



## **ECE6615: Sensor Networks**

**Spring 2016**

### **Homework 2 for Distance Learning Students**

**Given:** February 19, 2016

**Due:** March 11, 2016 (MIDNIGHT 11:59pm)

#### **Submission Instructions:**

1. Please put “[**ECE6615**] **HOMEWORK 2 - DL**” in the subject line.
2. Submit your homework as on-line files (such as a DOC or a PDF file) to [infocom@ece.gatech.edu](mailto:infocom@ece.gatech.edu).

No hard copy will be accepted!!

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## QUESTION 1 (ROUTING)

Consider the topology in Figure 1 and also in the given PPT, which shows the first step of flooding.

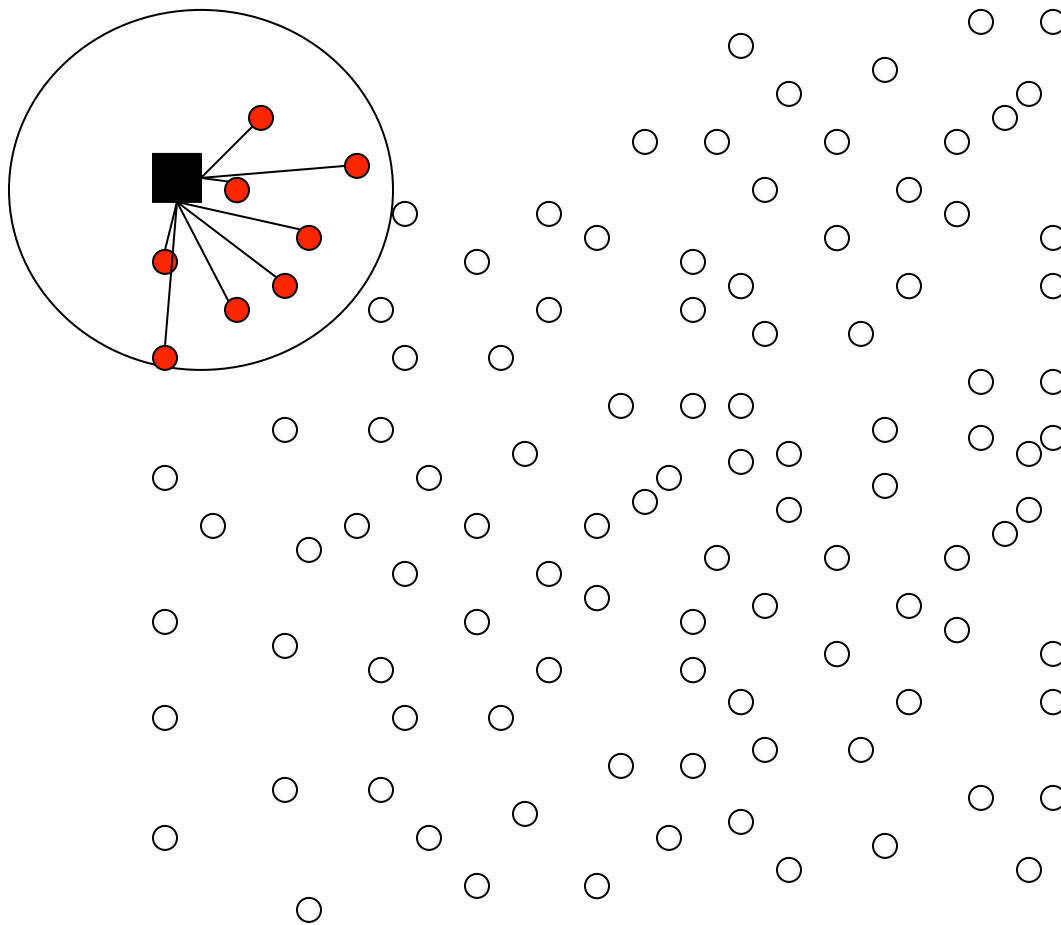


Figure 1

**Using the topology and the transmission range circle in the figure, show the evolution of flooding in terms of time steps. For each step, draw the state of the network until all nodes receive the flooding packets. Draw the resulting flooding tree at each step and then copy the slide for the next step to prevent confusions.**

Assume the following for the question:

1. Perfect channel condition inside the transmission circle. (All nodes inside the circle can receive the flooding packet successfully)
2. All the red nodes receive the flooding packet in the first step.
3. Only one node inside a transmission circle can transmit a packet at a step (denote these nodes as black nodes in each step).
4. At each step, start with randomly selecting one of the red nodes as a transmitter and draw its transmission range. The other red nodes that fall into this transmission range will be blue nodes. Repeat this until all red nodes are processed for that step.
5. Transmission of a packet takes one step.

6. If a node receives the flooding packet in two consecutive steps (a red node receives a packet in the next step), it does not continue flooding and drops all of its packets (denote these nodes as blue nodes in each step)

## QUESTION 2 (Error Control)

Given a sensor network in which all sensors have equivalent transmission range  $R = 20$  m, transmission rate  $r = 250$  kbit/s, and packet size  $L = 55$  bits. Consider a particular sensor node  $i$ , which is located at a distance  $D = 100$  m from the sink. Assume that within the transmission range of  $i$ , there exists only one sensor  $j$  and sensor  $j$  is closer to the sink than sensor  $i$ . The described network scenario is shown in Figure 2, and all nodes are distributed as shown.

- Calculate the estimated number of hops from sensor  $i$  to the sink.  
Hint: the actual advance distance from  $i$  to  $j$  is the projection of  $d_{ij}$  onto the line connecting sensor  $i$  and the sink.
- Assume the bit error rate (BER) or bit error probability  $P_b = 10^{-3}$ . Calculate the packet error rate (PER) of BCH code with BCH(15, 11, 1) and BCH(15, 5, 3), respectively.
- Based on the results of a) and b), evaluate the estimated END-TO-END reliability (i.e., PER) between sensor  $i$  and the sink provided that BCH code is employed for data transmissions at each hop.
- Assume that at each hop the sensor uses BCH code with BCH (15, 11, 1) and the energy consumption for encoding and receiving packets is negligible. Calculate the total estimated energy consumption of transmitting a packet from sensor  $i$  to the data sink. Consider the energy to run circuitry is:  $E_{tx\_elec} = 50$  nJ/bit and the energy for radio transmission is:  $e_{amp} = 100$  pJ/bit/m<sup>2</sup>.  
Hint: to compute the energy consumption for decoding, the decoding latency is given as

$$T_{dec}^{BL}(n, k, t) = (2nt + 2t^2)(T_{add} + T_{mult})$$

$$T_{add} + T_{mult} = 3 \left\lceil \frac{m}{8} \right\rceil t_{cycle} \quad \text{where } m = \lfloor \log_2 n + 1 \rfloor \text{ and } t_{cycle} = 250 \text{ ns}$$

- Assume that the total delay at each hop only consists of transmission delay and decoding delay. Calculate the estimated END-TO-END delay of transmitting a packet from sensor  $i$  to the data sink provided that BCH (15, 5, 3) is employed.
- Briefly comment the tradeoffs of end-to-end reliability, end-to-end delay, and total energy consumption under different BCH coding schemes.

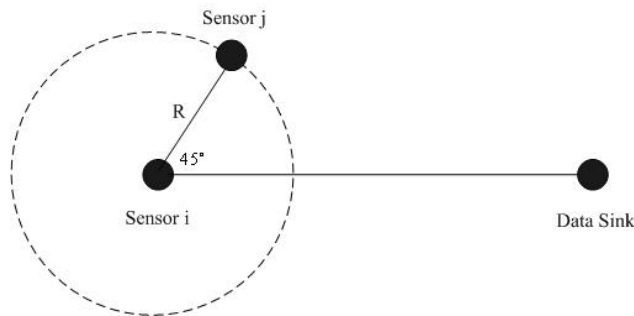


Figure 2

### QUESTION 3 (Transport Layer)

Figure 3 shows a wireless sensor network used to measure the temperature inside an industrial refrigerated room. In this picture, red nodes represent sensors that have detected a sudden increase in the temperature (corresponding to the same event). These nodes need to report this information to the sink or command center. The radio range of each node is  $r$ .

**Qualitatively** explain how PSFQ and ESRT will perform in this situation and compare both protocols in terms of total number of packets transmitted. How does this affect the total energy consumption? Under which protocol is the network more likely to be congested?

Assumptions:

1. Consider that the network has been working for some time and that ESRT is working under no congestion and with high reliability. Assume that in this condition, only 50% of the nodes will report the event.
2. Consider that all packets are sent using the shortest path and that routes have already been pre-established.
3. Consider that a simple MAC protocol is used and that only 1 of every 4 packets is lost.

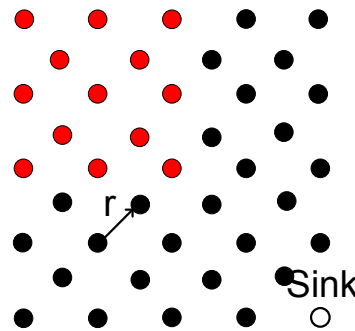


Figure 3

### QUESTION 4. (CROSS LAYER PROTOCOL SOLUTIONS)

XLM aims to provide high reliability with low energy consumption. However, XLM is not tailored for real-time data applications since end-to-end reliability and latency bounds are not guaranteed.

Comment on how XLM can be improved to support real-time communication in WSNs based on the following:

- a) How can the initiative concept be improved to support real-time traffic?
- b) How can local congestion control algorithm be improved to support real-time traffic?
- c) Can the routing algorithm be changed for real-time traffic?