ECE6615: Sensor Networks

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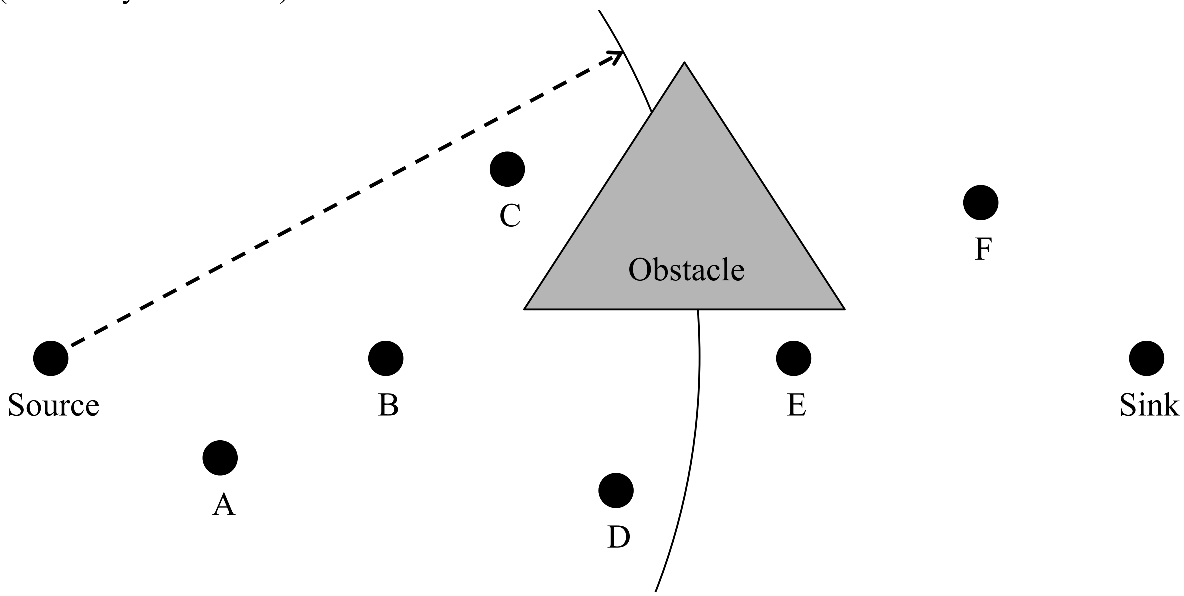
Instructions

- Put a **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.
- Each question has 20 points.
- Answer the questions **RIGHT TO THE POINT**.
- Avoid long explanations; couple sentences will be enough as long as they are correct!!

Question 1 (XLP: Cross Layer Protocol)

Consider the following wireless sensor network, in which all the nodes operate by following the XLP (Cross Layer Protocol) seen in class:



This is the status of each node:

	A	B	C	D	E	F	Sink
Source Channel SNR (ξ) [dB]	25	20	15	11	5	0	0
Relayed Traffic (λ_{relay}) [packet/sec]	5	6	5	2	5	6	5
Buffer Level (β) [%]	15	15	35	85	35	45	45
Remaining Energy (E_{rem}) [%]	70	70	60	10	50	50	50

The source wants to transmit a packet to the sink node. For this, it first transmits an RTS packet:

a) Compute the initiative function for the nodes that can hear the RTS packet. Consider that the minimum SNR to properly detect a packet is ξ=10 dB. The maximum relayed traffic that a node can support is λ_{relay}=10 packet/sec. A node can accept new packets as long as its buffer is less than 75% occupied and it has more than 25% of energy left in its battery.

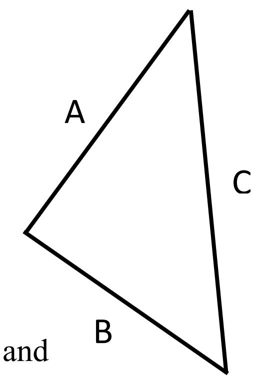
b) Which node will the source choose as the next hop?

c) Starting from the chosen relay node, which node will be the next hop? Why? Please explain in detail what is happening.

d) Which will be the final route that the packet will follow till reaching the sink?

Question 2 (Localization)

Consider a room whose walls form a triangular shape. The room walls, labeled as A, B, and C, have the following properties



1. Wall A is metallic (completely reflects electromagnetic waves) and acoustic echoing (reflects sound waves)
2. Wall B is metallic but acoustic anechoic (completely absorbs sound waves)
3. Wall C is radio-frequency anechoic (completely absorbs electromagnetic waves) but acoustic echoing

Imagine a sensor mote placed inside the room is equipped with both radio and ultrasound transceivers to find its location within the room. The sensor mote, after the emission of an electromagnetic pulse and a sound pulse, receives a total of:

- An electromagnetic pulse with RSS (Received Signal Strength) equal to P_{r1} = -31.13 dBm
- An electromagnetic pulse with RSS equal to P_{r2} = -36.12 dBm
- A sound pulse 17.5 msec after the transmission

Assuming that the electromagnetic pulse is transmitted with a power P_t = 0 dBm, the electromagnetic attenuation constant is equal to 4dB/m, and that the multipath/shadowing effects are negligible, identify the location of the sensor mote within the room, relative to the three walls. (The speed of sound is 343.2 m/s)

Question 3 (Wireless Multimedia Sensor Networks - Correlation-Based Communication)

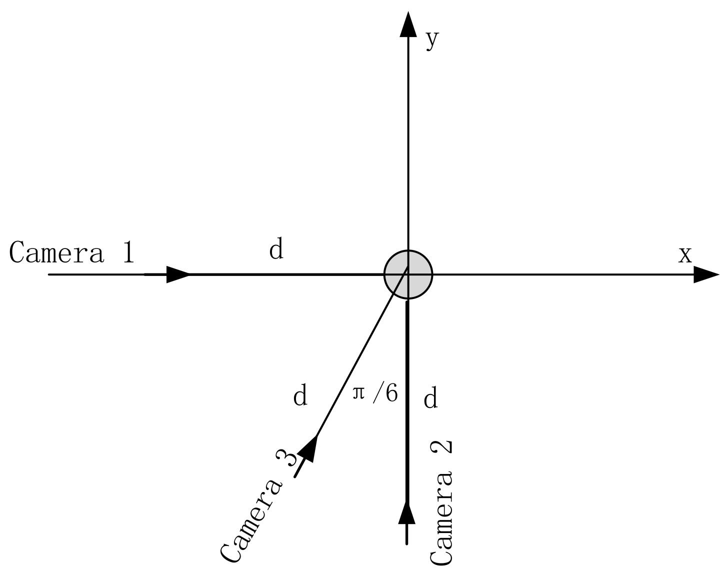
As shown in the figure below, three camera sensors are deployed to observe an area of interest in a WMSN. The area of interest is in the center of the coordinate system, and the locations and sensing directions of the cameras are given as shown in the figure. Suppose each camera has observed one image ($X_i (i = 1,2,3)$) 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 = 3 in the figure.)

a) What are the correlation coefficients of any two cameras in the figure?

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

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

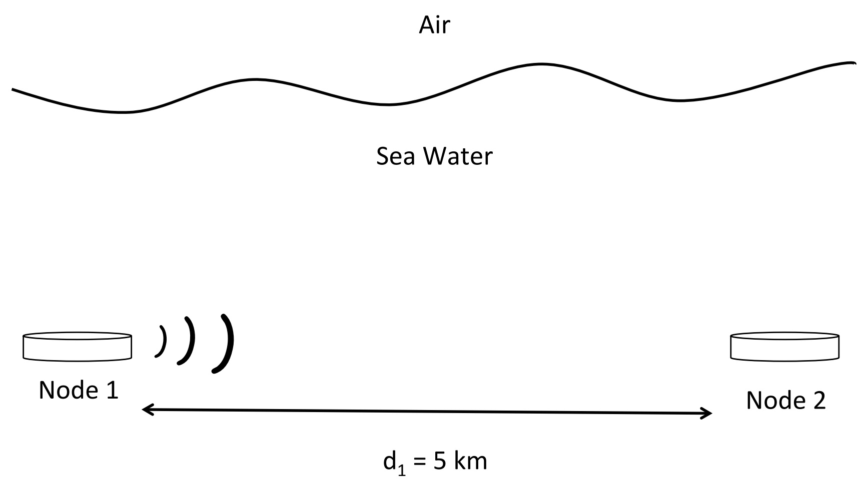
d) If camera 2 needs to select another camera to perform differential coding, which camera that camera 2 should select to minimize the differential coding rate?



Cameras deployed in a WMSN

Question 4 (Wireless Underwater Sensor Networks)

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



a) Compute the 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=5 km, the system operates at a frequency f=20 kHz, and the ambient noise is 75dBreµPa. For the path-loss, utilize the Urick Propagation Model with spreading factor k=2, medium absorption coefficient equal to 0.0006 dB/m, and transmission anomaly A=5 dB (consider H=1m).

b) Consider that a packet train with a total size of 1000 bytes is transmitted every hour at a transmission data rate of 5 kbps (kilobit-per-second). Which is the energy consumption per train packet in Joules? What is the total time (transmission time plus propagation time) needed for the train packet to be received at Node 2? Consider that the speed of sound in water is 1500 m/s.

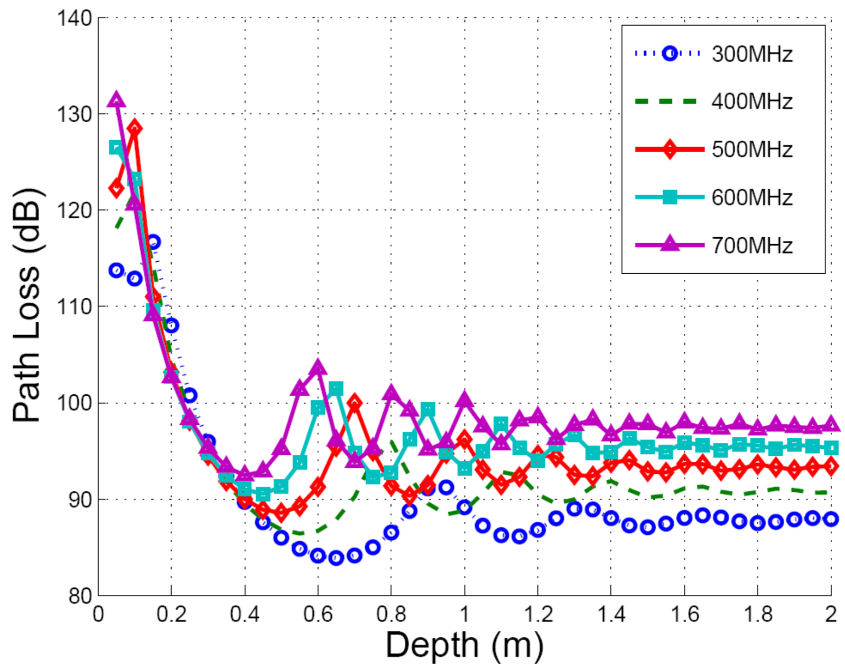
c) Consider that the battery of Node 1 has an initial charge of 10 kJ. What is the lifetime of Node 1? You can consider the sleeping energy to be negligible.

Question 5 (Underground Sensor Networks)

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

- The distance between the two sensors is 4m
- The volumetric water content is 20% ($\alpha = 3[m^{-1}]$, $\beta = 77[rad\ m^{-1}]$)
- The operating frequency is 500 MHz
- The antenna gains Gt=10 dB, Gr=5 dB.
- The transmitted power is 5 mW
- The received power is $1.426*10^{-5}$ mW

a) Using the curves in the following figure, compute the minimum possible depth at which the sensors are buried.



Two-way Path loss

b) How would the received power be if, instead of EM waves, we use MI (Magnetic Induction) as a communication medium?