Exam #1 for Computer Networks II (CIS 6930)

Spring 2003

>>> SOLUTION <<<

Welcome to Exam #1 in Computer Networks II (CIS 6930). You have 75 minutes. Read each problem carefully. There are seven required problems (each problem is worth 14 points - you get 2 points for correctly following instructions). You may have with you a calculator, pencils, eraser, blank paper, lucky rabbit's foot, and one 8.5 x 11 inch "formula sheet". On this formula sheet you may have anything you want (definitions, formulas, etc.) *handwritten by you*. You may use both sides. Computer generated text, photocopies, and scans are not allowed on this sheet. Please submit your formula sheet with your exam. Please start each numbered problem on a new sheet of paper and do not write on the back of the sheets (I do not care about saving paper!). Submit everything in problem order. No sharing of calculators. Good luck and be sure to show your work. A Z-transform table is included as part of this exam.

Problem #1

Answer the following short-answer questions in no more than one or two sentences:

a) What is performance?

A quantitative measurement of a system.

b) Give at least three performance measures of interest for computer networks.

Delay, throughput, loss (also resource consumption, utilization, reliability, availability).

c) What are the three causes of delay in a computer network? How can each of these delays be reduced?

Distance (propagation delay), Transmission time, and Queueing delay

Propagation delay can be reduced only be moving data closer to a user, transmission time can be reduced by increasing the link data rate, queueing delay can also be reduced be increasing the capacity in the system.

d) Briefly, what is research and what is development?

Research is the creation of new knowledge (new ideas). Development is the use of existing ideas to create new and useful products

e) "An abstract for a paper is a ___________ of the paper." Complete the sentence with one word.

summary

f) Give the names of three conferences and two journals in which networks research is published.

ICC, IPCCC, LCN, GLOBECOM, INFOCOM, and SIGCOMM are all conferences. IEEE/ACM Transactions on Networking, IEEE Transactions on Communications, IEEE Journal on Selected Areas in Communicatios, Computer Communications, and Computer Networks are all journals.

g) Who is Leonard Kleinrock? What is he famous for?

Leonard Kleinrock is one of the fathers of the Internet. He is one of the inventors of packet switching. He was also one of the first to applying queueing theory to computer networks. He is currently a faculty member at UCLA.

Problem #2

Here are some simple probability questions. Answer them.

a) Let the probability experiment be rolling a fair die. Let the random variable *X* take on the value of the number of dots that is rolled (i.e., *X* takes on values 1 to 6). Plot the pdf and PDF for *X*. Determine the mean and variance of *X*.

```
|   pdf
|
|
|
|   1/6
|   |   |   |   |   |   |
+---+---+---+---+---+---+---
    1   2   3   4   5   6
```

```
|
|
|   PDF                 +-- 1.0
|                       |
|                    +--+
|                    |
|                +---+
|                |
|            +---+
|            |
|        +---+
|        |
|    +---+
|    |
+---+---+---+---+---+---+---
    1   2   3   4   5   6
```

Mean = 1/6 * (1 + 2 + 3 + 4 + 5 + 6) = 3 1/2

Variance = 1/6 * (1*1 + 2*2 + 3*3 + 4*4 +5*5 + 6*6) - 3.5*3.5 = 2 11/12

b) Assume that bit errors are independent and identically distributed. Given Pr[bit error] = 1.0e-6 (that is, 0.000001) and assuming a packet length of 1500 bytes, how many packets, on average will be bad (i.e., have one or more bit errors) in a bulk transfer of a 1-Mbyte file? You may ignore overheads due to headers (i.e., each packet contains 1500 bytes of file data) and that the last packet in the file transfer may be smaller than 1500 bytes

1-Mbyte = 1048576 / 1500 = 700 packets. The Pr[packet is bad] = 1 - (1 - 1.0e-6)^(1500*8) = 0.019. Thus, in 700 packets there will be, on average, 700 * 0.019 = 8.35 bad packets.

Problem #3

Assume a noisy transmission line where errors can cause transmitted 0's to be received as 1's and transmitted 1's to be received as 0's. Let S1 and S0 be the events that a 1 and 0, respectively were sent. Let R1 and R0 be the events that a 1 and 0, respectively, were received. Let p = Pr[S1], p_a = Pr[R0 | S1], and p_b = Pr[R1 | S0]. If a zero is received, what is the probability that it is in error?

This is a Bayes Theorem problem. The solution is:

$$\Pr[S1 \mid R0] = \frac{\Pr[R0 \mid S1]\Pr[S1]}{\Pr[R0 \mid S1]\Pr[S1] + \Pr[R0 \mid S0]\Pr[S0]} = \frac{p_a p}{p_a p + (1 - p_b)(1 - p)}$$

Problem #4

Answer the following questions regarding the Poisson distribution.

a) Carefully define a Poisson process. Give the expression for the Poisson distribution.

"A process is Poisson when what we observe in any subinterval is statistically independent of what happens in any non-overlapping interval." Also, consider a time interval split-up into subintervals such that

- ***Pr[event in subinterval] = p,***
- ***Pr[no event in subinterval] = 1 – p, and***
- ***Pr[more than one event in subinterval] = 0.***

The expression for the pdf of a Poisson process is:

$$f(x) = \frac{\lambda^x}{x!} e^{-\lambda}$$

b) What is the relationship between the Binomial and Poisson distributions? You need not complete a derivation, but must at least set-up a derivation.

The Poisson distribution is the limit of the Binomial distribution as p goes to zero, n goes to infinity, and np = λ (constant). That is,

$$\lim_{n\to\infty} \binom{n}{x} p^x (1-p)^{n-x} \to \frac{\lambda^x}{x!} e^{-\lambda}$$

c) What is the relationship between the Poisson distribution and the exponential distribution? Prove it.

The distribution of time between arrivals in a Poisson process is exponential. That is, $F[t] = \Pr[T \le t] = 1 - \Pr[T > t]$ ***and that*** $\Pr[T > t]$ ***is the probability that no events occuring in*** $[0,t) = \Pr_o[t]$ ***we have,*** $F(t) = 1 - \Pr_0[t]$ ***and*** $\Pr[0] = \frac{(\lambda t)^0}{0!} e^{-\lambda t} = e^{-\lambda t}$***.*** ***Thus,*** $F(t) = 1 - e^{-\lambda t}$ ***which is the PDF for the exponential distribution.***

Problem #5

The pdf for a geometric distribution is $f(k) = (1-p)p^k$ for k = 0, 1, 2,… and where p is the probability of a failure. What is the pdf of a random variable, W, that is the sum of three geometrically distributed random variables X, Y, and Z all with the same value of p? What is the mean of W? Show your work.

We have that

$$\left(\frac{1-p}{1-p\cdot z}\right)\cdot\left(\frac{1-p}{1-p\cdot z}\right)\left(\frac{1-p}{1-p\cdot z}\right) \to \frac{(1-p)^3}{(1-p\cdot z)^3}$$

From our Z-transform table we find that

$$f(k) := (1-p)^3 \left[\frac{(k+1)(k+2)}{2}\right] p^k$$

The mean of W is trivially three times the mean of a single geometrically distributed random variable (so we know the answer!). We can find the mean this way (with z = 1):

$$\frac{d}{dz}\frac{(1-p)^3}{(1-p\cdot z)^3} \to$$

or this way:

$$\sum_{k=0}^{\infty}\left[k\cdot\left[(1-p)^{3}\left[\frac{(k+1)\,(k+2)}{2}\right]p^{k}\right]\right]\rightarrow 3\cdot(1-p)^{3}\cdot\frac{p}{(p-1)^{4}}$$

which simplifies to:

$$\frac{3}{(1-p)}\cdot p$$

Problem #6

Answer the following questions regarding time series:

a) What is a time series?

A series of tuplets (interarrival time and job size). Also, a series of values indexed by time.

b) What does autocorrelation measure? Be precise is your description.

Autocorrelation measures the amount of correlation (lack of independence) between successive events in a time series. The successive events are seperated by lag number of values. Autocorrelation ranges from -1 for completely inversely correlated, to 1 for completely positively correlated. A value of 0 implies independence (no correlation).

c) Using exponential smooth and an alpha value of 0.75, predict the next value in the following series:

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1, 2, 3, 2
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0 + 0.75*(1 - 0) = 0.75
0.75 + 0.75*(2 - 0.75) = 1.6875
1.6875 + 0.75*(3 - 1.6875) = 2.6719
2.6719 + 0.75*(2 - 2.6719) = 2.1680

Thus, 2.1680 is the predicted next value

Problem #7

Answer the following questions regarding measurement:

a) What are the three parameters of interest in timing (e.g., when using a stopwatch to time an event)?

Granularity (tick size), overhead for start and stop, and accuracy (does it keep time – too fast or too slow).

b) What does ping measure and in what time scale?

Ping measures network round trip time between two hosts in time scales of milliseconds (an operating system clock is not likely to have a tick value of less than 1 millisecond).

c) What is MRTG and, very briefly, how does it work?

MRTG is the Multi-Router Traffic Grapher. It is visual application that uses SNMP to get byte counts from routers and then plots these values on a graph. The graph is put in an HTML file and posted to a web server.

d) What do ttcp and netperf measure?

They measure TCP/IP throughput between two hosts.
