GLASGOW COLLEGE UESTC

Exam paper

Wireless Sensor Networks (UESTC 4020)

Date: 31st, December
Time: 09:30-11:30

Attempt all PARTS. Total 100 marks

Use one answer sheet for each of the questions in this exam.
Show all work on the answer sheet.

Make sure that your University of Glasgow and UESTC Student Identification Numbers are on all answer sheets.

An electronic calculator may be used provided that it does not allow text storage or display, or graphical display.

All graphs should be clearly labelled and sufficiently large so that all elements are easy to read.

The numbers in square brackets in the right-hand margin indicate the marks allotted to the part of the question against which the mark is shown. These marks are for guidance only.

DATA/FORMULAE SHEET IS PROVIDED AT THE END OF PAPER

Continued overleaf

Q1

(a) Compare and contrast between generic wireless network (WN) and wireless sensor network (WSN) in terms of design (purpose, objective and primary concern), operating environment, failure/maintenance, deployment environment and management strategy.

[7]

(b) Explain the core functionalities of sensing and processing units of a generic wireless sensor node.

[8]

(c) Analyse the following information for sensor network transceiver design and find the minimum required transmit power (in mW).
Transmit and receive antenna gain: 1,
Operating frequency: 900 MHz.
Minimum received power: -60 dBm
Distance between transmitter and receiver: 100 m

[8]

(d) Which module/unit of a sensor node consumes the most power in WSN?

[2]

Q2

(a) You are designing a WSN communication system with **slow** frequency hopped spread spectrum (FHSS) using minimum frequency shift keying (MFSK). Given parameters are: (M=4, k=2, PN=0011011000, and input binary data = 01110011110110000011). Explain with a time-frequency diagram, which spectrum sequences are to be transmitted. Your diagram should show appropriate bit, symbol, chip duration, MFSK and PN sequence.

[10]

(b) Consider the network topology in Figure **Q2**, where circles indicate the communication and interference range of each node, i.e., each node can hear the immediate neighbours to the left and right. Assume that Request To Send/ Clear To Send (RTS/CTS) is not being used. Analyse the following scenarios and answer associated questions:

[13]

(i) Node B is currently sending to node A and node C wants to send to node D. Is node C allowed to transmit (i.e., can it do so without causing a collision)? Will it decide to do transmit?

(3)

(ii) Node C is currently sending to node B and node E wants to send to node D. Is E allowed to transmit? Will it (E) transmit?

(4)

Continued overleaf

(iii) Node A is currently sending to node B and node D is currently sending to node C. Which other nodes are allowed to send at the same time?

(3)

(iv) Node A is currently sending to node B and node E is currently sending to node F. Which other nodes are allowed to send at the same time?

(3)

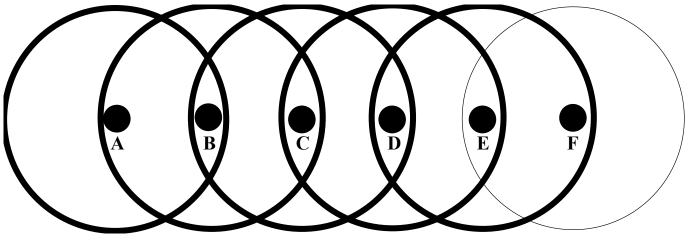

Figure Q2 : Wireless sensor network topology

(c) In what traffic condition contention-based Medium Access Control (MAC) is preferred over reservation-based MAC? [2]

Q3

(a) Consider the following WSN scenarios and explain why you would choose either a proactive or a reactive routing solution:

[10]

(i) A WSN is used to monitor air pollution in a city where every sensor reports its sensor data once every minute to a single remote base station. Most sensors are mounted on lamp posts, but some are also mounted on city buses.

(3)

(ii) A WSN is used to measure humidity in a field, where low-power sensors report measurements only when certain thresholds are exceeded.

(4)

(iii) A WSN is used to detect the presence of vehicles, where each sensor locally records the times of vehicle detection. These records are delivered to the base station only when the sensor is explicitly queried.

(3)

(b) Analyse the network topology shown in Figure Q3 and identify the optimal routes for source A to sink M according to the following criteria (Describe the process of computing the cost for the optimal route). The numbers X/Y along each link indicate the latency (X) and energy cost (Y) for transmitting a single packet over the link. The number Z under each node indicates the node's remaining energy capacity.

[15]

(i) Minimum number of hops.
(ii) Minimum energy consumed per packet.

Continued overleaf

(iii) Maximum average energy capacity.
(iv) Maximum minimum energy capacity.
(v) Shortest/Minimum latency.

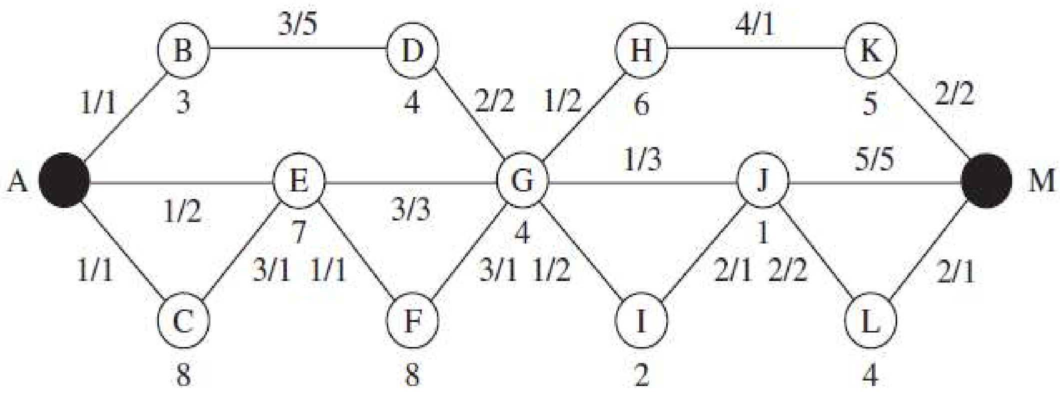

Figure Q3

Q4

(a) Describe the main challenges of synchronisation in wireless sensor networks?

[5]

(b) Analyse the two-dimensional topology in Figure Q4 and determine which 3 beacons (out of 6) the centre sensor node will select as basis for trilateration. Justify your answer.

[5]

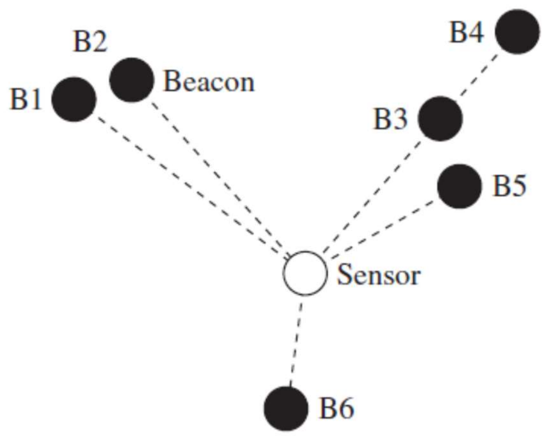

Figure Q4: Sensor Localisation scenario.

(c) Briefly describe 'Confidentiality Integrity Availability' (CIA) security model.

[6]

Continued overleaf

(d) Which service(s) of the CIA model you think are essential for the following scenarios. Justify your answers.

[9]

(i) A WSN that allows emergency response teams to avoid risky and dangerous areas and activities.

(3)

(ii) A WSN that collects biometric information at an airport.

(3)

(iii) A WSN that alerts a city of an impending earthquake.

(3)

Continued overleaf

Formula Sheet

Medium Access Control

ALOHA : $S = G^{-2G}$

Slotted ALOHA : $S = G^{-G}$

Queing System

Occupancy : $\rho = \frac{\lambda}{\mu}$

M/M/1

Queue length : $E[R] = \frac{\rho}{1-\rho}$

Total time in system : $E[T_R] = \frac{1}{\mu(1-\rho)} = \frac{1}{\mu-\lambda}$

Waiting time : $E[T_W] = \frac{\rho}{\mu(1-\rho)} = \frac{\rho}{\mu-\lambda}$

Delay bound : $\mathrm{P}\{T_R \leq t\} = 1 - e^{-\mu(1-\rho)^t}$

M/M/1/N

Blocking probability : $P_B = \frac{1-\rho}{1-\rho^{n+1}}\rho^n$

Carried traffic : $\gamma = \lambda(1 - P_B)$

Queue Length : $E[R] = \frac{1-\rho}{1-\rho^{n+1}}\sum_{k=1}^{n} k\rho^k$

Propagation:

Transmit power : $P_t = \frac{P_r\,(4\pi)^2 d^2}{\lambda^2 G_t G_r}$

Other Useful Formulae:

Geometric Series:

$$\sum_{k=0}^{n} ar^k = a\left(\frac{1-r^{n+1}}{1-r}\right)$$

$$\sum_{k=0}^{\infty} ar^k = \frac{a}{1-r}$$

End of question paper