ECE101: Exploring Digital Information Technologies **Fall 2022**
Week 2 Exercises (with solutions in red) **based on L3,L4; tested on Exam I**

Wifi and Cellular

These exercises are intended to help you master and remember the material discussed in lectures and explored in labs. In future semesters, we may make some or all of these exercises required, but for now they remain optional. We suggest that you do them as we go over the material, but you may also want to use them to review concepts before the exam.

Please note also that exercises are meant to be done with a calculator, while in exams, we just want you to be able to set up the equations correctly.

Rather than using this version directly, we suggest that you use the version without solutions to solve the problems before looking at the answers. Many studies have shown that people often trick themselves into believing that they know how to solve a problem if they are presented with the answer before they try to solve the problem themselves.

1. [L3] Why is it difficult to solve the problem of interference by moving your device away from other Wifi transmitters, such as your neighbor's laptop and Wifi router? What does Wifi do to solve the problem?

   Since other transmitters usually transmit at the same power as whatever signal you are trying to receive, you need to be significantly further away (10 to 30 times for SINR of 100x to 1000x) in order to obtain an SINR high enough to receive bits correctly. Wifi solves the problem by having transmitters take turns.

2. [L3] In fact, walls do usually reduce the power of a signal passing through them. First, review Slides 29 to 34 of Lecture 3. Now, assuming that each of the two walls reduces the power of a signal passing through them by 2×, recompute the fraction F of allowable distance between your router and your neighbor's router.

   A. For this part, make assumptions identical to those in the slides: specifically, signal strength is $1/R^2$ μW at distance R, noise can be ignored, and you need an SINR of at least 100× for a good signal.

      Interference I drops by 2× in passing through the two houses' walls, effectively reducing the required SINR to 25×. Carrying the change through the equations gives $F < 1/6$.

   B. Now change the assumptions slightly to assume that you need an SINR of at least 1000× for a good signal (other assumptions remain the same).

      As in Part A, interference I drops by 2× in passing through the two houses' walls, effectively reducing the required SINR to 250×. Carrying the change through the equations gives $F < 1/16.8$ (16.8 is $\sqrt{250} + 1$).

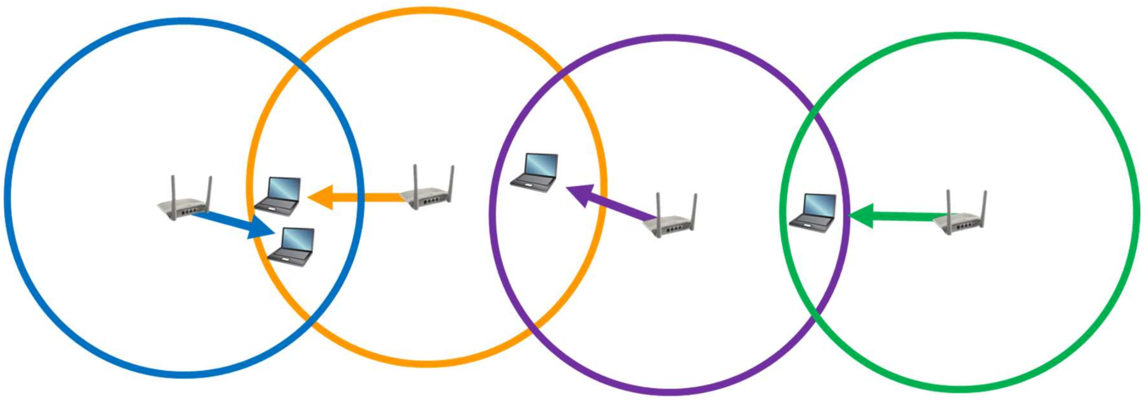
3. [L3] In Slide 42 of Lecture 3, the class together came up with a schedule in which six Wifi routers with overlapping interference ranges could transmit simultaneously. Remember that routers with non-overlapping circles can transmit at the same time, but routers with circles that overlap cannot. Given the four circles below, come up with…
   A. A schedule that is fair—in other words, each of the four routers gets an equal number of turns in the schedule.

      Turn 1: Blue and Purple transmit
      Turn 2: Orange and Green transmit

   B. A schedule that is not fair because some routers get to transmit more often. Hint: in the first turn, let blue and green transmit.

      Turn 1: Blue and Green transmit
      Turn 2: Orange and Green transmit
      Turn 3: Blue and Purple Transmit

      Note that turns 2 and 3 are identical to the fair schedule, so in practice Wifi should fall into the fair schedule after the first turn in this case (alternating between turns 2 and 3 without turn 1).



4. [L4] Solar radio bursts from the sun can increase the amount of background radiation by as much as 10,000×. One day, while using the campus Wifi at a distance of about 25 meters from the router, a radio burst occurs, raising the noise level. Assuming that signal power is $1/R^2$ μW at distance R and that noise N in your laptop is 10^{-6} μW, how much more noise B (noise is additive, so total noise is your laptop's noise plus noise from the solar radio burst) can your Wifi tolerate before you need to move closer to the router? Assume that you need an SINR of 100× to be able to use your Wifi. Assume no interference other than the extra noise from the solar radio burst.

   Let's call the solar radio burst B, giving SINR = $\frac{S}{N+B} = \frac{1}{25 \times 25\,(N+B)} > 100$. The two factors of 25 reflect the distance. Solving for (N + B) gives N + B < $\frac{1}{25 \times 25 \times 100} = 16 \times 10^{-6}$ μW. Subtracting N = 10^{-6} μW gives B < 15×10^{-6} μW.

5. [L4] Compute the bandwidth of the following bands:
   A. 2.40 to 2.41 GHz
      (2.41 – 2.40) GHz = 0.01 GHz = 10 MHz

   B. 5.13 to 5.15 GHz
      (5.15 – 5.13) GHz = 0.02 GHz = 20 MHz

   C. 60.4 to 61.2 GHz
      (61.2 – 60.4) GHz = 0.8 GHz = 800 MHz

6. [L4] Briefly explain two of the three reasons that make centralized control of cell towers better than using a collection of independently owned towers.

   There are many possible answers, but probably two of the three given in class are appropriate.

   1. Handoff is faster when a single entity makes a decision rather than requiring negotiations and multiple rounds of communication.
   2. Billing and accounting are also difficult when using independent routers—do they even agree to charge the same price? Do you want to negotiate a price with a tower before you use its services (you may, if the prices are up to each tower's owner)? What if some towers don't want to carry your traffic?
   3. Wifi tries to avoid interference by making independent decisions, but doesn't do as well when all of the transmitters are also in motion, as is usually the case with cellular. A central controller knows which devices are communicating with each tower and can easily distribute bandwidth resources in a fair and interference-free manner. As with handoff, doing so with independent control requires communication and negotiation.