv6 supports a 64-bit IP address.
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c) Name at least one key person in the development of the IPv6 standard.

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Steve Deering (from the class handout!).
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d) What is an RFC and what does "RFC" stand for?

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An RFC is a "Request for Comments" and is the standardization vehicle for the IP
community.
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e) Who is the IETF and what does "IETF" stand for?

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IETF = Internet Engineering Task Force and is the Internet (TCP/IP, etc.) standards
group.
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