ORIGINAL

NATIONAL UNIVERSITY OF SINGAPORE

EXAMINATION FOR

(Semester II : 2017/2018)

EE5132 – WIRELESS AND SENSOR NETWORKS

April / May 2018 – Time Allowed: 2 Hours

INSTRUCTIONS TO CANDIDATES

1. Please write your student number only. Do not write your name.
2. Please write the answers for each question on a new page.
3. This paper contains **FOUR (4)** questions and comprises **SIX (6)** printed pages.
4. Answer **ALL** questions.
5. The examination paper carries **100 marks** in total.
6. This is a **CLOSED BOOK** examination. Students are allowed to bring in **one A4 size help sheet**.
7. Supplementary Information is provided on Page 6.
8. Programmable calculators are **NOT ALLOWED**.

Q1. (a) An ad hoc network of 8 nodes is shown in Figure Q1.

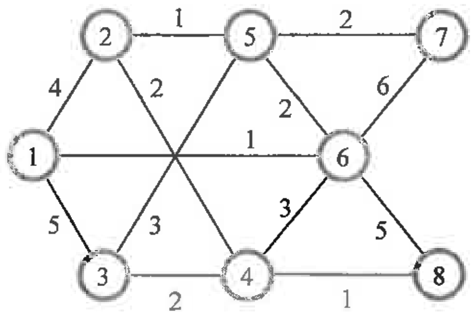

Figure Q1.

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)

(b) An ad hoc network has 80 mobile nodes, and node mobility results in one radio link being broken and another being established every 2 seconds. Each node is connected to exactly 3 adjacent nodes.

i. If a table-driven routing protocol is used and update messages are sent every 4 seconds, what is the average the number of update messages sent per second. Explain your answer.

(6 marks)

ii. If the destination node is located 7 hops apart from a given source node, what is the maximum possible number of alternate paths of length 7 hops.

(5 marks)

Q2. (a) In a slotted ALOHA satellite system, the average rate of arrival of packets, λ, is 10 packets/s, the data transmission rate is 100 kbits/s and the packet size is 10,000 bits which is also the size of a slot. Packet collisions result in retransmission attempts. Starting from a base backoff window of 1 slot, every failed transmission attempt results in a doubling of the backoff window. Assume that the ACK data packet also occupies one slot time, the ACK timeout is one time slot and the propagation delay is 0.2 seconds. Determine the average delay to successfully transmit a data packet.

(6 marks)

(b) Nodes A and B each have a data packet to transmit to node C as shown in Figure Q2. The CSMA/CA protocol based on RTS-CTS-DS-Data-ACK is used. Suppose that the propagation delay is α, and SIFS = 2α, DIFS = 4α, RTS = CTS = DS = ACK = 8α, and Data = 50α. Node A has a backoff of 4α and node B has a backoff of 7α. Determine the total time to complete the successful transmissions of both packet transmissions from nodes A and B, from the moment the channel first became available.

(7 marks)

Figure Q2.

(c) Briefly describe the differences between the Multi-Channel MAC (MMAC) protocol and the Multi-radio Unification Protocol (MUP) that are used for wireless mesh networks.

(6 marks)

(d) In a free space propagation environment, the transmission power is 1000 watts, the receiver is 10 km from the transmitter, the carrier frequency is 5 GHz, the transmitter and receiver gains are 10, the effective radii of the transmitter and receiver is 1 m, and the speed of propagation is 3×10^8 m/s.

i. Determine the receiver power.

(3 marks)

ii. Determine the power loss in dB.

(3 marks)

Q3. (a) Why is the *Mahalanobis distance* a good information utility measure for sensor selection in an information-driven sensor querying (IDSQ) sensor network?

(7 marks)

(b) In an IDSQ sensor network, the leader sensor node *S1* is at location $[45\ 70]^T$. Sensor node *S2* is at location $[30\ 40]^T$ and sensor node *S3* is at location $[60\ 50]^T$. *S1* holds the current belief related to the position of the target. The belief state is assumed to be well-represented by a Gaussian distribution, with current estimated mean, $\hat{x}$, and covariance, Σ, as shown below:

$$\hat{x} = \begin{bmatrix} 45 \\ 55 \end{bmatrix} \qquad \Sigma = \begin{bmatrix} 5 & 20 \\ 20 & 5 \end{bmatrix}$$

The composite objective function for selecting the next sensor has an information utility term and a communication cost term, with γ and $(1-\gamma)$ weighting between them, respectively. Using an information utility measure based on the Mahalanobis distance and a communication cost measure based on square of distance with $\gamma = 0.75$, determine whether sensor node *S2* or *S3* should be selected.

(10 marks)

(c) Explain what is the *probability of false alarm* for a particular class and write down its expression in terms of the elements of a confusion matrix.

Determine the probability of false alarm for each class in the following confusion matrix:

$$\begin{bmatrix} 27 & 7 & 6 \\ 10 & 32 & 8 \\ 5 & 9 & 29 \end{bmatrix}$$

(8 marks)

Q4. (a) Name two sources of energy wastage in a medium access control (MAC) protocol and explain how sensor network MAC protocols like S-MAC and B-MAC attempt to mitigate these effects.

(8 marks)

(b) Explain with the aid of a diagram the process of Clear Channel Assessment (CCA) in the B-MAC protocol.

How does it overcome the problem of false negatives encountered in other schemes?

How is the result of CCA used differently by a sender and a receiver?

(10 marks)

(c) Draw the timing diagram for a sender-receiver pair which shows the *preamble sampling* scheme in B-MAC. Indicate the *check interval* and *preamble* clearly on the timing diagram.

What is the drawback of having a long preamble?

(7 marks)

SUPPLEMENTARY INFORMATION

Relationship between antenna gain and effective area $G = \frac{4\pi A_e}{\lambda^2} = \frac{4\pi f^2 A_e}{c^2}$

Received power $P_r = \frac{A_e G_r P_t}{4\pi d^2}$

Transmitter/Receiver gain $G_{t/r} = \frac{4\pi A_e}{\lambda^2}$

Free space loss, isotropic antenna $\frac{P_t}{P_r} = \frac{(4\pi d)^2}{\lambda^2} = \frac{(4\pi f d)^2}{c^2}$

Free space loss, accounting for antenna gains $\frac{P_t}{P_r} = \frac{(4\pi)^2 (d)^2}{G_r G_t \lambda^2} = \frac{(\lambda d)^2}{A_r A_t} = \frac{(cd)^2}{f^2 A_r A_t}$

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

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: $P(0) = e^{-2T_{txm}\lambda}$

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

END OF PAPER