Student ID: ....Student Name: ....

PRINCE OF SONGKLA UNIVERSITY
FACULTY OF ENGINEERING

Final Examination: Semester I
Date: 3rd October, 2012
Subject: 241-552 Queuing Networks for Communication Networks

Academic Year: 2012
Time: (2 hrs.) 13.30-15.30
Room: R200

ทุจริตในการสอบ โทษขั้นต่ำคือ ปรับตกในรายวิชาที่ทุจริต และพักการเรียน 1 ภาคการศึกษา

- In this exam paper, there are SEVEN questions. Answer ALL questions,
- All kinds of notes and books are **not** allowed,
- Answers could be either in Thai or English,
- Calculator is allowed,

---

1. As shown in 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. One session's traffic goes over all n links, while the rest of the traffic goes over only one link.
   a. What is the maximum throughput that can be achieved? How does this happen (or what is the scenario)? (5 Marks)
   b. However, if our objective is to provide equal rate to all sessions, what is the system throughput? (5 Marks)
   c. Alternatively, if our objective is to provide equal resources to all sessions, what is the system throughput? (5 Marks)

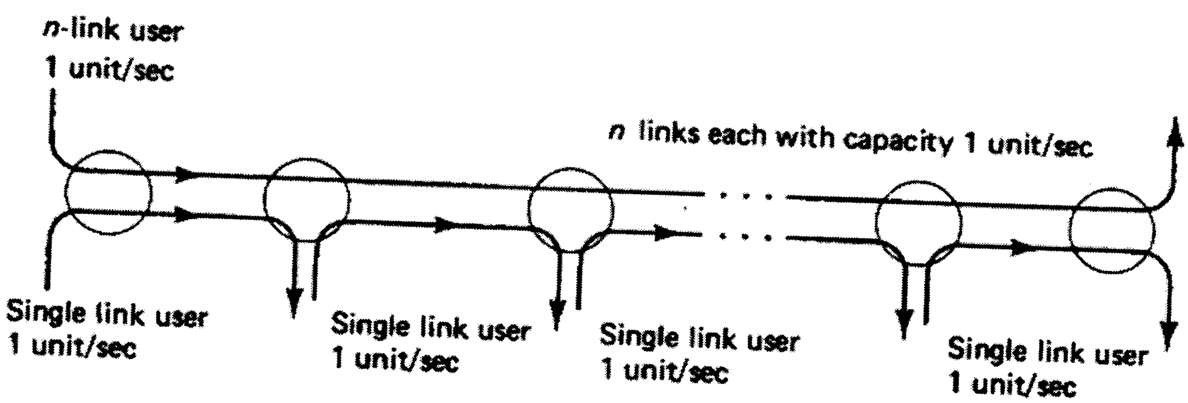


Figure 1 n-link user shares with n single-link users

Answer:

....

....

....

....

....

....

....

....

....

....

....

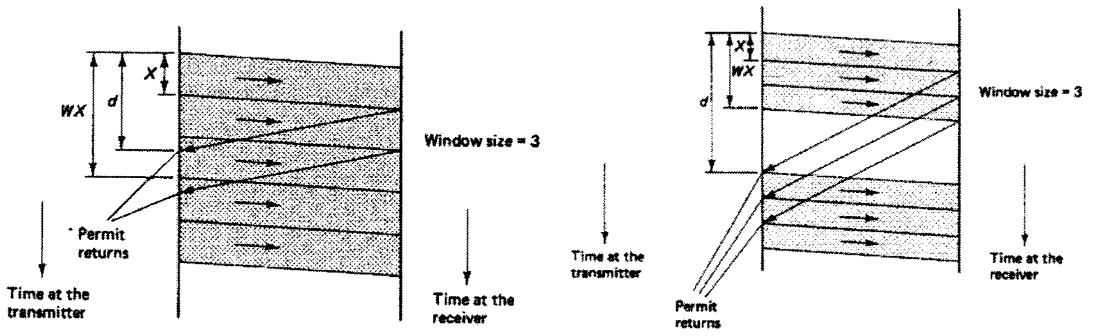
....

....

....

....

2. Suppose that 2 nodes of source and destination in the network given below are using ARQ system. There are 2 cases to be considered where the round trip time is smaller than the window size (Figure 2(a)), and the round trip time is greater than a full window of packets (Figure 2 (b)) (10 marks)



(a) (b)

Figure 2 Window flow control

Where:

d is the round-trip delay including round trip propagation delay, packet transmission time, and permit delay.

W is the window size,

X is the transmission time of a single packet at full speed.

Please show how to write a general equation to describe a transmission covering both cases.

Answer:

....

....

....

3. Using Figure 3 given below, explain how node-by-node windows for virtual circuits work (10 marks)

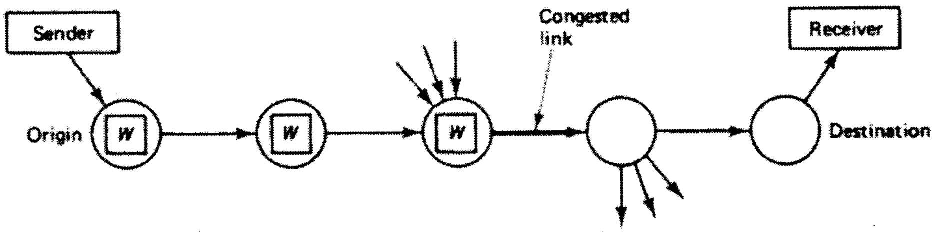
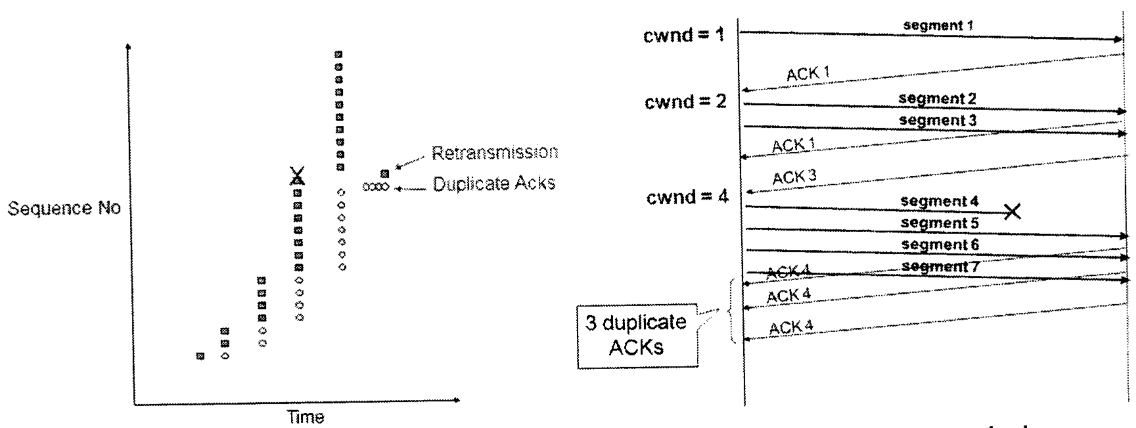


Figure 3 Node-by-node window flow control

<u>Answer</u>

4. "Fast retransmit" was introduced in a system known as 'TCP Reno'. The diagram in Figure 4 illustrates its behaviour.



(a)Fast re-transmission (b) Fast re-transmission

Figure 4 A sample of TRC Reno's behaviour.

Please draw the graph of TCP Reno's behaviour over time and window size, given and explanation (10 marks)

Answer:

Student ID: ....Student Name: ....

5. **Figure 5** depicts TCP periodic model, use the following information to answer the question below (15 marks)

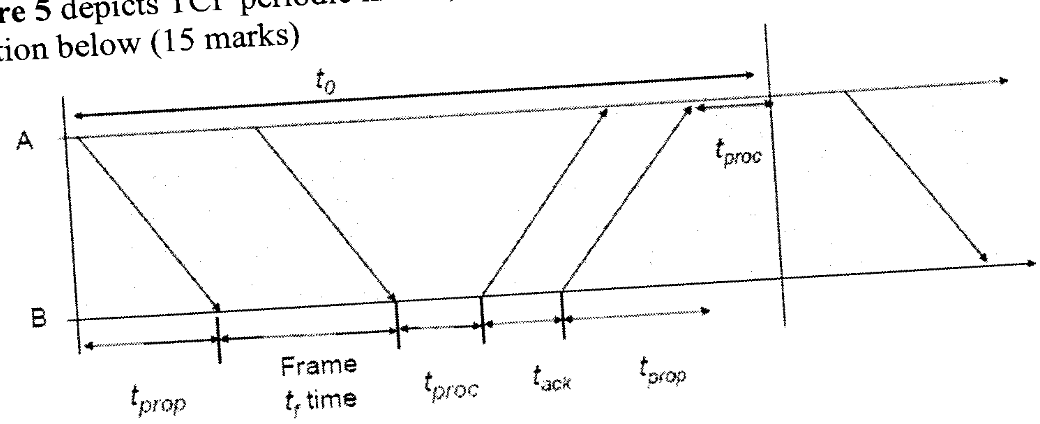


Figure 5 Delay components of Stop-and-Wait ARQ

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

$$t0 = 2tprop + 2tproc + tf + tack$$

$$= 2tprop + 2tproc + nf/R + na/R$$

Where

nf = number of bits in the information frame

Student ID: ....Student Name: ....

na = 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

$$Reff = (nf - n0)/t0$$

Where n0 = number of overhead bits in a frame (given by the total number of bits in the header and the number of CRC bits

- Let *Pf* be the probability that a frame transmission has errors and needs to be re-transmitted.
- The probability of no error frames is *1-Pf*

Stop-and-Wait ARQ on average requires *tSW=t0/(1-Pf)* 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 frame 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 10^-6, 10^-5, and 10^-4 (not probability of frame loss).

Answer:

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

6. This question concerns about TCP fairness (10 marks)

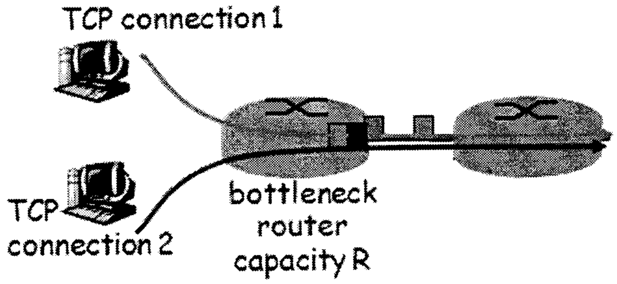


Figure 6 2 TCP connections share the same bottlenect router.

Fairness goal: if N TCP sessions share the same bottleneck link of bandwidth R, as shown in Figure 6, each should have average rate of R/N. Please explain why TCP is fair. Please use the graph given below, Figure 7, to show TCP fairness, how it works.

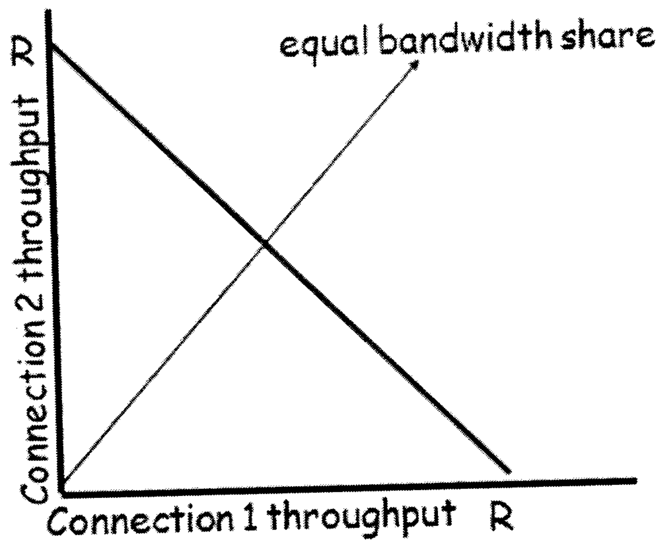


Figure 7 Connection throughputs of session 1 and session 2.

Answer

....

....

....

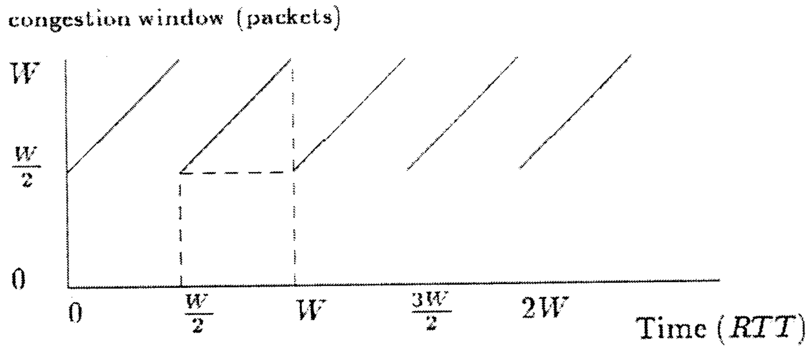
....

....

....

7. The graph in Figure 8 is TCP Periodic Model with the following assumptions:
   - The maximum window size is W,
   - The minimum window size is $W/2$,
   - Constant Packet loss Probability is p,
   - We approximate random packet loss at constant probability p by assuming that the link delivers approximately $1/p$ consecutive packets, followed by one drop,
   - TCP runs at steady state, so slow start (during start up) is not of concern.

Please show that this model gives "inverse square-root p law". (15 marks)



TCP window evolution under periodic loss

Each cycle delivers $(\frac{W}{2})^2 + \frac{1}{2}(\frac{W}{2})^2 = 1/p$ packets and takes $W/2$ round trip times.

Figure 8 TCP periodic model

Answer