ECE6615: Sensor Networks
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Final Exam: April 27, 2015

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Instructions

- Put your **SAME CODEWORD** next to your name on **EACH PAGE**!!!
- Open book exam (everything allowed except laptops, ipads, electronic devices, and cell phones, any communication devices).
- Duration: 170 minutes.
- Each question has the points as indicated below.
- Answer the questions **RIGHT TO THE POINT**.
- Avoid long explanations; couple sentences will be enough as long as they are correct!!
- Show the derivations of the equations in your answers.
- Return the Question sheet!!!

QUESTION 1. TCP ESRT SOLUTIONS (20 points)

This question is related to the operation of ESRT. Assume a wireless sensor network, where 10 nodes are in an event area. These nodes send event information at a particular reporting frequency f_i in each event detection interval i. The length of each interval is τ=10s. Assume for this network, that the maximum operation frequency, f_{max}, above which congestion occurs, is f_{max}=100 packets/s and that congestion is always perfectly detected by the algorithm.

The ESRT algorithm is given as follows:


```
k = 1;
ESRT()
  If (CONGESTION)
    If (η < 1)
    /* State=(C,LR) */
    /* Decrease Reporting Frequency
Aggressively */
      f = f^(η/k);
      k = k + 1;
    else if (η > 1)
    /* State=(C,HR) */
    /* Decrease Reporting Frequency
to Relieve Congestion; No Compromise on
Reliability */
      k = 1;
      f = f/η;
    end;
  else if (NO_CONGESTION)
    k = 1;
    If (η < 1 − ε)
    /* State=(NC,LR) */
    /* Increase Reporting Frequency
Aggressively */
      f = f/η;
    else if (η > 1 + ε)
    /* State=(NC,HR) */
    /* Decrease Reporting Frequency
Cautiously */
      f = (f/2)(1 + 1/η);
    end;
    else if (1 − ε ≤ η ≤ 1 + ε)
    /* Optimal Operating Region */
    /* Hold Reporting Frequency */
      f = f;
    end;
  end;
```

Assume for each node, the end-to-end path has a packet loss rate of 10% and the nodes are not correlated. The desired reliability R within the event detection interval is given as 600 packets and η=r/R, where r is the observed reliability and the tolerance is given as ε=5%.

When the network is in a congested state, the amount of received packets from each node, r_{node}, at the sink, has the following relationship with the reporting frequency, f_{node}:

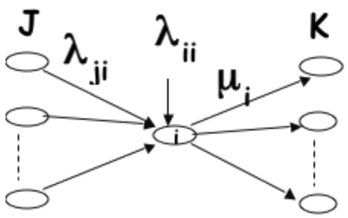
$r_{node} = 900 - 100*\log_{10}(f_{node}-f_{max})$

For initial reporting frequency, f_0 =200 packets/s, fill in the table to show the changes in the protocol state, achieved reliability, reporting frequency, and the parameter k in the above ESRT algorithm at the end of each interval. The last column, show the reporting frequency update policy for that state and indicate the new reporting frequency. This value should go to the second column in the following row. Only fill the rows until the optimal operating region (OOR) is reached.

Interval	f_i	Achieved Reliability (η)	Protocol State	k	Update policy
0-10	200				
10-20					
20-30					
30-40					
40-50					
50-60					
60-70					
70-80					
60-70					
70-80					

QUESTION 2. CROSS LAYER SOLUTION (15 points)

This question is related to the local cross-layer congestion control mechanism of XLP. Assume an edge of a network topology shown below



In this topology, node i has J upstream neighbors, from which it can receive relay packets, and K downstream neighbors, to which it can send its generated and relay packets. In this topology, the upstream neighbors (1,…j,…J) do not receive any relay packets and transmit only their generated packets.

Consider a sensing application where the sensing rate is 5 pkts/s with a packet size of 30 bytes for ALL sensors. Each upstream node j (1, …, j, … J), sends 20% of its data to node i and node i uses a routing metric that has an equal probability of sending its data to one of the K downstream nodes. The node operates with a duty cycle of δ.

Assume that the packet error rate in each link is equal to e_i

a) What is the generated packet rate λ_{ii} ?

b) What is the relay packet rate λ_{ji} coming from only 1 node of J upstream nodes? (as a function of packet error rate e_i.)

c) What is the total input packet rate λ_i ? (as a function of J and e_i)

d) What is the output packet rate μ_i ? (as a function of J and e_i)

e) Consider that the channel rate is 240kbps and ignore any overhead due to MAC protocol operation. What is the relay rate threshold $\lambda^{Th}_{i,relay}$? (as a function of e_i, and δ)

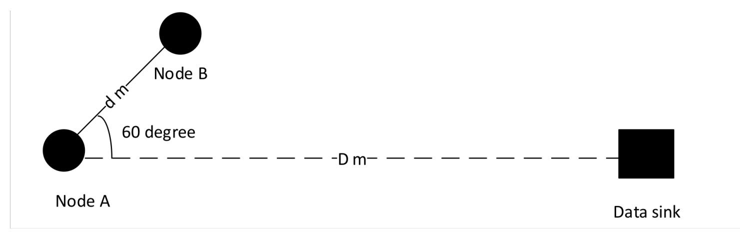
QUESTION 3. MULTIMEDIA SENSOR NETWORKS (15 points)

a) What is the major difference between WMSNs and conventional WSNs? (5 points)

b) What are the benefits of Ultra Wide Band technology when applied to WMSNs? (5 points)

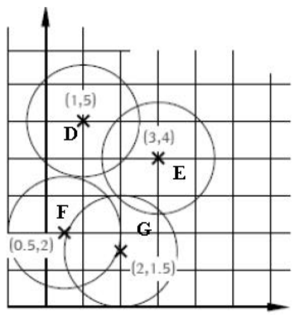
c) Given a sensor network in which all sensors have equivalent transmission range. Consider a particular sensor node A, which is located at a distance D meters away from the sink. Assume that A uses B as relay node and all the other nodes are placed with the same configuration and forward the packet of A to the sink.

Assume the end-to-end reliability requirement (i.e., packet loss rate) between sensor A and data sink is ε_{e-2-e}. Please estimate the hop reliability requirement ε_h between 2 nodes. (5 points)



QUESTION 4. LOCALIZATION (20 points)

Assume that the distance between two nodes cannot be estimated but is guessed according to which nodes a particular node overhears. In Figure, nodes A and B do not know their positions but they can overhear one another. Node A knows its neighbors D (1,5) and E (3,4) and B can hear its neighbors F (0.5,2) and G (2,1.5). The circular radio range of all nodes is 1.5 units.

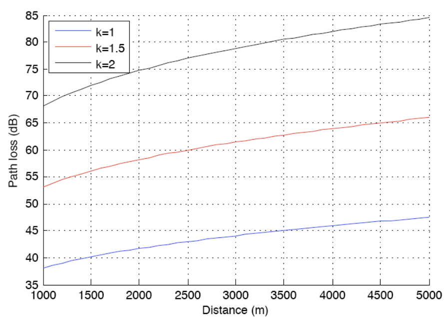


Figure

Determine whether (2,4) or (2,5) is a valid position of A and explain why.

QUESTION 5. UNDERWATER SENSOR NETWORKS (15 points)

The Transmission Loss (TL) of an underwater acoustic channel can be calculated using the Urick formula, i.e., TL_Urick(f0,d). An example of the Urick Transmission Loss is plotted as a function of distance as follows. Three different spreading factors (k=1, 1.5, and 2) are used. The carrier frequency f_0 is set to 20 kHz and the distance d ranges in 1-5Km.



The following parameters are given:

- The ambient noise N is 70dBreμPa and spreading factor of the channel k = 2.
- The target SNR at the receiver is 20 dB.
- The transmitter sends a packet of 25 bytes at each transmission with 1kbit/s data rate.
- The energy consumed for one transmission is 0.266 J.
- The depth of the nodes H is 1 m.

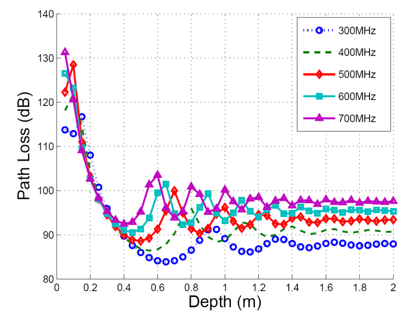
Determine the distance between each the transmitter and the receiver.

QUESTION 6. UNDERGROUND SENSOR NETWORKS (15 points)

Two EM wave-based wireless sensors are buried underground at the same depth. The following parameters are given:

- The depth at which the sensors are buried is 0.4m, as shown in the below figure
- The volumetric water content is 20% (α = 3[m^{-1}], β = 77[rad m^{-1}])
- The operating frequency is 500 MHz
- The antenna gains Gt=10 dB, Gr=9.55 dB.
- The transmitted power is 5 mW
- The minimum required received power is $1.426*10^{-5}$ mW

What is largest the transmission range to satisfy the minimum required received power? Choose from: However, show clearly the details of your answer!!
a. 4m
b. 4.1m
c. 4.2m
d. 4.3m



Two-way Path loss