NATIONAL UNIVERSITY OF SINGAPORE

CS4222/CS5422: Wireless Networking

(SEMESTER 2: AY 2020/2021)

Final Assessment

Time Allowed: 2 Hours

INSTRUCTIONS TO STUDENTS

1. Please write your Student Number only. Do not write your name
2. This assessment paper contains SIX (6) questions and comprises ELEVEN (11) printed pages.
3. Students are required to answer ALL questions.
4. Answer **ALL** questions within the box in this booklet.
5. This is an OPEN BOOK assessment.

STUDENT NUMBER: _____

This portion is for examiner's use only

Question	Score	Marks	Question	Score	Marks
(1)		10	(4)		10
(2)		12	(5)		10
(3)		8	(6)		10
Total	/ 60				

Q1: Short Questions (10pt)

(a) (3pt) Z-Wave is a wireless communication protocol used primarily for home automation, running on smart home devices such as smart lighting, thermostats and locks. Which frequency band is most likely to be used by Z-Wave (a) 1MHz, (b) 100MHz, (c) 866MHz, (d) 5GHz or (e) 60GHz? Justify your choice.

(b) (3pt) Consider transmission from A to B. The frequency band used is increased from 2GHz to 5GHz but the distance between A and B is reduced from 100m to 30m. How much will the received power change if all other parameters remain the same? Assume that the path loss component is 2.5.

(c) (2pt) What are the differences in terms of supported traffic type(s) between 3G and 5G cellular networks?

(2pt) The per-hop packet **error rate** on a path with four hops are 0.25, 0.1, 0.5, and 0.2. What is the path ETX?

Q2 (12pt) Energy Efficient MAC Protocols

Consider the RI-MAC protocol. A node wakes up periodically every 100ms and transmits for a total of 1ms to announce its presence and listen for response, if any. The radio bit rate is 200kbps. The transmission and reception/listening states draw 20mA. The sleeping state draws 0.1mA. You can assume that state transition is immediate.

(a) (2pt) Consider the scenario whereby there is no transmission. What is the average current consumption of a node?

(b) (8pt) Consider a scenario where sensor node A transmits a 100-byte packet to node B every 10s and B transmits a 100-byte packet to node A every 10s. You can assume that node A and node B will never transmit at the same time. Assume that ACK and other control messages incur no overhead. Calculate the average current consumption of node A.

(c) (2pt) Based on the scenario outlined in part (b), assume that a node C is in the communication range of nodes A and B but does not receive any packet from A or B. Calculate the average current consumption of node C.

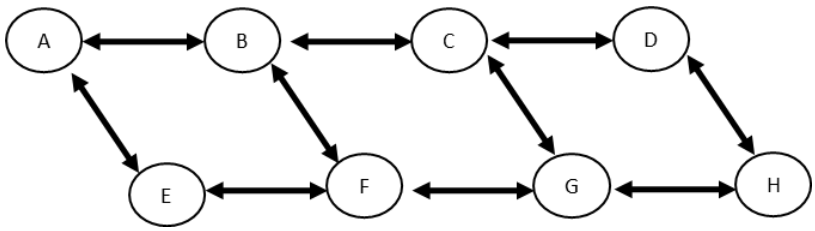
Q3: (8pt) Neighbor Discovery

(a) (4pt) Assume that the time it takes a node using GPS to synchronize its clock is 5s. The node also needs to synchronize with a server so that the time difference cannot be more than 100ms and the local clock drift is 50 ppm (part per million). What is the maximum duration between (start of) GPS synchronization to keep the node's clock within the maximum time difference of 100ms?

(b) (4pt) In implementation of discovery protocols, beacon transmissions to announce a node's presence are transmitted once at the beginning and once at the end of an active time slot. Explain the pros and cons of transmitting the beacons more often.

Q4: (10pt) Routing Protocols

(a) (6pt) In the figure below, the nodes are IEEE 802.11 stations. The bidirectional arrow indicates that the nodes on two ends of the arrow are able to communicate. For simplicity, we assume that the communication and interference ranges are the same. The stations perform carrier sensing follow by RTS/CTS before data is transmitted.



H is to send 1 data frame to A and E is to send 1 data frame to D. The data frames are of the same size and take 1 time unit to be transmitted.

- What is the minimum total time unit needed to complete the transfer of these 2 data frames?
- Write down the paths to be taken by the flows from H to A and E to D that can achieve this minimum total time. Examples of possible path from H to A are H->G->C->B->F->E->A or H->G->F->E->A.

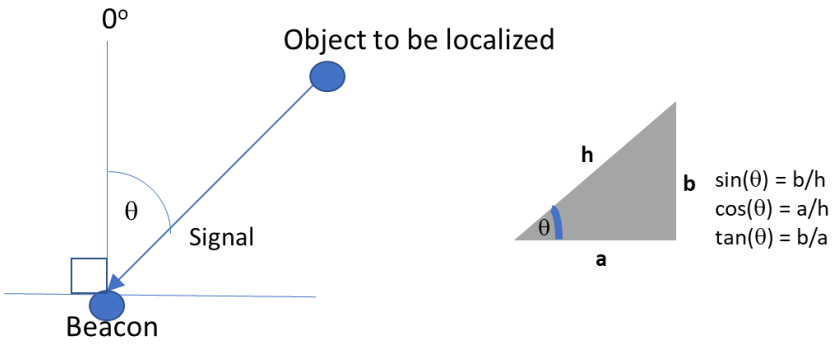
(b) (4pt) CTP uses distance vector based routing rather than link state based routing. Explain why.

Q5: (10pt) Localization

(a) (6pt) In the figure below, we try to localize an object along a straight line. Beacons 1 and 2 are located at the 0m and 9km mark. The clocks on the beacons are synchronized. Each beacon transmits a message that the object can receive. The message contains the beacon identifier as well as the time the message is transmitted by the beacon. The object receives a message with timestamp 1s from Beacon 1 when the local clock time is 1.0001s. The object also receives a message with timestamp 2s from Beacon 2 when the local clock is 2.00011s. Assume that speed of light is $3x10^8$ m/s.

Calculate the object's location (X) in terms of distance (in km) from Beacon 1 and the time difference between the object's clock time and the Beacons' clock time.

(b) (4pt) Localization can also be done by measuring the angle of (signal) arrival. In the left figure below, the signal angle of arrival is θ degree. The right figure below provides reference for some basic trigonometric relationships.



Consider a 2-D plane with two beacons. Beacon 1 is located at (0,0) and beacon 2 at (10,0). Let the (unknown) position of the object to be localized be (X,Y). The angle of signal arrival from the object to Beacon 1 is 40 degree and the signal angle of arrival from object to Beacon 2 is 300 degree. Write down 2 equations that determines the unknown location (X,Y). You **DO NOT** have to solve for X and Y.

Q6: (10pt) IoT Systems

(a) (5pt) In a sensor network deployment, CTP is used for routing and B-MAC is used as the MAC protocol. Each node wakes up every 125ms to sample the channel for 1ms. The radio bit rate is 19.2kbps and nodes have on the average 8 neighbors. Each node transmits a 100-byte packet every 1 second. Do you expect the system to perform well? Justify your answer.

(b) (5pt) You are asked to design a hybrid-MAC protocol to support both bulk data traffic and infrequent data transfer using a combination of 2 different MAC protocols. At any time instance, you only need to support one type of traffic (bulk or infrequent). Explain which 2 MAC protocols you would choose and how this "hybrid" MAC protocol works.

End-of-Paper