NATIONAL UNIVERSITY OF SINGAPORE

EE5132 – WIRELESS AND SENSOR NETWORKS

(Semester II : 2019/2020)

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. This is a **CLOSED BOOK** examination. One A4 sheet written on both sides is allowed.
4. Programmable calculators are **NOT ALLOWED**.

Q.1 (a) A cyclist carrying a smartphone is moving at a speed of 3 m/s away from a cellular base station. The smartphone is connected to the Internet using a 4G+ data connection operating at a carrier frequency of 2.6 GHz and experiences Rayleigh fading. The data transmission rate is 350 Ksymbols/s, the normalized fade margin $A/(\sqrt{2}\sigma)$ is 0.1 and the speed of propagation of the signal is 3×10^8 m/s. Determine the number of symbol durations over which the fades occur, and hence determine whether the smartphone is experiencing fast or slow fading.

(6 marks)

(b) Explain how Carrier Sense Multiple Access with Collision Avoidance (CSMA-CA) works.

(5 marks)

(c) Nodes A, B and C operate in a CSMA/CA wireless network in which nodes B and C intend to send data packets to node A.

The congestion window CW size is 7. The durations of the propagation delay is α, DIFS is 3α, SIFS is 2α, ACK is 5α, the data packet is 12α and the acknowledgement timeout is 8α.

Assume that the medium is busy at node A initially. At this time, a packet arrives at node B which selects a backoff counter of 5, and a packet arrives at node C which selects a backoff counter of 3.

When a packet is transmitted, the channel is busy for the duration of the packet length and propagation delay. All the transmitted packets reach their destination nodes successfully.

Draw a timing diagram to illustrate the data transmissions among the three nodes. How long does it take to complete the transmissions and acknowledgements of the two data packets from nodes B and C to node A?

(7 marks)

(d) Consider the situation where the packet from C does not reach its destination node A, i.e. the transmission is unsuccessful.

Explain what would happen compared to the situation in part (c).

Draw a timing diagram to illustrate the data transmissions among the three nodes. How long does it take to complete the transmissions and acknowledgements of the two data packets from nodes B and C to node A in this case?

Hint: ACK is not generated by node A for the transmission from node C.

(7 marks)

Q.2 (a) Six nodes numbered 1 to 6 are connected in a network as shown in Figure Q.2(a) where the individual link costs are also indicated. Using the Bellman-Ford algorithm, determine the optimal paths from node 1 to the other five nodes.

(7 marks)

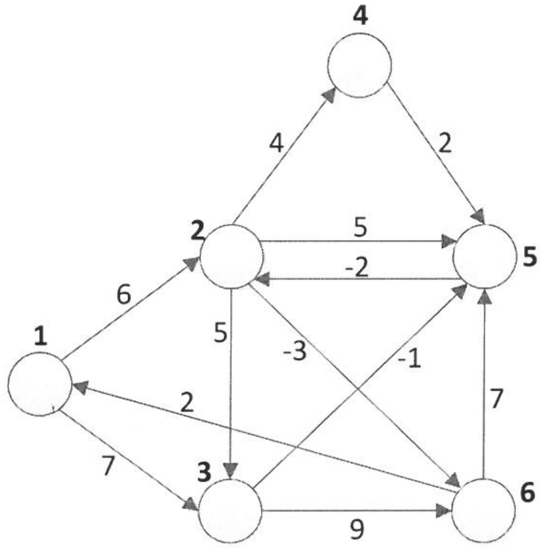

Figure Q.2(a)

(b) Comment on the optimal paths found and the possible drawback(s) when these paths are used to carry data traffic.

(3 marks)

(c) Determine the optimal paths from node 1 to the other five nodes using Dijkstra's algorithm.

Comment on the similarities and differences between the solution from the Bellman-Ford algorithm vs Dijkstra's algorithm.

(8 marks)

(d) In the Hybrid Wireless Mesh Protocol (HWMP) used in IEEE 802.11s Wi-Fi mesh networks, on demand routing is performed using the Radio Metric Ad Hoc On-Demand Distance Vector Routing (RM-AODV) protocol.

Explain the differences between RM-AODV and the original AODV protocol.

(7 marks)

Q.3 (a) A water utilities company wishes to use Internet of Things (IoT) technology to
(i) monitor the condition of its assets like pumps and water purifiers
(ii) measure the flow rate, quality and chemical composition of water in different parts of its nation-wide pipeline network, and
(iii) read the smart meters of its thousands of residential customers.

Specify with explanations which wireless IoT technology is suitable for each of these use cases.

(9 marks)

(b) What are the benefits of edge computing as more IoT devices are deployed?

(7 marks)

(c) Explain why the Maximum A Posteriori (MAP) classifier

$$C(x) = \arg \max_{j=1,\ldots,M} P(\omega_j | x)$$

can be implemented as

$$C(x) = \arg \max_{j=1,\ldots,M} P(x | \omega_j)$$

What is the name of this classifier?

Note that ω_j refers to class j, x is the event feature vector and M is the number of classes.

(9 marks)

Q.4 A wireless sensor node is able to operate at different sleep states s_k, each with power consumption P_k. The active state is state s_0 and has power consumption P_0. Event processing can only be done when the node is in the active state.

The transition from state s_0 to state s_k takes an interval $\tau_{d,k}$ while the transition from state s_k to state s_0 takes an interval $\tau_{u,k}$. The idle time between the end of processing for the previous event and the arrival of the next event is denoted by interval t_i. Figure Q.4 shows the relationship between these quantities.

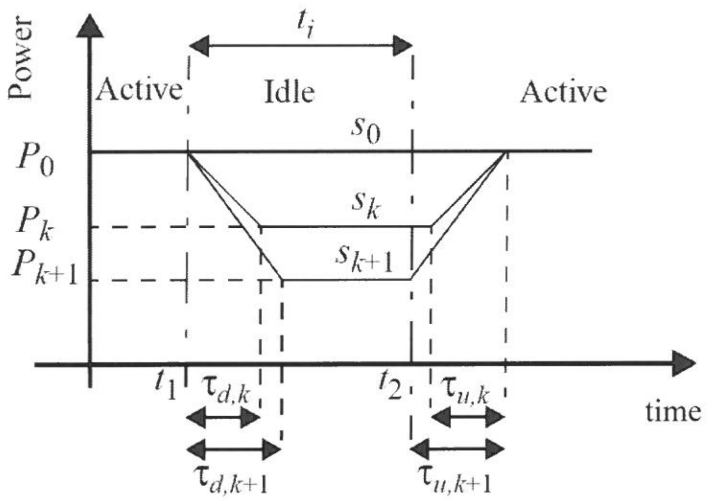

Figure Q.4

(a) Derive an expression for the energy saving $E_{s,k}$ that can be achieved by making a transition at time t_1 from the active state to state s_k, staying in state s_k until time (t_1+t_i) when an event arrives, at which point a transition is made from state s_k back to the active state. Show the key steps in the derivation.

(10 marks)

(b) Using your results from part (a), derive an expression for the transition time threshold $T_{th,k}$, which is the value of t_i when $E_{s,k} = 0$.

(5 marks)

(c) If the node is in state s_k when an event arrives, what is the latency between the time of arrival of the event and the moment the node can start processing the event?

(4 marks)

(d) State s_4 is the Deep Sleep state when even the sensors are off, thus preventing the node from detecting an arriving event. Design a method that would allow the node to enter the Deep Sleep state to conserve energy while retaining the desired event detection capability.

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

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