Name: **Student Number**:

THE UNIVERSITY OF MELBOURNE
Department of Electrical and Electronic Engineering

ELEN 90061 Communication Networks

Mid-Semester Test 2015

Time allowed: 50 minutes

This paper has 10 pages

Authorised materials:

Approved electronic calculators are permitted.

Mobile phones, tablets, and any other computing devices are NOT permitted!

This is a closed book and notes test!

Instructions to students:

Students should attempt **ALL** questions on the exam paper.

The marks for each question are indicated in brackets after the question.

The total marks for this test is **30**.

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Question 1 [8 marks]:

Please answer the following questions **briefly** with couple of sentences and/or calculations.

1.1 According to Metcalfe's law, what is the relationship between the value of a communication network and the number of its nodes? **[1 mark]**

> Bob Metcalfe postulated that the value of a network with N nodes is proportional to the number of connections that may be made between the nodes, or $O(N^2)$
> See Week 1 slides

1.2 List the two main things communication network protocols specify. **[1 mark]**

> Communication protocols define: 1) the format of messages, 2) order of messages sent and received among network 3) entities, actions taken on message transmission and receipt
> Any two of these is acceptable as an answer see Week 1 slides.

1.3 List the two major differences between connectionless and connection-oriented services. **[1 mark]**

> Connection oriented 1) keeps state at each end 2) end-to-end path setup
> Connectionless data is just forwarded to the destination.
> See Week 1 slides

1.4 List the two main disadvantages of the layered architecture in communication networks. **[1 mark]**

> 1) Encapsulation brings overhead. 2) Layers hide information preventing any cross-layer optimisation.
> See Week 1 slides.

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1.5 How does *Wavelength Division Multiplexing* WDM differ from *Frequency Division Multiplexing* FDM? **[1 mark]**

> Both are in fact similar and divide the channel the same way since wavelength x freq = light speed. WDM refers to multiplexing in fiber optics.
> See Week 2 slides.

1.6 Why is slotted ALOHA more efficient than pure ALOHA? **[1 mark]**

> Slotting in slotted ALOHA diminishes the chance of collisions as all frames have to start at the same time instance in a given slot. Therefore it is more efficient.
> See Week 2 slides.

1.7 Can a CSMA scheme prevent all collisions? Why? **[1 mark]**

> No. Collisions will still occur due to propagation delays and hidden terminal problem.
> See Week 2 slides.

1.8 What is a *Maximum Transmission Unit* (MTU)? **[1 mark]**

> The MTU is the maximum payload length for a particular transmission media, e.g. the MTU for Ethernet is typically 1518 bytes
> See Week 3 slides.

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Question 2 [10 marks]:

Consider the classic Ethernet with CSMA/CD, under heavy and constant load, and with ***k*** stations always ready to transmit. Assume for simplicity that each station transmits during a contention slot with probability ***p*** instead of the standard binary exponential back-off algorithm. Let the frame length be ***F***, the network bandwidth, ***B***, the cable length, ***L***, and the speed of signal propagation, ***c***.

Explain your answers for full credit. No explanation receives no credits!

2.1 Find the *minimum duration of* <u>*one*</u> *contention slot* in terms of the parameters defined above. **[2 marks]**

The propagation time for a frame to reach the other end of the cable is **τ=L/c**, the time it takes message to reach the other end of the cable.

Minimum duration is double the time to account for messages that have just started before τ at the other hand and/or for the collision noise to reach back to original sender.

Therefore, minimum duration is **2τ=2L/c**

2.2 If each station transmits during a contention slot with probability ***p***, find the probability ***A*** that some station acquires the channel in a slot, in terms of the parameters defined above.
. **[4 marks]**

Probability of one of the stations to acquire channel in a given slot: $p(1-p)^{k-1}$, i.e. one station transmits <u>and</u> all others (k-1) do not transmit.

A=some station acquires the channel in a slot=P(station 1 acquires)+ P(station 2 acquires)+….+ P(station k acquires)=k P(a station acquires)

Therefore, **A= $k\,p(1-p)^{k-1}$**

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2.3 Let the mean contention interval be ***e*** *times the duration of one contention slot*, which was derived in Part 1. Find the channel efficiency of the classical Ethernet under the assumptions made in terms of the given parameters.
Hint: *consider the transmission time of a single frame and contention overhead.*

[4 marks]

Mean contention interval is then **2τe=2Le/c.**

The time it takes to transmit a frame is T=F/B.

Efficiency is then given by $$\frac{T}{T+overhead} = \frac{T}{T+2\tau\mathrm{e}} = \frac{\frac{F}{B}}{\frac{F}{B}+\frac{2Le}{c}} = \frac{1}{1+\frac{2LeB}{cF}}$$

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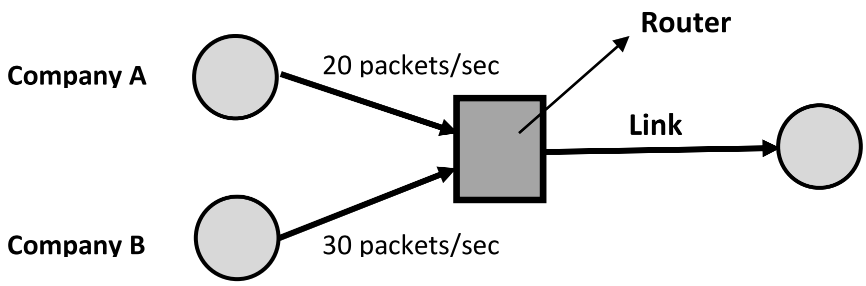
Question 3 [12 marks]:



Two different companies send their data through a single router to a data communication link. Company A generates Poisson traffic at a rate of 20 packets/sec. Company B generates Poisson traffic at a rate of 30 packets/sec. The packet lengths are exponentially distributed with a mean of 1000 bits. The transmission link has a capacity of 100 kbits/sec. There is a fixed propagation delay of 50 msec on the link. Assume that the router has infinite buffer for queuing packets.

Explain your answers for full credit. No explanation receives no credits!

3.1 A packet arrives to the router from Company A. Find its <u>average waiting time in the queue</u> given that it has just arrived. **[5 marks]**

Since both arrivals are Poisson, their sum is also Poisson with mean $\lambda = \lambda_A + \lambda_B = 50$ packets/sec. Therefore, this is an M/M/1 system. Hence, PASTA (Poisson arrivals see time averages) property holds and it is sufficient to find the average waiting time from M/M/1.

μ=100kbps/1kbits=100. Hence, $\rho=\lambda/\mu=50/100=0.5$

Waiting time in the queue is $W = \frac{\rho}{\mu-\lambda} = \frac{0.5}{100-50} = 0.01sec = 10msec$

Note that, this formula can be derived from the formula sheet using $W=N_q / \lambda$.

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3.2 Find the average total time a packet spends in the system, including the time spent at the router and on the link (until reaching the destination). **[3 marks]**

Average total time is $T=W+1/\mu+d_{prop}$.

Therefore, T=10msec+ 10msec+ 50 msec=70msec

3.3 Find the average number of packets that belong to Company B in the system, including those still in the router and on the link. **[4 marks]**

Average total time is $T=W+1/\mu+d_{prop}$ = 70msec

Using Little's law: $N_B=\lambda_B T$ = 30 packets/sec x 0.07 sec= 2.1 packets (on average)

END OF EXAM

Useful formulas

$$General: \quad N = \lambda T$$

$$P(X = x) = \frac{\lambda^x e^{-\lambda}}{x!} \ \ (Poisson)$$

$$f_X(x) = \lambda e^{-\lambda x}, \ x \geq 0 \ \ (Exponential)$$

$$p_k = p_0 \prod_{i=0}^{k-1} \frac{\lambda_i}{\mu_{i+1}} \ \ (General\ balance)$$

$$M/M/1: \quad \rho = \frac{\lambda}{\mu}$$

$$p_k = (1-\rho)\rho^k$$

$$\bar{N}_q = \frac{\rho^2}{1-\rho}$$

$$P[\geq k\ in\ system] = \rho^k$$

$$M/M/m: \quad \bar{N}_q = \left(\frac{(m\rho)^m \rho}{m!(1-\rho)^2}\right) p_0$$

$$p_0 = \left[\sum_{k=0}^{m-1} \frac{(m\rho)^k}{k!} + \frac{(m\rho)^m}{m!} \frac{1}{1-\rho}\right]^{-1}$$

$$\rho = \frac{\lambda}{m\mu}$$

$$p_k = p_0 \frac{(m\rho)^k}{k!}, \quad k \leq m, \ \rho < 1$$

$$p_k = p_0 \frac{(m\rho)^k}{m! m^{k-m}}, \quad k > m, \ \rho < 1.$$

$$P[queueing] = \frac{\frac{(m\rho)^m}{m!} \frac{1}{1-\rho}}{\left[\sum_{k=0}^{m-1} \frac{(m\rho)^k}{k!} + \frac{(m\rho)^m}{m!} \frac{1}{1-\rho}\right]} \ (Erlang\, C)$$

$$M/M/\infty: \quad \bar{N} = \frac{\lambda}{\mu}$$

$$M/M/1/K: \quad \bar{N}_q = \frac{\lambda/\mu}{1-\lambda/\mu} - \frac{(\lambda/\mu)\left[K(\lambda/\mu)^K + 1\right]}{1-(\lambda/\mu)^{K+1}}$$

$$M/M/1/K: \quad p_k = \frac{1-\rho}{1-\rho^{K+1}}\rho^k,\ 0 \le k \le K, \rho \ne 1.$$

$$p_k = 0,\ \text{otherwise.}$$

$$M/M/m/m: \quad p_m = \frac{(\lambda/\mu)^m/m!}{\sum_{k=0}^{m}(\lambda/\mu)^k/k!}\ (Erlang\,B)$$

$$M/G/1: \quad W = \frac{\lambda\overline{X^2}}{2(1-\rho)} = \frac{\lambda\overline{X^2}}{2(1-\lambda\bar{X})}$$

$$W = \frac{\lambda\overline{X^2}}{2(1-\rho)} + \frac{\overline{V^2}}{2\overline{V}}\ (with\ vacations)$$

$$\text{Non-preemptive priority}: \quad W_k = \frac{R}{(1-\rho_1-\cdots-\rho_{k-1})(1-\rho_1-\cdots-\rho_k)}$$

$$R = \frac{1}{2}\sum_{i=1}^{n}\lambda_i\overline{X_i^2}$$

$$\text{Preemptive resume priority}: \quad T_k = \frac{\frac{1}{\mu_k}(1-\rho_1-\cdots-\rho_k)+R_k}{(1-\rho_1-\cdots-\rho_{k-1})(1-\rho_1-\cdots-\rho_k)}$$

$$R_k = \frac{1}{2}\sum_{i=1}^{k}\lambda_i\overline{X_i^2}$$

$$G/G/1: \quad W \le \frac{\lambda(var^2_{intarrival} + var^2_{service})}{2(1-\rho)}$$