Faculty of Engineering - Ain Shams University (ASUENG)

Project

Course code: ECE353s

Course Title: Wireless communication networks

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Part (A)

(A) It is required to design using MATLAB/Python, a simple planning tool for a service provider that owns 340 channels in the 900 MHz band. Your code should ask for the GOS, city area, user density, SIR_{min}, and sectorization method. Assume blocked calls are cleared in this system. Then, it should produce the following design parameters:

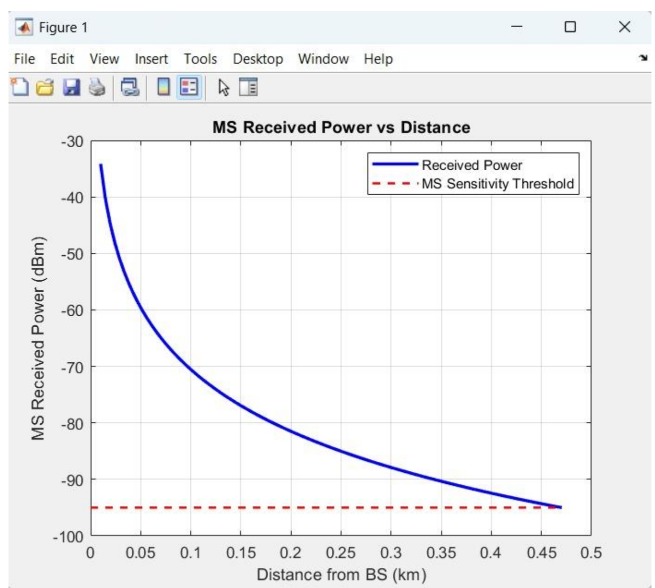
1) Cluster Size.
2) Total number of cells in city.
3) Cell radius.
4) Traffic intensity per cell and traffic intensity per sector.
5) Base station transmitted power.
6) A plot for the MS received power in dBm versus its distance from the BS.

In your design, Use Hata model (as outdoor propagation channel model) while assuming urban-medium city. Let, the traffic per user equals 0.025 Erlang, the effective heights of BS and MS equal 20 and 1.5 meters respectively, and MS sensitivity equals $-95\ dB$, and the path loss exponent equals 4.

Note: You can find Erlang B table in the second attachment.

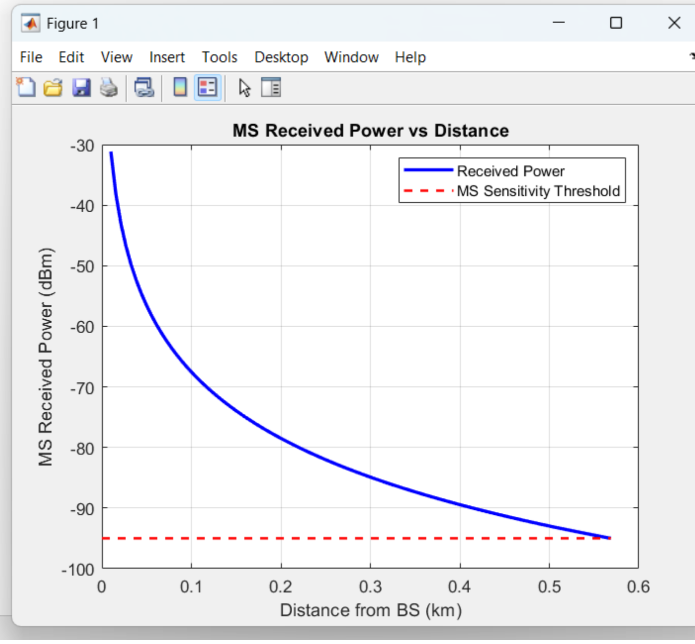
Result of figure 1 "input and output..design parameters"

```
---------------------------------------
Enter Grade of Service (GOS) (e.g., 0.02 for 2%): 0.02
Enter City Area (km^2): 100
Enter User Density (users/km^2): 1400
Enter Minimum SIR (dB): 19
Select Sectorization Method:
1. Omni-directional (no sectorization)
2. 120° sectorization (3 sectors)
3. 60° sectorization (6 sectors)
Enter your choice (1-3): 1
Channels per cell: 28
Channels per sector: 28
Cluster size (N): 12
Sectorization method: Omni-directional
Estimated traffic intensity A per sector: 20.2000 Erlangs
Supported users in the area: 9696

=== Design Parameters ===
Cluster Size (N): 12
Number of Cells in City: 174
Cell Radius: 0.47 km
Traffic Intensity per Cell: 20.20 Erlangs
Traffic Intensity per Sector: 20.20 Erlangs
Base Station Transmit Power: 21.92 dBm
Sectorization Method: Omni-directional
Using Erlang B table with GOS: 0.0200
```



Here we used omni let's try now to use 120 secotrication ..

```
Enter Grade of Service (GOS) (e.g., 0.02 for 2%): 0.02
Enter City Area (km^2): 100
Enter User Density (users/km^2): 1400
Enter Minimum SIR (dB): 19
Select Sectorization Method:
1. Omni-directional (no sectorization)
2. 120° sectorization (3 sectors)
3. 60° sectorization (6 sectors)
Enter your choice (1-3): 2
Channels per cell: 48
Channels per sector: 16
Cluster size (N): 7
Sectorization method: 120° sectorization
Estimated traffic intensity A per sector: 9.8300 Erlangs
Supported users in the area: 8257

=== Design Parameters ===
Cluster Size (N): 7
Number of Cells in City: 119
Cell Radius: 0.57 km
Traffic Intensity per Cell: 29.49 Erlangs
Traffic Intensity per Sector: 9.83 Erlangs
Base Station Transmit Power: 24.92 dBm
Sectorization Method: 120° sectorization
Using Erlang B table with GOS: 0.0200
fx >>
```



Procedure we followed

By using analytical equations we checked for the results and we used the same equations and steps in matlab code .

Analytical Solution

Number of channels = 340, Path loss exponent = 4, Traffic per user =0.025

Eralng, A = 100 km2, user density=1400 user/km2 , SIR = 10^(1.9),

Number of users = 100x1400=1.4e5, Traffic per City = 0.025x1.4e5 =3500

First For no sectorization:

10^(1.9) = (1/6)($\sqrt{3N}$ -1)^4 ----> N = 10.725 but nearest N ceiling value N=12

Channels per cell = floor(340/12) = 28

Au (Cell) from ErlangB TABLE = 20.2 Erlangs

Total Cells = ceil(Au(city)/Au(cell)) = 174 cells

Area Cell = Total Area / Total cells = 0.5747 km2 =(3xroot(3)/2)*(R^2)

Then Cell Radius R = 0.47 km

Second For 120 degree sectorization:

10^(1.9) = (1/2)($\sqrt{3N}$ -1)^4 ----> N = 6.9 but nearest N ceiling value N=7

Channels per Sector = floor(340/7x3) = 16

Au (Sector) from ErlangB TABLE = 9.83 Erlangs

Au (cell) = Au(sector) x 3 = 29.49 Erlangs

Total Cells = ceil(Au(city)/(Au(Sector)x3)) = 119 cells

Area Cell = Total Area / Total cells = 0.84 km2 =(3xroot(3)/2)*(R^2)

Then Cell Radius R = 0.569 km

same as from matlab.

Part (B)

(B) To validate your planning tool and understand the trade-offs between different design parameters it is required to deliver for a city of area equals $100\ km^2$ the following figures with reasonable comments. Each figure should contain three curves for omni-directional, 120° sectorization and 60° sectorization designs.

1) A plot for the cluster size versus $SIR_{min}(1dB\ to\ 30\ dB)$.

2) At SIR_{min}=$19dB$ and user density = 1400 users/km^2.
   (i) A plot for the number of cells versus GOS (1% to 30%).
   (ii) A plot for the traffic intensity per cell versus GOS (1% to 30%).

3) At SIR_{min}=$14dB$ & user density = 1400 users/km^2.
   (i) A plot for the number of cells versus GOS (1% to 30%).
   (ii) A plot for the traffic intensity per cell versus GOS (1% to 30%).

4) At SIR_{min} = 14dB & GOS = 2%
   (i) Plot the number of cells versus user density (100 to 2000 users/km^2).
   (ii) Plot the cell radius versus user density (100 to 2000 users/km^2).

5) At SIR_{min} = 19dB & GOS = 2%
   (i) Plot the number of cells versus user density (100 to 2000 users/km^2).
   (ii) Plot the cell radius versus user density (100 to 2000 users/km^2).

Procedure:

First from equaiton of SIR=(1/i_o)x(sqrt(3N)-1)^n ; i is the sectorization factor which is i=6 in case of omni and i=2 incase of 120 degree sectorization and i=1 incase of 60 degree sectorization .

-we get N and from S=kN we find K which is number of channel per cell.

-we know that Atot=Au*no.of user = 0.025x1400*100=3500.

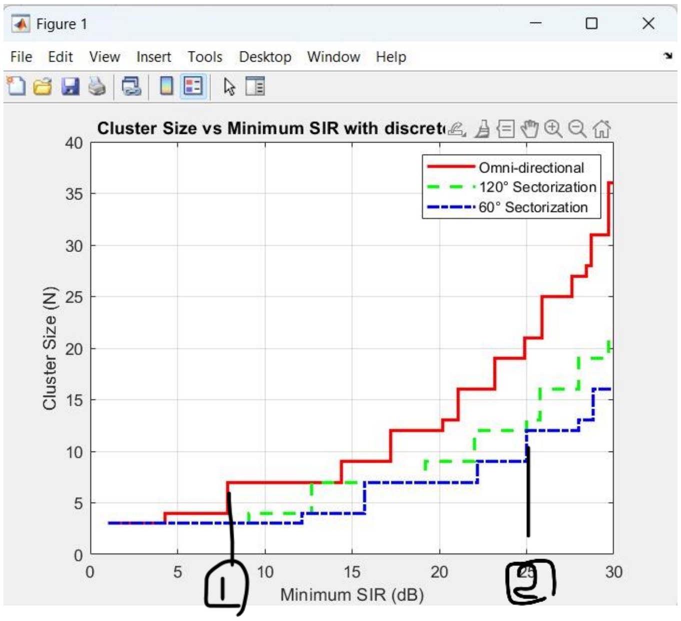
Omni case: with K go to erlang table and get corrospond Acell and by dividing Atot/Acell= number of cells , we have area of city divide Areaofcity/number of cell we get Area of cell then from Area=1/2 * R * root(3)/2 * R *6 we can get R

.

120 degree sectorization case :here we divide the K/number of sector , and with answer go to table and get Asector and then multiply it by number of sector and we got Acell and same steps is followed as omni case.

60 degree sectorization case : here only the number of sector is changed and follow the same steps .

Result (1):



Comment: The sectorization helps with the interference problem, that's why less N is needed for the same SIR.

And to increase the SIR more cluster size is needed.

Test 2 points in the graph analytical ..

At point 1 and point 2 .

omni

SIR = 7.9 dB

$$10^{\frac{7.9}{10}} = \frac{1}{6}\left(\sqrt{3N} - 1\right)^4$$

$\therefore$ $N \simeq 4.004$

$\therefore$ choose $N = 7$

60 deg.

@ SIR = 25 dB

$$10^{2.5} = \left(\sqrt{3N} - 1\right)^4$$

$N = 9.07$

$\therefore$ choose next valid value

$N = 12$

as appeared in graph when N just greater than 4 then it will be 7 not 5 since equation of N is :   N=i^2+k^2+i*k ;   i,k=0,1,2,3,.....etc.

Result (2,3):

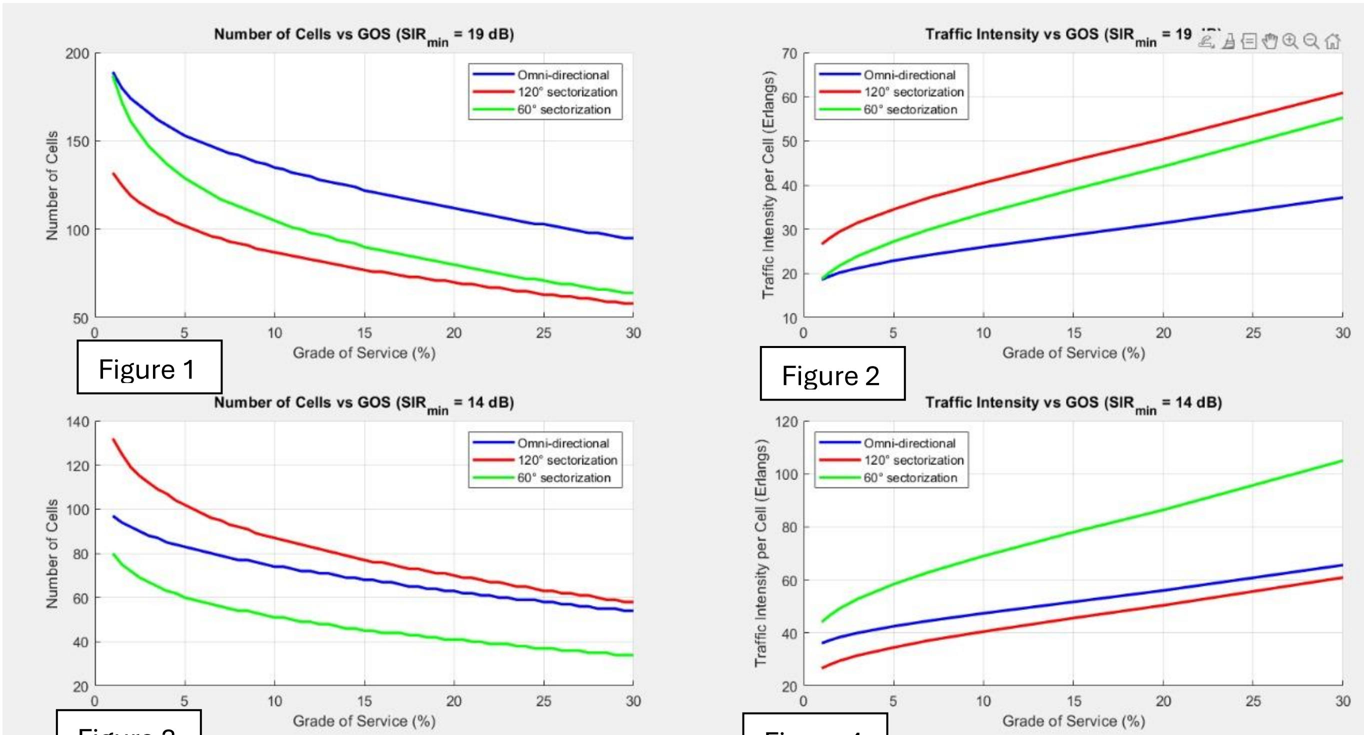


Figure 1

Figure 2

Figure 3

Figure 4

Comment:

-The sectorization offer more traffic per cell “as in figure2” since it divide the cell into sectors each sector has it’s own directional antenna so it give lower number of cells “as in figure1” ,In the case that cluster size decrease

-for the same number of channels as GOS increases the traffic intensity per cell increases which leads to needing a lower number of Cells.

-in case of 19 dB 120 deg sectorization provides the highest traffic per cell as $N_{omni} = 12 > N_{120} = N_{60} = 7$.

-in case of 14 dB 60 deg sectorization provides the highest traffic per cell as $N_{omni} = N_{120} = 7 > N_{60} = 4$.

Let’s check analytically 1st 2 curves for example at GOS=10%

Omni

$SIR = 19dB = 10^{1.9} = \frac{1}{6}(\sqrt{3N}-1)^4$

∴ $N = 10.725$

so use $\boxed{N = 12}$

$K = \frac{340}{12} = 28.33 = 28$

From table GOS = 10%

∴ $\boxed{A_{cell} = 26}$ → no. of cell = $\frac{3500}{26}$ = 134.615 = $\boxed{135}$

Area cell = $\frac{100}{135} = \boxed{0.74\ km^2}$

$0.74 \times 1000^2 = \frac{1}{2} R \times \frac{\sqrt{3}}{2} R \times 6$

∴ $R_{omni} = 0.533$ km

120 degree sectorization

$SIR = 10^{1.9} = \frac{1}{2}(\sqrt{3N}-1)^4 \rightarrow \boxed{N = 7}$

$K = \frac{340}{7} = 48 \div 3 = 16$

From table

$A_{sector} = 13.5 \rightarrow \boxed{A_{cell} = 40.5}$

∴ no. of cell = $\frac{3500}{40.5} = \boxed{87\ cell}$

60 degree sectorization

$SIR = 10^{1.9} = 1(\sqrt{3N}-1)^4 \rightarrow N = 5.29 = 7$

$K = 48 \div 6 = 8$

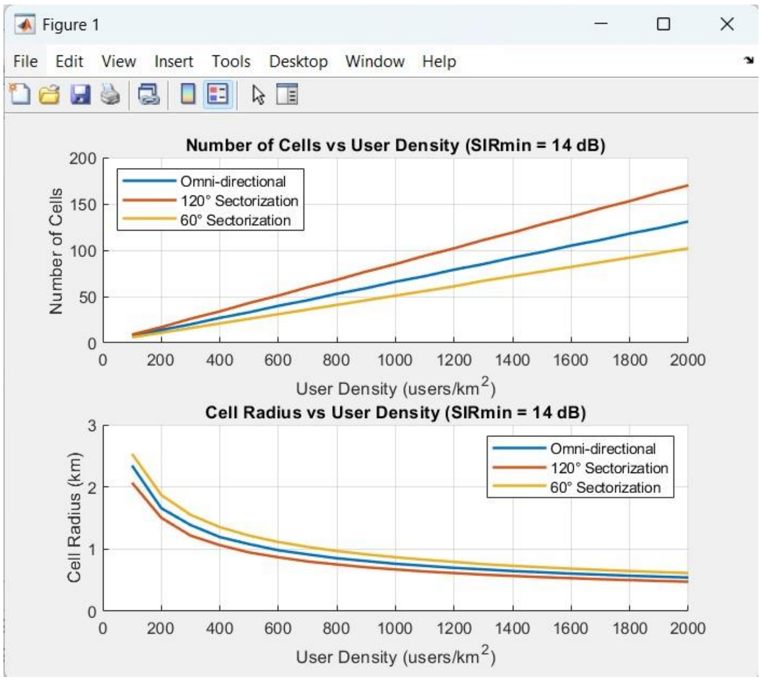
$A_{sector} = 5.597$

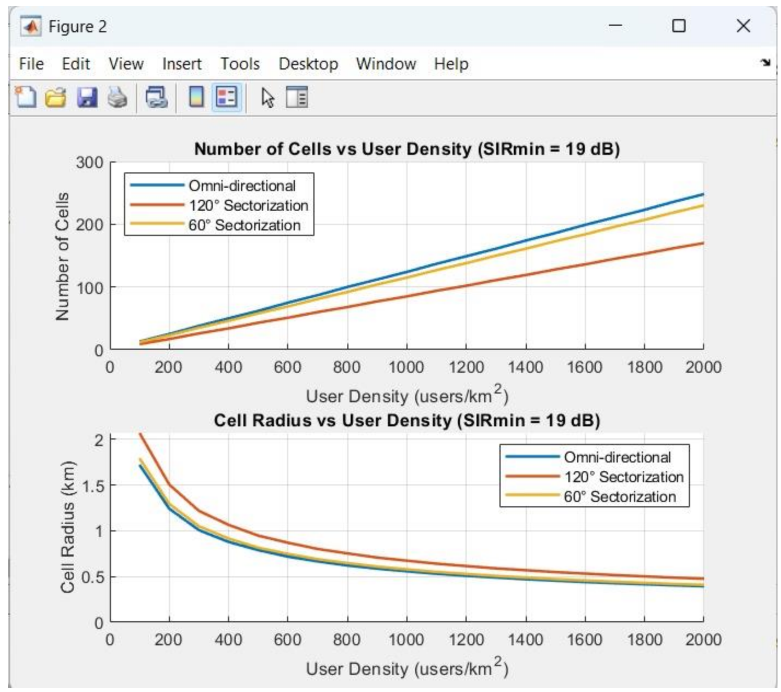
∴ $A_{cell} = A_{sector} \times 6 = \boxed{33.582}$

no. of cell = $\frac{3500}{33.582} = 104.22 = \boxed{105\ cell}$

as we see the order of the curves from higher to lower No. of cells is omni>60 deg>120 deg. And order of trafiic intensity is reversed.
Same calculations for SIR=14 db .
And the order will be 120 deg>omni>60 deg . and for traffic intensity it's revereseed.

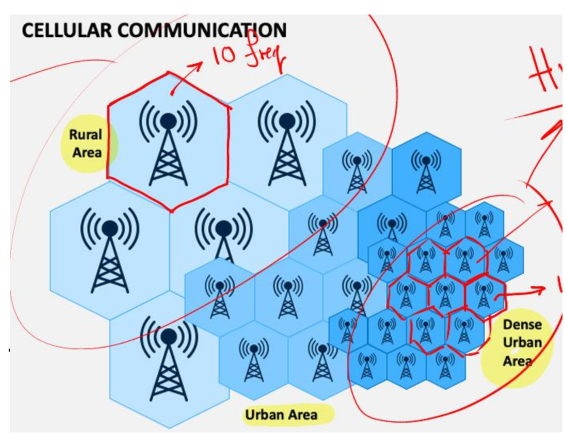
Result (4,5):





Comment:

As shown in figure as user density increases we need more number of cells to serve this higher density.
And more sectorization will give lower number of cells, in the case that the cluster size decreases, since it gives more traffic for each cell.
And the last 2 figures show that as user density increases the Cell radius decrease because the area is constant so the number of cell increase so radius or area of cell must decrease.
This picture to illustrate ..

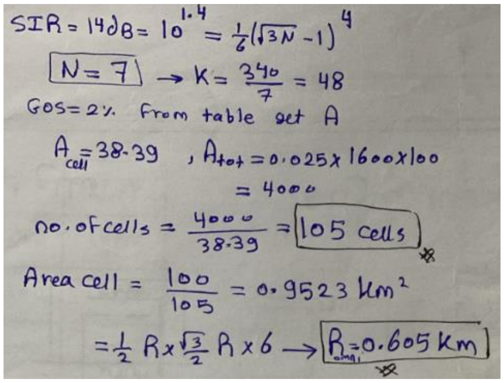


For 14 dB >> 60 deg sectorization provides the least Number of cells with the highest cell radius.
for 19 dB >>120 deg sectorization provides the least Number of cells with the highest cell radius.

Let's check for the curve.

Solving for user density = 1600 users/km^2 and SIR =

Omni



$SIR = 14dB = 10^{1.4} = \frac{1}{6}(\sqrt{3N}-1)^4$

$\boxed{N=7} \rightarrow K = \frac{340}{7} = 48$

GOS=2% From table get A

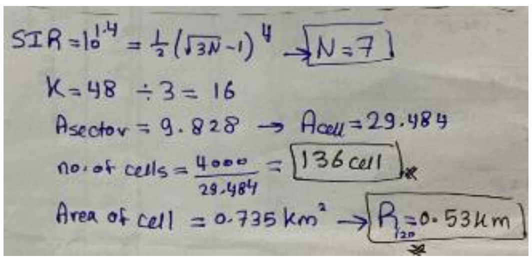
$A_{cell} = 38.39$, $A_{tot} = 0.025 \times 1600 \times 100 = 4000$

$\text{no. of cells} = \frac{4000}{38.39} = \boxed{105 \text{ cells}}$

$\text{Area cell} = \frac{100}{105} = 0.9523 \text{ km}^2$

$= \frac{1}{2} R \times \frac{\sqrt{3}}{2} R \times 6 \rightarrow \boxed{R_{omni} = 0.605 \text{ km}}$

120 deg sectorization



$SIR = 10^{1.4} = \frac{1}{2}(\sqrt{3N}-1)^4 \rightarrow \boxed{N=7}$

$K = 48 \div 3 = 16$

$A_{sector} = 9.828 \rightarrow A_{cell} = 29.484$

$\text{no. of cells} = \frac{4000}{29.484} = \boxed{136 \text{ cell}}$

$\text{Area of cell} = 0.735 \text{ km}^2 \rightarrow \boxed{R_{120} = 0.53 \text{ km}}$

60 deg sectorization the Acell=49.2 , and Number of cells=82 cells ,
And R_{60}=0.685km

Then from calculations the order of number of cells should be
120 deg> omni> 60 deg.

And the radius is 60deg>omni>120 deg.

Same Procedure for 19 dB .

Note

In code we defined the erlang-B table and did not use the exact formula so the solutions here may have small error.

Codes are in separate .m files

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