PRINCE OF SONGKLA UNIVERSITY
FACULTY OF ENGINEERING

Final Examination: Semester II — Academic Year: 2004
Date: 27 February 2005 — Time: 13.30-16.30
Subject: 240-542 Queueing and Computer Networks — Room: A201

ทุจริตในการสอบ โทษขั้นต่ำคือ ปรับตกในรายวิชาที่ทุจริต และพักการเรียน 1 ภาคการศึกษา

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

1. 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 given below, explain how node-by-node windows for virtual circuit works,

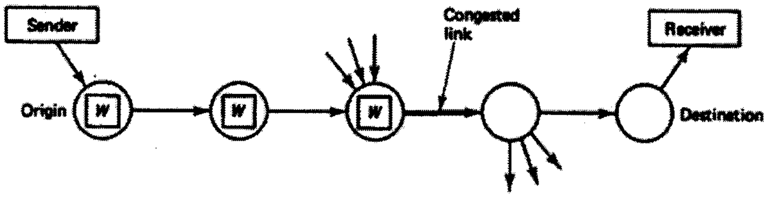

Figure 1 for question 1.4

   1.5 Figure below can be used to prove of Little's theorem, please explain:

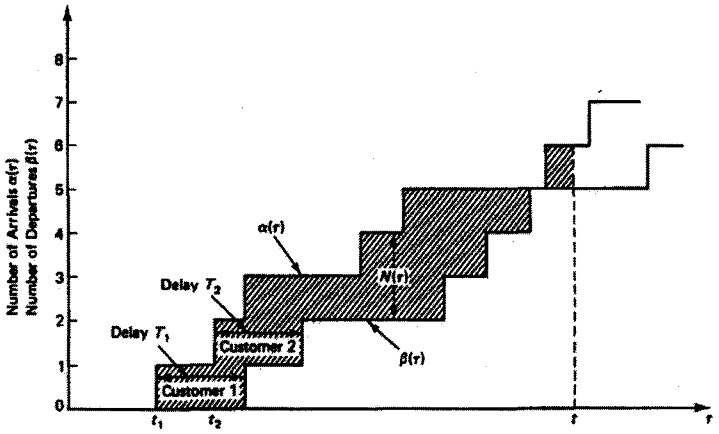

Figure 2 for question 1.5

2. There are two questions:

2.1 Two routers are connected by 2 Mbps link. There are 10 parallel sessions using the link. Each session generates Poisson with mean of 60 packets/sec. The packet lengths are exponential distributed with a mean of 2,000 bits. The network engineer must choose between giving each session a dedicated 200 kbps piece of bandwidth (using Time Division Multiplexing or Frequency Division Multiplexing) or having all packets compete for a single 2 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).

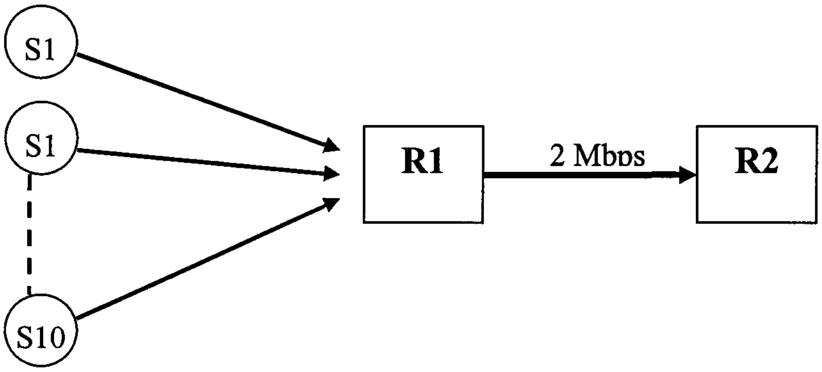

Figure 3 for question 2.1

2.2

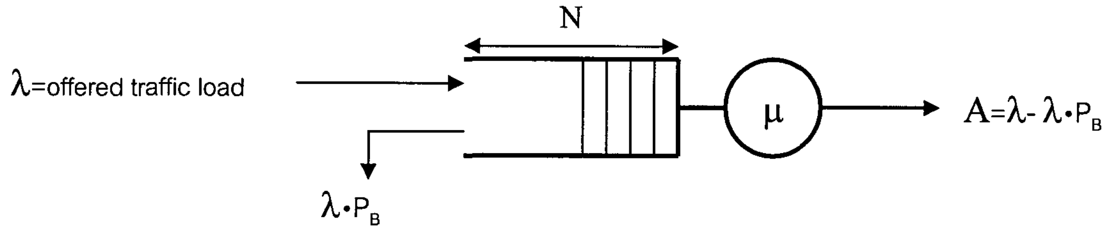

Figure 4 M/M/1/N queue model with blocking

From the **Figure 4**, we state the following assumptions:

- λ is offered traffic load,
- queue service discipline is M/M/1,
- N is a 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)

3. There are two questions:

3.1 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).

3.2 Suppose that the virtual circuit in question 3.1 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 delay 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 to an end-to-end window size that will allow maximum transmission rate summing no other traffic on the links.
c) Does it make a difference whether the terrestrial link is before or after satellite link?

4. **Figure 5** shows a periodic model of TCP window dynamics in steady state. In this model, we assume that: (20 Marks)

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

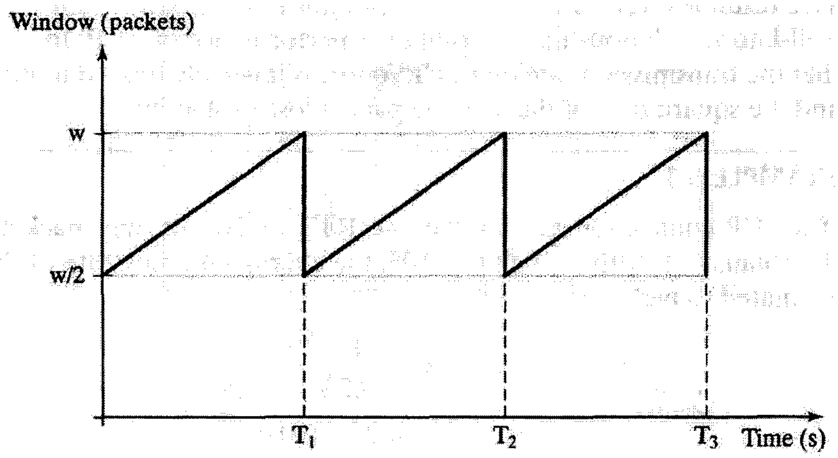

Figure 5 A periodic model of TCP window dynamic behaviour in steady state

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.

5. Below is the demonstration diagram of window flow control. Given a window size, W (the time to transmit data) as shown in **Figure 6**, the maximum transmission rate of the source is determined by the value of W in relation to the round-trip time delay D. Each data frame has the same size, F bits. Answer the following questions (20 marks):

5.1 What is the maximum rate of information transmission of the source?

5.2 If the service rate of the source is 1/R, (where R is the average time to transmission a data frame), what the minimum rate of the source is (in relation of 1/R, W, and D).

5.3 From 5.2, what is the maximum rate of the source if W is larger than D?

5.4 What is the optimal value of W?

5.5 Assuming that the time-out mechanism is activated after T seconds. If the acknowledgement signal from downstream is missing. What is the system throughput (in relation of 1/R, W, D, and T)?

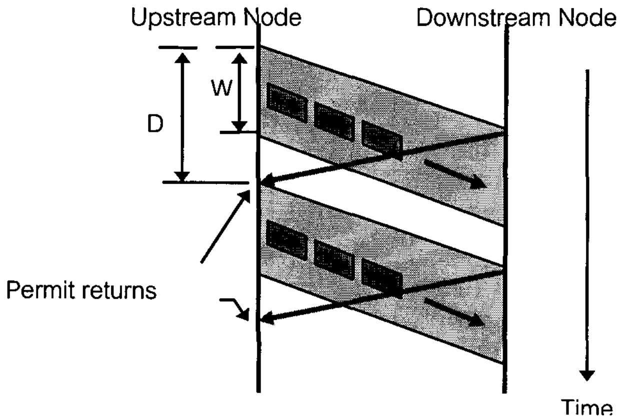

Figure 6 Windows flow control demonstration diagram used for question 5

The following information may be useful when students have to deal with queueing theory.

- **M/M/1**
  - **Number of Customers in the system in steady state**

$$L = \frac{\rho}{1-\rho}$$

where L is the number of customers in the system in steady state,
ρ is the utilisation factor or traffic intensity

  - **The mean queue length in steady state**

$$L_q = \frac{\rho^2}{1-\rho} \quad \text{or} \quad L_q = \frac{\lambda^2}{\mu(\mu-\lambda)}$$

where L_q = mean queue length in steady state
λ = average arrival rate
μ = average service rate

  - **Mean waiting time in the queue in steady state**

$$W_q = \frac{\lambda}{\mu(\mu-\lambda)}$$

where W_q is the mean waiting time in the queue in steady state

- **M/D/1**
  - **Number of Customers in the system in steady state**

$$L = \rho + \frac{\lambda^s}{2\mu^2(1-\rho)}$$

where L is the number of customers in the system in steady state,
ρ is the utilisation factor or traffic intensity
μ = average service rate

  - **The mean queue length in steady state**

$$L = \frac{\lambda^s}{2\mu^2(1-\rho)}$$

  - **Mean waiting time in the queue in steady state**

$$L = \frac{\lambda}{2\mu^2(1-\rho)}$$