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COURSEWORK: ENTS –656 FALL 2024 (CELLULAR COMMUNICATIONS)

PROJECT TITLE: SECTORED BASESTATION SIMULATION ANALYSIS.

Q1: Run your simulation for four hours with the parameters given. How many problems (e.g. drops, blocks, hand off failures) occur? What percentage of call attempts have a problem? Does this base station perform well? Which sector performs better?

Conditions: Length of the road= 3Km, Number of users = 160, Total simulation time = 4 hours

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After 3600 seconds    (1 hour)                After 7200 seconds (2 hours)

Statistics:                                   Statistics:
channels available - Alpha: 14, Beta: 13      channels available - Alpha: 10, Beta: 13
Call Attempts - Alpha: 181, Beta: 164         Call Attempts - Alpha: 328, Beta: 334
Call Blocks - Alpha: 0, Beta: 0               Call Blocks - Alpha: 0, Beta: 0
Call Drops - Alpha: 2, Beta: 27               Call Drops - Alpha: 2, Beta: 52
Successful Calls - Alpha: 154, Beta: 159      Successful Calls - Alpha: 297, Beta: 304
Handoff Attempts - Alpha: 79, Beta: 55        Handoff Attempts - Alpha: 139, Beta: 115
Successful Handoffs - Alpha: 79, Beta: 55     Successful Handoffs - Alpha: 139, Beta: 115
Failed Handoffs - Alpha: 0, Beta: 0           Failed Handoffs - Alpha: 0, Beta: 0
Active Calls - Alpha: 1,Beta:2                Active Calls - Alpha: 5,Beta:2
================================================================================
After 10800 seconds (3 Hours)                 After 14400 seconds (Simulation Completed)

Statistics:                                   Statistics:
channels available - Alpha: 13, Beta: 14      channels available - Alpha: 13, Beta: 13
Call Attempts - Alpha: 480, Beta: 506         Call Attempts - Alpha: 629, Beta: 688
Call Blocks - Alpha: 0, Beta: 0               Call Blocks - Alpha: 0, Beta: 0
Call Drops - Alpha: 4, Beta: 80               Call Drops - Alpha: 5, Beta: 110
Successful Calls - Alpha: 464, Beta: 435      Successful Calls - Alpha: 640, Beta: 558
Handoff Attempts - Alpha: 186, Beta: 176      Handoff Attempts - Alpha: 234, Beta: 252
Successful Handoffs - Alpha: 186, Beta: 176   Successful Handoffs - Alpha: 234, Beta: 252
Failed Handoffs - Alpha: 0, Beta: 0           Failed Handoffs - Alpha: 0, Beta: 0
Active Calls - Alpha: 2,Beta:1                Active Calls - Alpha: 2,Beta:2
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Number of problems: (After 4 hours of simulation)

- (Call drops + Call blocks + Handoff failures) = (Alpha sector) = 5
- (Call drops + Call blocks + Handoff failures) = (Beta sector) = 110
- Call attempts (alpha) = 629, Successful calls (alpha) = 640
- Call attempts (beta) = 688, Successful calls (beta) = 558

  =>Total call attempts in base station= (629 + 688 = 1317)

  => Total successful calls in base station = (640 + 558 = 1198), (Unsuccessful calls in base station = 119)

  => Percentage of call problems in alpha sector = 0.79%

  => Percentage of call problems in beta sector = 15.98%

  => Percentage of call problems in the base station = 9.03%

  - Alpha sector performs better than beta sector after analyzing the call problems, alpha sector can convert most of the calls attempted to successful calls.
  - The base station can handle the call attempts with 90.9% efficiency.

Q2: Change the length of the road from 3 km to 6 km and move the base station so it is still at the midway point (20m west and 3 km up from the bottom). Rerun your simulation for four hours. How many problems

occur now, and what is the new percentage? Compared to Q1, what is the main cause of the additional problems? (e.g. drops from signal strength? Or blocks from capacity? Or Hand off failures? Etc.)

Conditions: Length of the road= 6Km, Number of users = 160, Total simulation time = 4 hours

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==========================================================================
After 3600 seconds  (1 hour)                    After 7200 seconds  (2 hours)

Statistics:                                     Statistics:
channels available - Alpha: 9, Beta: 15         channels available - Alpha: 11, Beta: 15
Call Attempts - Alpha: 161, Beta: 167           Call Attempts - Alpha: 333, Beta: 332
Call Blocks - Alpha: 0, Beta: 0                 Call Blocks - Alpha: 0, Beta: 0
Call Drops - Alpha: 37, Beta: 117               Call Drops - Alpha: 84, Beta: 237
Successful Calls - Alpha: 121, Beta: 47         Successful Calls - Alpha: 234, Beta: 106
Handoff Attempts - Alpha: 36, Beta: 39          Handoff Attempts - Alpha: 88, Beta: 77
Successful Handoffs - Alpha: 36, Beta: 39       Successful Handoffs - Alpha: 88, Beta: 77
Failed Handoffs - Alpha: 0, Beta: 0             Failed Handoffs - Alpha: 0, Beta: 0
Active Calls - Alpha: 6,Beta:0                  Active Calls - Alpha: 4,Beta:0
==========================================================================
After 10800 seconds  (3 hours)                  After 14400 seconds(Simulation Completed)

Statistics:                                     Statistics:
channels available - Alpha: 13, Beta: 13        channels available - Alpha: 12, Beta: 13
Call Attempts - Alpha: 473, Beta: 518           Call Attempts - Alpha: 651, Beta: 696
Call Blocks - Alpha: 0, Beta: 0                 Call Blocks - Alpha: 0, Beta: 0
Call Drops - Alpha: 124, Beta: 370              Call Drops - Alpha: 179, Beta: 503
Successful Calls - Alpha: 336, Beta: 157        Successful Calls - Alpha: 438, Beta: 222
Handoff Attempts - Alpha: 131, Beta: 120        Handoff Attempts - Alpha: 184, Beta: 153
Successful Handoffs - Alpha: 131, Beta: 120     Successful Handoffs - Alpha: 184, Beta: 153
Failed Handoffs - Alpha: 0, Beta: 0             Failed Handoffs - Alpha: 0, Beta: 0
Active Calls - Alpha: 2,Beta:2                  Active Calls - Alpha: 3,Beta:2
==========================================================================
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Number of problems: (After 4 hours of simulation)

- (Call drops + Call blocks + Handoff failures) = (Alpha sector) = 179
- (Call drops + Call blocks + Handoff failures) = (Beta sector) = 503
- Call attempts (alpha) = 651, Successful calls (alpha) = 438
- Call attempts (beta) = 696, Successful calls (beta) = 222

  =>Total call attempts in base station= (651+ 696 = 1347)

  => Total successful calls in base station = (438 + 222 = 660), (Unsuccessful calls = 687)

  => Percentage of call problems in alpha sector = 27%

  => Percentage of call problems in beta sector = 72.27%

  => Percentage of call problems in the base station = 51%

- Alpha sector shows a low received signal strength compared to the threshold signal level Starting from –1000m south itself, similar behavior is shown by the beta sector from 1000m North. When road length is doubled from 3km to 6 km there is an increase in lot of positions on the road where the users receive low signal levels compared to the threshold level by both the sectors. This causes an increase in call drops and can be observed in the simulation results.

Q3: Change the length of the road back to 3 km (and put the base station back where it was). Quadruple the number of users (from 160 to 640). Rerun your simulation for four hours. How many problems occur now, and what is the new percentage? Compared to Q1, what is the main cause of the additional problems (e.g. drops from signal strength? or blocks or drops from capacity?) What is the effect on handover performance?

After 3600 seconds (1 hour)	After 7200 seconds (2 hours)
Statistics:	Statistics:
channels available - Alpha: 1, Beta: 0	channels available - Alpha: 3, Beta: 2
Call Attempts - Alpha: 577, Beta: 640	Call Attempts - Alpha: 1193, Beta: 1275
Call Blocks - Alpha: 44, Beta: 60	Call Blocks - Alpha: 102, Beta: 125
Call Drops - Alpha: 2, Beta: 89	Call Drops - Alpha: 5, Beta: 163
Successful Calls - Alpha: 521, Beta: 472	Successful Calls - Alpha: 1085, Beta: 963
Handoff Attempts - Alpha: 246, Beta: 300	Handoff Attempts - Alpha: 546, Beta: 607
Successful Handoffs - Alpha: 203, Beta: 207	Successful Handoffs - Alpha: 424, Beta: 435
Failed Handoffs - Alpha: 43, Beta: 93	Failed Handoffs - Alpha: 122, Beta: 172
Active Calls - Alpha: 14,Beta:15	Active Calls - Alpha: 12,Beta:13
After 10800 seconds (3 hours)	**After 14400 seconds (Simulation Completed)**
Statistics:	Statistics:
channels available - Alpha: 3, Beta: 0	channels available - Alpha: 3, Beta: 1
Call Attempts - Alpha: 1831, Beta: 1912	Call Attempts - Alpha: 2424, Beta: 2537
Call Blocks - Alpha: 162, Beta: 188	Call Blocks - Alpha: 214, Beta: 242
Call Drops - Alpha: 11, Beta: 246	Call Drops - Alpha: 14, Beta: 327
Successful Calls - Alpha: 1632, Beta: 1477	Successful Calls - Alpha: 2173, Beta: 1965
Handoff Attempts - Alpha: 871, Beta: 866	Handoff Attempts - Alpha: 1119, Beta: 1159
Successful Handoffs - Alpha: 655, Beta: 641	Successful Handoffs - Alpha: 855, Beta: 844
Failed Handoffs - Alpha: 216, Beta: 225	Failed Handoffs - Alpha: 264, Beta: 315
Active Calls - Alpha: 12,Beta:15	Active Calls - Alpha: 12,Beta:14

Number of problems: (After 4 hours of simulation) (Road length = 3km, Users = 640)

- (Call drops + Call blocks) = (Alpha) = 228, Handoff failures (Alpha) = 264
- (Call drops + Call blocks) = (Beta) = 569, Handoff failures (Beta) = 315
- Call attempts (alpha) = 2424, Successful calls (alpha) = 2173
- Call attempts (beta) = 2537, Successful calls (beta) = 1965

  =>Total call attempts in base station= (2424 + 2537 = 4961)

  => Total successful calls in base station = (2173 + 1965 = 4138), (Unsuccessful calls = 823)

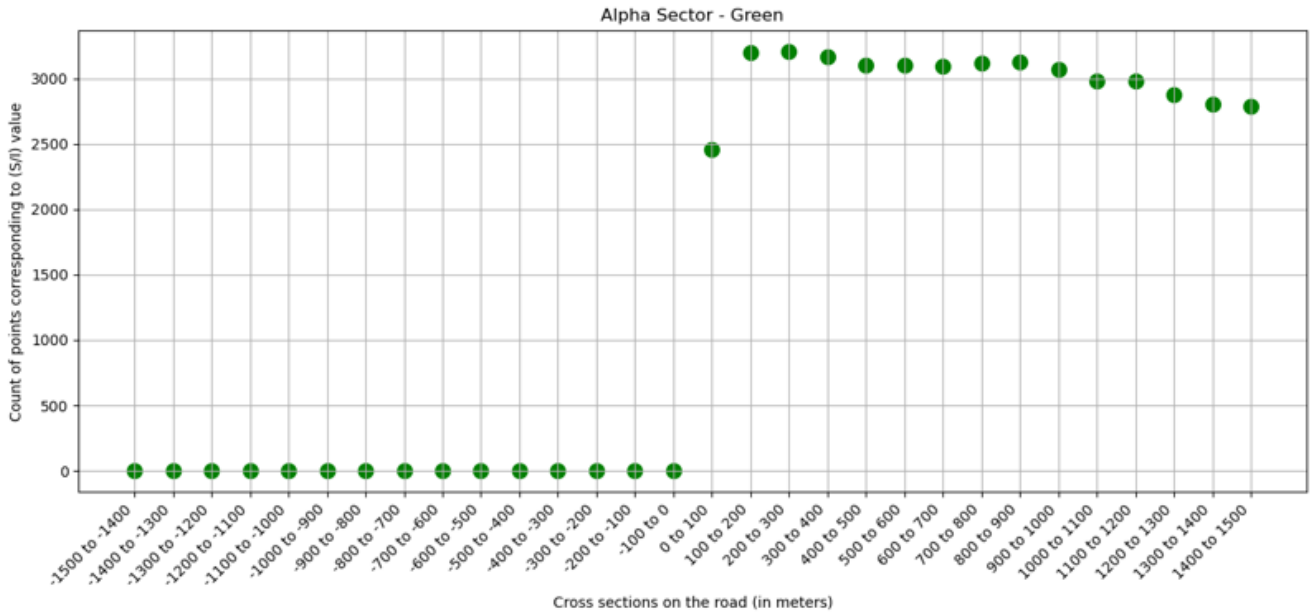
  => Percentage of call problems in alpha sector = 9.4%, Handoff failures (alpha) = 23.5%

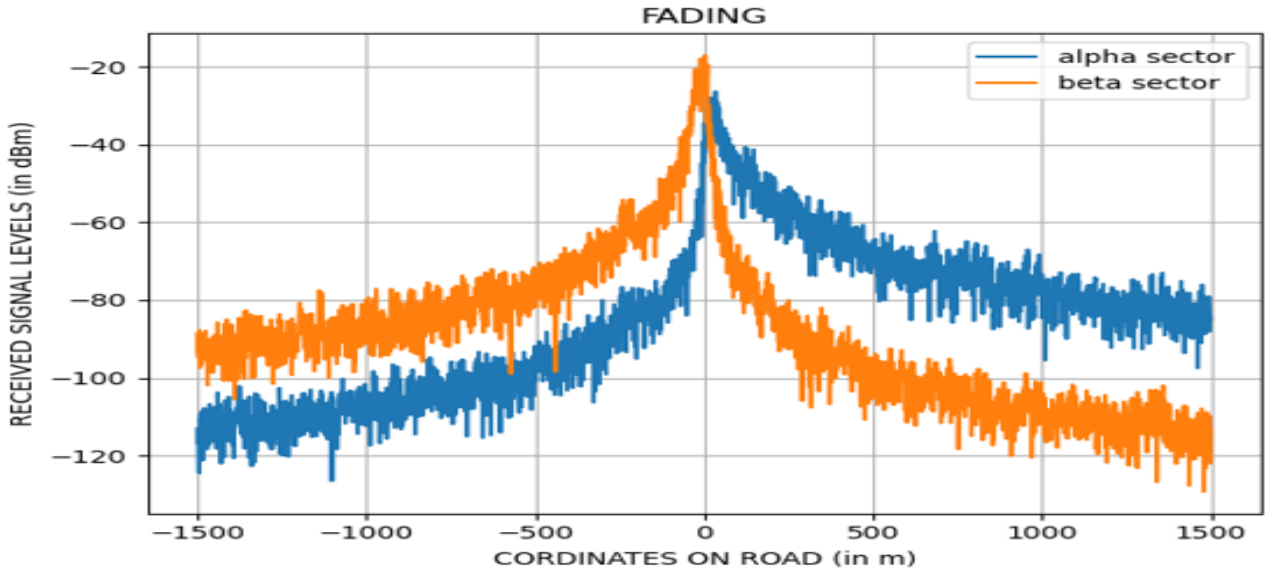
  => Percentage of call problems in beta sector = 22.4%, Handoff failures (beta) = 27.17%

  => Percentage of call problems in the base station = 16.58%

- Since the number of users has quadrupled from 160 to 640 this in turn increases handoff attempts of the base station in both alpha and beta sectors in a similar trend but the channel capacity remains constant in the base station sectors. This produces an increase in the number of call blocks and handoff failures in both the sectors of the base station whereas the received signal strengths remain the same as the situation in Q1.

Q4: **Look at the throughput graphs generated in question 1.**



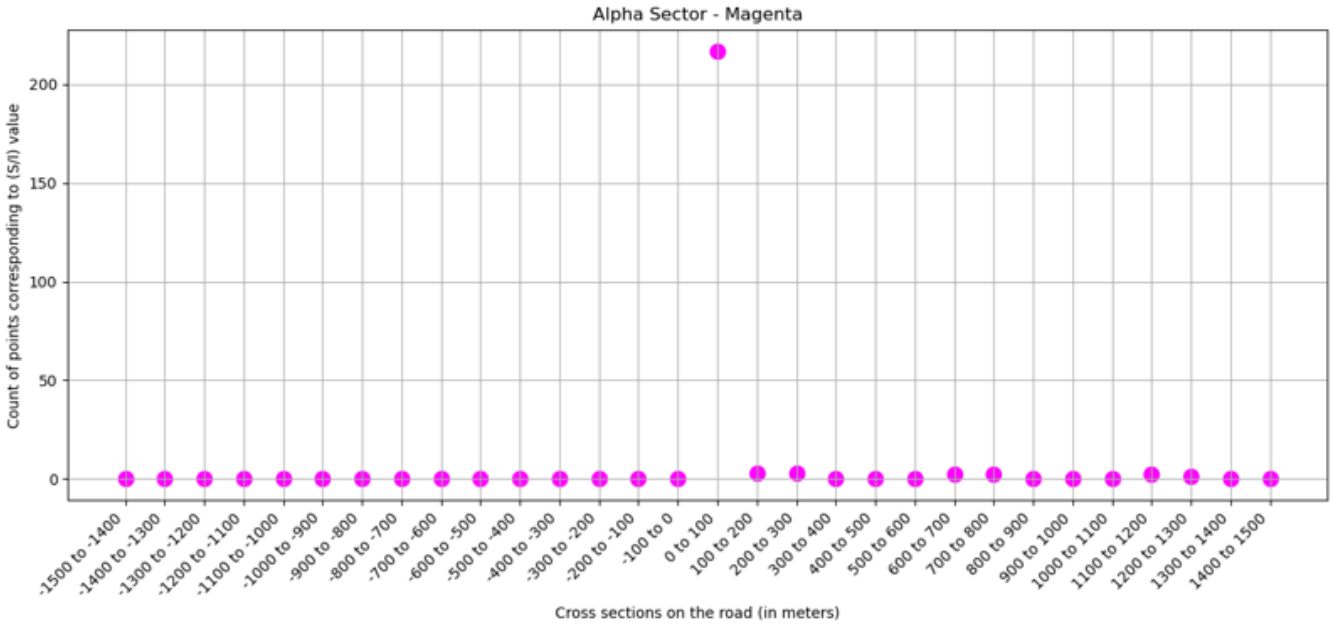


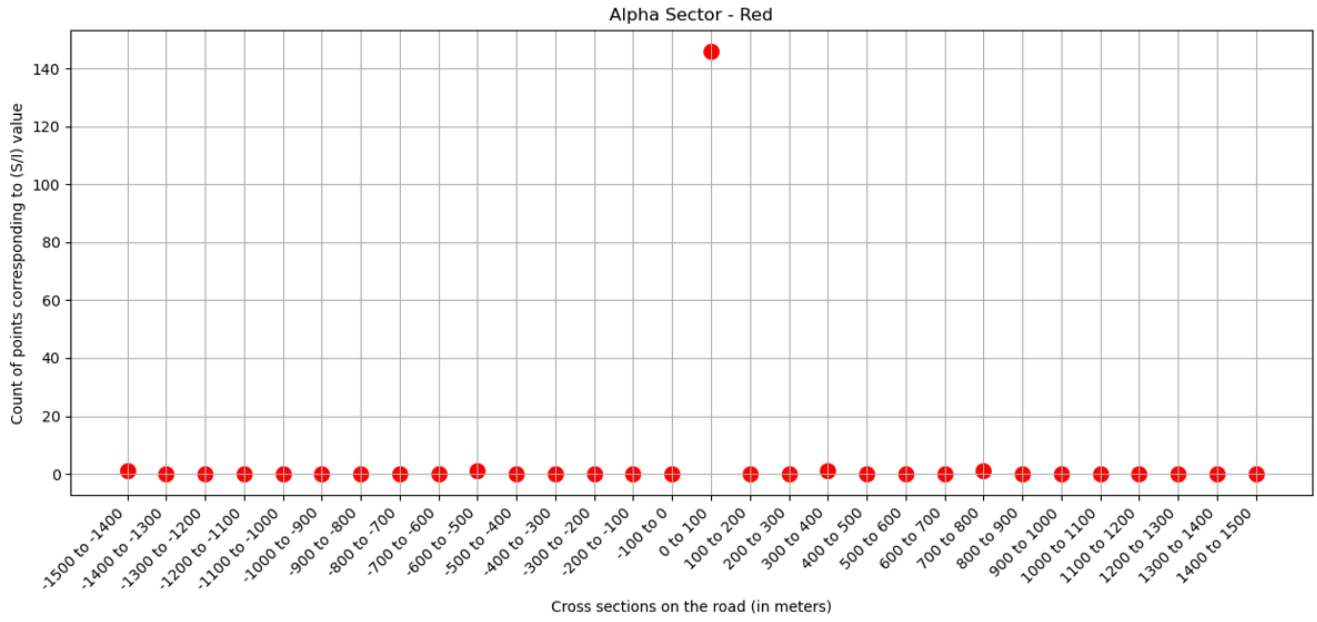
What area of the road (generally) shows the best performance (green) for the alpha sector?

The coordinates towards the North of the road starting from 0m to 1500 m show a better throughput performance for the alpha sector. Because the alpha antenna is aligned in the direction of the road providing a better signal strength. From the graph shown above we can observe that alpha sector provides more RSL between 0 and 1500 and there are few deep fades also in this region seen which adds to the received signal by the user and improves the throughput rate.

Where is performance mediocre (magenta) or poor (red)? (Alpha sector)

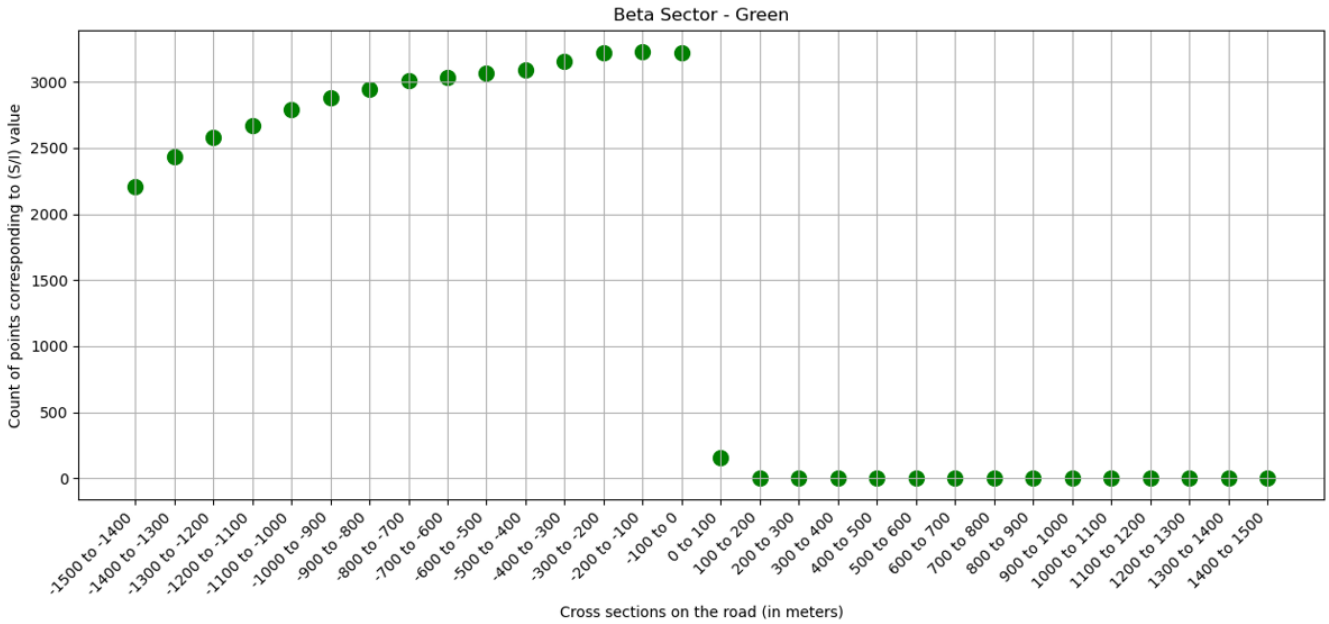
There are a few points that can be observed for the alpha sector on the road which are close to the base station (i.e., -100 m to 100 m). From the RSL graph attached we can observe that there are similar values in both alpha and beta sectors in this region. Due to this reason, users in that region receive very low values of signal to interference ratio (RSL_serving – RSL_neighbor). The graphs attached below represent the same.





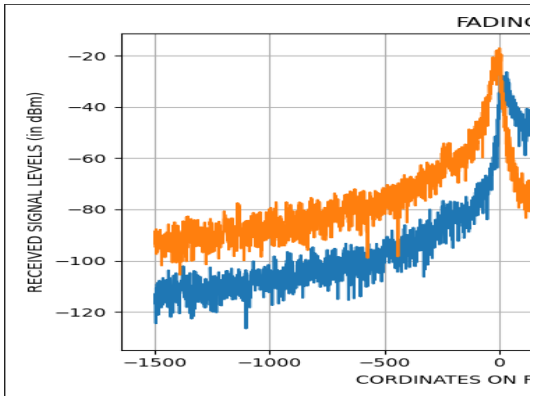
What about the beta sector (where is it best, mediocre, and poor)?

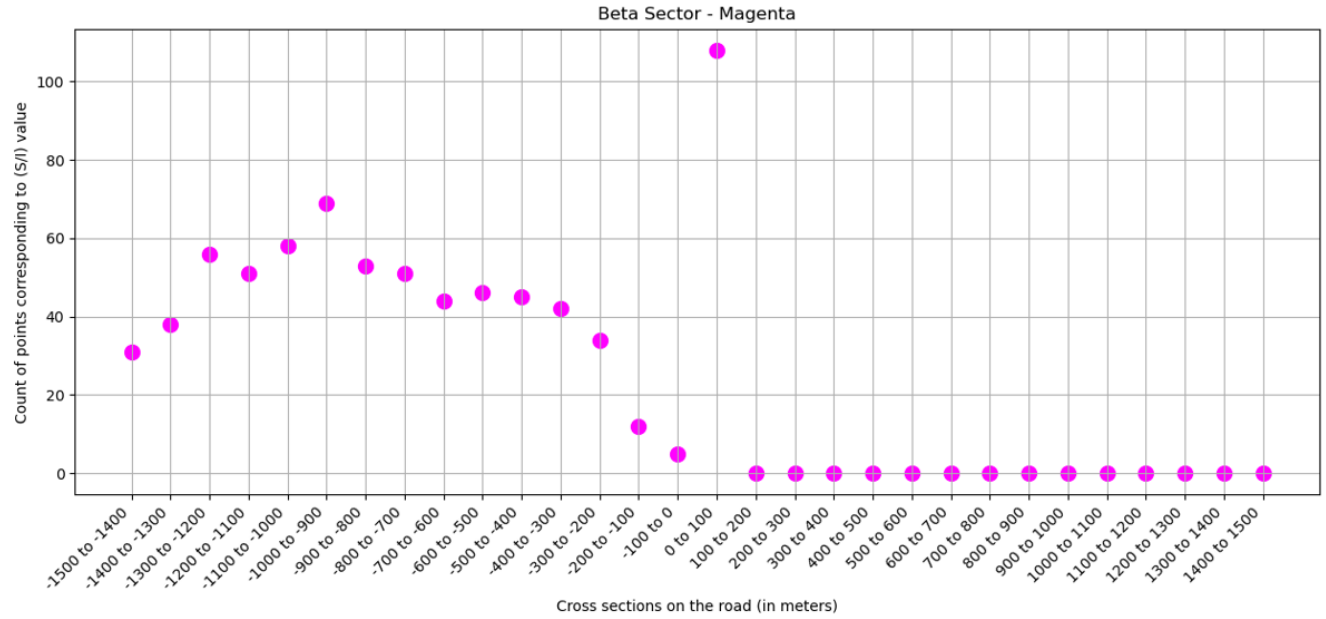
The coordinates towards the South of the road starting from –1500 m to 0 m show a better throughput performance for the beta sector. Because the beta antenna is positioned closer in the lower coordinates of the road providing a better signal strength in that region. From the graph shown above we can observe that beta sector is dominant compared to the alpha sector providing greater RSL between -1500 and 0 and there are few fades also in this region close to -500m seen which adds to the received signal by the user and improves the throughput rate.



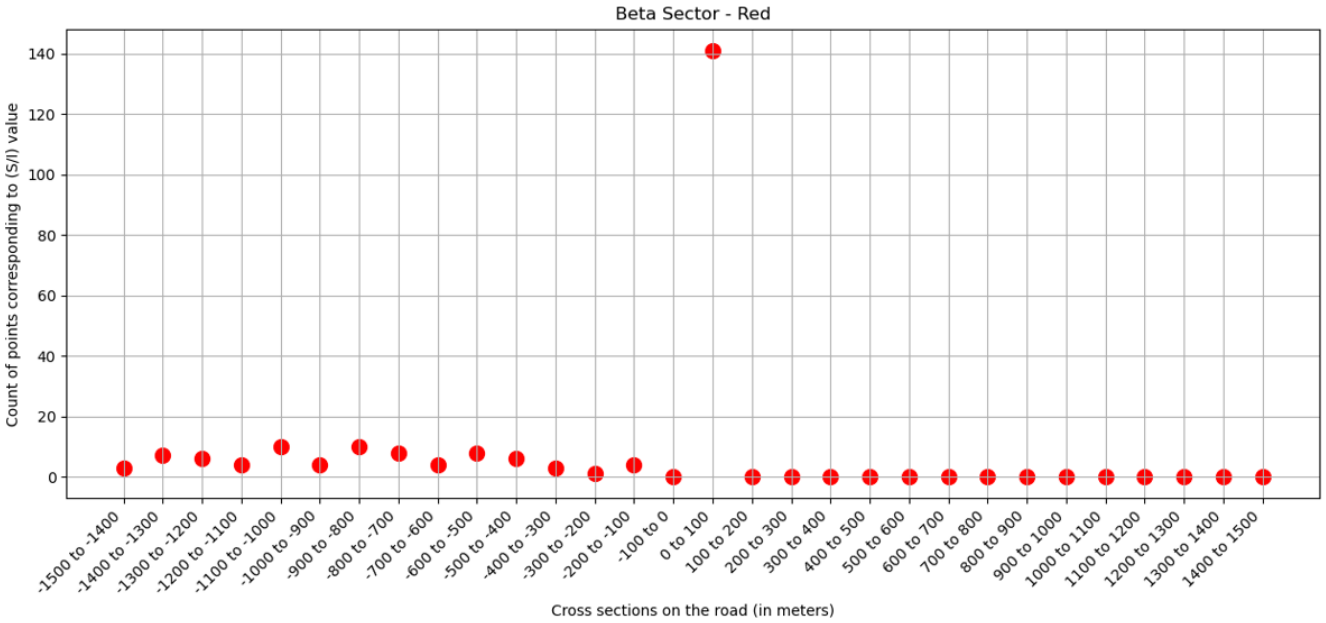
Which sector seems to have better performance (less magenta and red relative to green)?

The beta sector shows scattered signal to interference ratio points between –1500 m and 0 m. This is due to the dominant signal strength provided by the alpha sector in this region. The RSL graph obtained in the part 1 simulation shows us that there isn't much difference between the RSL_alpha and RSL_beta values in the range (-1500 m to 1500 m) leading to mediocre performance in this region of the road.





A similar trend is being observed for the beta sector, like the alpha sector where the throughput drops between –100 m to 100 m (close to the base station) due to very less signal to interference values / difference in RSL values from both the sectors.



How to execute the code:

My submission consists of three python files:

1. Part_1: Code to compute RSL values at different positions of the road taking path loss (COST-231 model, shadowing and fading into consideration).

2. Part_2: Code to simulate the base station sector performance analysis for different cases of users and dimensions of the road for a simulation time of 4 hours utilizing the functions from part 1 for computation of values.

3. Config.py - File to change the values of parameters required for performing the simulation.