Professional Engineers of Ontario

National Examinations – May 2018

16-Elec-B4, Information Technology Networks

3 Hours Duration

Notes:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper a clear statement of any assumptions made.
2. This is a **closed book** exam. **One of two calculators is permitted - any Casio or Sharp approved model.**
3. There are **5 questions** on this exam. **Any 4 questions constitute a complete paper.** Only the first 4 questions as they appear in your answer book will be marked, unless you **clearly** indicate which questions you want marked **on the front of your exam booklet.**
4. Marks allocated to each question are noted in the left margin. A complete paper is worth 100 marks.

(25 marks) **Question 1.** This question concerns cellular telephony.

(15 marks)   a. In the LTE downlink, consider an OFDM symbol

$$s(t) = \sum_{i=1}^{K} X(i)e^{j2\pi \frac{i}{T_s}t}$$

where T_s is the symbol duration, K is the number of subcarriers, and $X(i)$ is the information sent to the ith user. In the absence of noise, the following detector is used for the rth symbol:

$$d_r = \frac{1}{T_s} s(t)e^{-j2\pi \frac{r}{T_s}} dt.$$

Show that $d_k = X(k)$.

(5 marks)   b. In LTE, the physical resource block (PRB) contains 7 OFDM symbols, descrived in part a, with each symbol using 12 subcarriers. Suppose each symbol is selected from a 16-QAM constellation, and suppose four symbols from the entire PRB are used as reference symbols to estimate the channel, and cannot be used for data. If the PRB lasts 0.5 ms, what is the peak data rate of a PRB (in bits/s)?

(5 marks)   c. A city of size 42 km² is to be covered by a digital cellular phone network. The spectrum re-use cluster size is 7 cells, and each cell has area 1 km². Assume that the cells perfectly fit the city size without overlap. If the system bandwidth is 35 MHz, and FDM is used where each user is allocated 25 kHz including guardband, how many users can simultaneously use the system? How many can simultaneously use the system per cell?

(25 marks) **Question 2.** This question concerns transport layer protocols.

(5 marks)   a. Suppose you have a video streaming application over a mobile wireless link. Would you use TCP or UDP? Briefly explain your choice.

(5 marks)   b. Why does network congestion lead to dropped packets in wired networks?

(5 marks)   c. Using TCP, suppose the initial window size is 1, and the congestion threshold is 32. Assuming all packets are acknowledged, give an example showing how the window size evolves up to and beyond the threshold.

(5 marks)   d. Repeat part b, assuming a packet in the third window is not acknowledged, and TCP enters slow start. In your example, illustrate all relevant features of TCP.

(5 marks)   e. In a wired network, packet loss is usually caused by congestion, but in a wireless network, packet loss is often caused by momentary fading. Explain why "slow start" leads to poor performance in wireless networks.

(25 marks) **Question 3.** This question concerns shortest-path routing.

Apply Dijkstra's algorithm to find the paths from **node A** to all other nodes in the following network, with the given edge distances. Show all work; credit will not be awarded unless Dijkstra's algorithm is correctly followed.
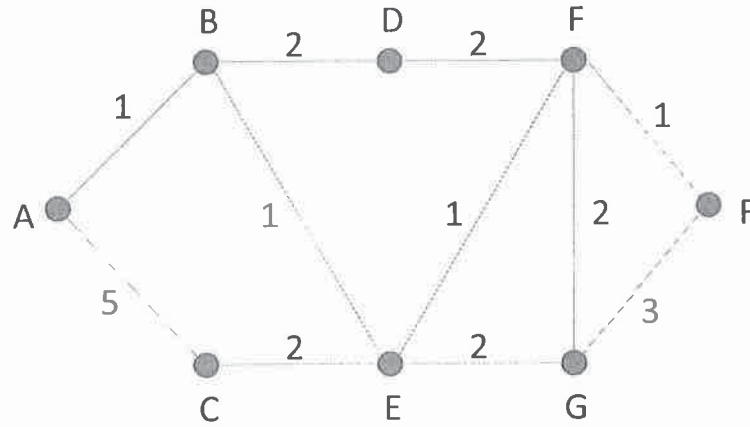
(25 marks) **Question 4.** This question concerns the WiFi and Bluetooth wireless protocols.

(5 marks)   a. Briefly describe the structure of a Bluetooth piconet, including Master, Slave, and Parked devices. How many of each type of device are allowed?

(5 marks)   b. Frequency hopping spread spectrum is used to share the medium among devices in a Bluetooth piconet. Briefly explain how this works.

(5 marks)   c. Suppose two Bluetooth piconets are operating at the same time. For simplicity, assume their frequency hops are synchronized. If Bluetooth uses 79 hop carriers, each with 1 MHz of bandwidth, what is the probability that there will be a collision in a given slot?

(5 marks)   d. In a WiFi network, what services are provided by each of Basic Service Set (BSS) and Extended Service Set (ESS)?

(5 marks)   e. Briefly describe medium access sharing in WiFi, making specific reference to inter-frame spacing.

(25 marks) **Question 5.** This question concerns layered architecture.

(10 marks)   a.   Name each layer of the OSI seven-layer model, and describe it in one sentence. (Be brief; marks may be deducted for unnecessary detail!)

(10 marks)   b.   Of the seven layers in the OSI model, name the layer (or layers, if more than one) where each of the following is used or found.

      i.   End-to-end error correction and in-order packet delivery.
      ii.   The SMTP protocol.
      iii.   TCP/IP.
      iv.   Ethernet.
      v.   Signal voltages.
      vi.   Encryption and decryption.
      vii.   Character display, such as ASCII.
      viii.   The HTTP protocol.

(5 marks)   c.   Why is layered architecture used in complex networks, such as the internet?