ORIGINAL

NATIONAL UNIVERSITY OF SINGAPORE
FACULTY OF ENGINEERING

EXAMINATION FOR
(Semester II : 2016/2017)

EE5132 – WIRELESS AND SENSOR NETWORKS

April / May 2017 – Time Allowed: 2 Hours

INSTRUCTIONS TO CANDIDATES

1. This paper contains **FOUR (4)** questions and comprises **SIX (6)** printed pages.
2. Answer **ALL** questions.
3. The examination paper carries **100 marks** in total.
4. This is a **CLOSED BOOK** examination. However, candidates are allowed to bring **ONE** A4 sheet of information.
4. Supplementary Information is provided in Page 6.
5. Programmable calculators are **NOT ALLOWED**.

Q.1 (a) Assuming the speed of a vehicle is 20 m/s, carrier frequency, f_c = 900 MHz, propagation speed, $c = 2.5 \times 10^8$ m/s and rms delay spread $\tau_d = 2$ μsec, calculate the coherence bandwidth. At a coded symbol rate of 19.2 kbps and a normalized fade margin, $A^2/(2\sigma^2)$, of 0.02, what percentage of time will fading be encountered? Is it slow or fast fading?

(13 marks)

(b) Under the CSMA/CA protocol, suppose there are n users and the contention window for each user is W. What is the collision probability?

(6 marks)

(c) In a CSMA protocol, the persistent value p is varied as a function of load G, from 1 to 0.5 to 0.1 to 0.01. Describe how you would select the persistent value p for different load values of G? Is there any specific advantages of having such changes?

(6 marks)

Q.2 (a) A WLAN accommodates 50 stations running the same application. The transmission rate per station is 2 Mbps and the stations use slotted ALOHA protocol. The total traffic produced by the stations is assumed to form a Poisson process. What is the maximum throughput in Erlangs? What is the maximum throughput in Mbps? What is the maximum throughput in Mbps for each station?

(5 marks)

(b) An ad hoc network of 8 nodes is shown in Figure Q.2.

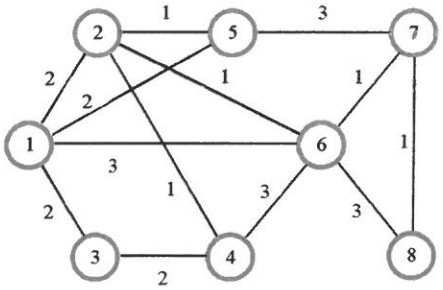

Figure Q.2

i. Determine the link costs from node 1 to all the other nodes using the Dijkstra algorithm

(7 marks)

ii. Determine the link costs from node 1 to all the other nodes using the Bellman-Ford algorithm

(7 marks)

(c) What are the advantages and disadvantages of reactive and proactive routing protocols? Under what conditions are each of these protocols preferred.

(6 marks)

Q.3 (a) In the μAMPS wireless sensor node, there will be a nett energy saving for making a transition from the active state to a lower energy state if the idle time t_i is larger than the transition time threshold T_{th} shown in the fourth column of Table Q.3.

State	P_k (mW)	τ_k (ms)	$T_{th,k}$ (ms)
Active	1040	-	-
Ready	400	5	8
Monitor	270	15	20
Look	200	20	25
Sleep	10	50	50

Table Q.3. Energy states, power, latency and thresholds for node k.

The sensors of the node remain on for all states except the Sleep state and can cause the node to make a transition from that state to the active state when an event is detected. If the probability that at least one event occurs in duration T_{th} is given by

$$p_{th,k}(T_{th}) = 1 - e^{-\lambda_k T_{th}}$$

where λ_k is the event arrival rate, determine the probability that there will NOT be nett energy saving for each of the Ready, Monitor and Look states. The node has been switched on for 100 seconds and 25 events have been observed.

(10 marks)

(b) Based on energy consumption considerations, should the radio of a wireless sensor node be turned off when it is not in use? What are the factors to bear in mind when answering this question?

(8 marks)

(c) There are 4 feature vectors in a training set where 2 of them are from class A and 2 of them are from class B: (1,1) (class A), (2,1) (class A), (1,2) (class B) and (2,2) (class B). Determine the class that a test feature vector (1.6,1.6) will be classified as when the nearest neighbour (NN) classification method is used.

(7 marks)

Q.4 (a) Draw the timeline of operation of the LEACH (Low Energy Adaptive Clustering Hierarchy) protocol showing key aspects such as start-up phase, steady state phase, round, slot and time division multiple access (TDMA) schedule or frame.
Is there any other significant duration that is longer than a round?

(9 marks)

(b) What are the shortcomings of the standard LEACH algorithm?

(6 marks)

(c) Describe a method that can alleviate these shortcomings and draw the flowchart of this method for the operations at each node.

(10 marks)

SUPPLEMENTARY INFORMATION

Gaussian distribution: $$p(x) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left[\frac{\left(x-\bar{x}\right)^2}{2\sigma^2}\right]$$

Rayleigh distribution: $$p(x) = \frac{x}{\sigma^2} e^{-\frac{x^2}{2\sigma^2}}$$

Rician distribution: $$p(x) = 2x(1+K_R)\exp\left[-x^2(1+K_R) - K_R\right] I_0\left(\sqrt{4[1+K_R]K_R}\right)$$

Fading – Average level crossing rate: $$N_A = \sqrt{2\pi} f_d \frac{A}{\sqrt{2}\sigma} e^{-\frac{A^2}{2\sigma^2}}$$

Fading – Average fade duration: $$\bar{t}_F = \frac{1}{\sqrt{2\pi} f_d} \frac{\sqrt{2}\sigma}{A}\left[e^{\frac{A^2}{2\sigma^2}} - 1\right]$$

Fading – Average inter-fade duration: $$\bar{t}_{IF} = \frac{1}{\sqrt{2\pi} f_d} \frac{\sqrt{2}\sigma}{A}$$

ALOHA – Probability of successful transmission: $$P(0) = e^{-2T_{tom}\lambda}$$

Slotted ALOHA – Probability of successful transmission: $$P(0) = e^{-T_{tom}\lambda}$$

END OF PAPER