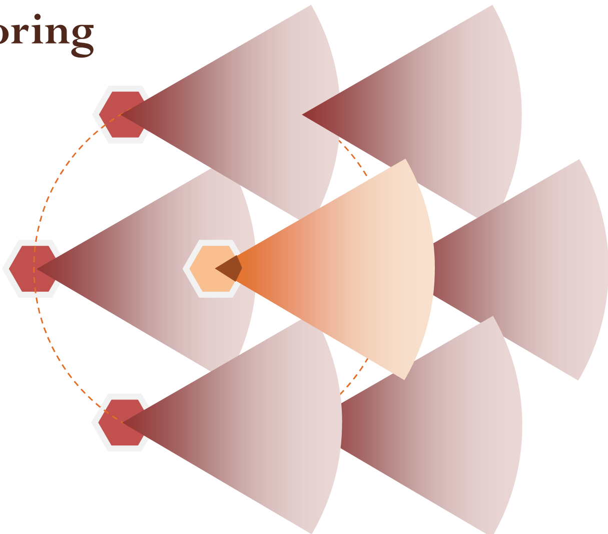
# ECS455 Chapter 2

## Cellular Systems

### 2.3 Sectoring



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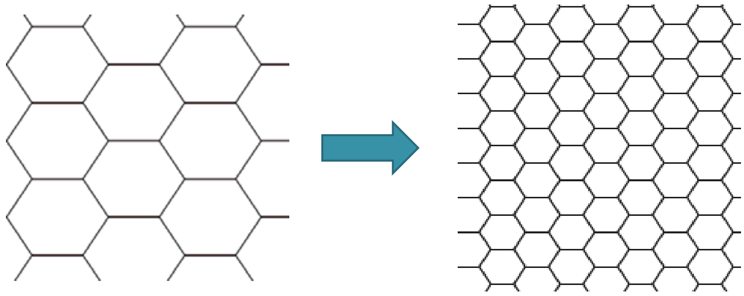
# Improving Coverage and Capacity

- As the demand for wireless service increases, the number of channels assigned to a cell eventually becomes insufficient to support the required number of users.
- At this point, cellular design techniques are needed to provide more channels per unit coverage area.
- Easy!?

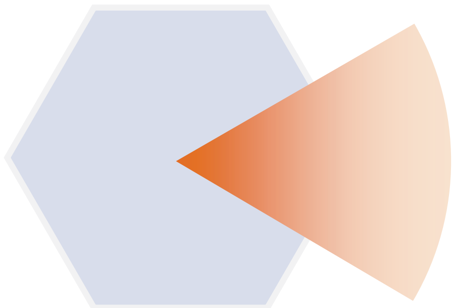
$$C = \frac{A_{\text{total}}}{A_{\text{cell}}} \times \frac{S}{N}$$



If cells can be reduced in size, more of them can be added in a given area, increasing the overall capacity.

# Sectorization (sectoring)

- Use directional antennas instead of omnidirectional antennas.
- When 120° sectorization is used, one cell that usually covers 360° is divided into three 120° regions.
- When 60° sectorization is used, one cell that usually covers 360° is divided into six 60° regions.
- These regions are called **sectors**.



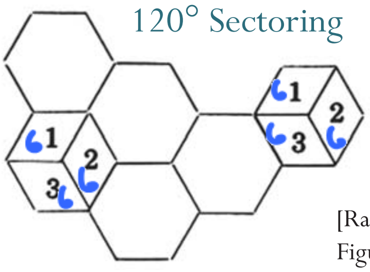
Analogy: Flashlight



# Sectoring (N = 7)

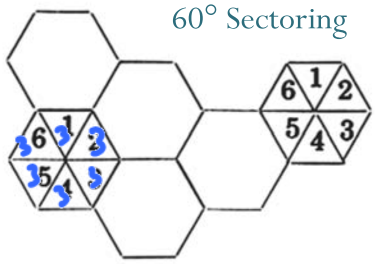

- Ex.
  - With no sectoring, suppose we have $m = 18$ channels/cell
  - With 120° sectoring, we have 6 channels/sector
  - With 60° sectoring, we have 3 channels/sector

120° Sectoring



[Rappaport, 2002, Figure 3.10]

60° Sectoring



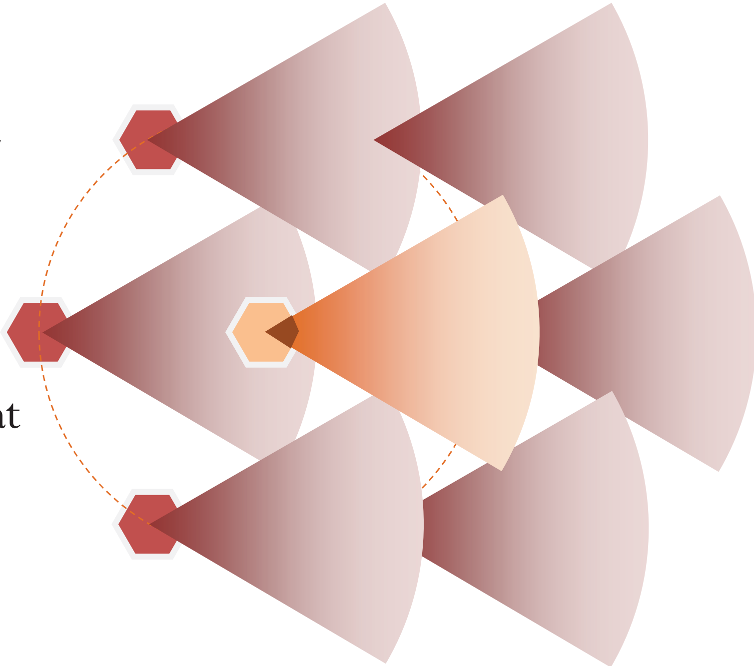
- Can support "the same" number of users per cell
  - In the next section, we will consider better definition of capacity. From such view on capacity, sectoring will give smaller capacity.
- Why is this better?

From previous section

$$\text{SIR} \approx \frac{1}{K}\left(\sqrt{3N}\right)^{\gamma}$$

# 60 Degree Sectoring

- Out of the 6 co-channel cells in the first tier, only one of them interfere with the center cell.
- If omnidirectional antennas were used at each base station, all 6 co-channel cells would interfere the the center cell.

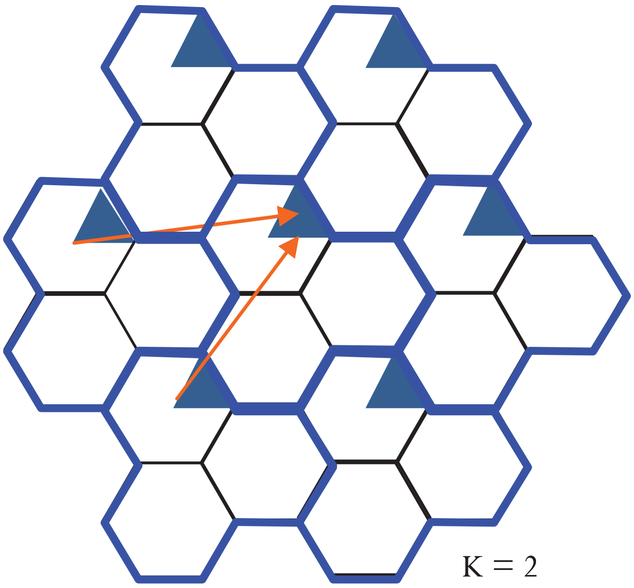


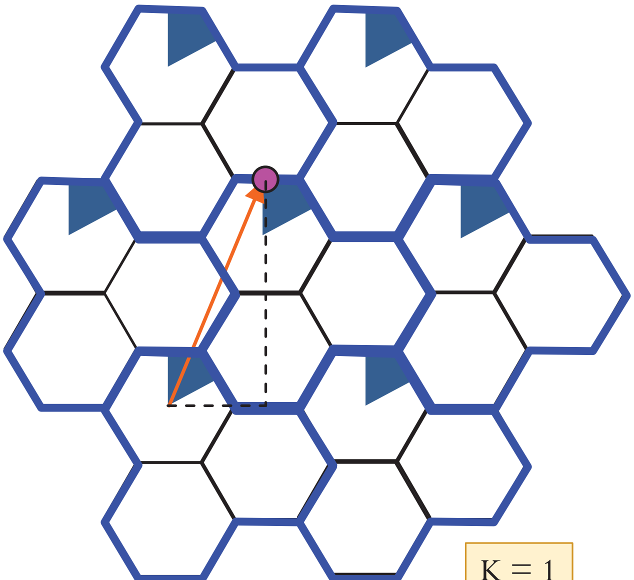
The value of K changes from 6 to 1!



$$\text{SIR} \approx \frac{1}{K}\left(\sqrt{3N}\right)^{\gamma}$$

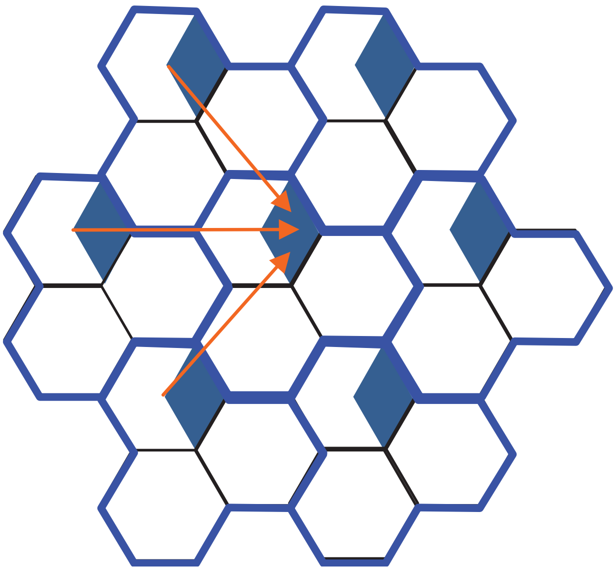
# Sectoring (N = 3 , 60°)



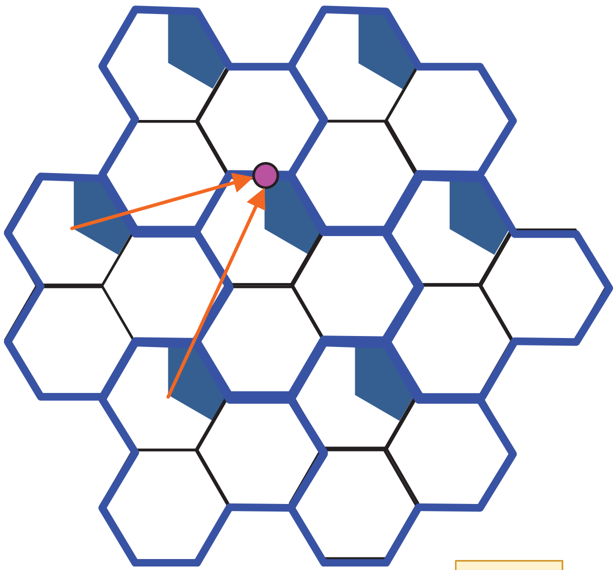



$$\mathrm{SIR} \approx \frac{1}{K}\left(\sqrt{3N}\right)^{\gamma}$$

# Sectoring (N = 3, 120°)



K = 3

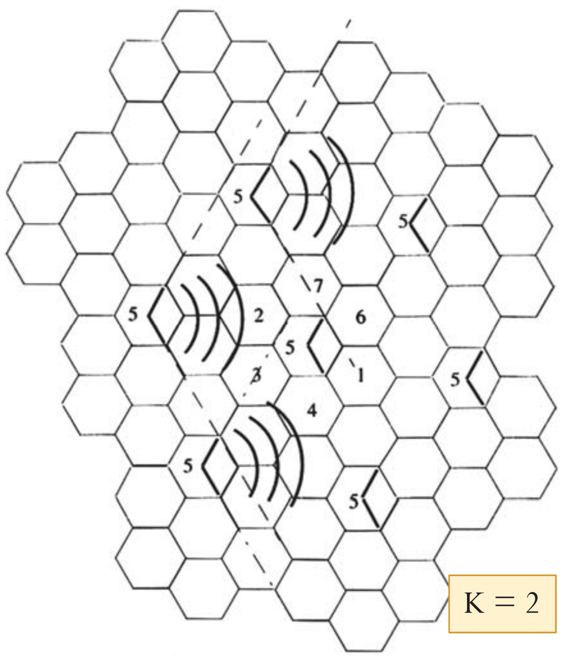


K = 2



# Sectoring (N = 7, 120°)

Assuming seven-cell reuse, for the case of 120° sectors, the number of interferers in the first tier is reduced from six to two.



K = 2

[Rappaport, 2002, Fig 3.11]

# Summary:

$S$ = total # available duplex radio channels for the system

Frequency reuse with **cluster size $N$**

Path loss exponent

"Capacity" $C = \frac{A_{\text{total}}}{A_{\text{cell}}} \times \frac{S}{N}$

Tradeoff

$$\frac{S}{I} \approx \frac{kR^{-\gamma}}{K \times \left(kD^{-\gamma}\right)} = \frac{1}{K}\left(\frac{D}{R}\right)^{\gamma} = \frac{1}{K}\left(\sqrt{3N}\right)^{\gamma}$$

m = # channels allocated to each cell.

Omni-directional: K = 6
120° Sectoring: K = 2
60° Sectoring: K = 1

SIR is improved by a factor of 6 ≈ 7.77 dB

SIR is improved by a factor of 3 ≈ 4.77 dB

SIR is improved by a factor of 2 ≈ 3.01 dB

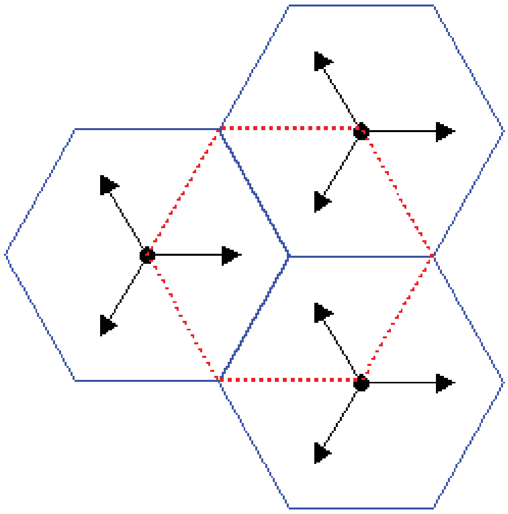


# Sectoring

- Advantages
  - Reduce interference by reducing $K$
    - Increase SIR (better call quality).
    - The increase in SIR can be **traded** with reducing the cluster size ($N$) which increase the capacity.
- Disadvantages
  - Cost: Increase number of antennas at each base station.
  
  - Next section: Decrease **trunking efficiency** due to channel sectoring at the base station.
    - The available channels in the cell must be subdivided and dedicated to a specific antenna.

# Location of the BS

- Center vs. Corner





# Visualizing the Cellular Signals

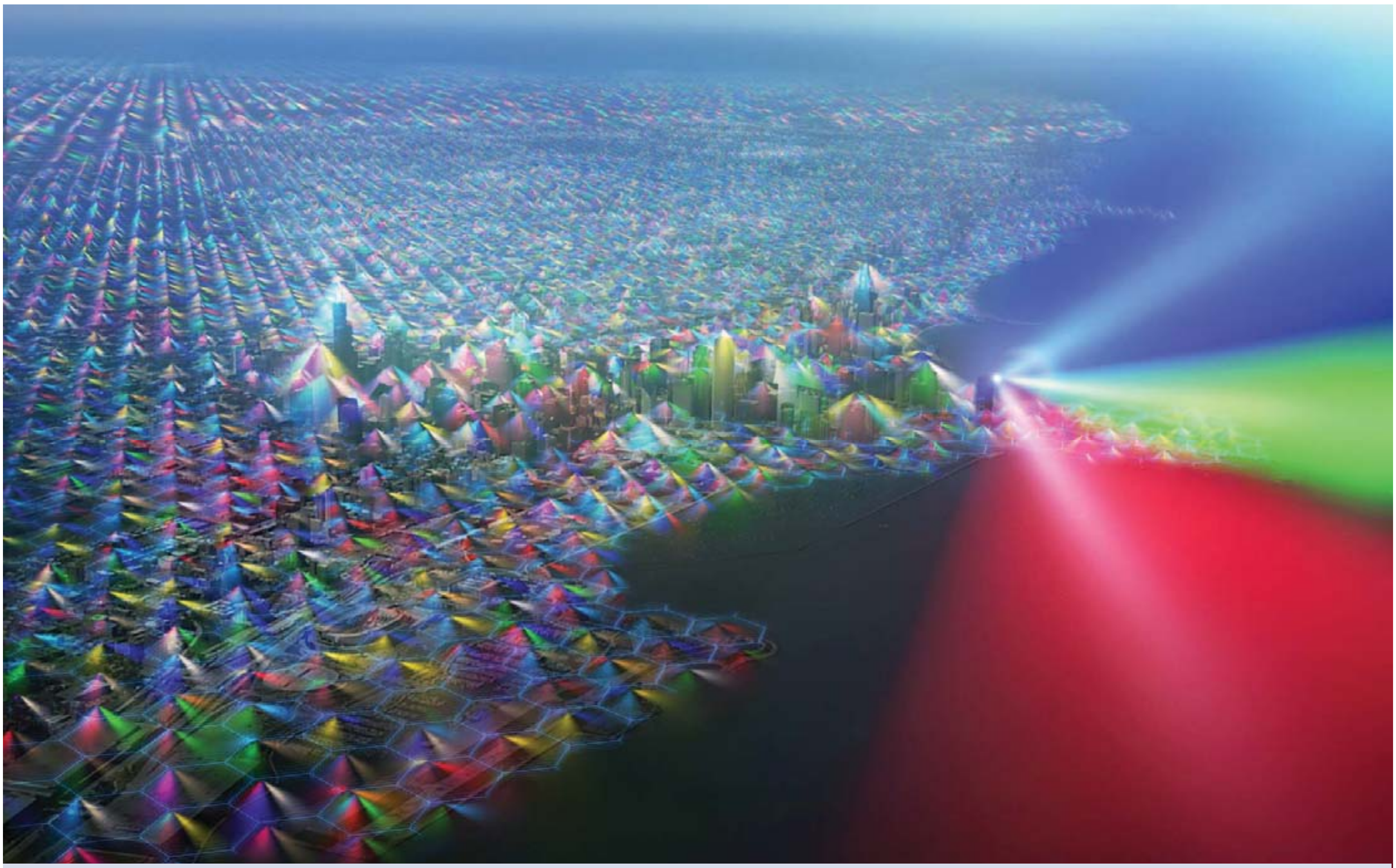
- Artist: Nickolay Lamm
- Use data from antennasearch.com to approximate the number of stations in each city and imposed a theoretical hexagonal grid over Chicago and New York.
- Color representation:
  - The area within each sector antenna radiation pattern has different users being assigned different frequencies and their signals combine to form a single perceived color in that instant.
  - Different channel combinations from sector to sector are indicated by different colors.
  - The channel combinations are not static, but rather change rapidly in time as different users are assigned different channels. But, if you were to take a photo of these rapid changes, you'd likely see a wide array of colors as seen in the illustration.
- With some technical check by
  - Danilo Erricolo, professor of electrical and computer engineering at the University of Illinois, and
  - Fran Harackiewicz, a professor at Southern Illinois University Carbondale who teaches antenna theory and design.

[http://motherboard.vice.com/blog/here-are-what-cell-phone-signals-would-look-like-if-you-could-see-them]

Sector radiation patterns from two hypothetical base-station sites on the Capitol. The strongest signals are at the center of the radiation patterns.

Cell sites on top of buildings provide much wireless coverage for New York City. The hexagon pattern is a theoretical grid for antenna placement.

How cellular signals might appear in the Hollywood Hills if we could see the electromagnetic radiation at these frequencies as we can in the visible spectrum. The long-distance tower is radiating three channel combinations in three directions indicated by the red, yellow and blue radiation patterns. In the background are cell stations each of which have 3 sector antenna radiation patterns as well.



A regular, hexagonal grid of cellular base-station sites is conceptualized for Chicago, with **stations at the corners of the hexagons**. Near the downtown area more users are likely to be found and the hexagonal cells are smaller to serve approximately the same numbers of users found in larger cells elsewhere. Antenna signals extending beyond the original cells provide coverage over part of Lake Michigan.

Coverage provided by a base station located at the Herbert C. Hoover Building in Washington D.C. Hexagonal cells and their related coverage are also shown in the background.

# Wireless coverage mapping

- http://opensignal.com/
- Crowdsource data on carrier signal quality from users who have its consumer mobile application installed.
- Also provide maps of cell tower locations (useful but not comprehensive)