**PRINCE OF SONGKLA UNIVERSITY**
**FACULTY OF ENGINEERING**

Final Examination: Semester I — Academic Year: 2011
Date: 5October 2011 — Time: 09.00 – 12.00
Subject: 241-552 Queueing and Computer Networks — Room: A400

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 could be either in Thai or English,
- Calculator is allowed,

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 can be achieved? How does this one happen (what scenario is)? (5 Marks)
   b. However, if our objective is to give equal rate to all session, what is the system throughput? (5 Marks)
   c. Alternatively, if our objective is to give equal resources to all session, what is the system throughput? (5 Marks)

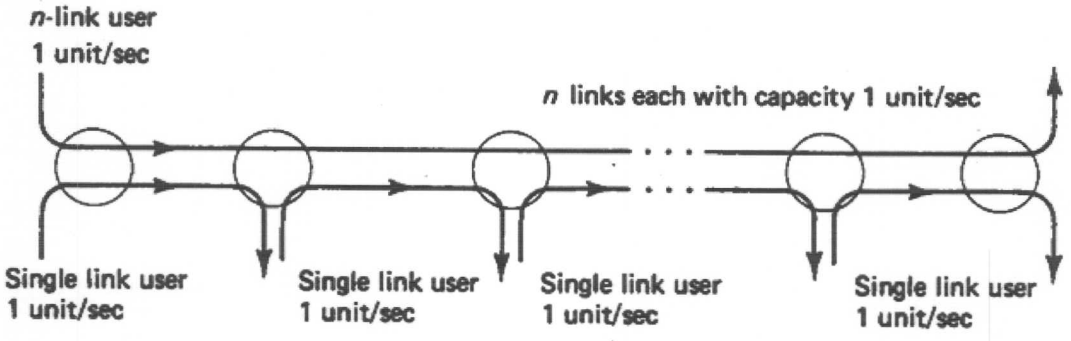


Figure 1 for question 1

**Answer:**

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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 a round trip time is smaller than a window size (Fig 2.(a)), and a round trip time is greater than a full window of packets (Fig 2. (b)).

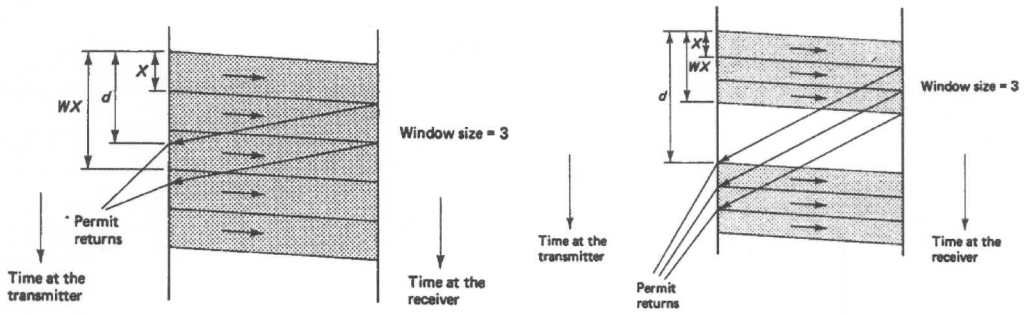


Figure 2 for question 2

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 the full speed.

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

**Answer:**

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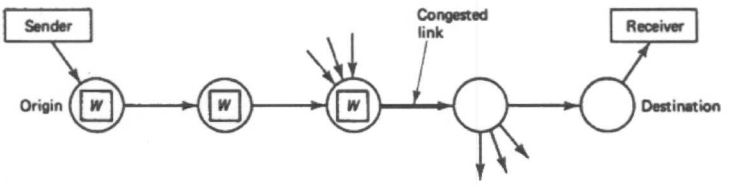
3. From figure given below, explain how node-by-node windows for virtual circuit works,




Answer

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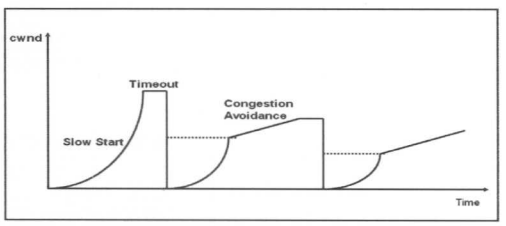
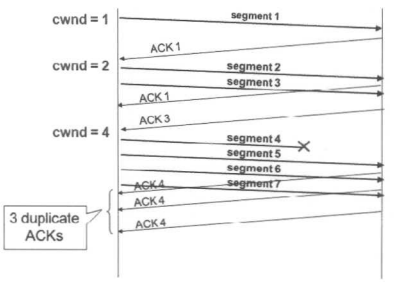
4. There are 2 questions:

4.1 The figure below shows 'TCP slow start' which has some drawbacks.




(a)TCP Slow start




(b) Fast re-transmission

The 'fast retransmit' was introduced, known as 'TCP Reno' with the following mechanism:

- Resend a segment after 3 duplicate ACKs
- Recall: a duplicate ACK means that an out-of sequence segment was received
- After a fast-retransmit set cwnd to ssthresh/2, i.e., don't reset cwnd to 1
- But when RTO expires still do cwnd = 1

Please draw the graph of TCP Reno's behavior and its explanation.

Answer:

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4.2 The given below traffic behavior is drawn from TCP periodic model where: Stop-and-Wait ARQ Protocol performance: use the following information to answer the question below.

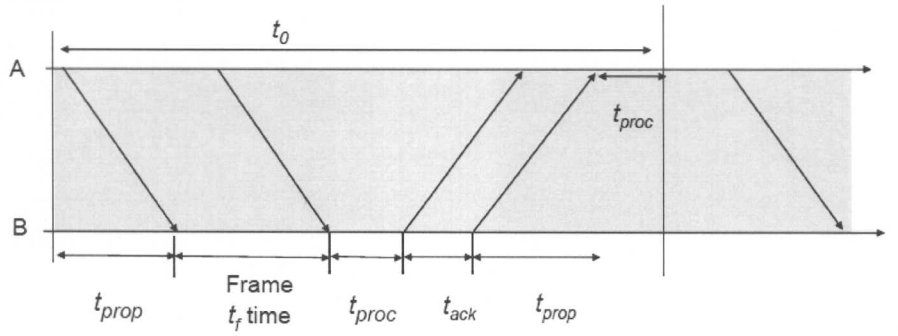


Figure 3 Delay components of Stop-and-Wait ARQ

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

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

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

Where

*nf* = number of bits in the information frame

*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:

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

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

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5. A small router has only one output port with a large single FIFO queue. Packets arrive at this output port at random from 1 to 8 seconds apart. Each possible value of inter arrival time has the same probability of occurrence, as shown in Table 1. The service times vary from 1 to 6 second with the probability shown in Table 2. Table 3 and Table 4 show a set of generated data for 20 packets of arrival and departure processes. The problem is to analyse the system by simulating the arrival and service of 20 packets. Please fill up an appropriated simulated data in. (20 Marks)

Table 1 Distribution of time between arrivals

| Time between arrival (seconds) | Probability | Cumulative probability | Random digit assignment |
|---|---|---|---|
| 1 | 0.125 | 0.125 | 001-125 |
| 2 | 0.125 | 0.125 | 126-250 |
| 3 | 0.125 | 0.125 | 251-375 |
| 4 | 0.125 | 0.125 | 376-500 |
| 5 | 0.125 | 0.125 | 501-625 |
| 6 | 0.125 | 0.125 | 626-750 |
| 7 | 0.125 | 0.125 | 751-875 |
| 8 | 0.125 | 0.125 | 876-000 |

Table 2 Service time distribution

| Service time (seconds) | Probability | Cumulative probability | Random digit assignment |
|---|---|---|---|
| 1 | 0.10 | 0.10 | 01-10 |
| 2 | 0.20 | 0.30 | 11-30 |
| 3 | 0.30 | 0.60 | 31-60 |
| 4 | 0.25 | 0.85 | 61-85 |
| 5 | 0.10 | 0.95 | 86-95 |
| 6 | 0.05 | 1.00 | 96-00 |

Table 3 Time-between-arrival determination

| Packet No. | Random digits | Time between arrivals (seconds) | Packet No. | Random digits | Time between arrivals (seconds) |
|---|---|---|---|---|---|
| 1 | - | - | 11 | 109 | 1 |
| 2 | 913 | 8 | 12 | 093 | 1 |
| 3 | 727 | 6 | 13 | 607 | 5 |
| 4 | 015 | 1 | 14 | 738 | 6 |
| 5 | 948 | 8 | 15 | 359 | 3 |
| 6 | 309 | 3 | 16 | 888 | 8 |
| 7 | 922 | 8 | 17 | 106 | 1 |
| 8 | 753 | 7 | 18 | 212 | 2 |
| 9 | 235 | 2 | 19 | 493 | 4 |
| 10 | 302 | 3 | 20 | 535 | 4 |

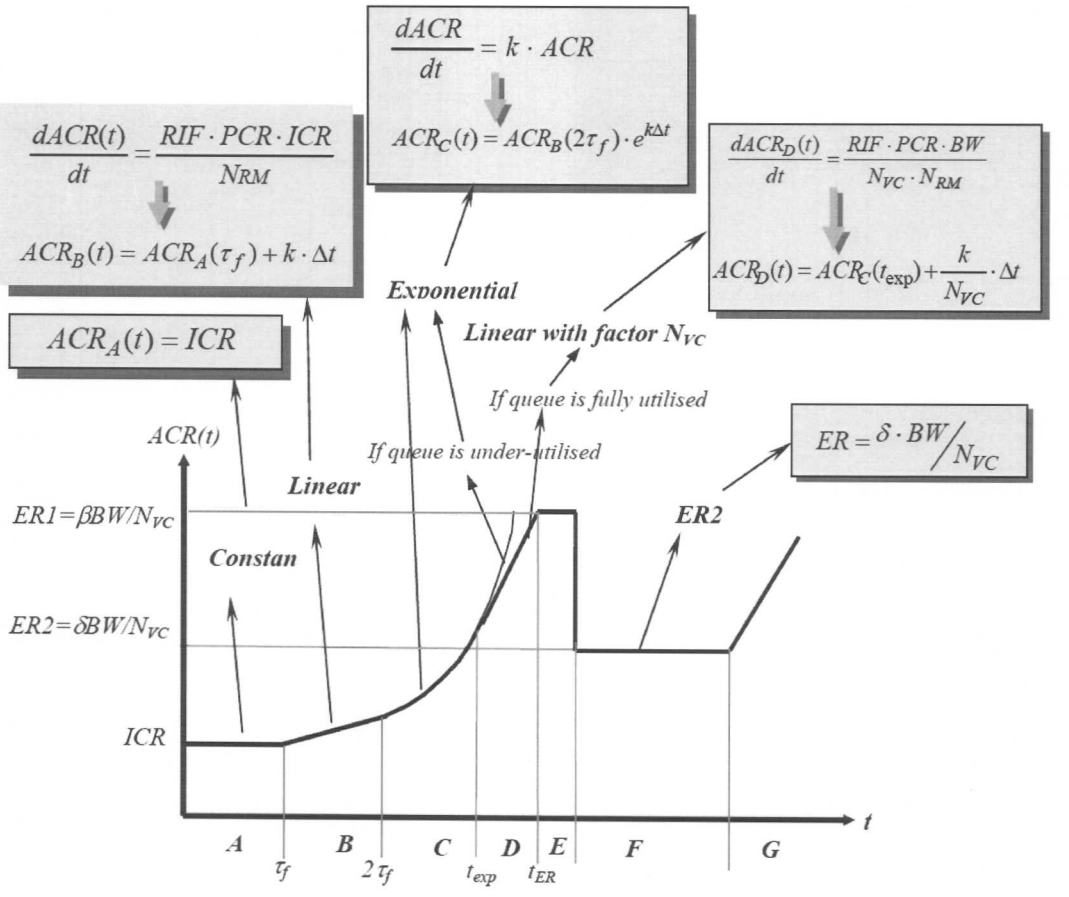
Table 4 Service time generated

| Packet No. | Random digits | Service time (seconds) | Packet No. | Random digits | Service time (seconds) |
|---|---|---|---|---|---|
| 1 | 84 | 4 | 11 | 32 | 3 |
| 2 | 10 | 1 | 12 | 94 | 5 |
| 3 | 74 | 4 | 13 | 78 | 4 |
| 4 | 53 | 3 | 14 | 05 | 1 |
| 5 | 17 | 2 | 15 | 79 | 5 |
| 6 | 79 | 4 | 16 | 84 | 4 |
| 7 | 91 | 5 | 17 | 52 | 3 |
| 8 | 67 | 4 | 18 | 55 | 3 |
| 9 | 89 | 5 | 19 | 30 | 2 |
| 10 | 38 | 3 | 20 | 50 | 3 |

Answer the following questions:

(a) What is the average waiting time for a packet? (3 Marks)
(b) What is the probability that a packet has to wait in the queue? (3 Marks)
(c) What is the system utilisation? (3 Marks)
(d) What is the average service time? (3 Marks)
(e) What is the average between arrivals? (3 Marks)
(f) What is the average time a packet spends in the system? (3 Marks)
(g) What is the average number of packets waiting in queue? (2 Marks).

6. From the graph shown below, please answer the following questions:
   - 6.1 Why is the transmission rate 'constant' during phase A?
   - 6.2 Why is the rate in phase B linearly increment?
   - 6.3 Why is the rate in phase C exponentially increment?
   - 6.4 There are 2 possibilities of phase D, please explain both of them how each one happens.



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

**(Used for Question 5)**

Table 5 Simulation table

| Packet No. | Time since last arrival (seconds) | Arrival time | Service time (seconds) | Time service begins | Time packet waits in queue (seconds) | Time service ends | Time packets spend in system (seconds) | Idle time of server |
|---|---|---|---|---|---|---|---|---|
| 1 | - | 0 | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
| 4 | | | | | | | | |
| 5 | | | | | | | | |
| 6 | | | | | | | | |
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**Answer:**

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