PRINCE OF SONGKLA UNIVERSITY
FACULTY OF ENGINEERING

Final Examination: Semester II | Academic Year: 2005
Date: 24 February 2006 | Time: 9.00-12.00
Subject: 240-542 Queueing and Computer Networks | Room: R300

ทุจริตในการสอบ โทษขั้นต่ำคือ ปรับตกในรายวิชาที่ทุจริต และพักการเรียน 1 ภาคการศึกษา

- In this exam paper, there are SIX questions. Answer ALL questions,
- All notes and books are not allowed,
- Answers can be either in Thai or English,
- Only un-programmable calculator is allowed,

Q1. Please describe the following terms and definitions clearly: (20 marks)

1.1 ***Why does M/D/1 give better performance than M/M/1***?

1.2 ***How does End-to-end window flow control works?***

1.3 ***What are the limitations of end-to-end windows?***

1.4 From the figure 1, there are n+1 sessions each offering 1 unit/sec of traffic along a sequence of n links with capacity of 1 unit/sec.

(a) ***What is the maximum throughput of the system*** (regardless of fairshare)?

(b) If our objective is to give equal rate to all session, ***what is the system throughput?***

(c) If our objective is to give equal resources to all sessions, ***what is the link rate of each session?***

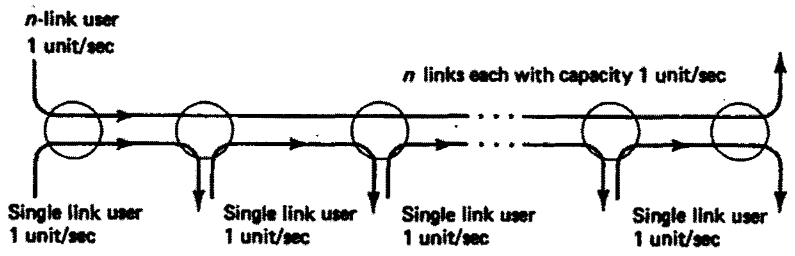

Figure 1 for question 1.4

Q2. Two routers are connected by 10 Mbps link. There are 10 parallel sessions using the link. Each session generates packets with a Poisson distribution with mean of 100 packets/sec. The packet lengths are exponentially distributed with a mean of 2,000 bits. The network engineer must choose between giving each session a dedicated 1 Mbps piece of bandwidth (using Time Division Multiplexing or Frequency Division Multiplexing) or having all packets compete for a single 10 Mbps shared link (using Statistical Multiplexing). ***Which alternative gives a better response time?*** You need to show how you obtain the answer clearly. (10 marks)

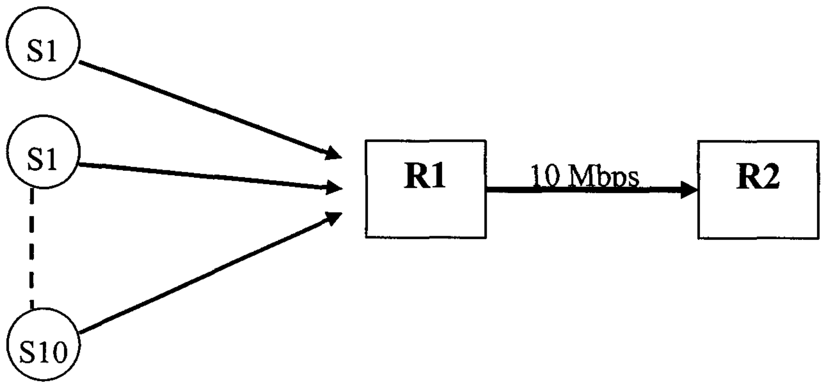

Figure 2 for question 2

Q3. From the **Figure 3**, we state the following assumptions:

- λ is offered traffic load,
- queue service discipline is M/M/1,
- N is the buffer size of queue,
- P_B is blocking probability,
- μ is service rate,
- A is system throughput.

What is minimum required buffer size (N) to provide blocking probability of 10^{-5} when traffic intensity (ρ) is 0.5? (10 marks)

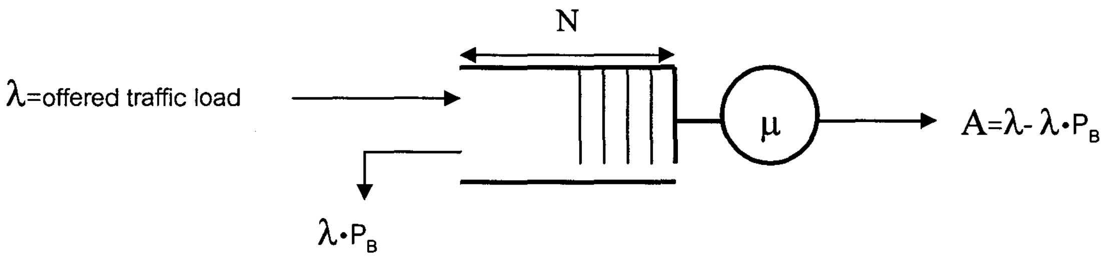

Figure 3 M/M/1/N queue model with blocking

Q4. This question has two parts:

4.1 Consider a window flow controlled virtual circuit going over a satellite link, all packets have a transmission time of 5 msec. The round-trip processing and propagation delay is 0.5 sec. ***Find a lower bound on the window size for the virtual circuit*** to be able to achieve maximum speed transmission when there is no other traffic on the link. (10 marks)

4.2 Suppose that the virtual circuit in question 4.1 goes through a terrestrial link in addition to the satellite link. The transmission time on the terrestrial link is 20 msec, and the processing and propagation delays are negligible. (10 marks).

(a) ***What is the maximum transmission rate in packets/sec*** that can be attained for this virtual circuit assuming no flow control?

(b) ***Find a lower bound for the end-to-end window size*** that will allow maximum transmission rate assuming no other traffic on the links.

(c) ***Does it make a difference*** whether the terrestrial link is before or after the satellite link? ***Why.***

Q5. **Figure 4** shows a periodic model of TCP window dynamics in steady state. In this model, we assume that: (20 Marks)

- The maximum window size is W,
- The minimum window size is W/2
- Constant Packet loss Probability is *p*
- So, *1/p* packets are transmitted between each packet loss,
- TCP runs in steady state, so *slow start* (during start up) is not relevant.

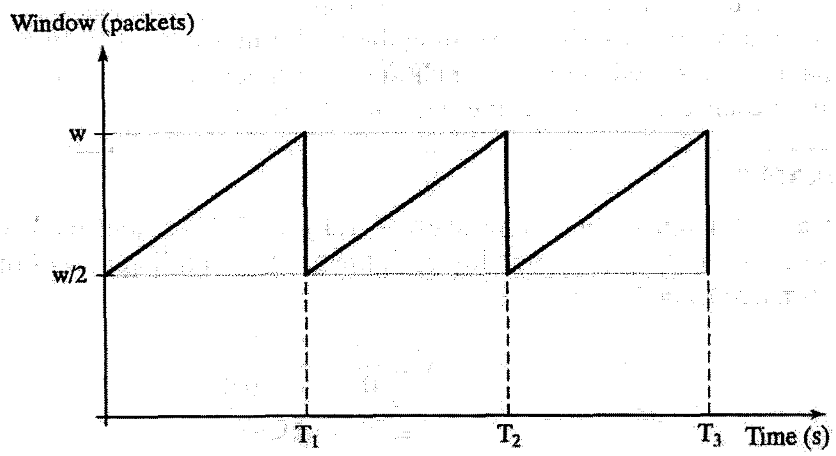

Figure 4 A periodic model of TCP window dynamic behaviour in steady state

Use the above information answer the following question

a) ***Prove that the number of packet transmitted*** during each period of window is

$$\text{Number of Pkts} = \frac{1}{2}\frac{T}{RTT}\left(\frac{W}{2} + W\right)$$

Where *T* is the periodic between detecting packet losses.

b) ***Prove that the average transmission rate*** in this model is

$$\frac{1}{RTT}\sqrt{\frac{3}{2p}}$$

The result is known as the ***inverse square-root p law***

c) If a TCP connection has an average round trip time of 200 ms, and packets are lost along the connection with probability 0.05, **please *find the average rate of the TCP source.***

Q6. Stop-and-Wait ARQ Protocol performance: use the following information to answer the question below.

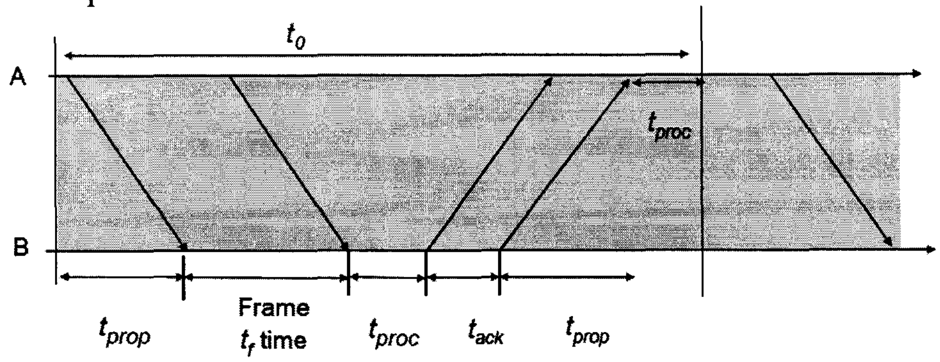

Figure 5 Delay components of Stop-and-Wait ARQ

- The basic time to send a frame and receive an ACK, in the absence of errors, is given by

$$t_0 = 2t_{prop} + 2t_{proc} + t_f + t_{ack}$$

$$= 2t_{prop} + 2t_{proc} + n_f / R + n_a / R$$

Where n_f = number of bits in the information frame

n_a = number of bits in the ack frame

R = bit rate of the transmission channel

** The effective information transmission rate of the protocol in the absence of errors

$$R_{eff} = (n_f - n_0)/t_0$$

Where n_0 = number of overhead bits in a frame (given by the total number of bits in the header and the number of CRC bits)

- Let P_f be the probability that a frame transmission has errors and the frame needs to be re-transmitted.

- The probability of no error frames is $1\text{-}P_f$

Stop-and-Wait ARQ on average requires $t_{SW}=t0/(1\text{-}P_f)$ seconds to get a frame through. Thus the efficiency of Stop-and Wait ARQ with packet loss is:

$$\eta_{SW} = \frac{\dfrac{n_f - n_a}{t_{SW}}}{R} \qquad \eta_{SW} = \frac{1 - \dfrac{n_0}{n_f}}{1 + \dfrac{n_a}{n_f} + \dfrac{2(t_{prop} + t_{proc})R}{n_f}}(1 - P_f)$$

Suppose that frames are 1,250 bytes long including 25 bytes of overhead. Also assume that ACK frames are 25 bytes long. ***Calculate the efficiency of Stop-and-Wait ARQ in the system*** that transmits at R=1 Mbps and with reaction time of 1 msec for channels with a bit error rate of each of 10^{-6}, 10^{-5}, and 10^{-4} (not probability of frame loss).