ECE6615: Sensor Networks
Spring 2012
Final Exam: May 3, 2012

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Instructions

- Put **YOUR SAME CODEWORD** next to your name in **EACH PAGE**!!! (e.g., Austin, James Bond, Casanova).
- Open book exam (everything allowed except laptops and cell phones).
- Duration: 170 minutes.
- Answer the questions **RIGHT TO THE POINT**.
- Avoid long explanations; couple sentences will be enough as long as they are correct!! Give short answers!!!

QUESTION 1 (Error Control) (15 Points)

Consider a sensor network in which all sensors have equivalent transmission range R = 20 m, transmission rate r = 14 kbits/s, and packet size L = 16 bits. Assume that the bit error rate (BER) is 10^{-3}. As shown in Figure 1, a particular sensor node 1 is located at a distance D = 40 m from the data sink, while another sensor 2 resides closer to the sink than sensor 1. Consider the case where sensor 1 selects sensor 2 as the next hop to transmit packets to data sink.

a) At each hop, let the sensor node encode packets by using BCH code with BCH (7,4,1). Calculate the estimated end-to-end packet error rate and end-to-end delay from sensor 1 to the data sink. (Note that propagation delay and queuing delay are negligible)
b) Now, at each hop, let the sensor node NOT use error control at all. Under this case, calculate the estimated end-to-end packet error rate and end-to-end delay from sensor 1 to the data sink. Based on a) and b), please briefly comment the performance of FEC and non-FEC schemes (Note that propagation delay and queuing delay are negligible).

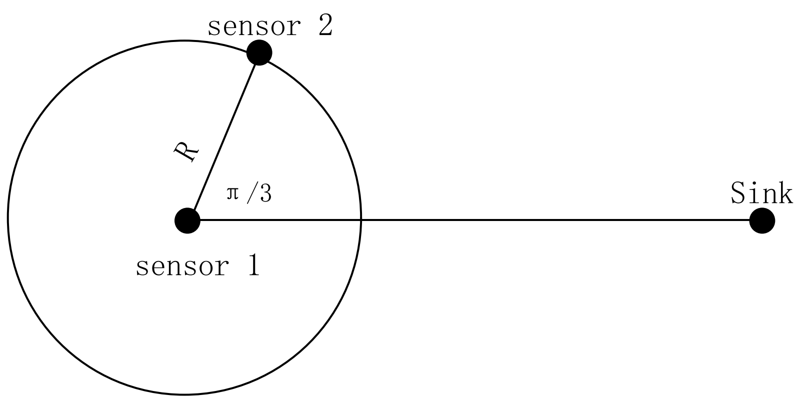

Figure 1

QUESTION 2 (Localization) (15 Points)

Consider three sensor nodes with the following IDs: 1, 2, and 3. All three nodes have on board two transceivers at different frequencies and a clock (counting seconds elapsed from the instant the node is switched on). Assume each node sends two signals at the same time instant by using the two transceivers. Each signal contains the ID of the sender node. Each node, upon reception of a signal, stores the clock value and the ID contained in the signal.

After some time, the three nodes have stored the following timer values:

2	**35**
1	**36**
1	**39**
2	**39**

2	**236**
3	**239**
2	**241**
3	**242**

1	**171**
1	**176**
3	**179**
3	**183**

Guess all the possible reciprocal positions of the three nodes (sketch the node locations with their reciprocal distance values).

Please, note that the sensors are in a medium where the two frequencies have the following propagation speed:

- Propagation speed first frequency: v_1 = 306 m/sec
- Propagation speed second frequency: v_2 = 316 m/sec

QUESTION 3 (Wireless Multimedia Sensor Networks) (10 Points):

a) What is "GOOD CITIZEN" or "TCP FRIENDLY PROBLEM" in WMSNs?

b) What parts of protocol stack not implemented in the Cross Layer Module on UWB for WMSNs as explained in the class?

c) What are the major problems of UWB?

d) What is the major problem of the XLAYER module of the terrestrial WSNs? How will you solve the problem?

QUESTION 4 (Wireless Multimedia Sensor Networks - Correlation-Based Communication) (15 Points)

As shown in Figure 5, three camera sensors are deployed to observe an area of interest in a WMSN. The area of interest is in the center of the coordinate system, and the locations and sensing directions of the cameras are given as shown in the figure. Suppose each camera has observed one image ($X_i (i = 1,2,3)$) and the entropies of the individual images are the same ($H(X_i) = H(\cdot)(i = 1,2,3)$). Consider the case that we need to select two cameras to report to the sink. (Suppose all cameras have the same d = 2 in the figure.)

a) Which two cameras should be selected to maximize the amount of information gained at the sink?

b) If we perform joint coding on the selected two cameras, which two cameras should be selected to minimize the joint coding rate?

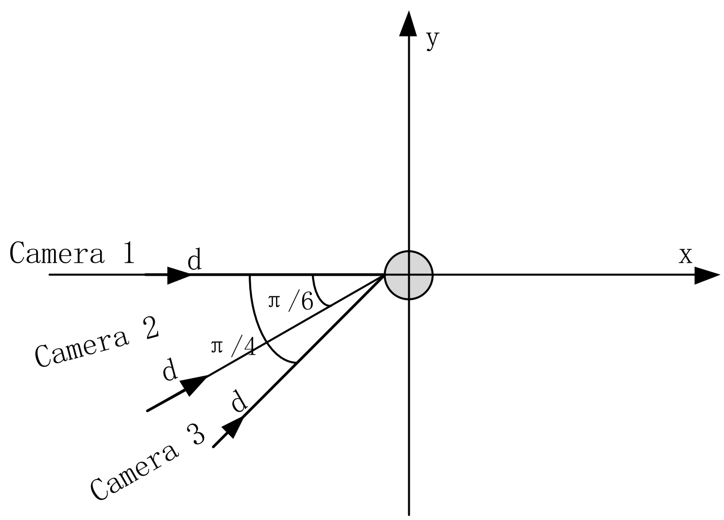

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Figure 5. Cameras deployed in a WMSN

QUESTION 5 (Wireless Underwater Sensor Networks) (15 Points):

a) In addition the class notes where three architectures are given, **three more architectures for underwater sensor networks were presented in the class. Please draw at least 2 of those additional architectures for underwater sensor networks.**

b) What are the effects of SHADOW ZONES for underwater sensor networks?

c) Which Error Control Scheme, FEC, ARQ or Hybrid ARQ would you use for Underwater Sensor Networks? Explain the reasons.

d) Why is the TDMA type scheme not appropriate for Underwater Sensor Networks?

e) Why may the terrestrial Localization Algorithms have problems for underwater applications?

QUESTION 6 (Wireless Underwater Sensor Networks) (15 Points)

Consider the scenario given by Figure 1, in which two underwater sensors are exchanging information by means of acoustic communication.

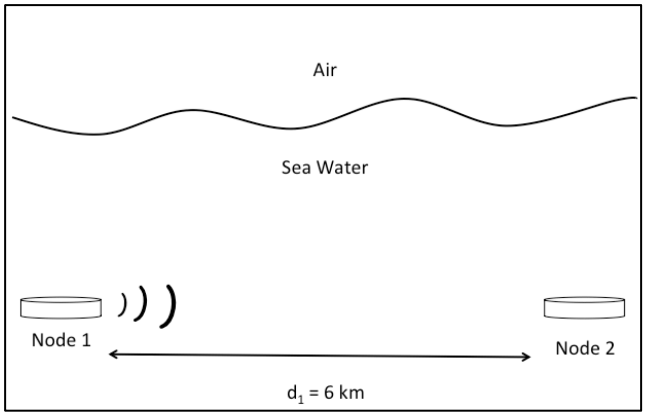

Figure 1

a) Compute the acoustic transmission power in Watts for the transmitter, Node 1, which is necessary to guarantee a Signal to Noise Ratio (SNR) of 20 dB at the receiver, Node 2. The distance between Node 1 and Node 2 is d_1=6 km, the system operates at a frequency f=20 kH*z*, and the ambient noise is 70dBreμPa. For the path-loss, utilize the Urick Propagation Model with spreading factor k=2, medium absorption coefficient α=0.0006 dB/m, and transmission anomaly A=5 dB (consider H=1m).

b) Consider that the packet size is 100 bytes and that the transmission data rate is 1 kbps. Which is the energy consumption per packet in Joules? What is the total time (transmission time plus propagation time) needed for the packet to be received at Node 2? Consider that the speed of sound in water is 1500 m/s.

QUESTION 7 (Underground Sensor Networks) (15 Points)

In an EM wave-based wireless underground sensor network in soil medium, the system and environmental parameters are given as:

- The two underground sensors are buried in the same depth, which is 0.9 m below the ground surface.
- Volumetric water content in soil is 5%.
- The transmitting power of each sensor is 5 mW.
- The operating frequency is 500 MHz.
- The minimum received power for correct demodulation is -100 dBm.
- The antenna gains Gt=10 dB, Gr=5 dB.

a) Using the soil medium path loss given in Fig.1 and Fig.2 to determine the transmission range between two underground sensors.

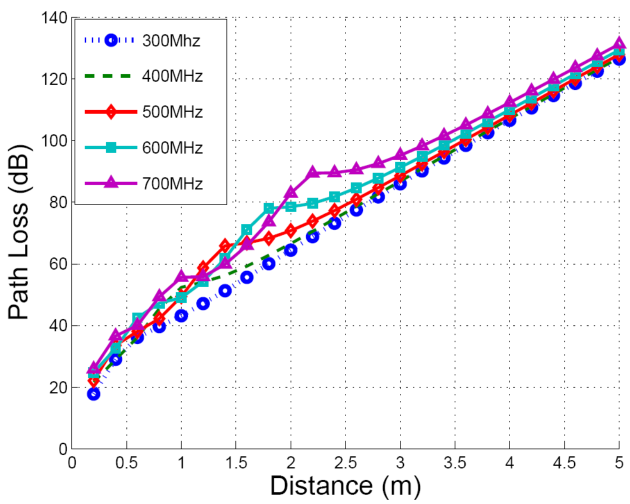

Fig. 1 Two-way path loss

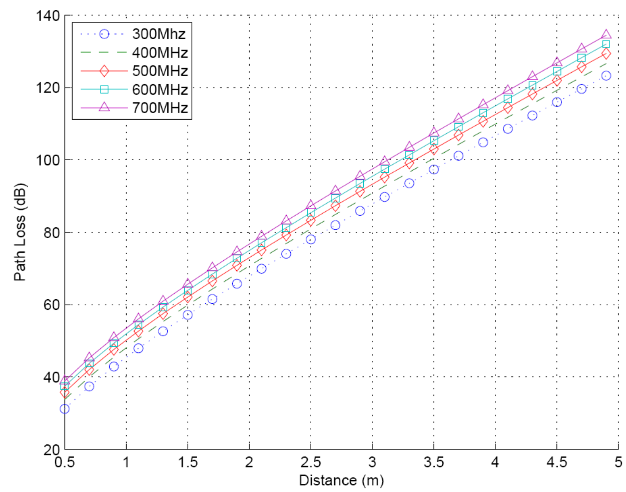

Fig.2 One-way path loss

b) If the underground sensors are randomly deployed according to a homogeneous Poisson point process in a region with 15000 m^2 area. Calculate the probability that there is no isolated sensor in this underground sensor network. Using the same parameters in a), determine which of the following sensor density λ (sensor per m^2) is the minimum to guarantee the probability that there is no isolated sensor can be larger than 90%.

A. $\lambda = 0.14$ B. $\lambda = 0.145$ C. $\lambda = 0.15$ D. $\lambda = 0.155$ E. $\lambda = 0.16$