

PRINCE OF SONGKLA UNIVERSITY
FACULTY OF ENGINEERING

Mid-Term Examination: Semester II

Academic Year: 2007

Date: 5 January 2008

Time: 09.00-11.00 (2 hours)

Subject: 240-542 Queueing and Computer Networks

Room:

ทฤษฎีในการสอบ โทษขั้นต่ำคือ ปรับตกในรายวิชาที่ทฤษฎี 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,
- Calculator is allowed,

1. A packet arrives at a transmission line every K seconds with the first packet arriving at time 0. All packets have equal length and require αK seconds for transmission what $\alpha < 1$. The processing and propagation delay per packet is P seconds. The arrival rate here is $\lambda = 1/K$. Please find (10 marks)
- i. Average time (T) the packet spent in the system.
 - ii. Average number of packets in the system (N)

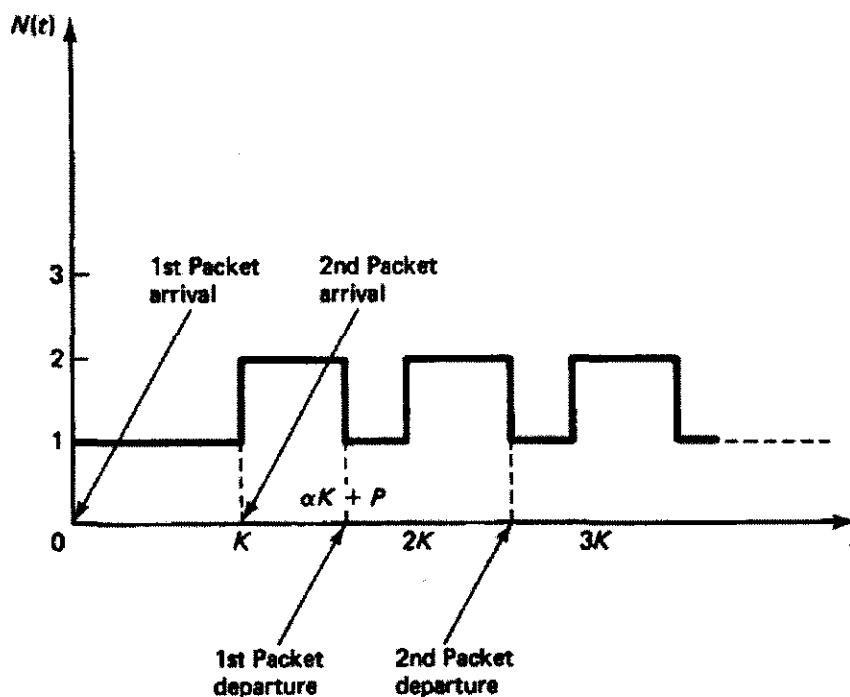


Figure 1 for question 1

2. In a fast-food restaurant, customers arrive at a rate of 100 per hour and take 30 seconds to be served. (10 Marks)
- How much time do they spend in the restaurant?
 - How much time waiting in line?
 - How many customers in the restaurant?
 - What is the server utilisation?

3. There are 2 questions (20 Marks)

- 3.1 Below is the pseudo code of TCP slow start mechanism. Please draw a graph of the source transmission rate (10 marks)

Initially:

```

cwnd = 1;
ssthresh = infinite;

```

New ack received:

```

if (cwnd < ssthresh)
    /* Slow Start*/
    cwnd = cwnd + 1;
else
    /* Congestion Avoidance */
    cwnd = cwnd + 1/cwnd;

```

Timeout: (loss detection)

```

/* Multiplicative decrease */
ssthresh = win/2;
cwnd = 1;

```

- 3.2 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).

4. **Figure 2** 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.

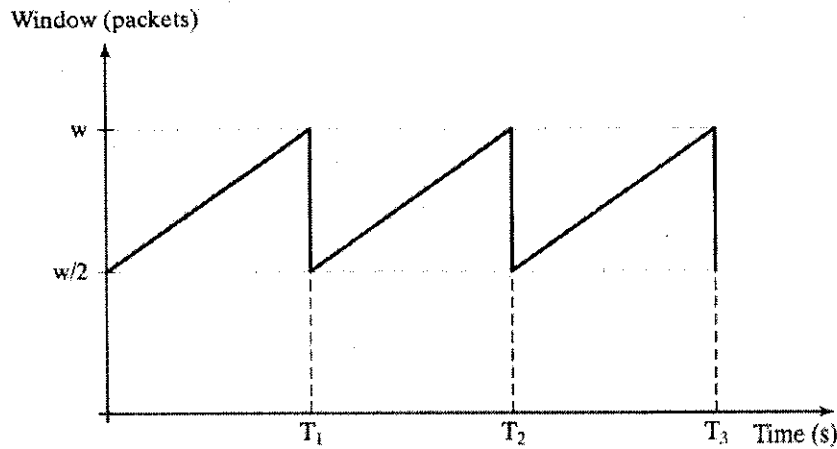


Figure 2 A periodic model of TCP window dynamic behaviour in steady state

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. Stop-and-Wait ARQ Protocol performance: use the below information to answer the following question. **Calculate the efficiency of Stop-and-Wait ARQ in the system that transmits at $R=1$ Mbps and with reaction time of 1 mse: for channels with a bit error rate of 10^{-6} , 10^{-5} , and 10^{-4} (be careful, these are not probability of frame loss).**

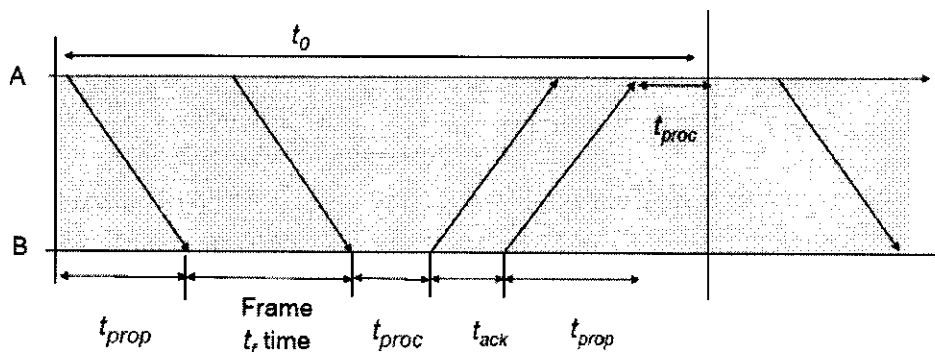


Figure 3 Delay components of Stop-and-Wait ARQ

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

$$\begin{aligned} t_0 &= 2t_{prop} + 2t_{proc} + t_f + t_{ack} \\ &= 2t_{prop} + 2t_{proc} + n_f/R + n_a/R \end{aligned}$$

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 needs to be re-transmitted.
- The probability of no error frames is $1 - P_f$

Stop-and-Wait ARQ on average requires $t_{SW} = t_0/(1 - P_f)$ seconds to get a frame through. Thus the efficiency of Stop-and Wait ARQ with packet loss is:

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

Suppose that frames are 1,250 bytes long including 25 bytes of overhead. Also assume that ACK frame are 25 bytes long.

The following information may be useful when students have to deal with queuing 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**

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

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**

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

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

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