Homework 3 submission

ECET 512 — Wireless Systems

Cameron J. Calv

January 28, 2020

1 Submitted files

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

1.1 SRC Folder

+ *"mainHandoff.m"*: The MATLAB script will run a simulation that accomplishes the goal of Problem A. It simulates a single mobile user moving directly from one base station to another, modeling power received by both with and without shadowing effects. It then determines the power threshold for which handoff should be initiated both ideally without shadowing and with a 95% confidence worst-case for consideration with shadowing.

+ *"mainMultiUser.m"*: The MATLAB script will run a simulation that accomplishes the goal of Problem B. It draws 20 users into the span of a single cell cluster and then plots the occupancy of each cell over the duration of the simulation.

/ "*calcRXPower.m*": This function was modified to include calculation of receive power with the *pathLossExponent* function taking on now a coefficient of 2.9 and with a shadowing standard deviation of 4 dB. It also includes a scenario to plot receive power in the worst case of shadowing within a 95% confidence interval.

1.2 DOC Folder

+ *"handoff_video.avi":* This is a video that shows the results for Problem A. It showcases a single mobile user moving between cell base stations A and B within a single cell cluster. The line drawn indicates the users traveled, and to-be-traveled path.

+ *"many_users.avi":* This is a video that shows the results for Problem B. It shows a collection of 20 mobile users with semi-random starting positions moving through a single cell cluster.

+ *"TwentyUsersFinalFrame.jpg":* This picture shows the final frame of the *many_users* video and is to be used to compare to the graph shown in *UsersInCellCluster.jpg.* This is merely one frame of the whole video to be used in the report.

+ *"UsersInCellCluster.jpg":* This picture illustrates the final result of Problem B showcasing the graph of the occupancy of each cell in the cell cluster as a function of time. Notice the consistent high number in the central cell.

+ *"UserTravelingForHandoff.jpg":* This picture shows a single frame snapshot of the video found in *handoff_video.avi* and is meant to represent the video within the report.

+ *"HandoffThresholdPlot.jpg":* This picture shows the graph of the received signal powers from both base stations without shadowing and lines representing the dropout threshold and the threshold for which handoff should begin at minimum.

+ *"HandoffThresholdPlotPlusShadowing.jpg":* This picture shows the graph of the received signal powers from both base stations with shadowing and lines representing the dropout threshold and the threshold for which handoff should begin at minimum. The shadowing curve represents the worst case scenario in a 95% confidence interval.

+ *"SignalPowerOverHandoffPath.jpg":* This picture shows the graph showing the signal power received from both base stations with and without shadowing effects. Two additional lines show the worst-case scenario for shadowing given a 95% confidence interval. The signal dropout power is also plotted in pink.

2 Code execution

The MATLAB programming language was used to create the simulations for this homework. To run the simulations, simply run the "*mainHandoff.m*" script for problem 4.A and the "*mainMultiUser.m*" script for problem 4.B. Each script 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 simulations under different conditions which vary between scripts.

3 Homework 2 Solution

3.A Determining the Handoff Threshold when Traveling Between BSs

This problem asks to simulate a mobile user traveling directly between two base stations. The setup deems that the mobile user is traveling at about 50 MPH, so the speed of the frames was made equal to one second meaning that it took the mobile user about 90 frames (seconds) to get from one base station to the other. A snapshot of the animation video can be found below in Figure 1.

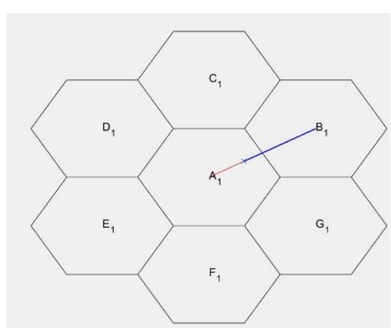

Figure 1: Figure showing one of the mid-frames of the video illustrating handoff procedure for a mobile user. Figure generated in MATLAB R2019a.

The receive power experienced by the mobile user was tracked for three separate situations over the course of the simulation. One is the normal path loss power as explored in the previous homework with a path loss coefficient of 2.9. One is the path loss with shadowing under the same conditions but with this time the shadow standard deviation set to 4 dBm. The final curves represent a non-shadowed simulation that is degraded by a factor corresponding to a number of standard deviations lower than the usual deterministic value. For a 95% confidence interval, meaning what we hope the signal power to be above 95% of the time, the signal waveform was attenuated by 1.96*4 dBm at each point. This adds a level of shadowing showcasing the "worst-case" for the point of link budget considerations. A plot of all the power signals as well as the call drop threshold is seen below in Figure 2.

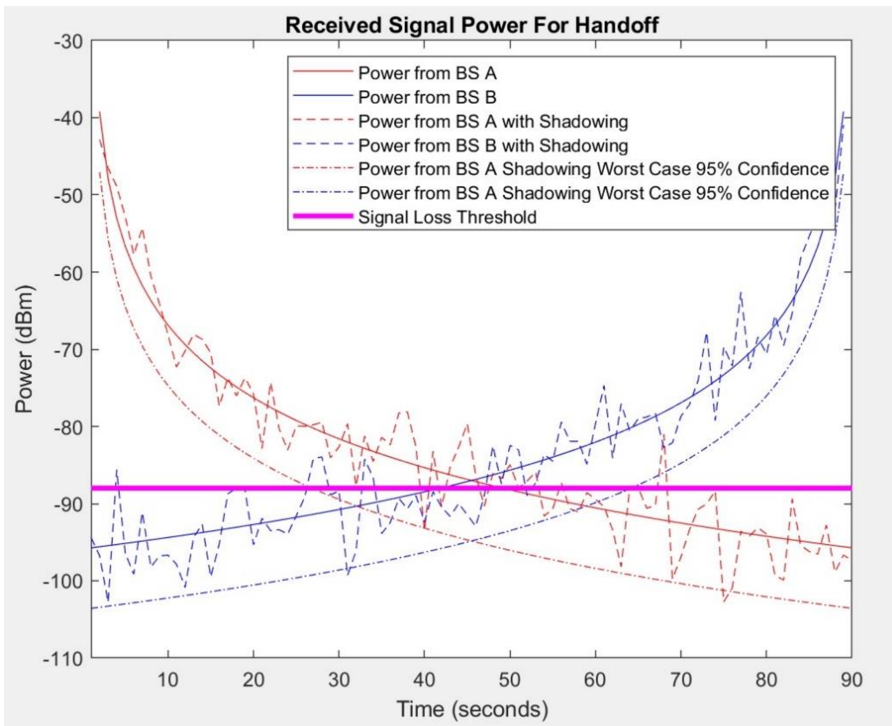

Figure 2: Plot showing the received signal power at the mobile user's location over time. Illustrates combined deterministic and non-deterministic scenarios caused by shadowing and worst-case effects. Figure generated in MATLAB R2019a.

Finally, for both the purely deterministic scenario and the worst-case shadowing scenario, the handoff threshold was calculated. The point at which the receive power from the first base station drops below the call drop threshold is determined. The problem gives that it takes at 4.5 seconds to complete handoff. This time was subtracted from the point where dropping would occur. The corresponding power at that new point was determined and subtracted from the dropping threshold and is represented by a 'delta minimum' for both cases. In the case of the purely deterministic case, the delta was 1.142 dB and the case for worst-case shadowing was 2.618 dB. The graphs for both simulations showing the signal levels and thresholds are showing in Figure 3 and Figure 4 below.

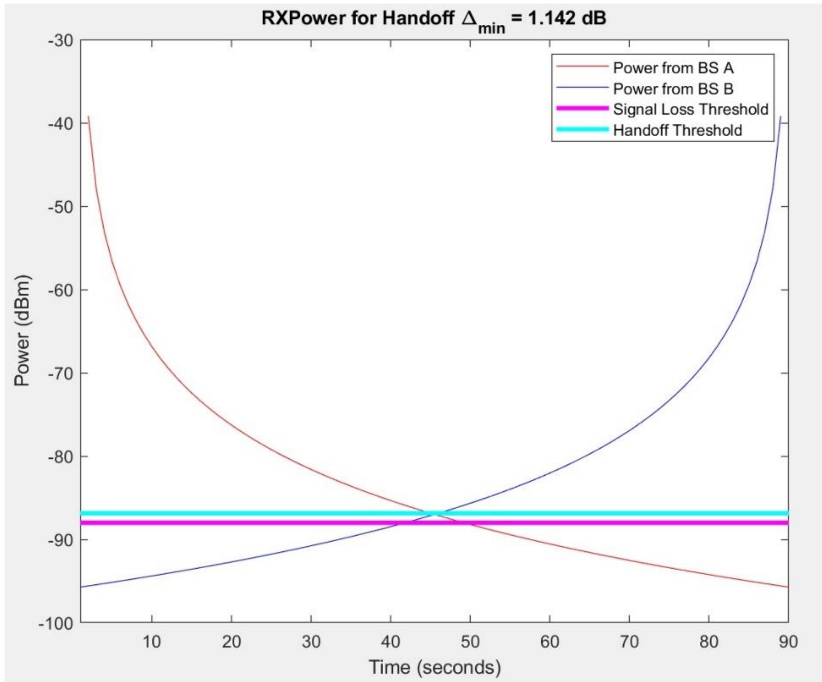

Figure 3: Figure showing the handoff threshold for a deterministically decreasing cell system signal. Figure generated in MATLAB R2019a.

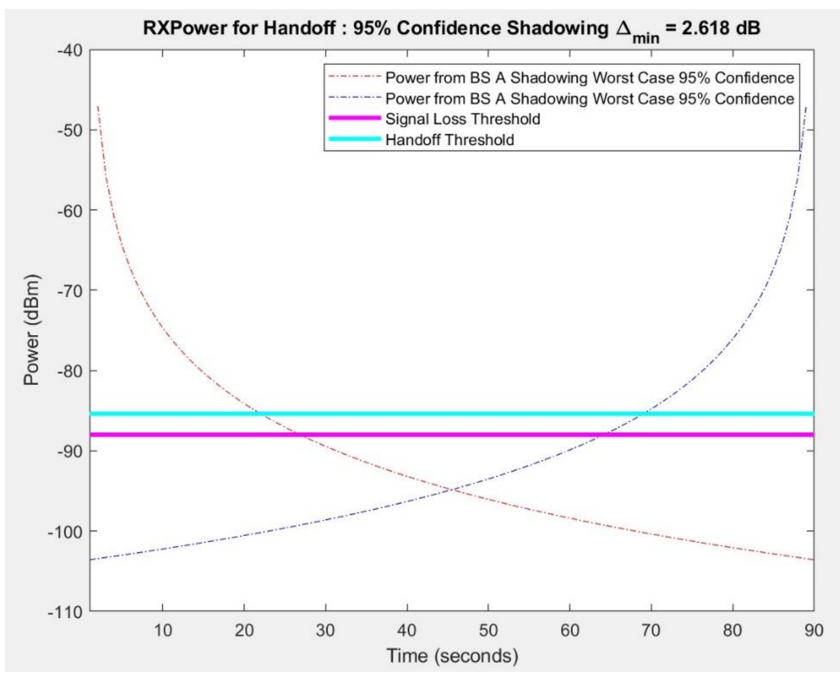

Figure 4: Figure showing the handoff threshold for a worst-case (within 95% confidence), non-deterministically decreasing cell system signal. Figure generated in MATLAB R2019a.

Note that in the case of the worst-case shadowing, hand off between the base stations will not prevent call dropping. In this case, a system must be designed that places the two base stations closer together so as to not allow any point where dropping would occur before, during and after handoff.

3.B Simulating Many Mobile Users to Characterize User Density per Cell

This problem asked for a simulation that showed multiple users in a cell system, which is much more realistic given today's prevalence of mobile devices. Twenty total users were added to the plot and given semi-random starting and ending positions. The randomness basically set it so that the users would stay within the cell cluster. The program then ran frame for frame counting how many users were being served by a particular cell at any given time. A snapshot of the video of all users moving about is found in Figure 5.

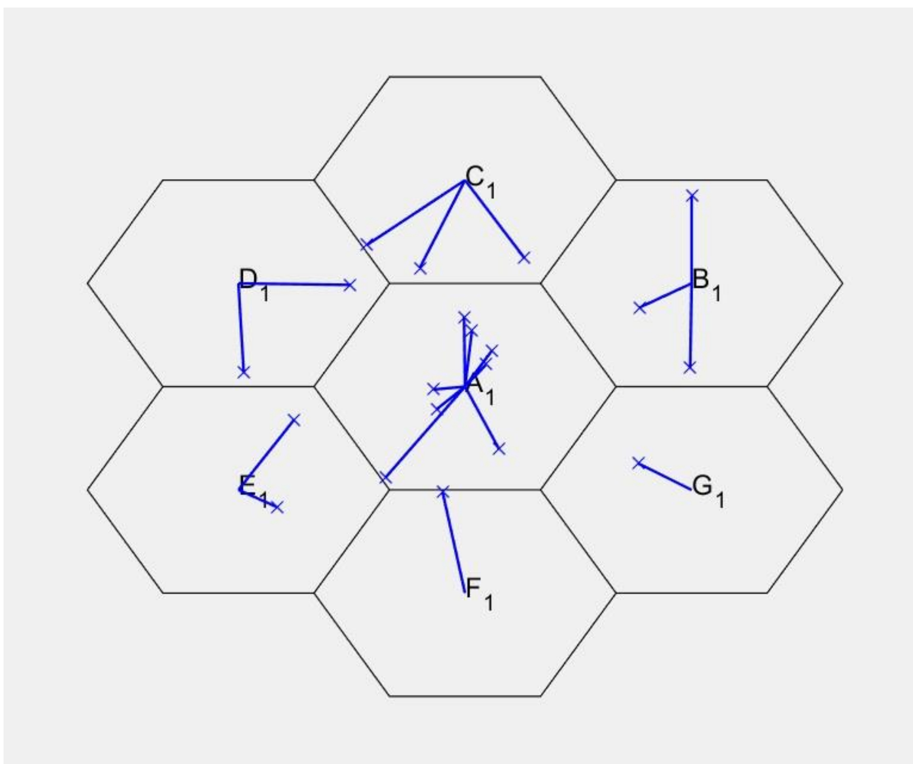

Figure 5: Figure showing the final frame of the simulation drawing twenty mobile users all traveling through a cell cluster. Figure generated in MATLAB R2019a.

Given the distribution of users in each cell (shown in Figure 6), it is clear that some methods of trunking must be used to properly distribute resources to each user should they need to use it.

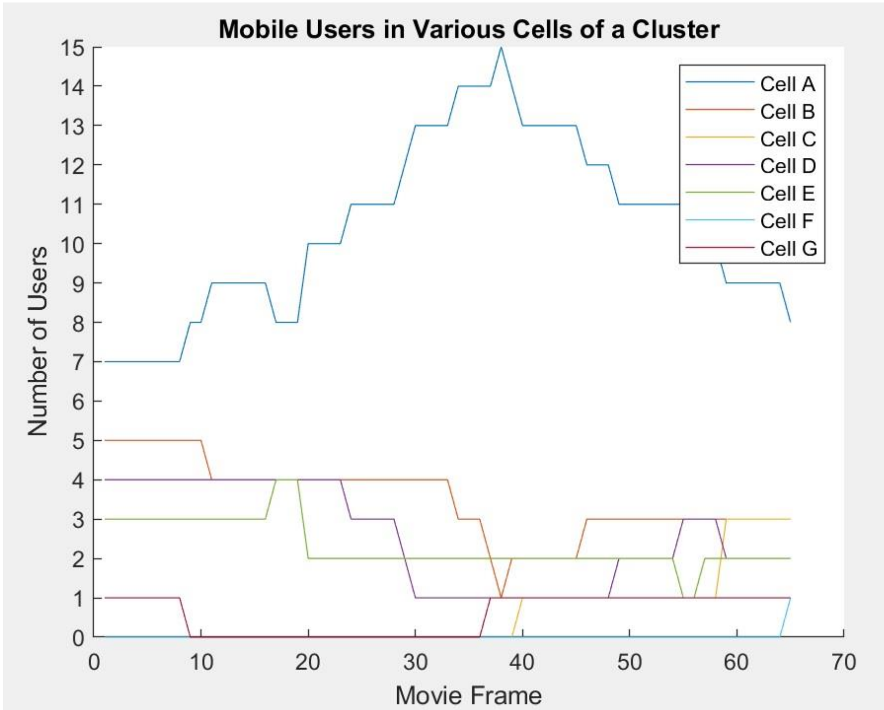

Figure 6: Plot showing the number of users in a given cell of a single cluster at any given time. Given the distribution of traveling users, it is clear that service from the central base station would need the most channels. Figure generated in MATLAB R2019a.

For populations that may have inconsistent densities of mobile users, it may be more efficient to implement hierarchical cell architectures or sectoring methods in order to serve areas that have a higher number of mobile users. In this simulation it is clear that the more central cells (in this case, only cell A) have more users that may request service within its boundaries. The probability of whether calls would be dropped or not would be a function of queueing theory using the model suggested by Erlang-B. If a queuing system were implemented, the probability that users were placed in a queue awaiting a vacant channel, the Erlang-C distribution would be preferred.

3.C MATLAB Movies

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