ORIGINAL

NATIONAL UNIVERSITY OF SINGAPORE

EXAMINATION FOR

(Semester II : 2015/2016)

EE5132 – WIRELESS AND SENSOR NETWORKS

April / May 2016 – 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) A vehicle moving at 20 m/s communicates with a radio tower at a carrier frequency of 200 MHz and a propagation speed of 2.5 x 10^8 m/s. If the average bit error probabilities are 10^{-2} and 10^{-6} in and outside a fade, respectively, determine what is the normalized fade margin, $A^2 / (2\sigma^2)$, to attain an overall bit error probability of 10^{-4}.

(10 marks)

(b) Terminals A, B and C have a data packet each to send to Terminal D using the CSMA/CA protocol. Suppose that the maximum propagation delay is δ seconds, and DIFS is 4δ, SIFS is 2δ, and the transmission durations of the data packet and ACK packet are 8δ and 4δ, respectively. Terminal A has a backoff time of 3δ, Terminal B has a backoff time of 5δ, and Terminal C has a backoff time of 4δ. From the moment that the channel is first sensed to be idle, determine the total time when Terminal C will complete its successful transmission, including receiving the acknowledgement.

(10 marks)

(c) Briefly describe two methods in which wireless networks mitigate the occurrence of path loops.

(5 marks)

Q.2 (a) Consider an ad hoc network in which data packet transmission is to take place from node X to node Y. The route has already been established and a data packet is to be transferred over n hops. To transfer the packet, the k^{th} node uses the following medium access protocol:

- It waits for time $t(k)$ after the channel becomes free.
- It transfers the data packet to the next hop in α time units.
- It receives an acknowledgement, which takes another $\alpha/2$ time units.

The time $t(k)$ before the k^{th} node actually transmits the data packet is given by $t(k) = k\alpha$ time units.

i. Find an expression for the time taken for the data to cover n hops, i.e., from node 1 to node $n + 1$.

[Hint: $\sum_{i=1}^{n}\left[i+\frac{3}{2}\right]=\left(\frac{n^2}{2}+2n\right)$]

(10 marks)

ii. If the time taken to traverse n hops is $T = 2n\sqrt{n\alpha}$, what is the value of n?

(5 marks)

(b) A snapshot of an ad hoc network is shown in Figure Q.2.

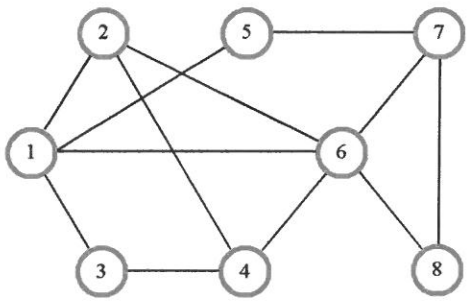

Figure Q.2

i. Describe how you find a route from the source node 1 to the destination node 7 using the DSR algorithm.

(5 marks)

ii. What changes would you do to part (b).i if you use the AODV protocol?

(5 marks)

Q.3 (a) Eight nodes are connected in a network as shown in Figure Q.3 where the individual link costs are also indicated.

i. Using the Dijkstra algorithm, determine the optimum paths from node 1 to the other 7 nodes.

(10 marks)

ii. Using the Bellman-Ford algorithm, determine the optimum paths from node 1 to the other 7 nodes.

(10 marks)

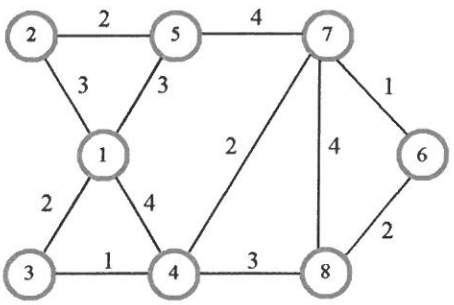

Figure Q.3

(b) Explain how the MACAW protocol improves node fairness.

(5 marks)

Q.4 In a sensor network, the energy consumed by different functions by a sensor are as follows:

Mode	Energy consumed (nJ/bit)
Sleep mode	0
Sensing or idle mode	0.5
Aggregation	5
Communication to cluster head	100
Cluster head to base station	1000

Assume that the total number of nodes is P, the number of non-cluster nodes is n, the number of cluster heads is m, and the frame size is B bits.

(a) Find the power consumption, during a frame period if sensing and communication to the cluster head are done during every frame, assuming that half the nodes are sleeping at any one time.

(6 marks)

(b) Find the power consumption in the idle frame when sensing and communication to the cluster head is done in every alternate frame. Remember that power is consumed even in sleeping mode of the cycles, when sensing is not carried out.

(3 marks)

(c) Find the total power consumption in different frames if sensing is done every alternate cycle, while transmission to the cluster head is done every fourth frame.

(8 marks)

(d) Repeat part (c) if there are 10 clusters, with each cluster consisting of 8 sensor nodes and aggregation is done by the cluster head every 8 frames while the cluster head to the base station communication takes place every 16-frames.

(8 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