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INTRODUCTION TO CELLULAR NETWORKS

FALL 2021 PROJECT REPORT

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SUBMISSION DATE: 12/12/2021

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1. INTRODUCTION

The Aim of this project is to explore the effects of downtilting antennas on cell performance, both from a coverage and an interference/throughput point of view.

Base station and mobile Parameters:

- **Height**: h_b = 50 m (This is the basestation antenna height)
- **Location**: d_ortho=15 m orthogonal to the road at each end of the road as pictured
- **TX Power:** Tx_p= 43 dBm
- **Line/connector Losses:** Loss= 1 db
- **Antenna Gain:** G= 14.8 dBi (at boresight)
- **Antenna Tilt:** tilt = 2° typically, but can be between 0° and 10° for this project
- **Number of Traffic Channels:** CH= 15 per sector
- **Frequency:** Both basestations will operate at f_{MHZ} = 800 MHz
- **Shadowing:** log normal with μ = 2 dB and σ = 2 dB (**see channel properties below**)
- **Shadowing Resolution:** 20 meters
- **Mobile Height:** h_m = 1 meter (users are assumed to be in a car)
- **Handoff margin**: HOm = 3 dB (this will be used to reduce ping-ponging between basestations)
- **Mobile Rx Threshold**: RSL_{THRESH} = -100 dBm

User Parameters

- **Number of Users:** U = 150
- **Call Rate: λ =**2 calls per hour (on average)
- **Average Call Duration:** H=3 minutes/call (= 180 seconds/call)
- **User Speed:** Constant but Gaussian distributed with mean μ = 12 m/s and std σ = 3 m/s
- **Direction:** Users appearing on the road will head to the most distant basestation.

Channel Properties and Path Loss

Propagation Loss: Using the Okamura-Hata model adjusted for a small city

Shadowing: Normally follows a log-normal distribution (i.e. a normal distribution in dB) with a mean μ = 2 dB and σ = 2 dB.

Fading: Using numpy.random.rayleigh function have zero mean and unit variance

Q1_Solution: Given Parameters are tilt = 2, Users = 150, Simulation Time = 4Hrs

```
Enter the Simulation Time in Hours 4

Enter the Number of users 150

Enter the tilt angle 2


  STATISTICS FOR 1 HOUR OF SIMULATION TIME IS  BS-1  BS-2
0             No of channels currently in use     3     6
1                       No of call attempts   145   114
2                    No of successful calls   122   102
3                 No of successful handoffs  4091  4085
4                   No of handoff faliures      0     0
5      No of call drop due to signal strength    14    12
6             No of call drop due to capacity     0     0
7         No of blocked calls due to capacity     0     0


  STATISTICS FOR 2 HOUR OF SIMULATION TIME IS  BS-1  BS-2
0             No of channels currently in use     4     6
1                       No of call attempts   306   237
2                    No of successful calls   260   214
3                 No of successful handoffs  9380  9363
4                   No of handoff faliures      0     5
5      No of call drop due to signal strength    25    34
6             No of call drop due to capacity     0     0
7         No of blocked calls due to capacity     0     0


  STATISTICS FOR 3 HOUR OF SIMULATION TIME IS   BS-1   BS-2
0             No of channels currently in use      5      4
1                       No of call attempts    418    378
2                    No of successful calls    368    338
3                 No of successful handoffs  13750  13737
4                   No of handoff faliures      0      5
5      No of call drop due to signal strength     32     49
6             No of call drop due to capacity      0      0
7         No of blocked calls due to capacity      0      0


  STATISTICS FOR 4 HOUR OF SIMULATION TIME IS   BS-1   BS-2
0             No of channels currently in use     11      3
1                       No of call attempts    561    512
2                    No of successful calls    489    461
3                 No of successful handoffs  18873  18858
4                   No of handoff faliures      0      5
5      No of call drop due to signal strength     46     63
6             No of call drop due to capacity      0      0
7         No of blocked calls due to capacity      0      0
```

Figure-1.1

From the Simulation results we can observe, Number of Call drops due to signal strength for Base station-1 and Base station-2 is 46 and 63 respectively.

And **NO CALL DROP** and **CALL BLOCK** due to Capacity , 5 Hand-off Failure at Base station-2

And Total Call attempts are for Base station-1 and Base station-2 are 561 and 512 respectively.

% OF CALL DROP DUE TO SIGNAL STRENGTH : (Total call drop due to signal strength)/ Total Call attempts = (46+63)/(561+512)*100 = 10%

% OF HAND-OFF FAILURES ARE: Total no of Failure hand-off/Total no of hand-off=0% (Nearly)

The Major cause of the drop is due to signal strength, which account to **10% of the Total number of call attempts.**

PERFORMANCE: As call drops due to signal strength is 10% of the total call attempts. So Base-Station performance is not so good**.**

Below Graphs depicts, for each 100m section of roadway, the number of points which have S/I >= 10 dB (green points), the number with 10 dB> S/I >=5 dB (magenta points) and the number with S/I < 5 dB (red points)

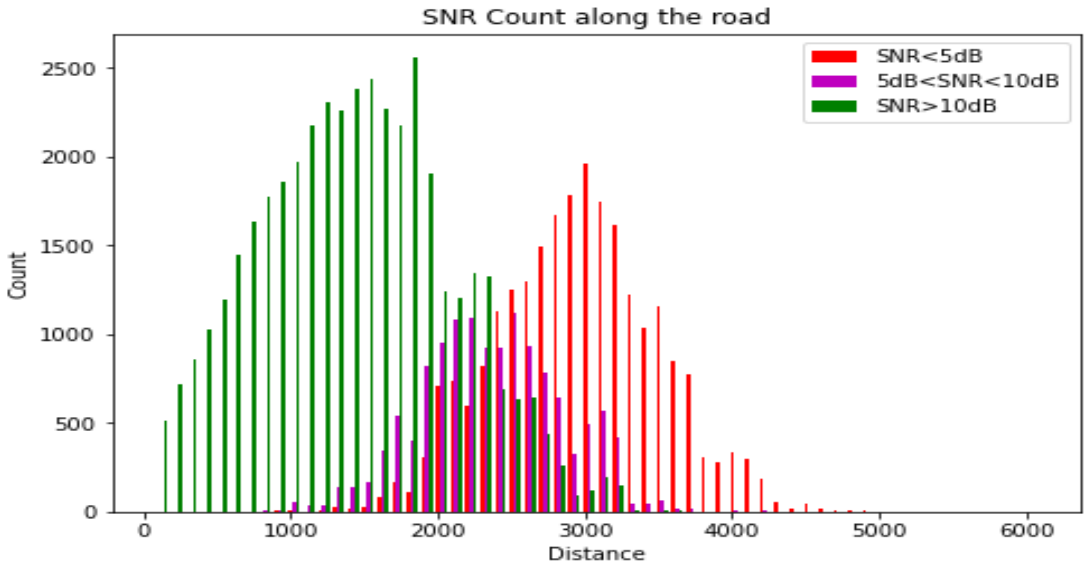

Figure-1.2- S/I Count for Base station-1

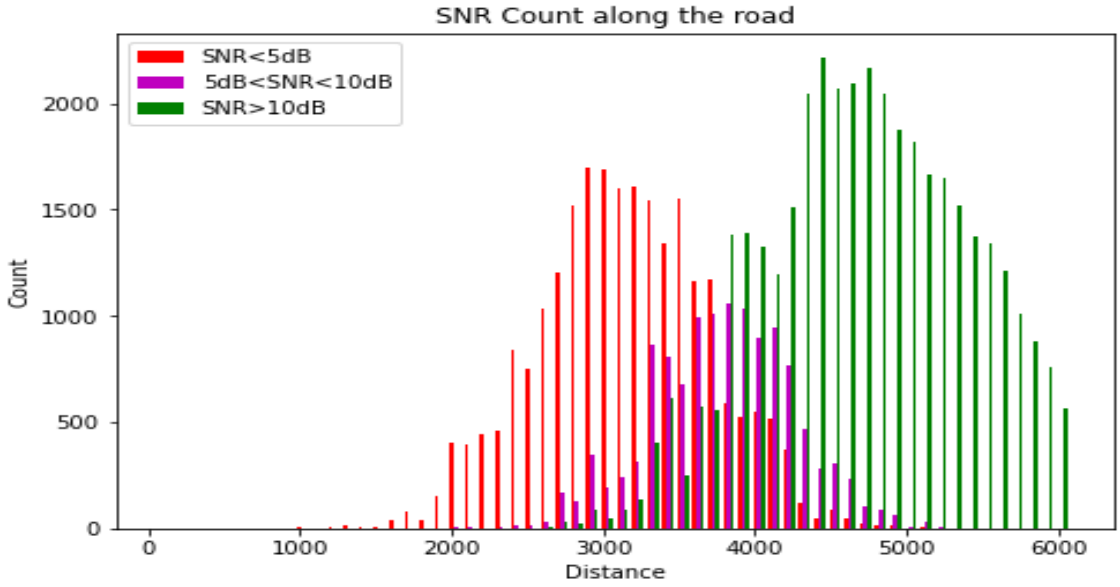

Figure-1.3 S/I Count for Base station-2

Q-2A) Solution: Given Parameters are Tilt=5, Users = 150, Simulation Time = 4Hrs

```
Enter the Simulation Time in Hours 4

Enter the Number of users 150

Enter the tilt angle 5


  STATISTICS FOR 1 HOUR OF SIMULATION TIME IS  BS-1  BS-2
0             No of channels currently in use     5     1
1                       No of call attempts   135   131
2                   No of successful calls    103    96
3                 No of successful handoffs  4588  4599
4                   No of handoff faliures      0     0
5      No of call drop due to signal strength    38    23
6             No of call drop due to capacity     0     0
7         No of blocked calls due to capacity     0     0


  STATISTICS FOR 2 HOUR OF SIMULATION TIME IS  BS-1  BS-2
0             No of channels currently in use     5     6
1                       No of call attempts   264   281
2                   No of successful calls    204   211
3                 No of successful handoffs  8934  8954
4                   No of handoff faliures      0     0
5      No of call drop due to signal strength    75    44
6             No of call drop due to capacity     0     0
7         No of blocked calls due to capacity     0     0


  STATISTICS FOR 3 HOUR OF SIMULATION TIME IS   BS-1   BS-2
0             No of channels currently in use      3      3
1                       No of call attempts    392    440
2                   No of successful calls     340    322
3                 No of successful handoffs  13770  13818
4                   No of handoff faliures       0      0
5      No of call drop due to signal strength     97     67
6             No of call drop due to capacity      0      0
7         No of blocked calls due to capacity      0      0


  STATISTICS FOR 4 HOUR OF SIMULATION TIME IS   BS-1   BS-2
0             No of channels currently in use      2      6
1                       No of call attempts    536    584
2                   No of successful calls     451    449
3                 No of successful handoffs  18212  18256
4                   No of handoff faliures       0      0
5      No of call drop due to signal strength    127     85
6             No of call drop due to capacity      0      0
7         No of blocked calls due to capacity      0      0
```

Figure-2.1

From the Simulation results we can observe, Number of Call drops due to signal strength for Base station-1 and Base station-2 is 127 and 85 respectively.

And **NO CALL** and **CALL BLOCK** due to capacity, **NO HAND-OFF FAILURES**

And Total Call attempts are for Base station-1 and Base station-2 are 536 and 584 respectively.

% OF CALL DROP DUE TO SIGNAL STRENGTH : (Total call drop due to signal strength)/ Total Call attempts = (127+85)/(536+584)*100 = 18%

so the Major cause of the drop is due to signal strength, which account up to **18% of the Total number of call attempt**

PERFORMANCE: As call drops due to signal strength is 18% of the total call attempts. So Base-Station performances is degraded when compared with previous simulation results(when tilt=2).

Below Graphs depicts, for each 100m section of roadway, the number of points which have S/I >= 10 dB (green points), the number with 10 dB> S/I >=5 dB (magenta points) and the number with S/I < 5 dB (red points)

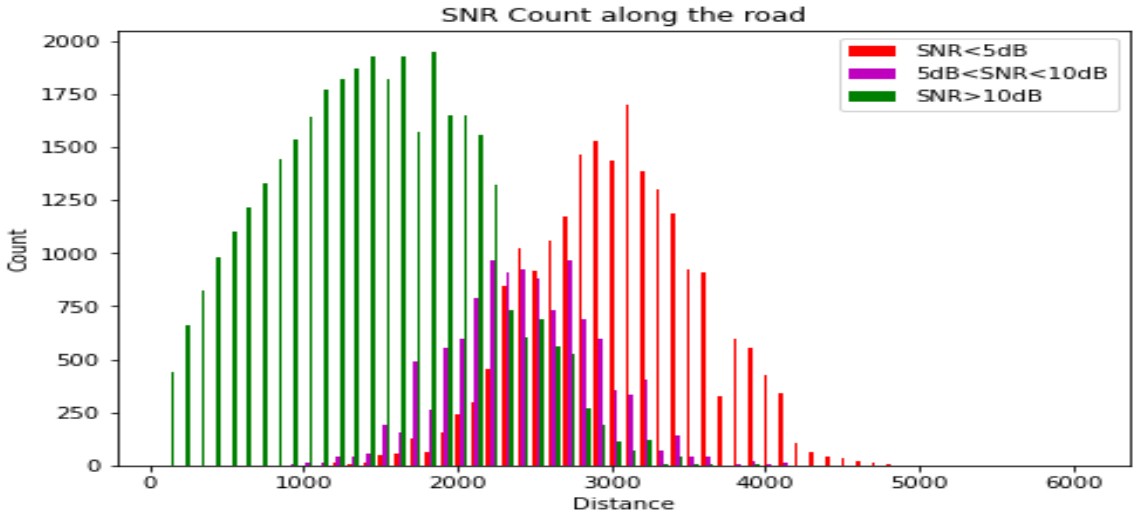

Figure-2.2 (S/I Count for Base station-1)

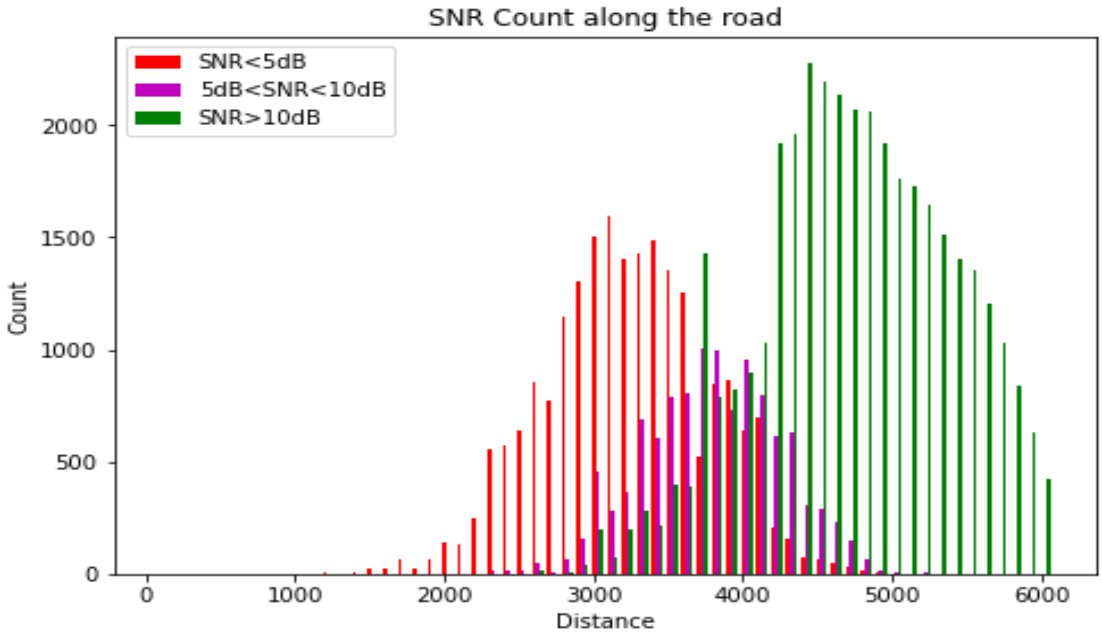

Figure-2.3 (S/I Count for Base station-2)

Q2B_Solution Given Parameters are Tilt=10, Users = 150, Simulation Time = 4Hrs

```
Enter the Simulation Time in Hours 4

Enter the Number of users 150

Enter the tilt angle 10


  STATISTICS FOR 1 HOUR OF SIMULATION TIME IS  BS-1  BS-2
0             No of channels currently in use     2     3
1                        No of call attempts   133   154
2                     No of successful calls    56    68
3                  No of successful handoffs  2455  2458
4                    No of handoff faliures      0     0
5      No of call drop due to signal strength    78    80
6             No of call drop due to capacity     0     0
7         No of blocked calls due to capacity     0     0


  STATISTICS FOR 2 HOUR OF SIMULATION TIME IS  BS-1  BS-2
0             No of channels currently in use     0     4
1                        No of call attempts   283   323
2                     No of successful calls   124   138
3                  No of successful handoffs  4916  4934
4                    No of handoff faliures      0     0
5      No of call drop due to signal strength   177   163
6             No of call drop due to capacity     0     0
7         No of blocked calls due to capacity     0     0


  STATISTICS FOR 3 HOUR OF SIMULATION TIME IS  BS-1  BS-2
0             No of channels currently in use     2     2
1                        No of call attempts   421   442
2                     No of successful calls   185   194
3                  No of successful handoffs  6786  6806
4                    No of handoff faliures      0     0
5      No of call drop due to signal strength   254   226
6             No of call drop due to capacity     0     0
7         No of blocked calls due to capacity     0     0


  STATISTICS FOR 4 HOUR OF SIMULATION TIME IS  BS-1  BS-2
0             No of channels currently in use     3     2
1                        No of call attempts   557   599
2                     No of successful calls   239   265
3                  No of successful handoffs  9012  9031
4                    No of handoff faliures      0     0
5      No of call drop due to signal strength   334   313
6             No of call drop due to capacity     0     0
7         No of blocked calls due to capacity     0     0
```

Figure-2.4

From the Simulation results we can observe, Number of Call drops due to signal strength for Base station-1 and Base station-2 is 334 and 313 respectively.

And **NO CALL** and **CALL BLOCK** due to capacity, **NO HAND-OFF FAILURES**

And Total Call attempts are for Base station-1 and Base station-2 are 557 and 599 respectively.

% OF CALL DROP DUE TO SIGNAL STRENGTH : (Total call drop due to signal strength)/ Total Call attempts = (334+313)/(557+599)*100 = 55%

So the Major cause of the drop is due to signal strength, which account up to **55% of the Total number of call attempt**

PERFORMANCE: As call drops due to signal strength is 55% of the total call attempts. So Base-Station performances is worse, As almost half of the calls are dropped due to low signal strength.

Below Graphs depicts the, for each 100m section of roadway, the number of points which have S/I >= 10 dB (green points), the number with 10 dB> S/I >=5 dB (magenta points) and the number with S/I < 5 dB (red points)

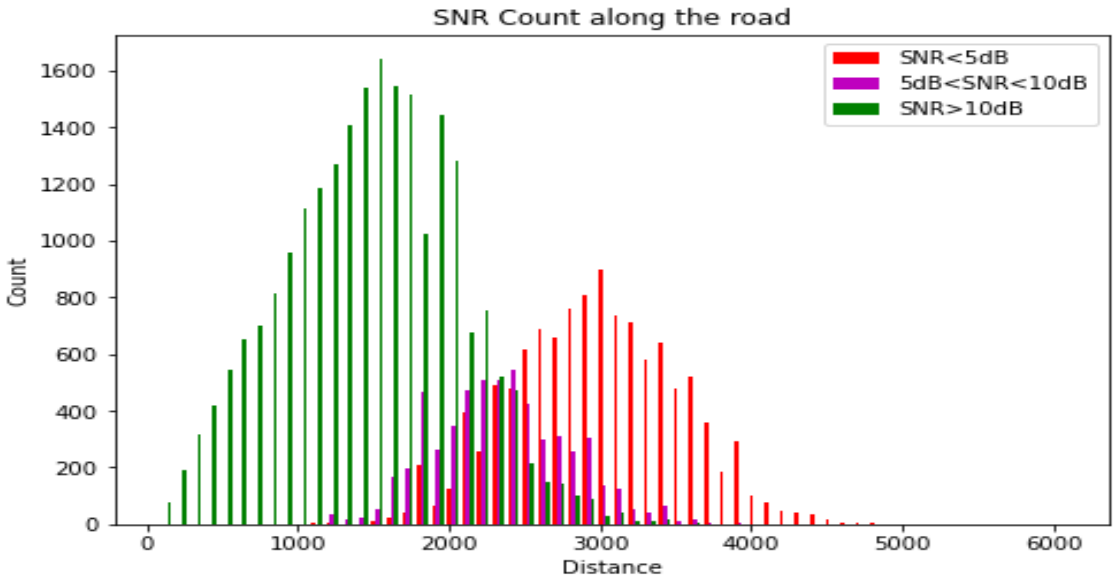

Figure-2.5 (S/I Count for Base station-1)

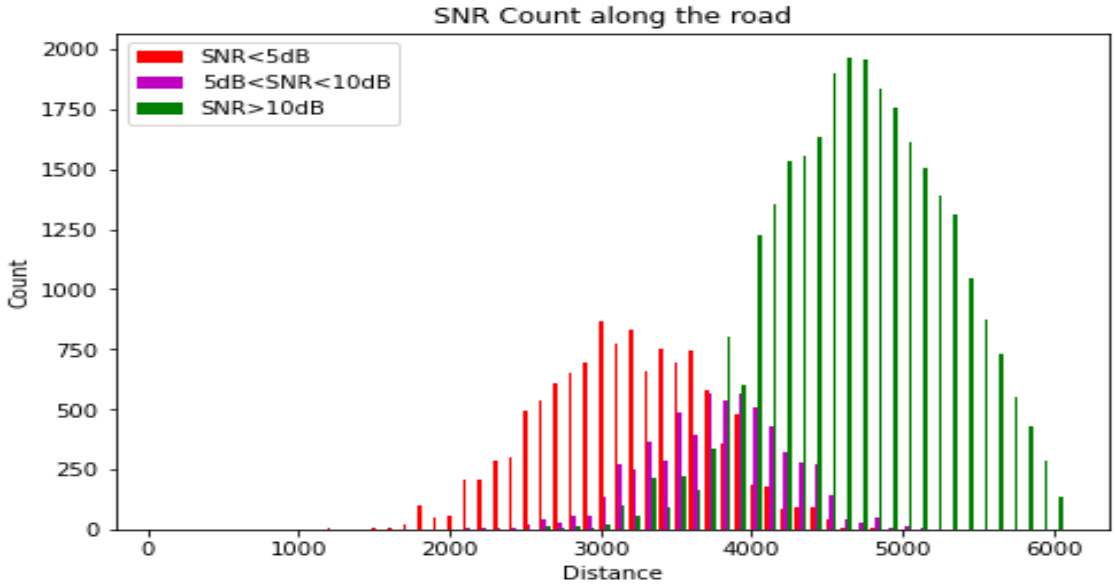

Figure-2.6 (S/I Count for Base station-2)

Question-3: Given Parameters are Tilt=2, Users = 400, Simulation Time = 4Hrs

```
Enter the Simulation Time in Hours 4

Enter the Number of users 400

Enter the tilt angle 2
```

	STATISTICS FOR 1 HOUR OF SIMULATION TIME IS	BS-1	BS-2
0	No of channels currently in use	10	13
1	No of call attempts	347	359
2	No of successful calls	248	280
3	No of successful handoffs	8964	8929
4	No of handoff faliures	2809	2233
5	No of call drop due to signal strength	51	61
6	No of call drop due to capacity	13	17
7	No of blocked calls due to capacity	58	82

	STATISTICS FOR 2 HOUR OF SIMULATION TIME IS	BS-1	BS-2
0	No of channels currently in use	10	14
1	No of call attempts	757	722
2	No of successful calls	536	553
3	No of successful handoffs	16890	16838
4	No of handoff faliures	6471	6056
5	No of call drop due to signal strength	101	114
6	No of call drop due to capacity	60	67
7	No of blocked calls due to capacity	180	204

	STATISTICS FOR 3 HOUR OF SIMULATION TIME IS	BS-1	BS-2
0	No of channels currently in use	15	15
1	No of call attempts	1133	1125
2	No of successful calls	827	810
3	No of successful handoffs	25220	25168
4	No of handoff faliures	11594	10156
5	No of call drop due to signal strength	152	191
6	No of call drop due to capacity	103	112
7	No of blocked calls due to capacity	298	346

	STATISTICS FOR 4 HOUR OF SIMULATION TIME IS	BS-1	BS-2
0	No of channels currently in use	15	14
1	No of call attempts	1507	1515
2	No of successful calls	1120	1085
3	No of successful handoffs	33476	33434
4	No of handoff faliures	15032	13569
5	No of call drop due to signal strength	212	240
6	No of call drop due to capacity	149	144
7	No of blocked calls due to capacity	398	453

Figure-3.1

From the Simulation results we can observe,

Number of Call drops due to signal strength for Base station-1 and Base station-2 is 212 and 240 respectively.

Number of Call drops due to capacity for Base station-1 and Base station-2 is 149 and 144 respectively.

Number of blocked calls due to capacity for Base station-1 and Base station-2 is 398 and 453 respectively.

And Total Call attempts are for Base station-1 and Base station-2 are 1507 and 1515 respectively.

Number of Successful call for Base station-1 and Base station-2 is 1120 and 1085 respectively.

% OF SUCCESSFUL CALL=Total number of successful call/ Total number of call attempts
=(1120+1085)/(1507+1515)*100=73 %

% OF CALL ATTEMPTS THAT END UP DROPPED=100%-73%=27%

% OF CALL DROP DUE TO SIGNAL STRENGTH : (Total call drop due to signal strength)/ Total Call attempts = (212+240)/(1507+1515)*100 = 15%, which accounts to major percentage of call drop.

Additional problems are:

While % OF CALL DROP DUE TO CAPACITY : (Total call drop due to capacity)/ Total Call attempts = (212+240)/(1507+1515)*100 = 9.6%

% OF CALL BLOCKS DUE TO CAPACITY : (Total call block due to capacity)/ Total Call attempts = (212+240)/(1507+1515)*100 = 28 %

% OF HAND-OFF FALIURES: (Total Hand-off failure's)/ Total number of hand-off's = (15032+13569)/((15032+33476)+(33434+13569))*100 = 30%

From Question-1 results, We can observe that Percentage of drop call due to signal strength is increased by 5%, while percentage of drop call and block call due to capacity is increased by 9.6% and 28% respectively.

And Percentage of Hand-off failure are increased by nearly 30 %

Below Graphs depicts the, for each 100m section of roadway, the number of points which have S/I >= 10 dB (green points), the number with 10 dB> S/I >=5 dB (magenta points) and the number with S/I < 5 dB (red points)

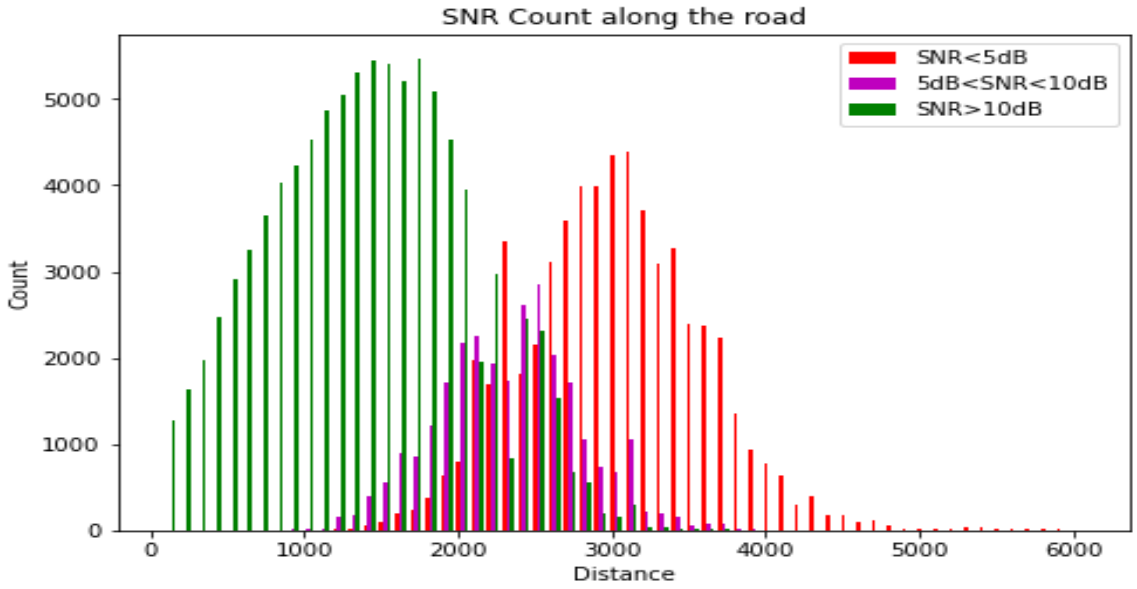

Figure-3.2 (S/I Count for Base station-1)

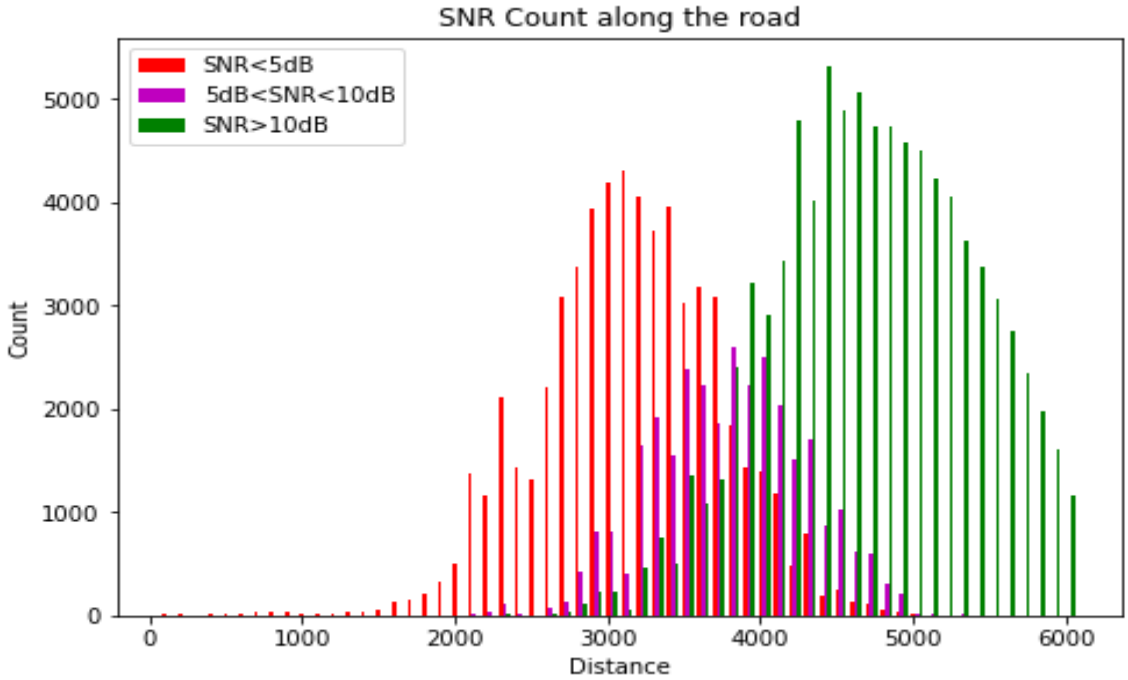

Figure-3.3 (S/I Count for Base station-2)

17. CONCLUSION

From the above Simulation we can observe that as we Increase the tilt angle, The call drop due signal strength is increased, as RSL of serving base station is getting below threshold value and also, as we add more number of users (150 to 400 users) to the network, then there is an additional drop due to capacity. Moreover, as we add number of users from 150 to 200 , then there is an additional number of call drop due to signal strength and capacity. So base station should provide considerable number of channels to serve the users accordingly