Faculty of Engineering
ECE Department

ECE353s - Wireless Networks

Instructor: Michael Ibrahim

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Project Report

Submitted by:

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A) Design Procedures

1.Cluster size calculation:

$$10^{\frac{SIR_{mindB}}{10}} = \frac{1}{q}(\sqrt{3N} - 1)^n$$

Compute theoretical N , it takes specific values

$$N = i^2 + k^2 + ik \text{ where } i\,, k = 0, 1, 2, ..$$

2.Number of channels :

Per cell

Channels per cell = Floor [total channels / N]

Per sectors

Channels per sectors = Floor [Channels per cell / sectors]

3.Traffic intensity :

Calculate total traffic intensity

A_total = user_density x city_area x A_user

From Erlang Table

Get traffic intensity per sector by using: channels per sector and GOS

Calculate traffic intensity per sector

A_cell = A_sector x sectors

4.Cell radius:

Calculate cell radius using traffic intensity and density

A_user = 0.025

Calculate number of users per sector

Users per sector = A_sector / A_user

Calculate area of sector

$\text{Area}_{\text{sector}}$ = users per sector / user density

Calculate area of cell

$\text{Area}_{\text{cell}}$ = $\text{Area}_{\text{sector}}$ x sectors

Calculate Radius

Radius = sqrt($\text{Area}_{\text{cell}}$ / (1.5*sqrt(3)))

5.Total number of cells in city :

Total cells = ceil(city area/ $\text{Area}_{\text{cell}}$)

6.Transmit Power Calculation:

Using Hata model

The generic closed form expression for path loss (***PL***) in ***dB*** scale, is given by

$$P_L(dB) = A + Blog_{10}(d) + C$$

where, the Tx-Rx separation distance (***d***) is specified in kilometers (valid range ***1 km to 20 Km***). The factors ***A,B,C*** depend on the frequency of transmission, antenna heights and the type of environment, as given next.

$$A = 69.55 + 26.16\ log_{10}(f_c) - 13.82\ log_{10}(h_b) - a(h_m)$$
$$B = 44.9 - 6.55\ log_{10}(h_b)$$

- f_c = frequency of transmission in MHz, valid range – 150 MHz to 1500 MHz
- h_b= effective height of transmitting base station antenna in meters, valid range ***30 m to 200 m***
- h_m=effective receiving mobile device antenna height in meters, valid range ***1m to 10 m***
- $a(h_m)$ = mobile antenna height correction factor that depends on the environment (refer table below)
- ***C*** = a factor used to correct the formulas for open rural and suburban areas (refer table below)

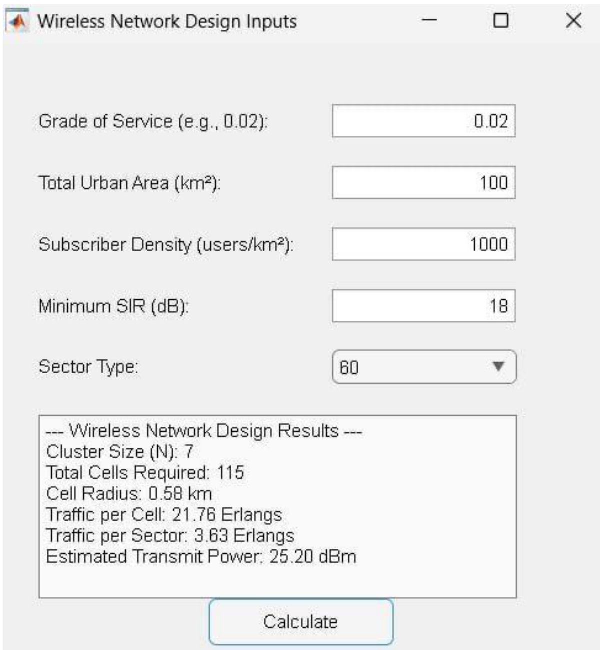
Environment	$a(h_m)$	C
Open	$[1.1log_{10}(f_c) - 0.7]h_m - [1.56log_{10}(f_c) - 0.8]$	$-4.78[log_{10}(f_c)]^2 + 18.33log_{10}(f_c) - 40.98$
Suburban		$-2[log_{10}(f_c/28)]^2 - 5.4$
Small/medium city		0
Metropolitan ($f_c \leq 200\ MHz$)	$8.29[log_{10}(1.54h_m)]^2 - 1.1$	0
Metropolitan ($f_c > 200\ MHz$)	$3.2[log_{10}(11.75h_m)]^2 - 4.92$	0

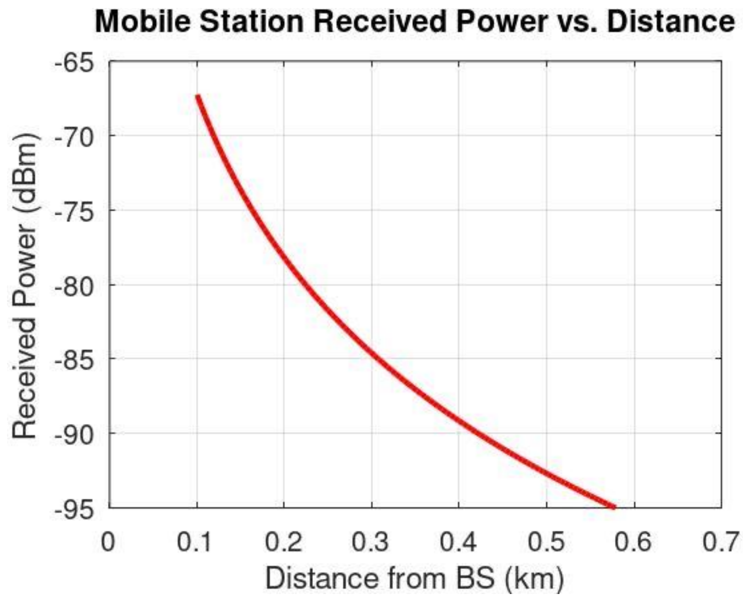
6.Received Power Calculation :

$P_{\text{Received}} = P_{\text{transmitted}} - P_{\text{losses}}$

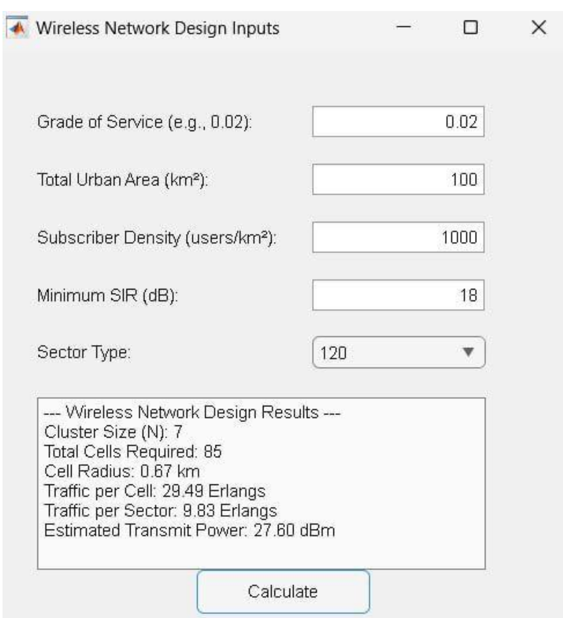
B) Test cases

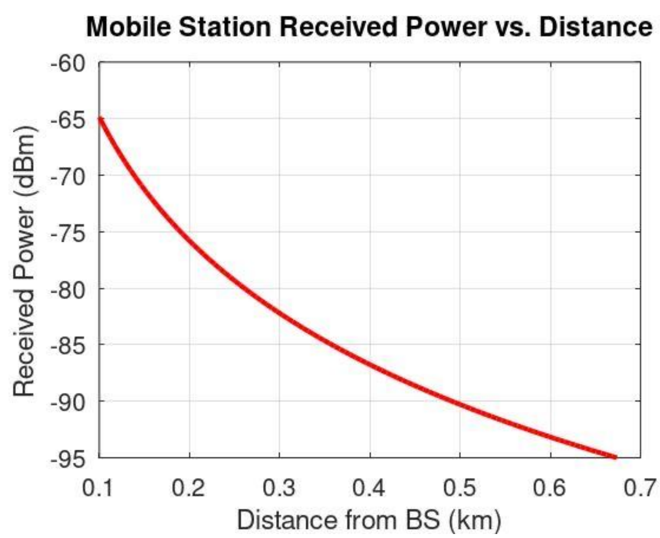
1.



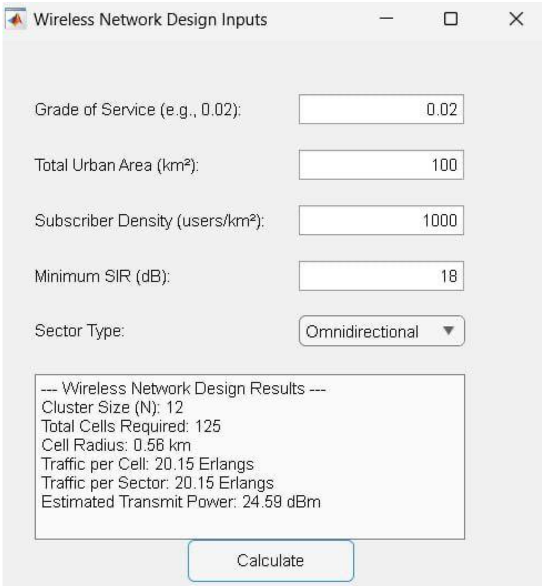


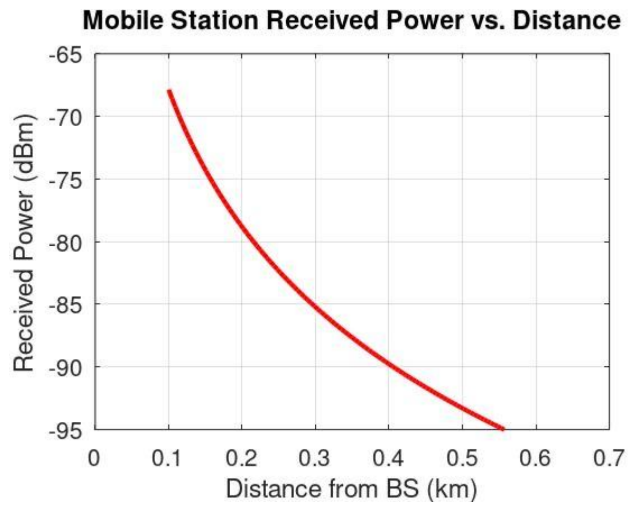
2.





3.


Wireless Network Design Inputs
Grade of Service (e.g., 0.02):
0.02
Total Urban Area (km²):
100
Subscriber Density (users/km²):
1000
Minimum SIR (dB):
18
Sector Type:
Omnidirectional
--- Wireless Network Design Results ---
Cluster Size (N): 12
Total Cells Required: 125
Cell Radius: 0.56 km
Traffic per Cell: 20.15 Erlangs
Traffic per Sector: 20.15 Erlangs
Estimated Transmit Power: 24.59 dBm
Calculate


Mobile Station Received Power vs. Distance
Received Power (dBm)
-65
-70
-75
-80
-85
-90
-95
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
Distance from BS (km)

B) Validation of the Planning Tool and Trade-offs Analysis

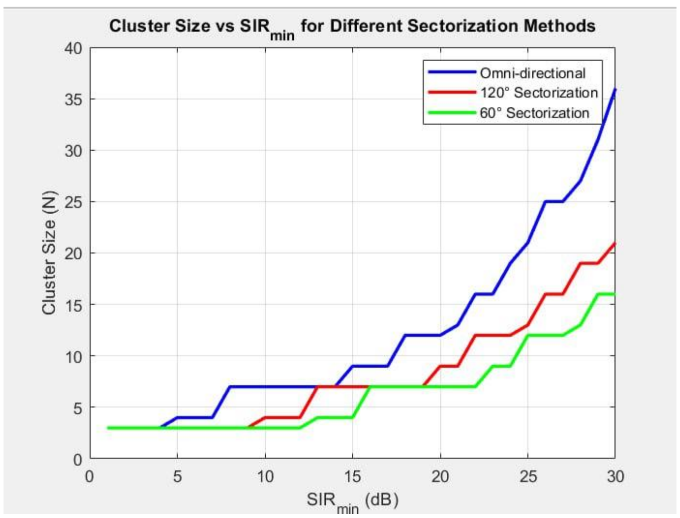
Introduction

In this section, we validate the planning tool developed in Part A by analyzing the trade-offs between different design parameters. The analysis is performed for a city area of 100 km², considering three sectorization methods: omni-directional, 120° sectorization, and 60° sectorization. The performance indicators include cluster size, number of cells, cell radius, traffic intensity per cell, and base station transmitted power. The results are presented through plots and analyzed to understand the impact of various parameters such as SIR_{min}, GOS, and user density.

1. Cluster Size vs. SIR_{min} for Different Sectorization Methods

Plot Description

- Figure 1 : Cluster Size vs. SIR_{min} for Different Sectorization Methods.



- Parameters :
  - SIR_{min} ranges from 1 dB to 30 dB.
  - Three sectorization methods: omni-directional, 120° sectorization, and 60° sectorization.
- Observations :
  - As SIR_{min} increases, the cluster size (number of cells per cluster) increases for all sectorization methods.
  - The omni-directional method requires the largest cluster size compared to 120° and 60° sectorization.
  - 60° sectorization requires the smallest cluster size, indicating better spectral efficiency and coverage optimization.
  - The increase in cluster size with SIR_{min} *is more pronounced for higher values of* SIR_{min}.

Analysis

- Higher SIR_{min} values require more cells to maintain the desired signal quality, leading to larger cluster sizes.

- Sectorization methods (120° and 60°) reduce the need for additional cells compared to omni-directional due to improved spatial reuse and interference management.

- This highlights the trade-off between system capacity and signal quality: higher SIR_{min} improves signal quality but increases infrastructure complexity.

2. Traffic Intensity vs. GOS at SIRmin = 19 dB

- Figures :

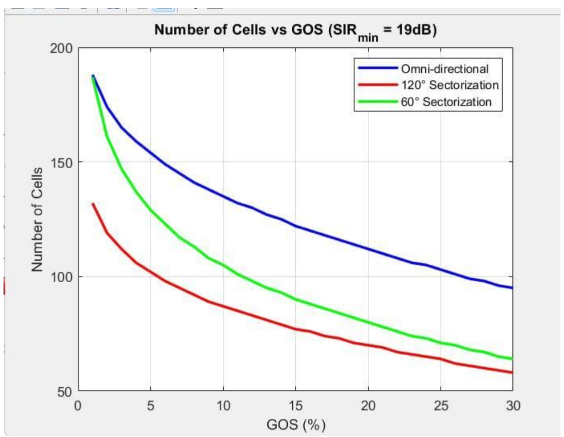


Figure 2 : Number of cells vs. GOS for SIR_{min} = 19 dB

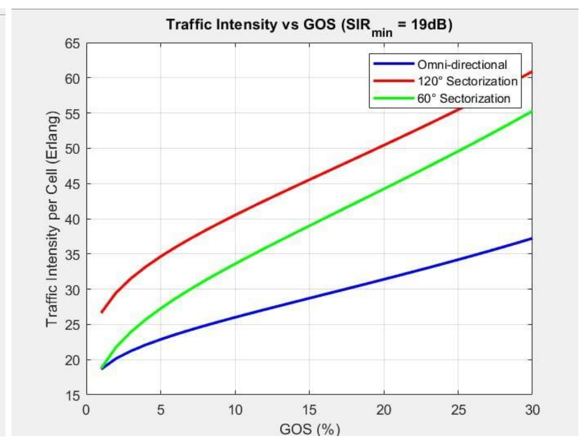


Figure 3 : Traffic Intensity vs. GOS for SIR_{min} = 19 dB

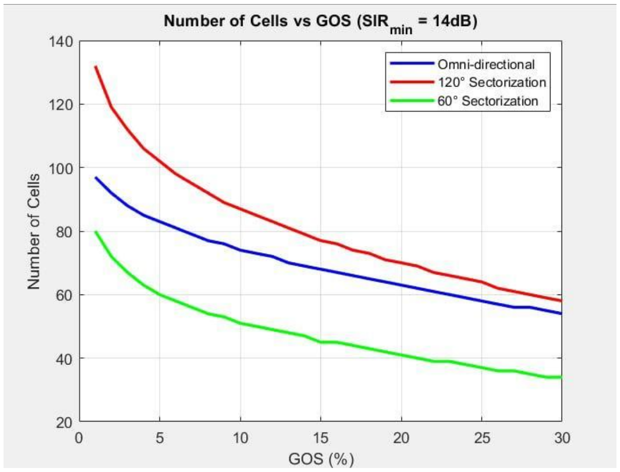
1. Effect of Sectorization : 120° sectorization consistently outperforms 60° and omni-directional , requiring the fewest cells and supporting the highest traffic intensity per cell.

2. Impact of GOS : As GOS increases (more call blocking allowed), the number of cells decreases while traffic intensity per cell increases , showing a trade-off between service quality and network efficiency.

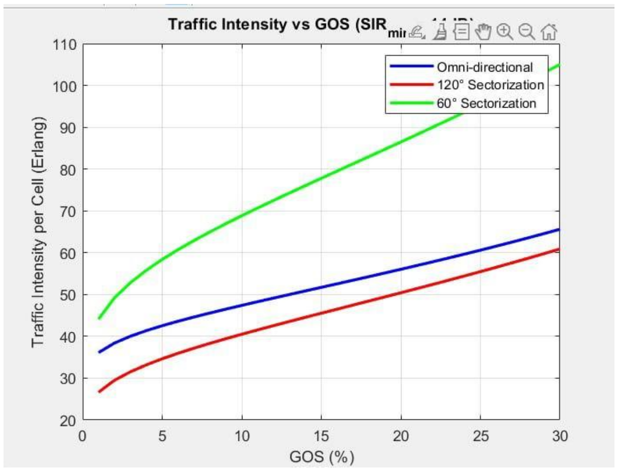
3. Performance at Higher SIRmin (19 dB) : Compared to 14 dB, a higher SIRmin results in larger cluster sizes , more cells , and lower traffic per cell , due to stricter signal quality requirements reducing spectral efficiency.

3. At $SIRmin$=14dB & user density = 1400 users/km2.

(i) Number of Cells vs. GOS



ii) Traffic intensity per cell vs GOS



1. Sectorization Efficiency :

    - 60° sectorization uses the fewest cells and supports the highest traffic per cell , due to better interference management and higher spectral efficiency compared to 120° and omni-directional.

2. GOS Trade-off :

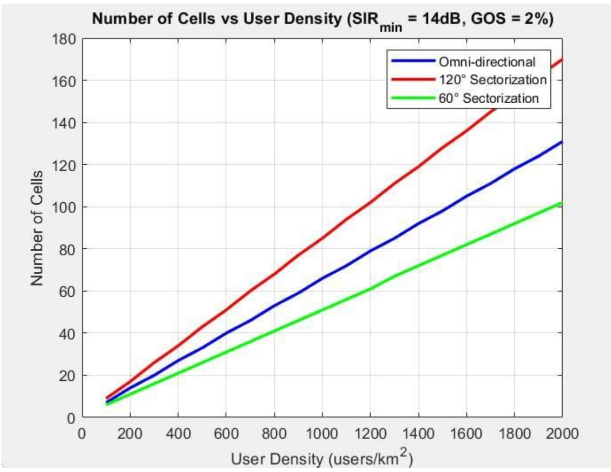
    - As GOS increases (more call blocking allowed), the number of cells decreases and traffic intensity per cell increases , showing the trade-off between service quality and network capacity.

3. Impact of Lower SIRmin (14 dB) :

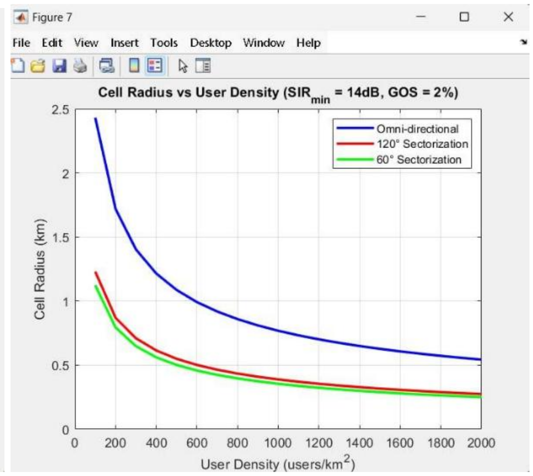
    - Compared to 19 dB, a lower SIRmin allows smaller cluster size and more aggressive frequency reuse, resulting in fewer cells and higher traffic per cell for the same GOS and user density.

4. At $SIRmin$=14dB & GOS = 2%.

i) Number of cells vs user density



ii) Cell radius vs user density



1. Number of Cells vs. User Density

- Observation : As user density increases, the number of cells required increases for all sectorization methods.
- Key Insight :
  - Higher user density necessitates more cells to handle the increased traffic load while maintaining *SIR*min=14dB and GOS = 2%.
  - 60° Sectorization requires the fewest cells , indicating better spectral efficiency.
  - Omni-directional requires the most cells , reflecting its lower capacity per cell.

2. Cell Radius vs. User Density

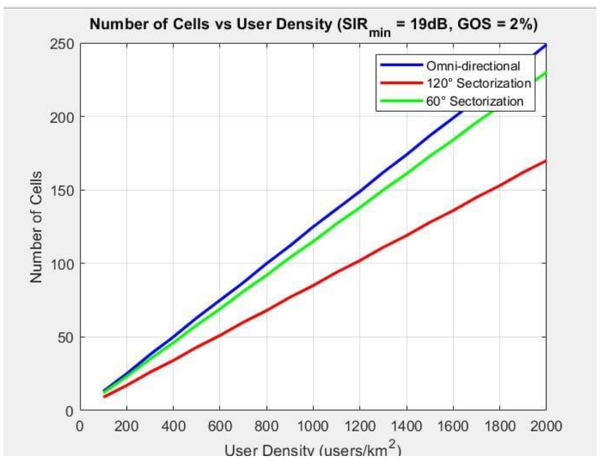
- Observation : As user density increases, the cell radius decreases for all sectorization methods.
- Key Insight :
  - Higher user density requires smaller cell radii to reduce interference and maintain signal quality.
  - Omni-directional Sectorization maintains the largest cell radius, showing superior spatial reuse.
  - 60° has the smallest cell radius , indicating less efficient frequency reuse.

3. Trade-off Between Cell Radius and Number of Cells

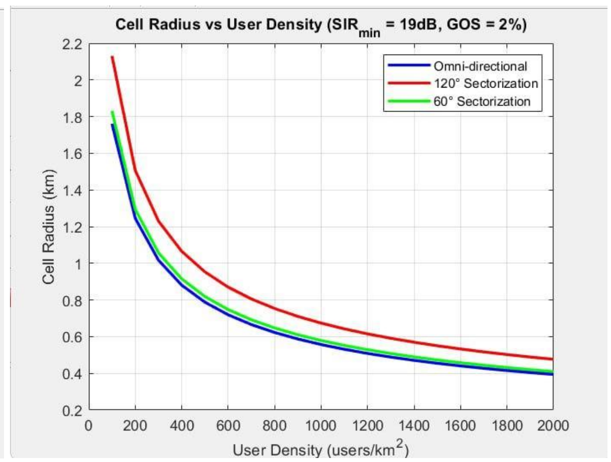
- Observation : There is an inverse relationship between cell radius and the number of cells:
    - Larger cell radii (lower user density) require fewer cells. Smaller cell radii (higher user density) require more cells.
- Key Insight : Sectorization optimizes this trade-off:
    - 60° Sectorization achieves the best balance by maintaining larger cell radii while requiring fewer cells.
    - Omni-directional struggles with both metrics, requiring smaller cell radii and more cells.

5. At $SIRmin$=19dB & GOS = 2%.

i) Number of cells vs user density



ii) Cell radius vs user density



1. Cell Radius vs. User Density

- Observation : As user density increases, the cell radius decreases for all sectorization methods.
- Key Insight : Higher user density requires smaller cell radii to reduce interference and maintain *SIR*min=19dB.

2. Number of Cells vs. User Density

- Observation : As user density increases, the number of cells required also increases for all sectorization methods.
- Key Insight : Higher user density necessitates more cells to handle the increased traffic load while maintaining *SIR*min=19dB and GOS = 2%.

3. **Comparison Between *SIR*min=19dB and *SIR*min=14dB**

   1. **Number of Cells vs. User Density**

      - **Key Point : At higher *SIR*min (e.g., 19 dB), the number of cells required increases more steeply with user density compared to lower *SIR*min (e.g., 14 dB).**

        - **Reason : A higher *SIR*min requires stricter signal quality, which necessitates smaller cell sizes and more cells to maintain the desired signal-to-interference ratio across the city area.**

   2. **Cell Radius vs. User Density**

      - **Key Point : At higher *SIR*min (e.g., 19 dB), the cell radius decreases more rapidly with increasing user density compared to lower *SIR*min (e.g., 14 dB).**

        - **Reason : To meet the stricter signal quality requirements at higher *SIR*min, smaller cell radii are needed to reduce interference and ensure adequate signal strength for users.**