ECE6615: Sensor Networks
Spring 2018
Homework 3

Given: **March 26, 2018**
Due: **April 20, 2018 (Midnight) + 1 week for "off Campus" students**

Submission Instructions:

Submit your homework as a **single** DOC or PDF file to infocom@ece.gatech.edu
Attach the MATLAB codes as a single zip file.
Mention "**[ECE6615] Homework 3**" in the subject line.
No hardcopies will be accepted. Scanned pages are fine.

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Question 1 (Internet of Things – 6LowPAN)

i) What is the the minimum number of bytes of the header overhead (PHY, MAC, NET, TRAN) for a single-hop packet sent using 6LoWPAN and compressed UDP?

ii) Node A is sending a 1kB IPv6 packet to Node D. A can only talk to B, B talks to C, and C talks to D. Show the fragmentation, and representative headers and payload sizes for the packet flow between B and C, assuming that uncompressed IPv6 and uncompressed TCP headers are used. Include the TCP ACK in your packet flow. You can use as much header compression as you can.

Question 2 (Internet of Things – DODAG)

Given the following topologies (a) through (d), answer the following questions:

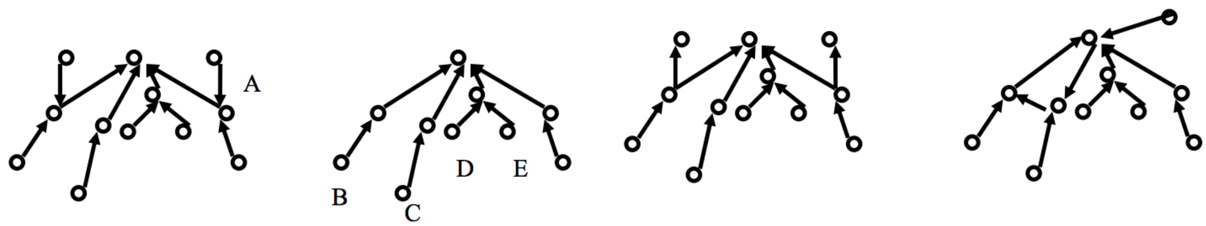
i) Which of the following is not a DODAG and why?

ii) What is the direction of Link A? (Up or Down)

iii) Assuming each link has a distance of 1, what is the rank of node B?

iv) Show the paths from B to C if the DODAG is non-storing.

v) Show the paths from D to E if the DODAG is storing.



(a) **(b)** **(c)** **(d)**

Question 3 (Low Power Wide Area Networks)

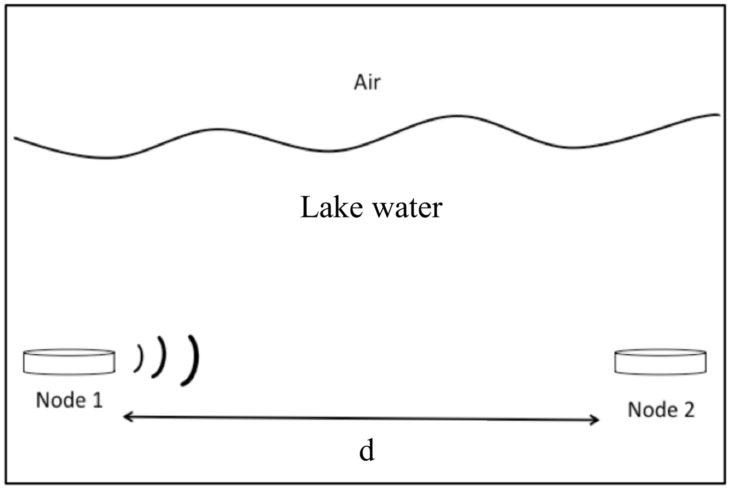
i) What are the main differences at the physical layer between LoRaWAN and Sigfox?

ii) How is information encoded using chirps in LoRa?

iii) What is the spreading factor? For the same channel bandwidth, which would take longer: a packet transmitted with SF7 or SF10? Show your calculation.

Question 4 (Internet of Underwater Things)

Consider the scenario given by the figure below, in which two underwater sensors are exchanging information by means of both acoustic and magnetic induction communication in ***lakewater.***



i) The Transmission Loss (TL) of an underwater acoustic channel can be calculated using the Urick formula, i.e., TL_Urick(f0,d).

$$TL(d, f) = \chi \cdot log(d) + \alpha(f) \cdot d + A$$

The carrier frequency f_0 is set to 20 kHz, $\alpha(f)$=0.0006; A=7.5 dB, χ=20.

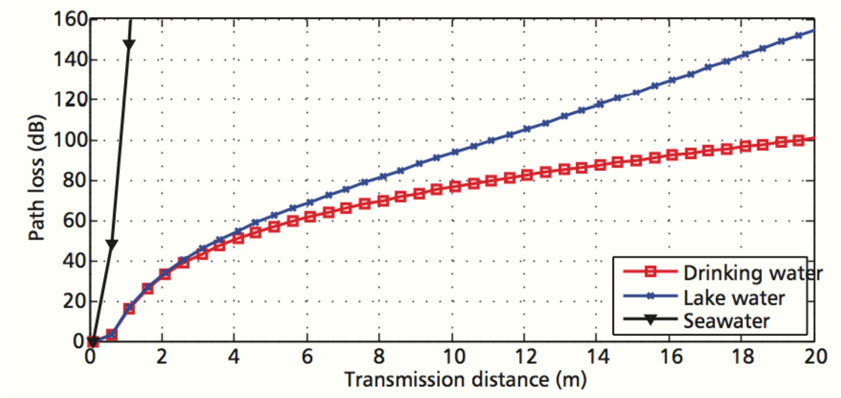
The following parameters are given:

- The ambient noise N is 70dBreµPa.
- The target SNR at the receiver is 20 dB.
- The energy consumed for one transmission is 175 dBreµPa.

Determine the distance between each the transmitter and the receiver using Urick's formula. The distance is a multiple of 1000 m.

ii) Now, the nodes will use magnetic induction communication. However the range of magnetic induction communication is in the order of ~10-100 m. Therefore, we will consider that there are N relay nodes between Node 1 and Node 2.

First calculate the maximum range of MI relays using Fig 1, where P_{tx}=20 dBm, noise power=-80 dBm and minimum required SNR for reception is 20 dB.



iii) For MI, how many relays are needed to deliver a packet from Node 1 to Node 2.

iv) Now, we will compare the delays for both communication alternative for a packet of 100 bytes.
The total end-to-end delay is composed of transmission delay and propagation delay considering 1 hop for acoustic and N hops for MI.
Use:

- Acoustic: Data rate for transmission is 1 kbit/s, propagation speed of acoustic waves is 1500 m/s.
- MI: Data rate for transmission is 0.1 Mbit/s, propagation speed of MI waves is 3.33×10^7 m/s.
(For MI case, the processing times at relays are negligible.)

Question 5 (Internet of Underground Things)

Consider an underground channel using EM waves. Two EM wave-based wireless devices are deployed with the same burial depth, which is 1.8 meters below the ground surface. The distance between the two devices is 4.8 meters. Both devices use 300 MHz EM waves for wireless communications. There is no obstruction in the underground environment. The system bandwidth is 30 MHz. Assume that the propagation speed of EM waves in this underground environment is 2×10^8 meters per second. Calculate the delay spread of this underground channel. (40% of total points)

*The delay spread of a communication channel is the difference between the time of arrival of the earliest path component (typically the line-of-sight component) and the time of arrival of the latest path components (reflected path).

Question 6 (Internet of Nano Things)

i) If we want to design a wireless nano-link at 4.25 THz. What is the main difference between the Terahertz Band channel (between 100 GHz and 10 THz) and the conventional channel for frequencies below 5 GHz?

ii) We want to design a graphene-based plasmonic nano-antenna to operate with fundamental resonant frequency equal to 25 THz. Which are the main differences between a plasmonic antenna and a metallic antenna?

iii) In Internet of Nano Things modulation and coding, why are "0"s transmitted as silence in TS-OOK?

Question 7 (Internet of BioNano Things)

Suppose we have a diffusion-based molecular communication link between a transmitter and a receiver that is realized by following the basic design. We know that the molecular transmitter emits a signal whose average (frequency zero) has amplitude of A [#molecules/sec], and whose frequency components higher than frequency zero have an amplitude that decreases from the average amplitude to zero by following a quadratic law as the frequency value increases ($A-\omega^2$), which means that the amplitude $A' = A - \omega^2$, where A is the initial amplitude and ω is the angular frequency larger than zero. Consider only positive frequencies and that no frequency component has amplitude below zero. Write down the expression that you would use to compute the channel capacity of this molecular channel. This expression should only be a function of the following parameters:

- the angular frequency $\omega = 6.28 \times 10^2$ rad/sec, with bandwith 10 Hz,
- the signal amplitude A = 10^6 in [#molecules/sec],
- the diffusion coefficient D = 0.25 in [m^2/sec],
- the transmitter-receiver distance d = 30 in [mm],
- the number of chemical receptors at the receiver N_R = 1,
- the radius of the spherical receptor volume ρ = 3 in [cm],
- the temperature of the environment T = 310 Kelvin.