Homework 2 submission

ECET 512 — Wireless Systems

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1 Submitted files

For this assignment, this report and the archives outlined below were created or added to and submitted.

1.1 SRC Folder

/ *"main.m"*: The MATLAB script will run a simulation that shows a mobile user moving through a set of generated hexagonal cells just as in Homework 1. The script concludes by plotting the signal strength received by the mobile user as they 'move' through the simulation in dBm for four scenarios of exponential path loss with or without random shadowing effects.

/ "*calcRXPower.m*": This function calculates the receive power in dBm encountered by the mobile user as a result of the closest base station. It takes the mobile user's position, the position of the serving cell, the transmission frequency and a string denoting which scenario the simulation uses to calculate. Each string denotes a scenario with its own receive power calculating function and parameters to modify that function. Currently this function accepts 'friis' for Friis Path Loss modeling and 'path_loss_exponent_3', 'path_loss_exponent_4', 'path_loss_exponent_3_with_shadowing', 'path_loss_exponent_4_with_shadowing' for the scenarios of this homework.

+ " *pathLossExponent.m*": This function calculates receive power of a mobile user based on the Exponential Path Loss Equation. The function takes as its parameters the distance from the base station, the reference distance in meters, the reference power in dBm, the path loss exponent, the shadow standard deviation and a Boolean. The Boolean determines if random shadowing is included in the calculation. It returns a receiving power in dBm.

+ " *mw2dbm.m*": This function converts power in milliwatts to dBm. It is used for convenience for when a function, such as the one for Friis Free Space Path Loss, returns power in milliwatts.

+ " *dbm2mw.m*": This function converts power in dBM to milliwatts. It is used for convenience for when adding signal power is necessary, such as when putting together the total interference for all 1^{st}-tier interferers.

1.2 DOC Folder

+ *"1st_tier_interferers.avi":* This video shows an animation of a mobile user traveling through various cells in a collection of clusters (generated using N = 7). A blue line is drawn from the user to the serving base-station, and other lines connect the user to the interfering base-stations from co-channel interfering cells.

+ *"1stTierInterferenceExponentPathLoss.jpg"*: Contains the chart generated for a particular simulation showcasing the combined interference power in dBm experienced by the mobile user as they travel from cell to cell.

+ *"MobileUser&1stTierInterferers.jpg":* A snapshot of the video of the mobile user traveling through different cells with lines drawn from them to the serving base-station, and from them to the interfering cell centers.

+ *"RxPowerExponentPathLoss.jpg":* Contains the chart generated for a particular simulation showcasing the received signal strength in dBm experienced by the mobile user as they travel from cell to cell.

+ *"SIRExponentPathLoss.jpg":* Contains the chart generated for a particular simulation showcasing the signal or carrier to interference ratio experienced by the mobile user as they travel from cell to cell.

2 Code execution

The MATLAB programming language was used to create the simulation for this homework. To run the simulation, simply run the "*main.m*" script file. It provides options to run the simulation for various cluster number values, various values of N for the number of cells in each cluster, as well as the option to record of a video of the simulation. Various other points in the code can be modified to run the simulation under different conditions either with randomness or purely deterministic.

3 Homework 2 Solution

3.A Exponential Path Loss with and without Shadowing

The function '*pathLossExponent*' takes all of the parameters necessary for calculating the receive power of the model user with or without the effects of random shadowing. The '*main*' program calls the function four times per frame calculating the effect in all four conditions for the user's current position. For this portion, it does not take into account co-channel interference. The graph for all four conditions can be found below in Figure 1 which plots the received power in dBm for a given simulation.

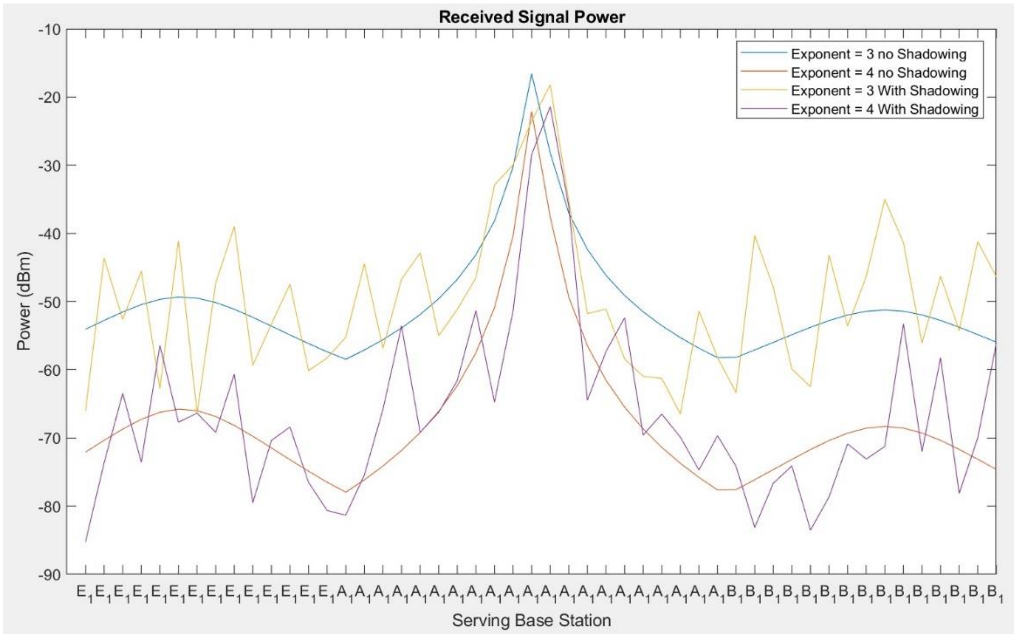

Figure 1: Figure of the received power for a user passing through multiple center excited hexagonal cells. The power calculated follows the exponential path model with and without random shadowing. Feature generated using MATLAB R2019a

The traces shown without shadowing are much more smoothing than those with shadowing. This is to simulate the user passing behind or in front of structures or geography that would shadow the signal in such a way that the shadowing varies as a normal variable. Essentially, a random die at each position determines the value of attenuation subtracted from or added to the signal value. For the traces that differ only in the value of the path loss exponent, this is merely that as the path loss exponent gets larger, the rate at which the signal fades increases. This is why the signals with *n* equaling four are at a lower power than the signals calculated with *n* equaling three.

3.B 1st-Tier Interference Illustration and Total Downlink Interference

The animation was generated with the same code given for homework 1. A snapshot of the simulation with serving and interference lines are shown below in Figure 2.

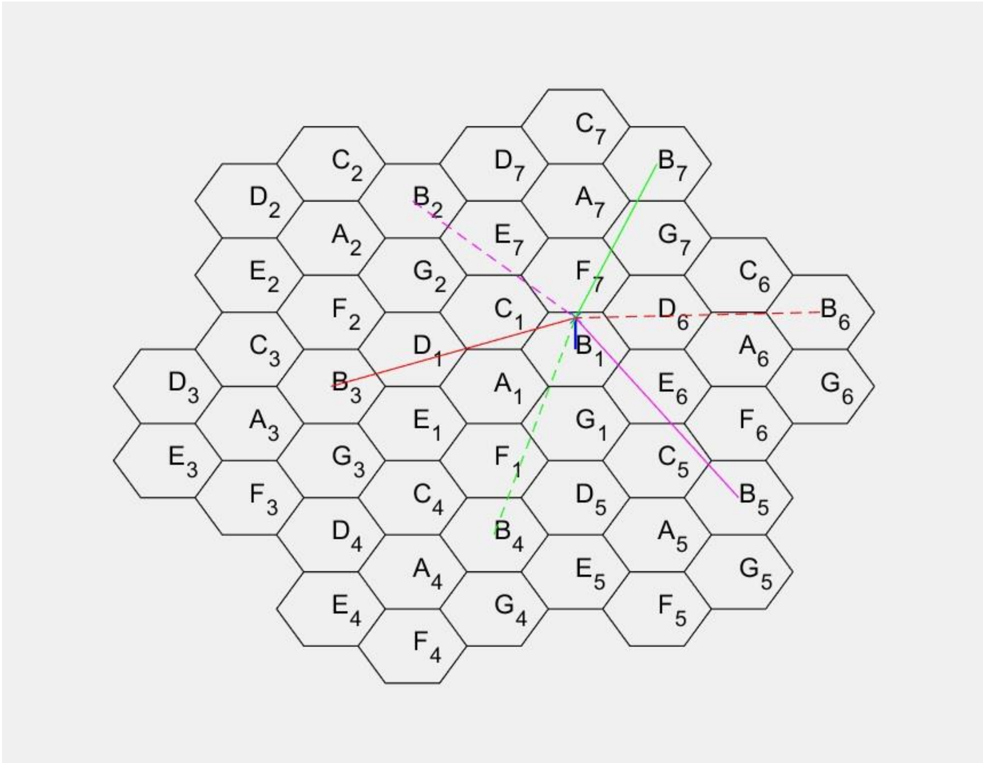

Figure 2: Snapshot of the moving user experiencing signals from the serving base-station and the 1st-tier interfering cells.

The interference experienced by the mobile user is plotted below in Figure 3 and is plotted for all four scenarios required for this problem.

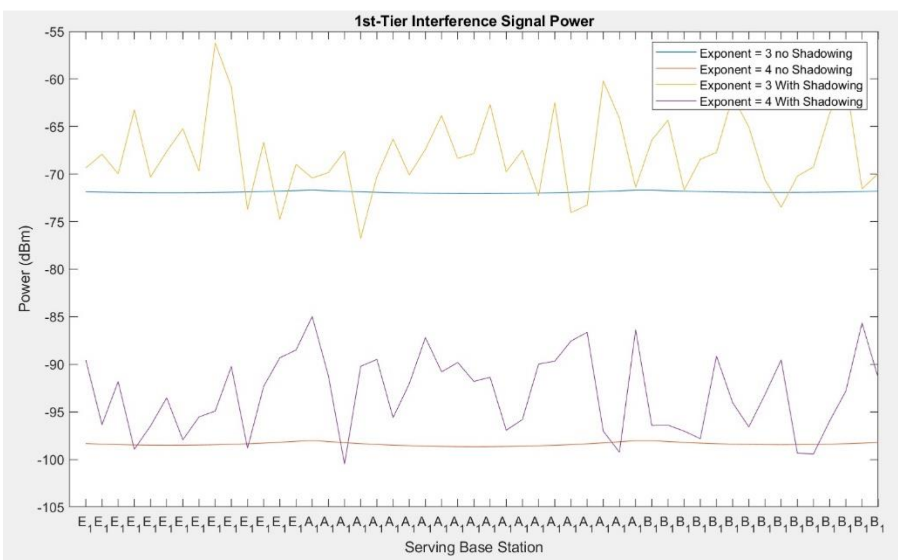

Figure 3: The total interference power in dBm experienced by the mobile user. The power shows considerable variation when non-deterministic parameters are used for calculation. Figure generated in MATLAB R2019a.

The interference experienced by the shows relative consistency when plotted without shadowing. This means that the model for interference and power is purely deterministic and is just a function of distance between the user and the interfering stations. There are slight peaks at the cell boundaries which is when the user is closest to all interferers. On the contrary, there are small troughs when the user is near the center of the serving cell. When the loss coefficient is higher, the signal interference is significantly less since there is a larger distance between the user and the interferers and the power drops off faster. This explains the dip in strength for both the deterministic and non-deterministic plots.

The difference when shadowing is added is that the interference is not constant as the user moves around. There is a randomness associated with simulated geographical or structural features of the environment which block or enhance the interference signals. As can be seen, this interference can have a great or large effect on the total interference depending on how the randomness affected the signal as it 'traveled' towards the user.

3.C Signal to Interference Ratio with and without Some Assumptions

The signal to interference ratio of the simulation is plotted below in Figure 4. Plots without assumptions were calculated point by point by dividing the magnitude of the signal strength by the magnitude of the total interference experienced at that point. For plots with assumptions made, the ratio was calculated directly using the equations covered in class. Assumption one assumed that the distance between the user and the interferers was all the same no matter where the user was in the serving cell. Assumption two assumed that the distance between the user and the farthest interfering cells, the nearest interfering cells, and those that fall in the middle only differed by a distance in magnitude equal to that of the cell radius.

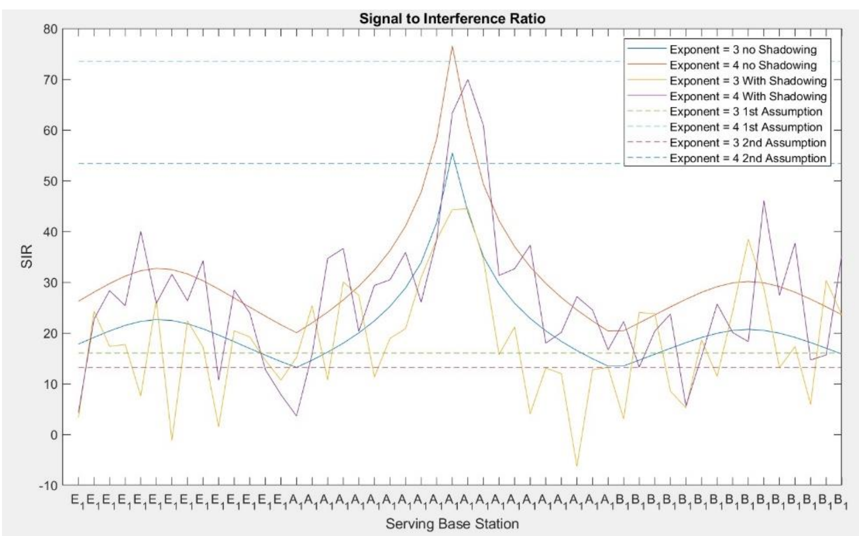

Figure 4: Plot showcasing the signal to interference ratio calculated for the four requested scenarios. Plot also includes the baseline interference expected under two assumptions regarding how close the user is to the interfering cells. Plot generated using MATLAB R2019a.

The signal to interference ratio differs in each scenario by slight changes in magnitude while maintaining the same general shape. The shape follows that the ratio is at its largest towards the center of the cells (where naturally signal strength is highest and interference strength is deterministically lowest) and lowest toward the cell boundaries. The difference in average magnitude of the scenarios differing only in the path loss exponent is caused by the rate of signal attenuation as the user moves away from the base-stations. Note that in this case, since the rate of attenuation is greater for higher exponents, the interference is much less and the serving signal is greater, meaning that for a larger exponent the magnitude of the ratio is greater. The randomness of the scenarios with shadowing around the base of the ratio in the purely deterministic scenarios are a result of, naturally, the randomness that affects the signal strength and interference strengths.

The geometric assumptions were functions of the path loss coefficient and the cell radius do not change as the user moves through the cells. There is no differing from a constant rate since in both assumptions, the user's relative distance from the interfering cells does not change. The change in magnitudes is a result of the change in the path loss exponent, as was seen previously. The second assumption, having a more accurate measure of distance between the mobile user and the interferers creates a lower ratio than the first assumption that is closer the average ratio for the deterministic and non-deterministic scenarios.

3.D MATLAB Movie

To view the movie illustrating the movement of the mobile user, refer to the flick found in the DOC archive.