Homework 4 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

+ *"mainHornAntenna.m"*: The MATLAB script will run a simulation that accomplishes the goal of Problem A. It plots the radiation intensity of a horned antenna in three-dimensional space with the radius at each angle corresponding to the relative strength. Additional plots are added for the azimuth and elevation planes.

/ *"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. This simulation adds the ability to use various sectoring angles and draws an additional plot for the serving area of these sectors.

+ "*sphere3d.m*": A MATLAB function provided by J De Freitas on the Mathworks File Exchange. It allows convenient plotting of spherical coordinates such as those for radiation patterns. Credit: J De Freitas (2020). 3D Plot on a Spherical Surface (https://www.mathworks.com/matlabcentral/fileexchange/8585-3d-plot-on-a-spherical-surface), MATLAB Central File Exchange. Retrieved February 8, 2020.

1.2 DOC Folder

+ *"many_users_sectorized.avi":* This is a video that shows the results for Problem B. It showcases a group of 20 mobile users traversing through 90-degree sectorized cells in a single cell cluster.

+ *"HornRadiation3D.jpg":* This picture shows the radiation pattern as plotted using the 'sphere3d' function utilized from Mathworks. It shows the relative radiation intensity for any given angle in three-dimensional space.

+ *"HornRadiationAzimuth.jpg":* This picture shows the radiation pattern of a horned antenna as viewed from the azimuth plane.

+ *"HornRadiationElevation.jpg":* This picture shows the radiation pattern of a horned antenna as viewed from the elevation plane.

+ *"NonSectorizedOccupancy.jpg":* This plot shows the occupancy of the cells in the cell cluster as 20 users move randomly through the cluster.

+ *"SectorizedMobileUsers.jpg":* This image shows a snapshot of the video for Problem B requesting the animation of 20 mobile users traversing a completely sectorized cell cluster.

+ *"SectorizedOccupancy.jpg":* This plot shows the occupancy of the sectors within each cell in the cell cluster as 20 users move randomly through the cluster.

2 Code execution

The MATLAB programming language was used to create the simulations for this homework. To run the simulations, simply run the "*mainHornAntenna.m*" script for problem 4.A and the "*mainMultiUser.m*" script for problem 4.B. The first script outlines various characteristics of a horn antenna as best visualized by the functions in MATLAB. The second 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 Plotting the 3D, Azimuth and Elevation Radiation Pattern (Horn Antenna)

This problem asked to plot the radiation pattern of a horn antenna situated to be facing in the positive Z direction. For every theta and phi value between maximum values corresponding to a complete sphere, the radiation intensity was calculated using the equations given in the homework sheet. Radiation intensity values were converted to dBi and plotted using the "*sphere3d"* function that can be found on the Mathworks File Exchange. An image of the 3D plot can be found in Figure 1.

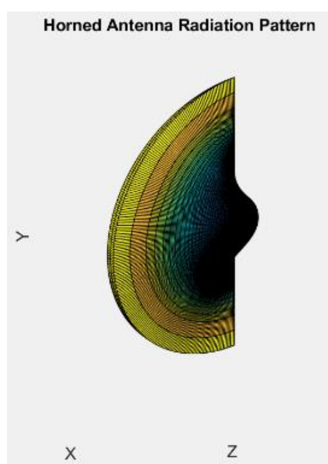

Figure 1: Figure showing one of the mid-frames of the video illustrating handoff procedure for a mobile user. Figure generated in MATLAB R2019a.

Note that the shape of the graph very oddly shows that the emission of the antenna is most notable in the plus Z direction. Given the way that the function plotted logarithmic values, all negative values were mapped to the opposite side of the sphere with a greater magnitude of log (thereby corresponding to a smaller value) being more accented than the smaller magnitude values. All values were negative log values which is why the intensity is actually strongest in the direction of the graph where there is the darkest coloration, not the lightest.

In order to better visualize the characteristics of the antenna, the azimuth and elevation planes for the radiation patter were plotted in Figure 2 and Figure 3. In these plots it is a bit easier to see the angled directivity of the horn antenna.

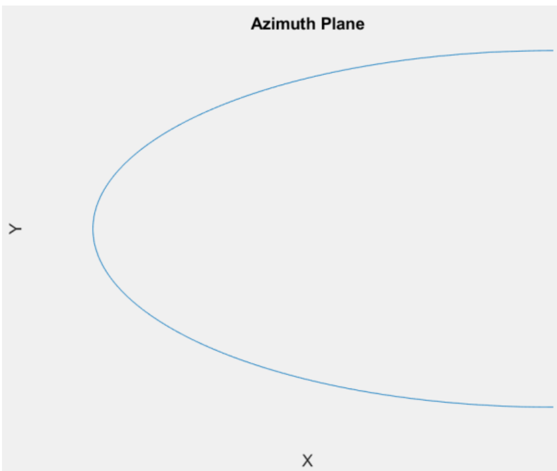

Figure 2: Plot showing the received signal power at the mobile user's location over time. Illustrates combined deterministic and non-deterministic scenarios caused by shadowing and worst-case effects. Figure generated in MATLAB R2019a.

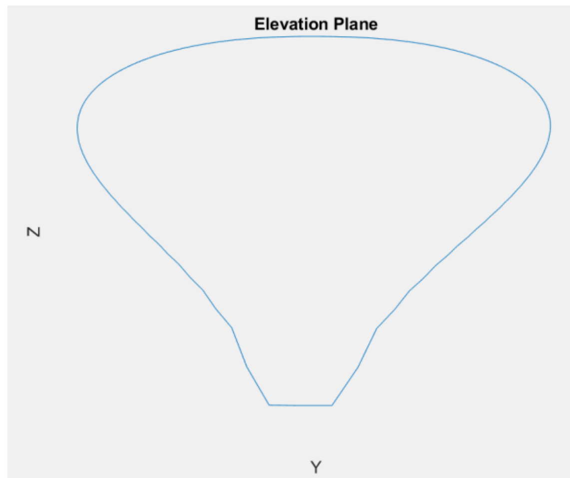

Figure 3: Figure showing the handoff threshold for a deterministically decreasing cell system signal. Figure generated in MATLAB R2019a.

The figures show (as best as they can) that in the azimuth plane, the intensity is small and in a wider range making the average radiated pattern in that area very small. In the elevation plane that points in the Z direction (where the antenna is pointed) the radiation pattern shows a lobe that spans about a <u>90-degree</u> angle sweep. For this reason, the sectoring angle chosen for the next problem was 90 degrees splitting each cell into four parts. The gain of this antenna calculated by integrating the radiation intensity over all direction and dividing the maximum intensity by that value was found to be about <u>130 dB</u>.

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

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. Additionally, each cell was split according to a parameter chosen based off of the plot from Problem A. A sectoring angle of 90 degrees was used and each cell was split into four sectors. A snapshot of the video of all users moving about is found in Figure 4.

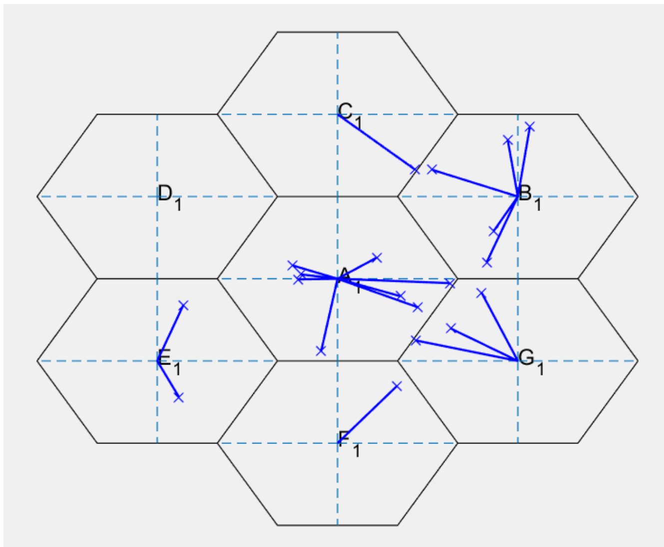

Figure 4: Figure showing the final frame of the simulation drawing twenty mobile users all traveling through a sectorized cell cluster. Figure generated in MATLAB R2019a.

Given the distribution of users in each cell (shown in Figure 5), it is clear that some methods of trunking must be used to properly distribute resources to each user should they need to use it.

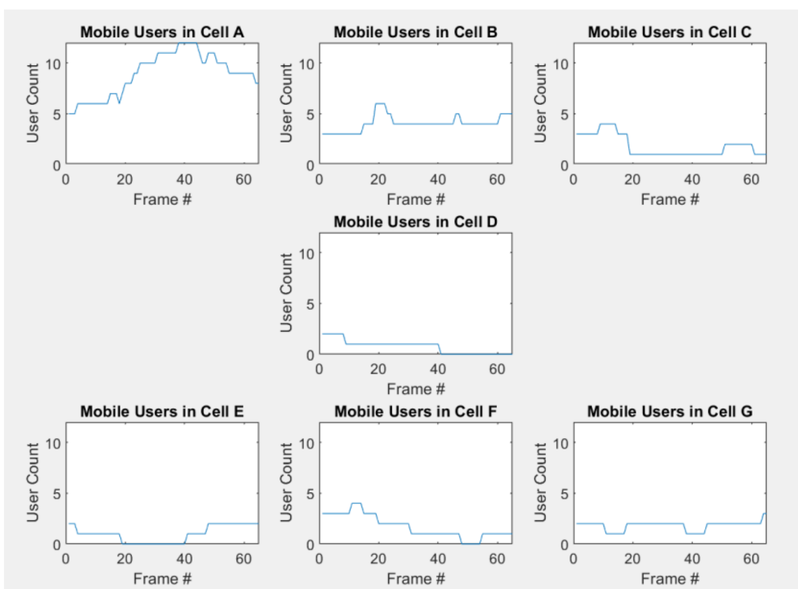

Figure 5: Plot showing the number of users in a given cell of a single cluster at any given time. Given the distribution of traveling users, it is clear that service from the central base station would need the most channels. Figure generated in MATLAB R2019a.

For each cell the occupancy per sector was also plotted assuming that at the base station there is a horn antenna oriented in the azimuth plane in the NW, NE, SW, and SE orientations. The occupancy of each sector per cell is shown below in Figure 6

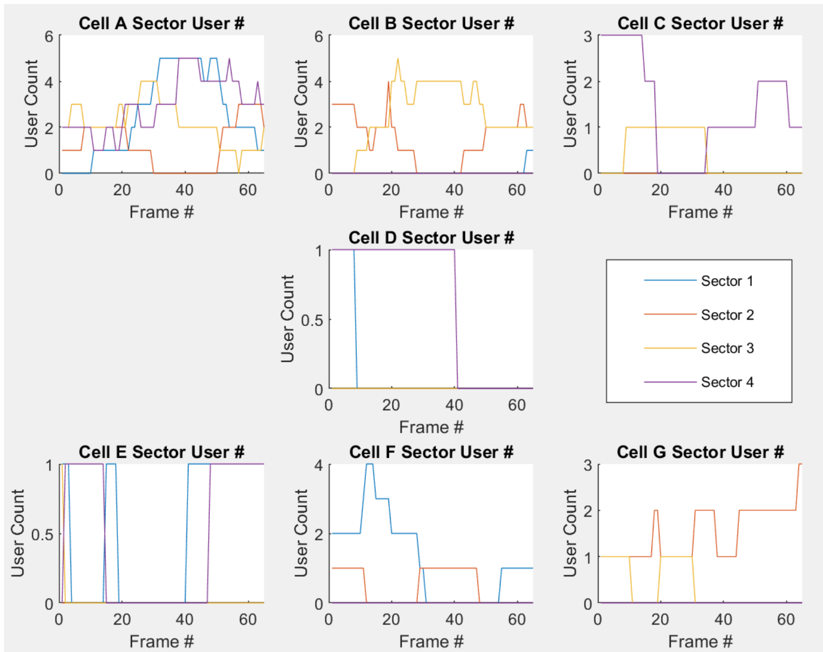

Figure 6: Plot showing the number of users in a given sector of a cell in a single cluster at any given time. Given the distribution of traveling users, it is clear that sectoring may not have to occur in absolutely every cell. Figure generated in MATLAB R2019a.

It appears that some cells don't retrieve nearly as much traffic as those oriented toward the center of the cluster (at least in this example). In this case it may be necessary to sector some of the cells in a cluster but not all of them. Where there may be uneven densities or even high numbers of users, sectoring has the advantage of more evenly segmenting bandwidth for densities that may be uneven or large. This would increase the trunking efficiency as methods can be used to space available channels more optimally with more sections.

3.C MATLAB Movies

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