The Cellular Concept

- **History of Communication**
- **Frequency Planning**
- **Coverage & Capacity**

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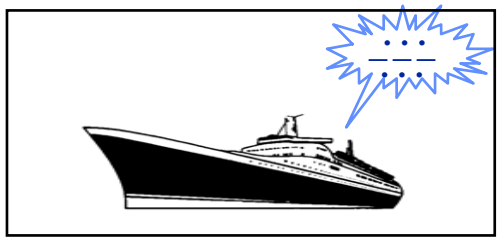
Before GSM: Mobile Telephony Mile stones

1876

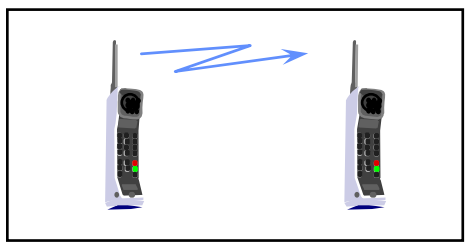
Electric transmission
(Graham Bell)

1897



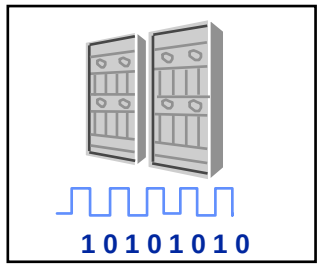
1st wireless
transmissions
(Marconi)

1946



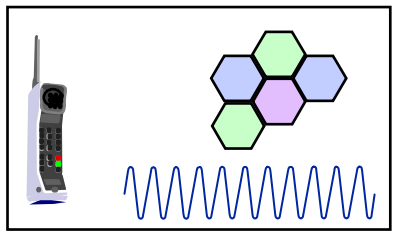
1st public mobile
telephone

1970



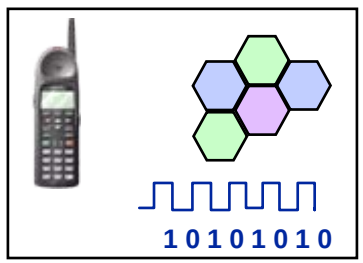
Digital Technology
(1st digital switch)

1982



1st analog cellular
network

1992



1st GSM communication
(digital cellular network)

What is GSM?

ETSI:

European Telecommunications Standards Institute

SMG:

Special Mobile Group

GSM 900:

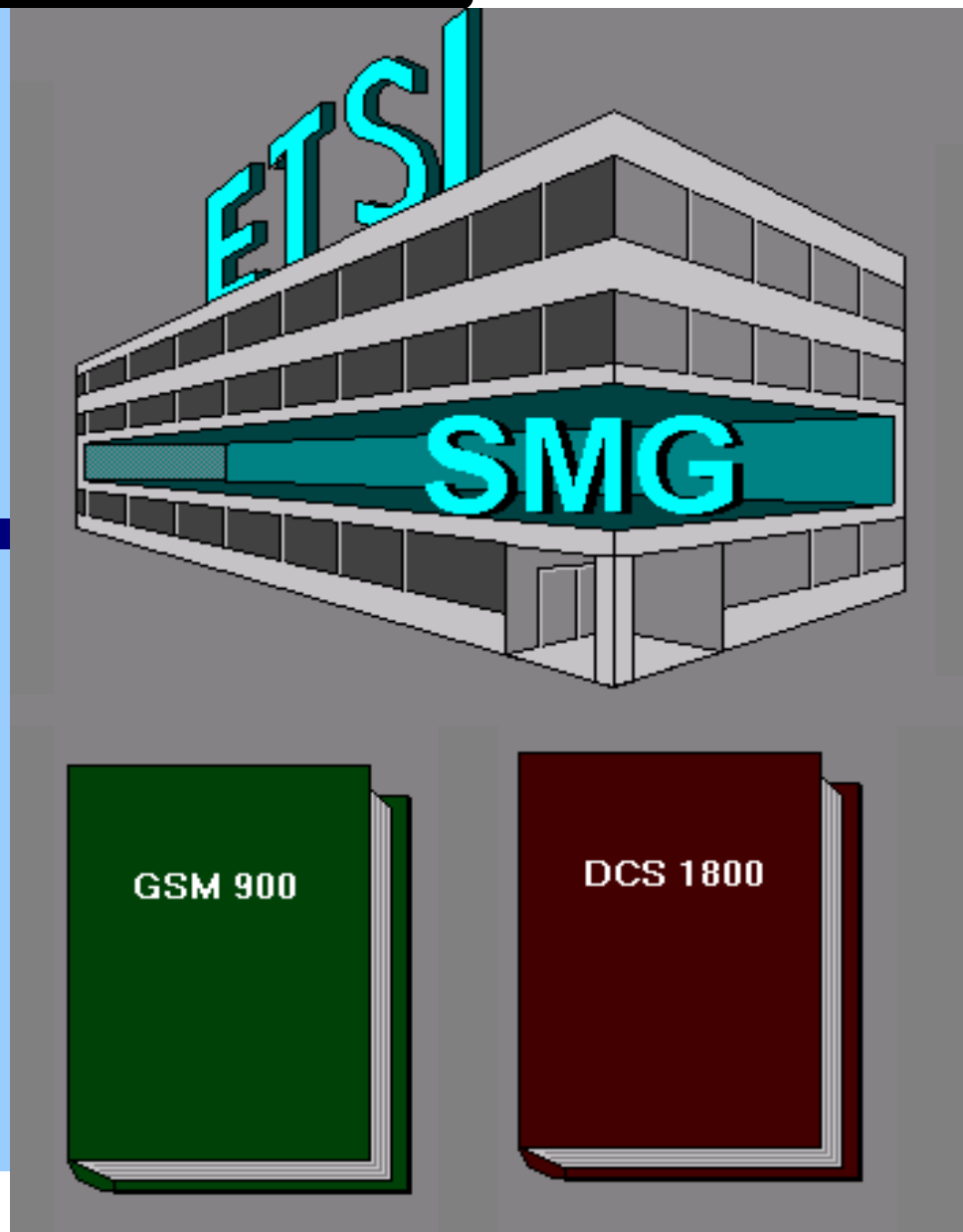
Global System for Mobiles

900 MHz Band.

DCS 1800:

Digital Cellular System

1800 MHz Band.



Development of the GSM Standard

1982: Groupe Spécial Mobile (GSM)

1985: List of recommendations are settled and intensely supported by the industry.

1987: Initial MoU (Memorandum of Understanding) aside the drafting of technical specifications was signed by network operators of 13 countries:

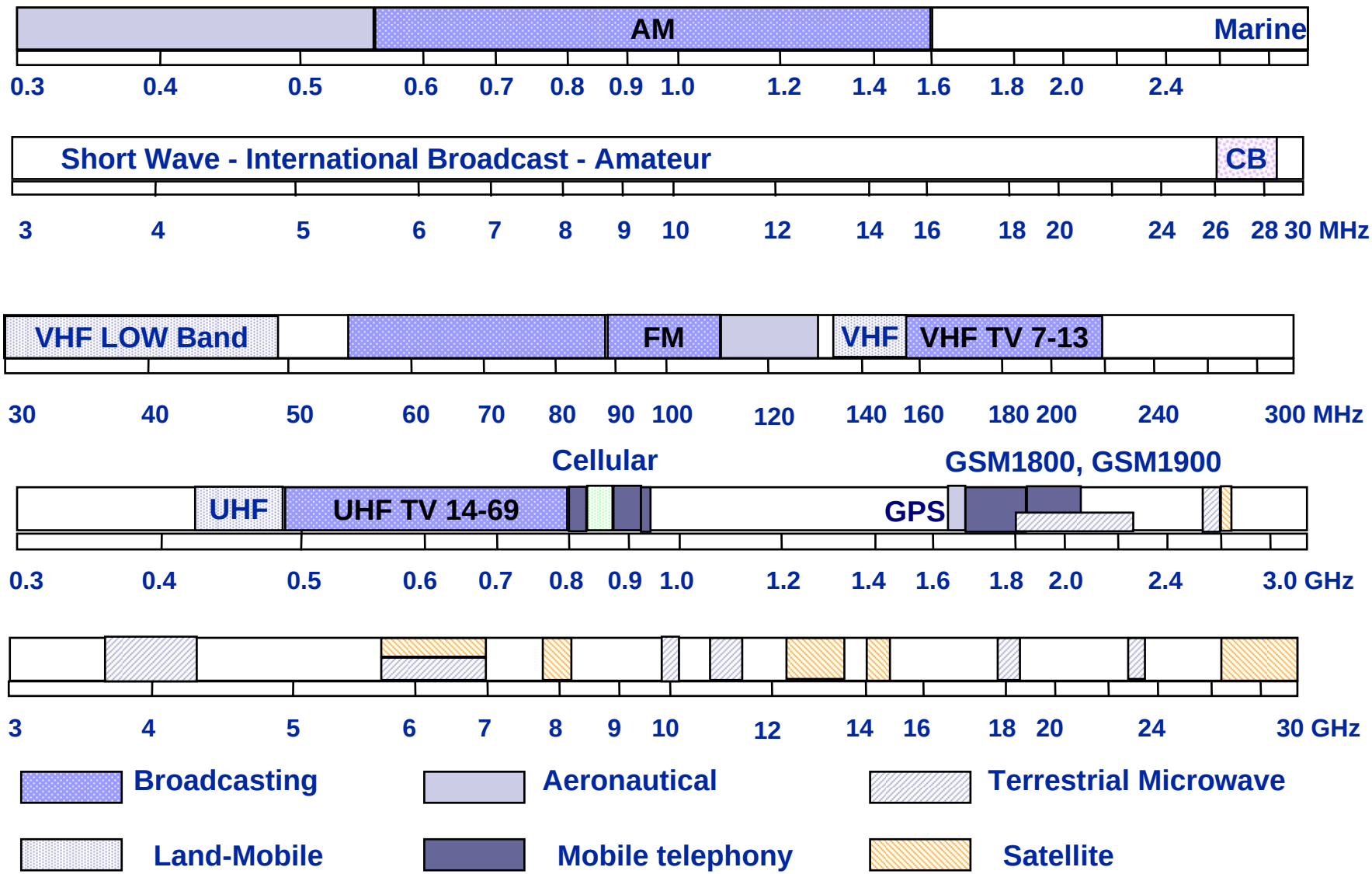
- time-scales for the procurement and deployment,
- compatibly of numbering and routing plans,
- tariff principles and definition of accounting.

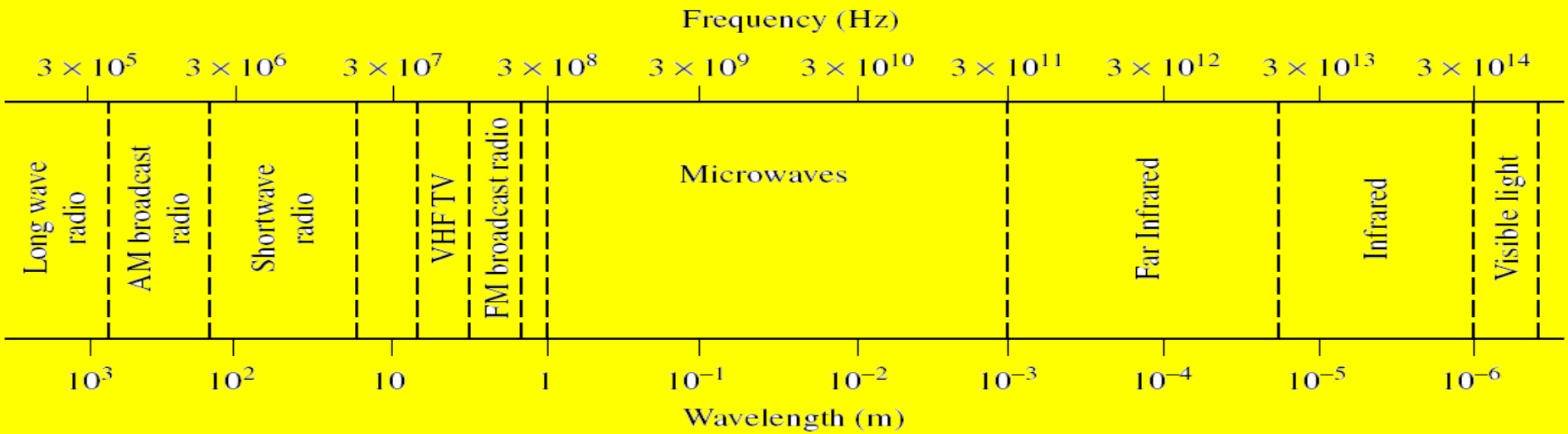
1990:

- The GSM specifications for the 900 MHz are frozen.
- Specifications start for the 1800 MHz GSM systems.
- GSM stands as

"Global System for Mobile communications"

The Application of the Radio Spectrum





Typical Frequencies

AM broadcast band	535–1605 kHz
Short wave radio band	3–30 MHz
FM broadcast band	88–108 MHz
VHF TV (2–4)	54–72 MHz
VHF TV (5–6)	76–88 MHz
UHF TV (7–13)	174–216 MHz
UHF TV (14–83)	470–890 MHz
US cellular telephone	824–849 MHz
	869–894 MHz
European GSM cellular	880–915 MHz
	925–960 MHz
GPS	1575.42 MHz
	1227.60 MHz
Microwave ovens	2.45 GHz
US DBS	11.7–12.5 GHz
US ISM bands	902–928 MHz
	2.400–2.484 GHz
	5.725–5.850 GHz
US UWB radio	3.1–10.6 GHz

Approximate Band Designations

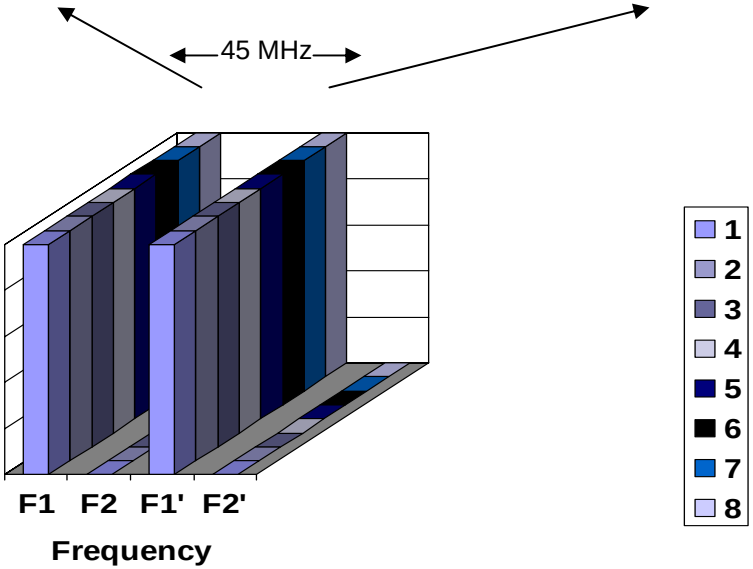
Medium frequency	300 kHz to 3 MHz
High frequency (HF)	3 MHz to 30 MHz
Very high frequency (VHF)	30 MHz to 300 MHz
Ultra high frequency (UHF)	300 MHz to 3 GHz
L band	1–2 GHz
S band	2–4 GHz
C band	4–8 GHz
X band	8–12 GHz
Ku band	12–18 GHz
K band	18–26 GHz
Ka band	26–40 GHz
U band	40–60 GHz
V band	50-75 GHz
E band	60-90 GHz
W band	75-110 GHz
F band	90-140 GHz

Land-Mobile Mobile telephony Satellite

GSM Architecture

MS Transmission
Band : 890 – 915
MHZ

BS Transmission
Band : 935 – 960
MHZ

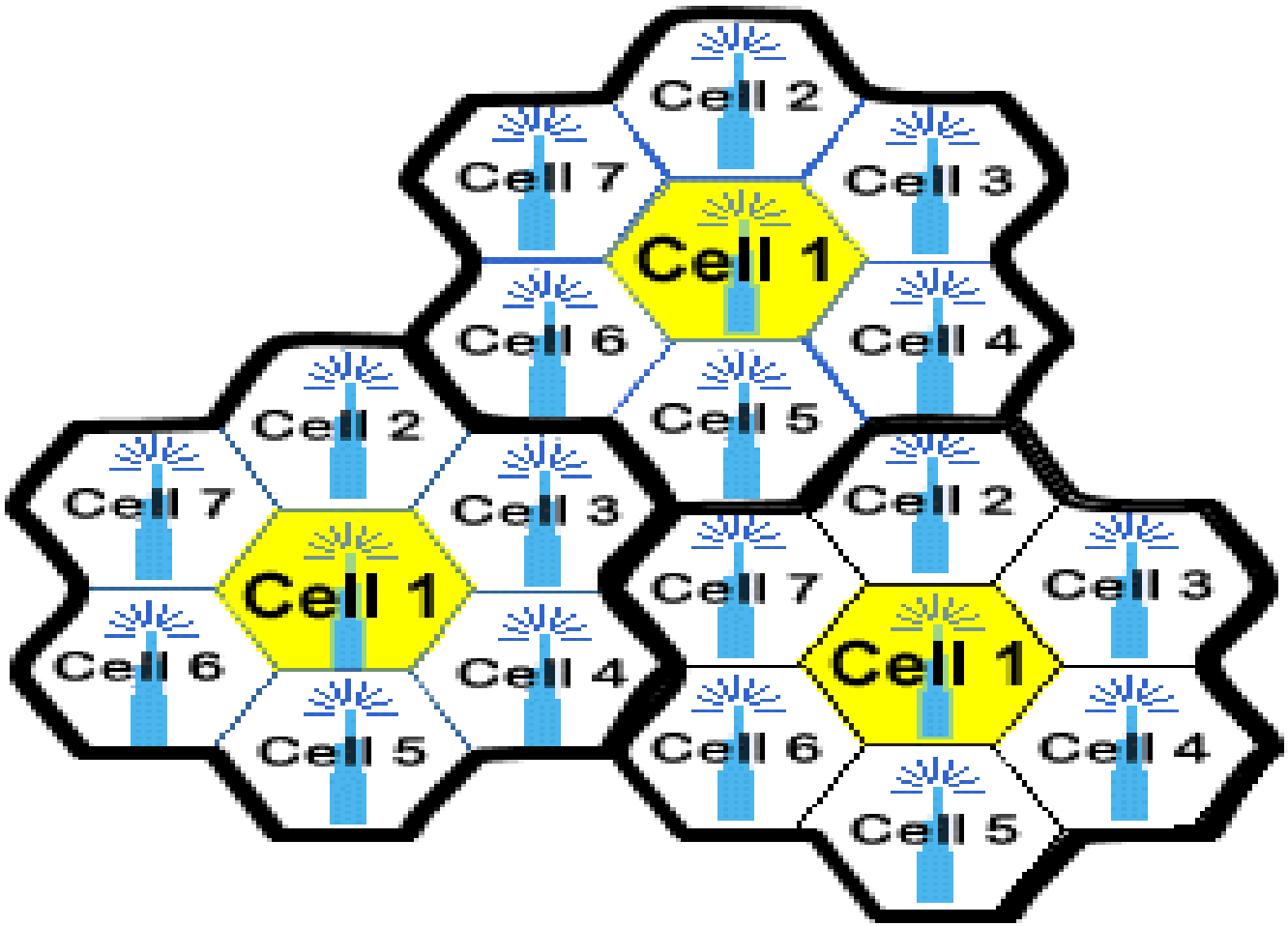


Year Introduced	1990
Access method	TDMA
Channel Bandwidth	200 kHz
Number of duplex channels	125
Users per channel	8
Speech coding bit rate	13 kbps
Data coding bit rate	12 kbps
Frame size	4.6 ms

The cellular concept

- Earlier systems used single high power transmitter. So no frequency reuse
- Cellular concept solve the problem of spectral congestion and user capacity without any major technological changes.
- Replaces single high power transmitter with many low power transmitters.
- Each base station is allocated portion of available channels.
- Distribution to neighbors so that minimize interference.

Contd.


Cell 2
Cell 7
Cell 3
Cell 1
Cell 6
Cell 4
Cell 5
Cell 2
Cell 7
Cell 3
Cell 1
Cell 6
Cell 4
Cell 5
Cell 2
Cell 7
Cell 3
Cell 1
Cell 6
Cell 4
Cell 5

Frequency reuse

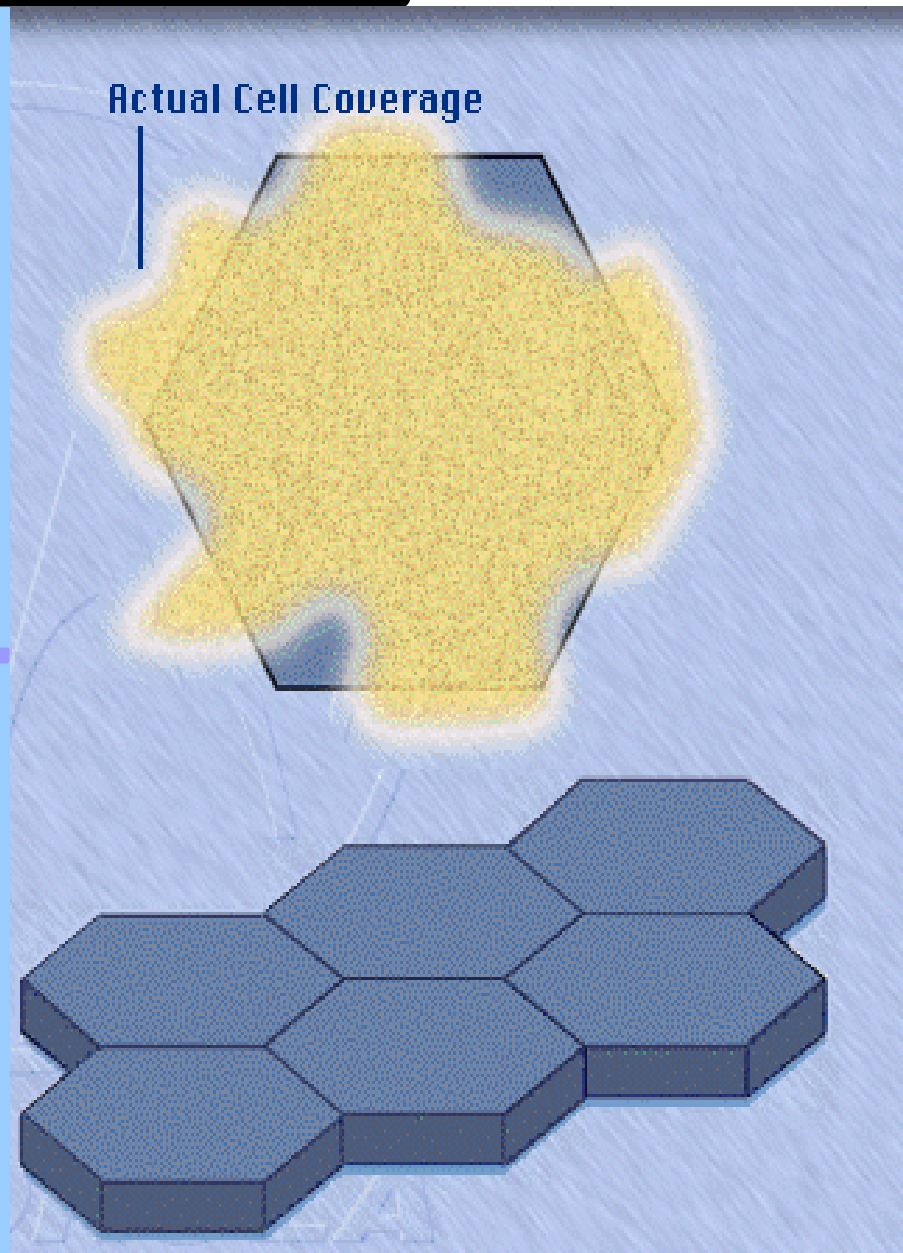
- Hexagonal shape is only logical shape.

Actual coverage of cell is known as f*ootprint* and is determined by measurements and prediction models. Cell must be designed to serve the weakest mobile at edge in *footprint.*

Cell Shape & Coverage

Actual Shape:

Irregular Shape depending on terrain or result from planning.



Theoretical Shape:

Hexagon is used for showing a cell footprint.

Frequency reuse

- *S=kN*
- *C=MkN =MS*
- *N is called cluster size typically equals to 4,7,12*
- *If N is reduced (cluster size) keeping cell size constant more clusters are required to cover a given region so more capacity is achieved. But increases co channel interference.*

S total duplex channels
k duplex channel allocated to one cell (k<S)

N number of cells which use together full channels S.

M if cluster is repeated M times

C total capacity

Frequency reuse

- Smallest possible value of N is desirable to increase capacity.
- Frequency reuse factor of cellular system is given by 1/N as each cell in cluster is only assigned 1/N of total available channels in system.
- Number of cells per cluster N can only

have values which satisfies eq

$N=i^2+ij+j^2$

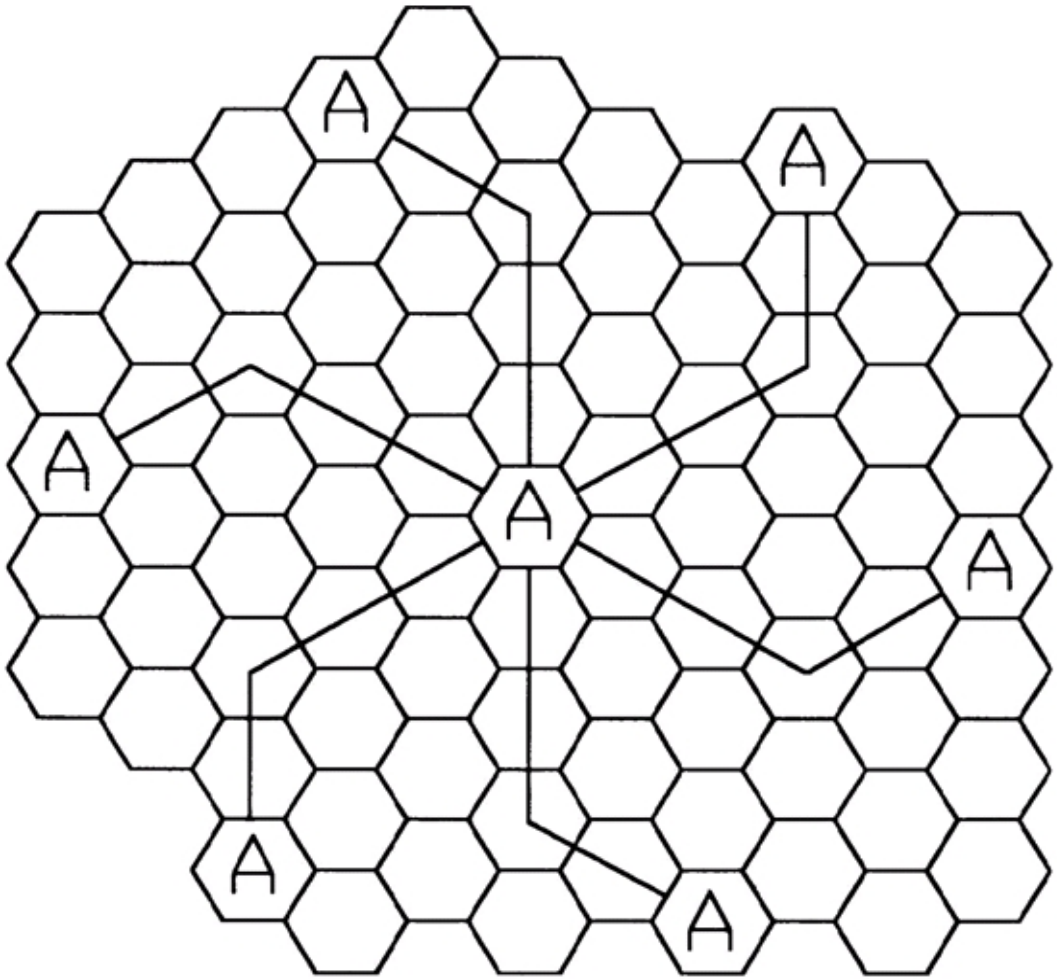
Frequency reuse

- i and j are non negative numbers •

Follow the steps to find nearest co channel interferer.

1. Move i cells along any chain of hexagonal.
2. Turn 60 degree anticlockwise or 120 degree clockwise and move j cells.

Frequency reuse



Method of locating co-channel cells in a cellular system.
In this example, $N = 19$ (i.e., $I = 3$, $j = 2$).

Frequency Reuse

- Small number of radio channel were available for mobile systems.
- Find way to reuse radio channels.
- Mobile telephone system architecture is restricted into cellular concept.

Numerical

- Total Bandwidth 33MHz.
- Uses two 25Khz simplex channel to provide full duplex voice and control channels.
- Compute the total number of channels avaliable per cell if a system uses:
- 4 cell/cluster
- 7 cell/cluster
- 12 cell/cluster
- If 1 MHz of the allocated spectrum is dedicated to control channels and voice channels in each cell for each of three systems.
- Self practice question 3.4 page no.97.

Co-Channel and Adjacent Channel Interference

- CCI is interference from two different radio stations on the same frequency.
- ACI is interference caused by extraneous power from a signal in an adjacent channel.
- Caused by inadequate filtering.
- ACI is distinguished from crosstalk.

Smaller N is greater capacity

Table 3.1 Co-channel Reuse Ratio for Some Values of N

	Cluster Size (*N*)	**Co-channel Reuse Ratio (*Q*)**
$i = 1, j = 1$	3	3
$i = 1, j = 2$	7	4.58
$i = 2, j = 2$	12	6
$i = 1, j = 3$	13	6.24

Signal to Interference Formula

$$S/I = (D/R)n/i0$$

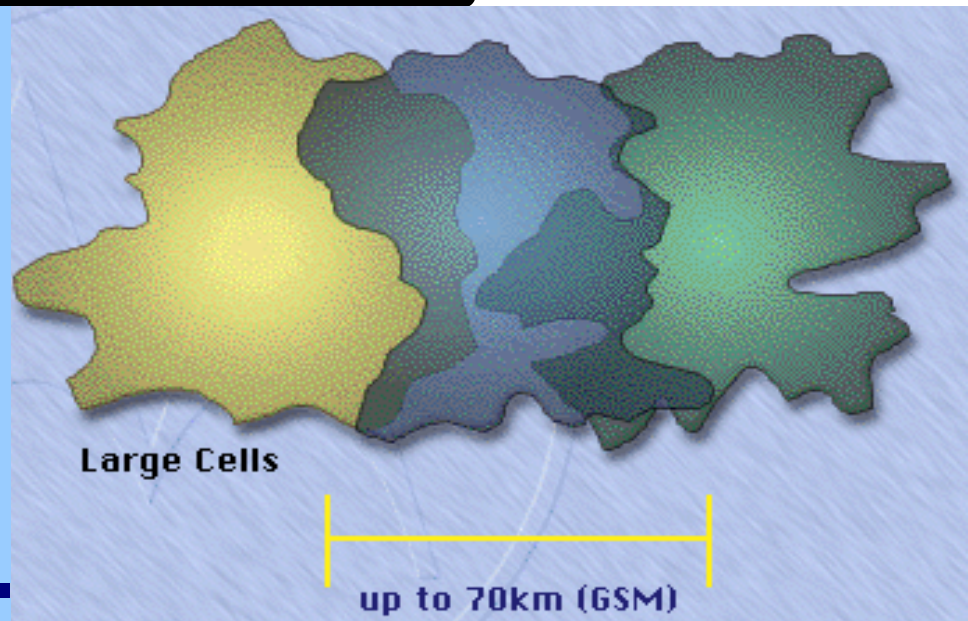
- S is desired signal power.
- I Interference power.
- *i* 0 number of co-channel interfering cells.
- D/R co-channel reuse ratio.
- S/I signal-to-interference ratio.

Cell Size (Max & Min)

Large Cells:

Low Subscriber Density

Unobstructed Terrain



Small Cells:

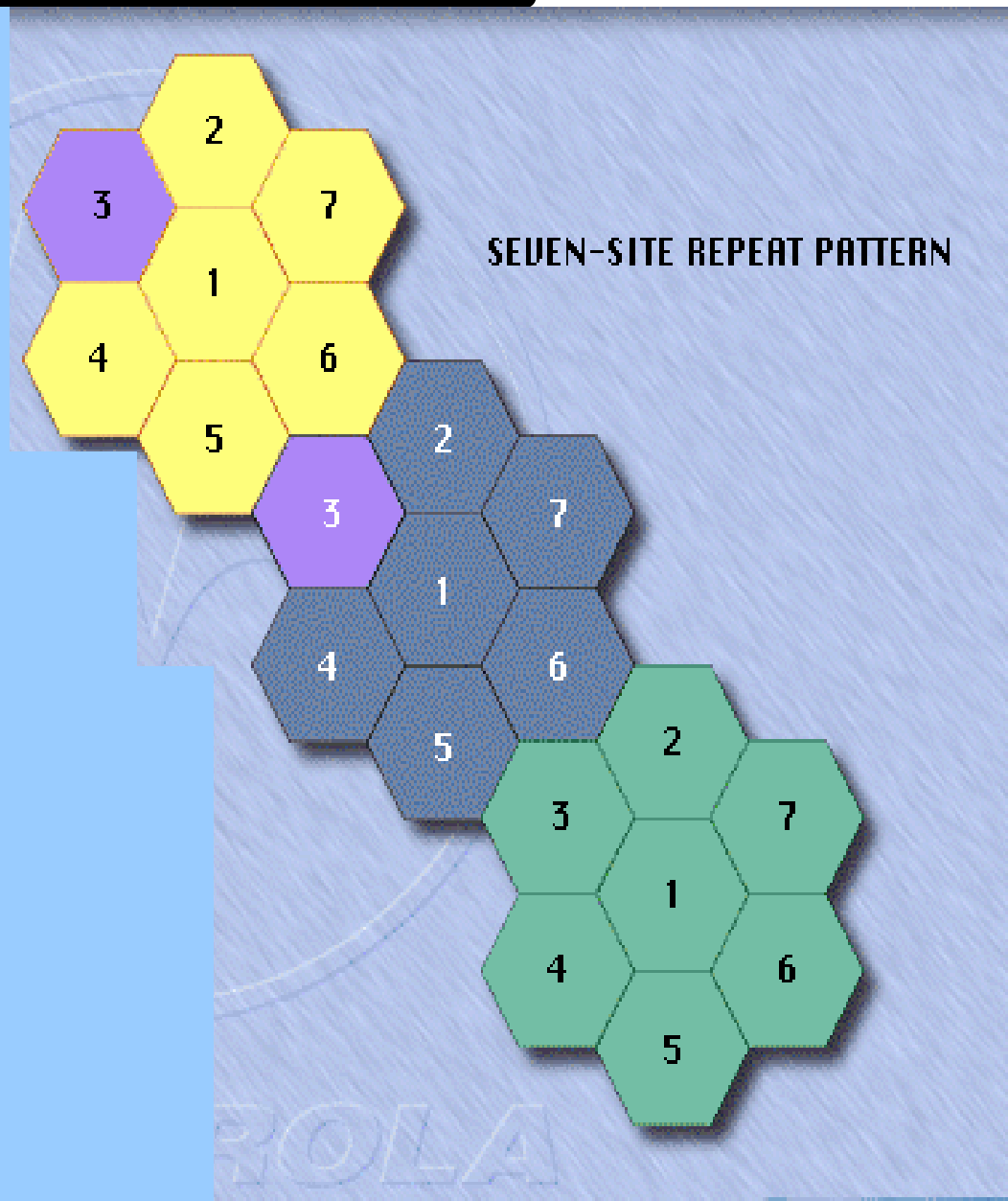
High Subscriber Density

Urban Terrain

Frequency Re-Use

Co-Channel Cells:

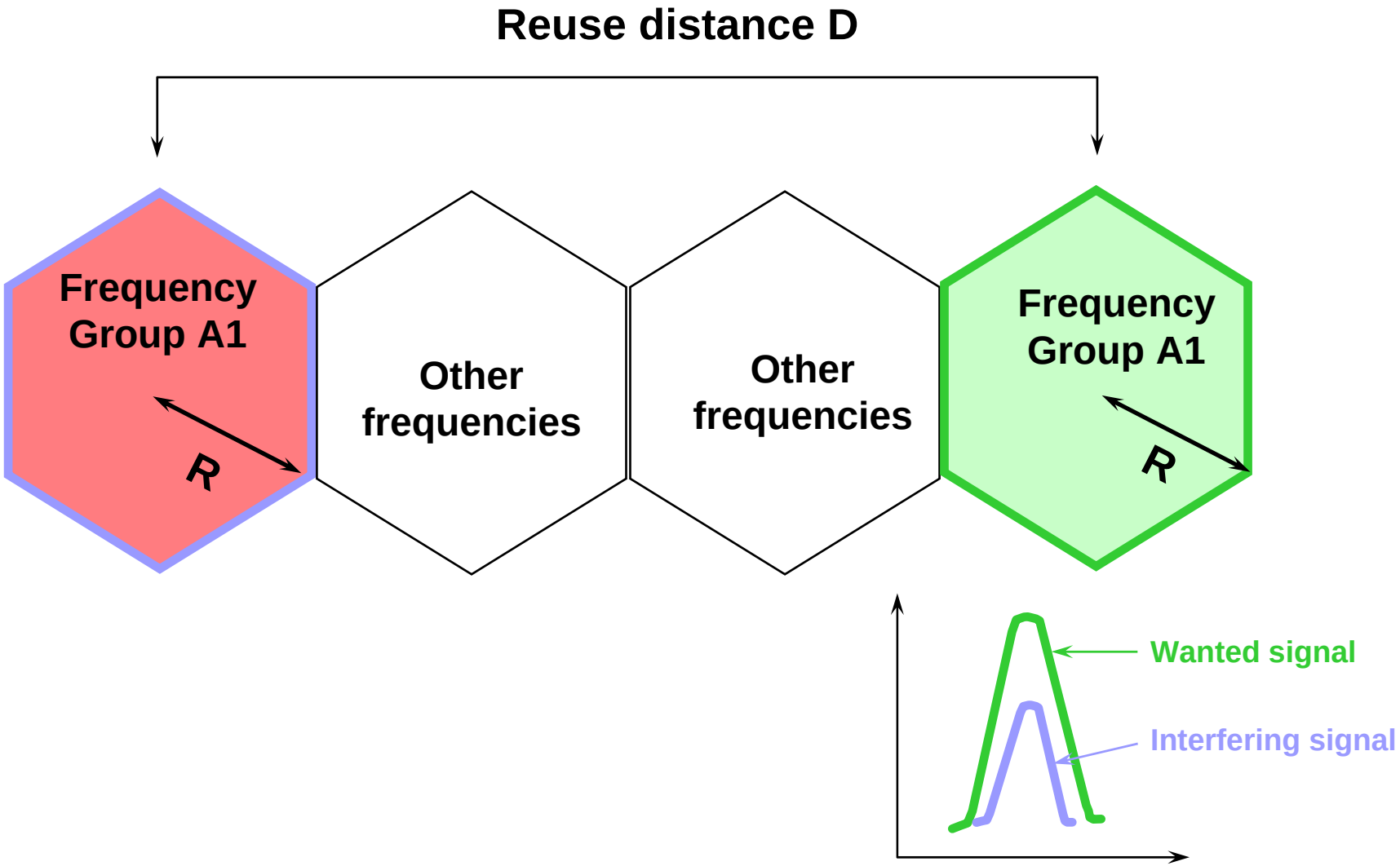
Cells using same frequency must be positioned far enough so as to avoid Co-Channel Interference.



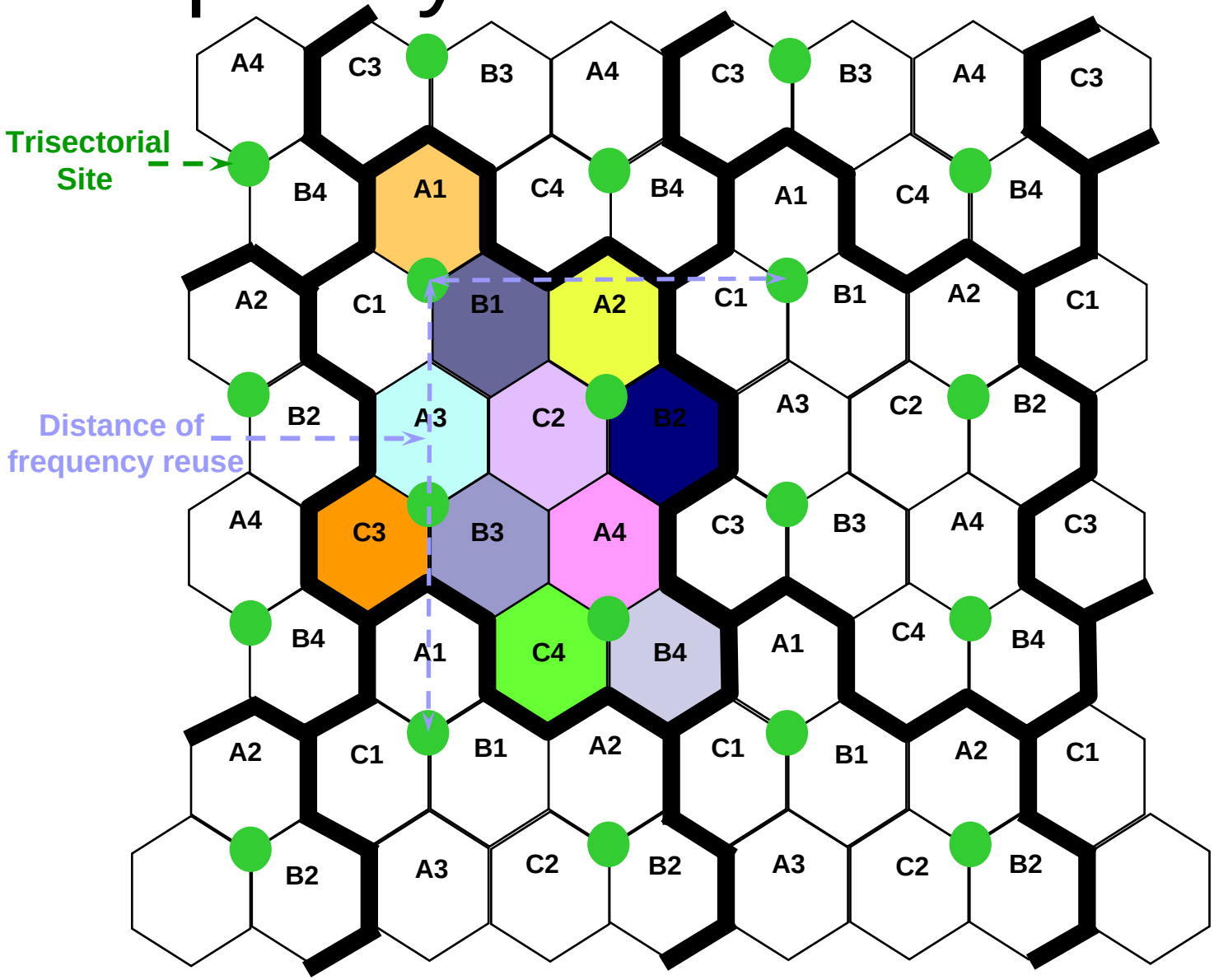
Repeat Pattern:

3,4, or 7 cell repeat patterns are common.

The Frequency Reuse Distance

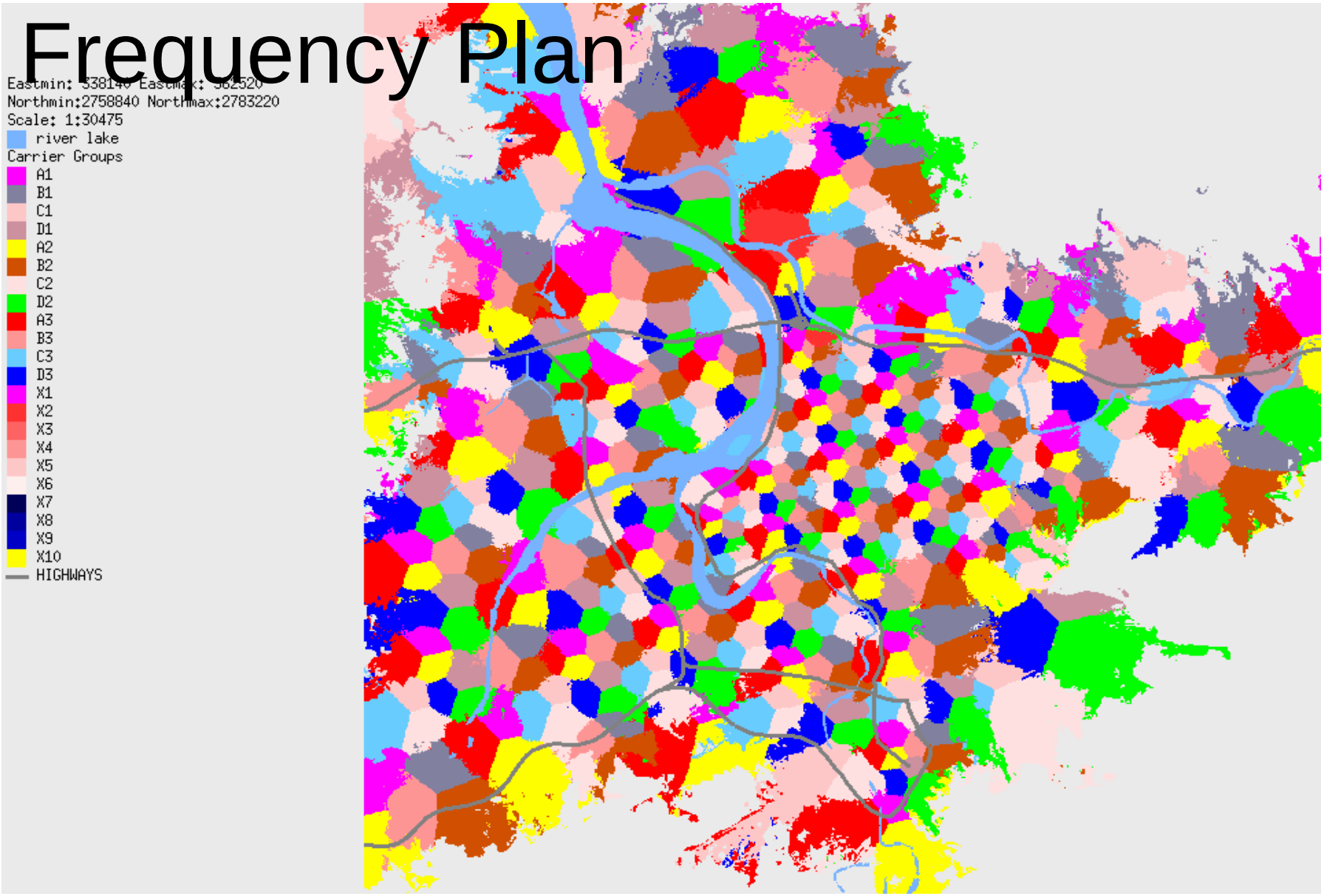


Frequency Reuse Pattern

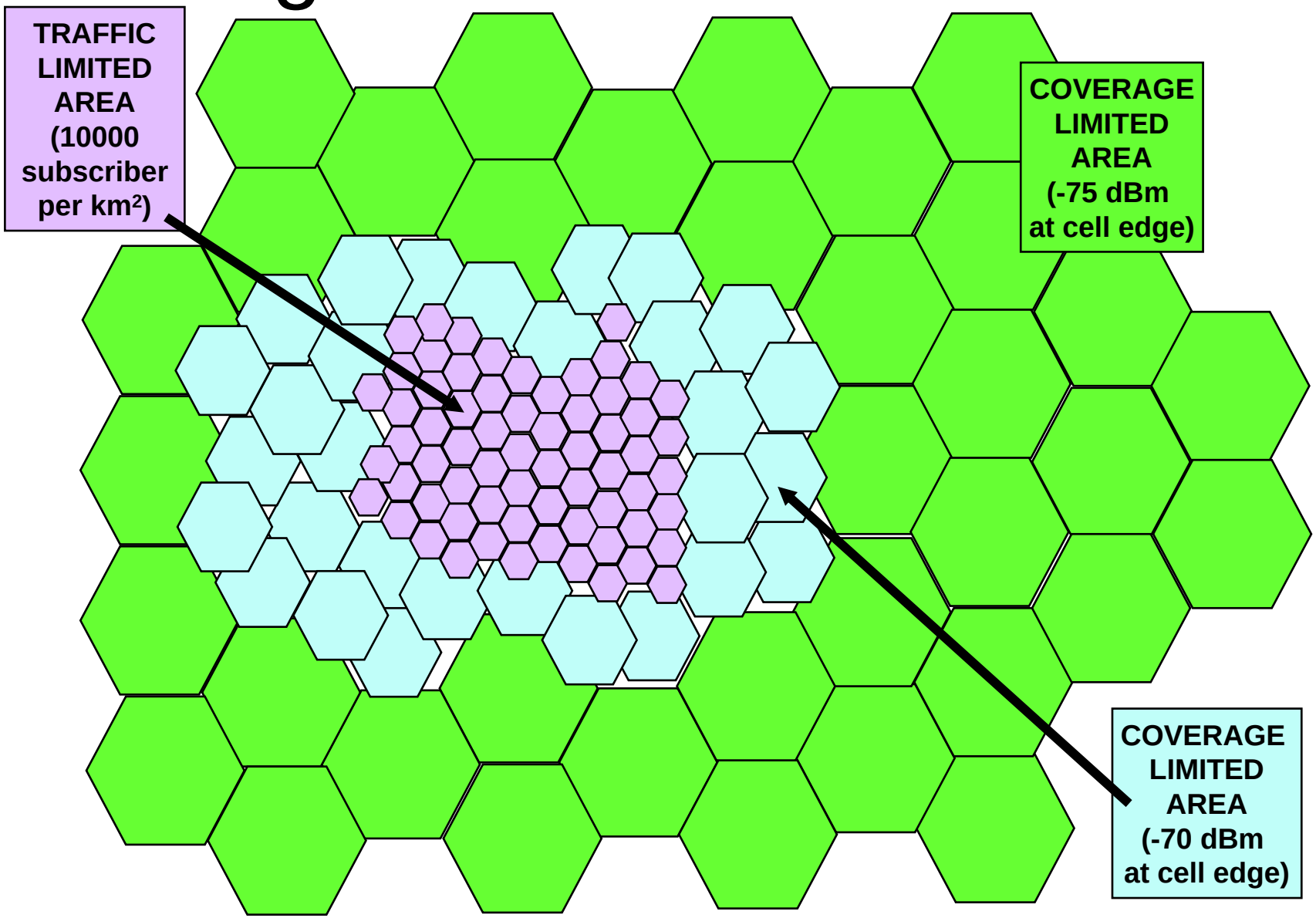


4*3 Reuse Pattern of 12 cells

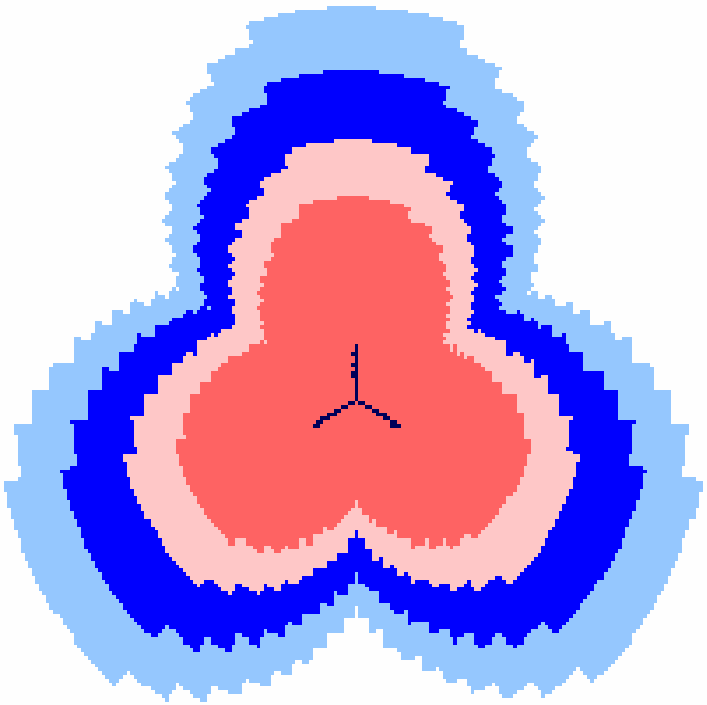
Frequency Plan



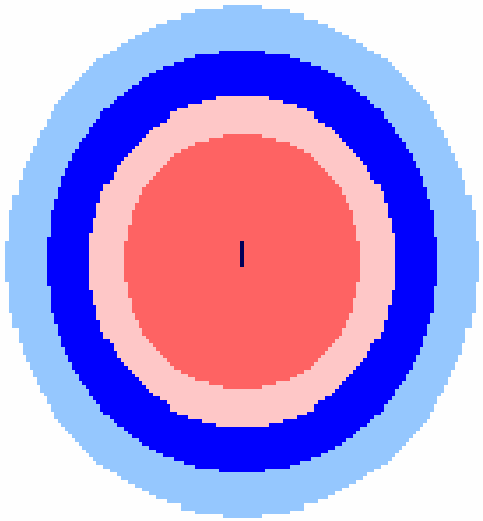
Coverage or Traffic Limitations



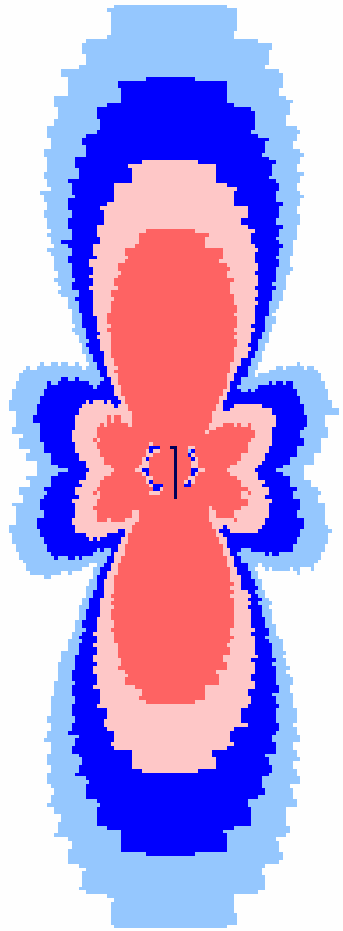
Cell Sectorization



TRI

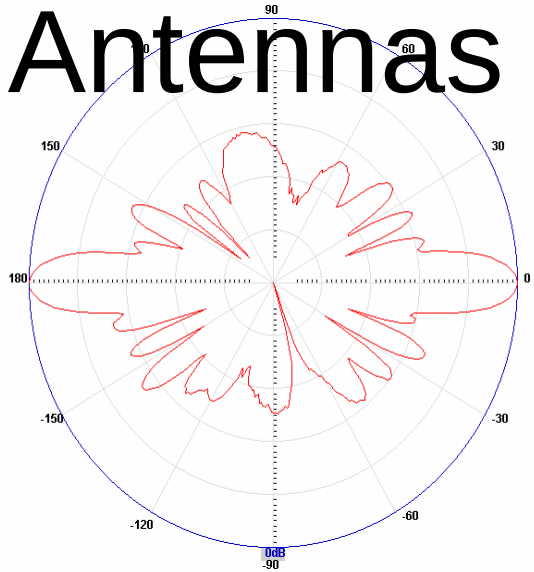


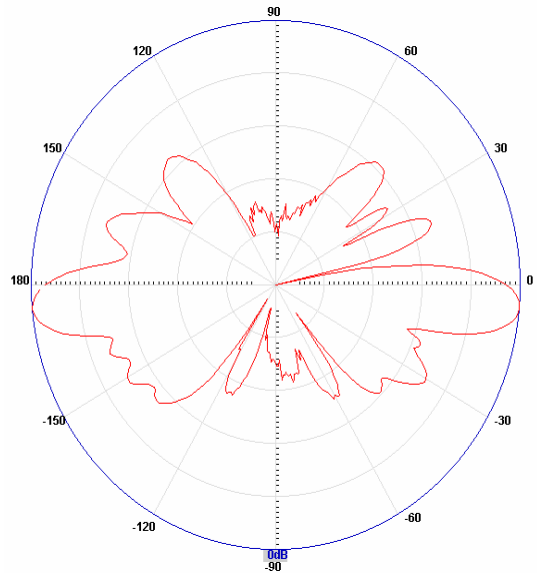
OMNI



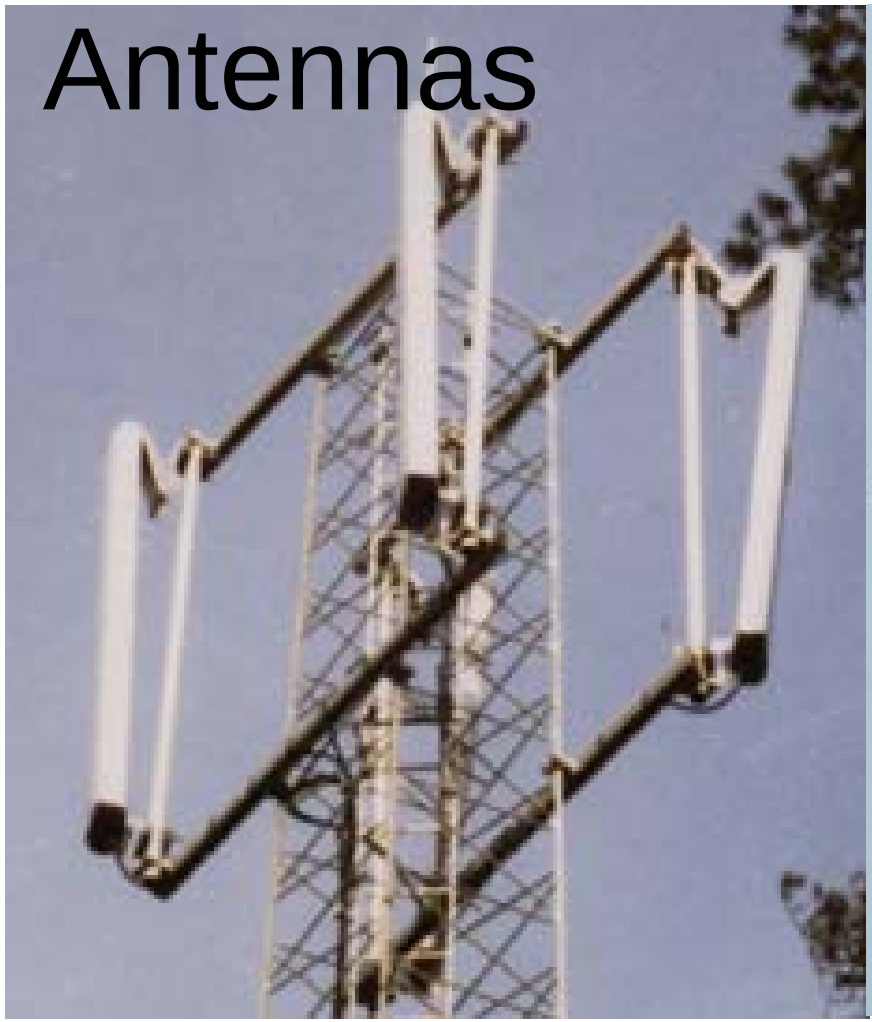
BI

Omnidirectional Site Antennas





Bi and Trisectorial Site Antennas



HANDOVER – Serving / Neighbour Cells

Best Neighbours:

Mobile monitors signal strength from neighboring cells.

Handover Criteria:

Signal Strength

Signal Quality

Channel assignment strategies

- Two types of channel assignment

  Fixed vs dynamic

  Fixed:

  cell is allocated predetermined set of channels. If all channels are occupied then call is blocked. To avoid this problem borrowing strategy is used in which channel is borrowed from neighbor cell supervised by MSC (mobile switching center).

Dynamic assignment

- Voice channels are not allocated to different cells permanently.
- Each time serving base station requests a channel from MSC.
- MSC plays major role by monitoring reuse distance, cost function and other issues. • MSC needs to collect real time data on channel occupancy, traffic distribution and radio signal strength indications (RSSI) this increases the storage and computational load but provides the advantage of increased channel utilization and decreased probability of blocked calls.

Handoffs - the basics

Handoff is initialized at signal level of about -90dBm and -100dBm

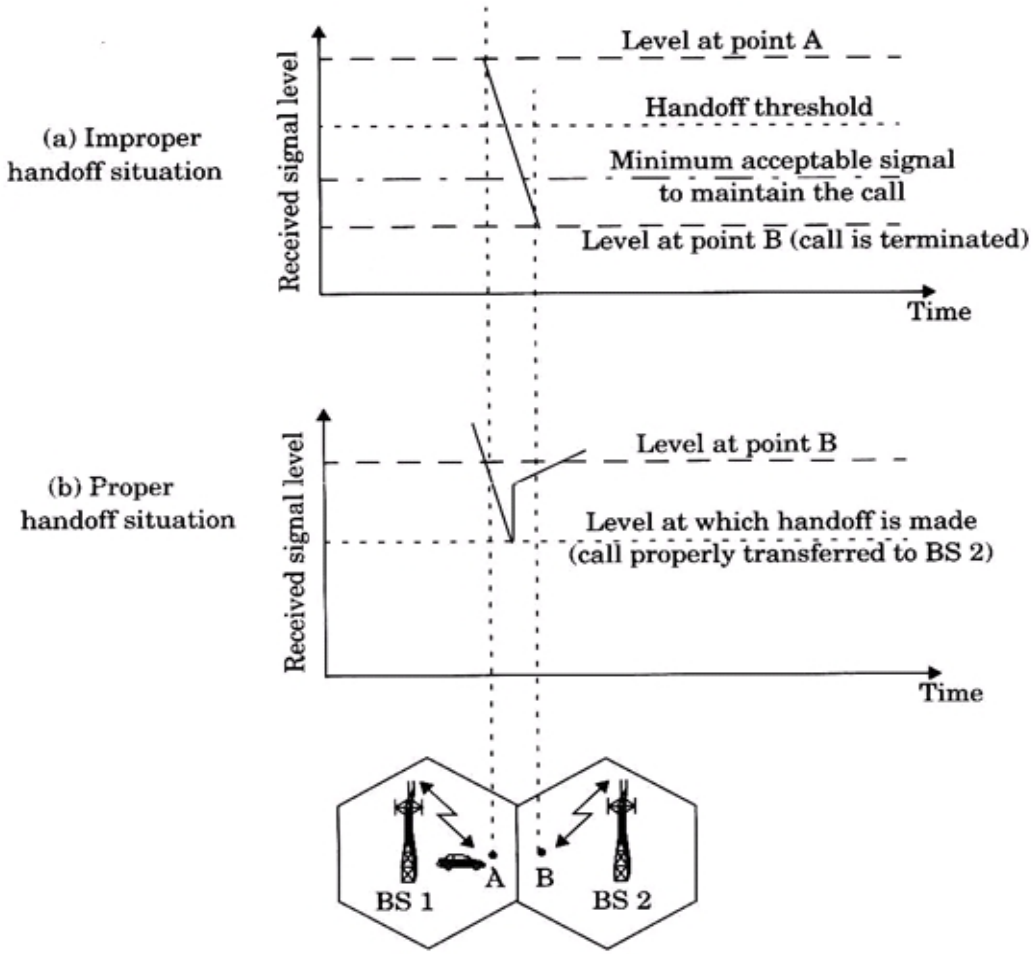


Figure 3.3 Illustration of a handoff scenario at cell boundary.

The umbrella cell approach

To avoid frequent handover for fast user. Fast moving user is assigned frequency from umbrella cell and slow moving users are provided treated in micro cells

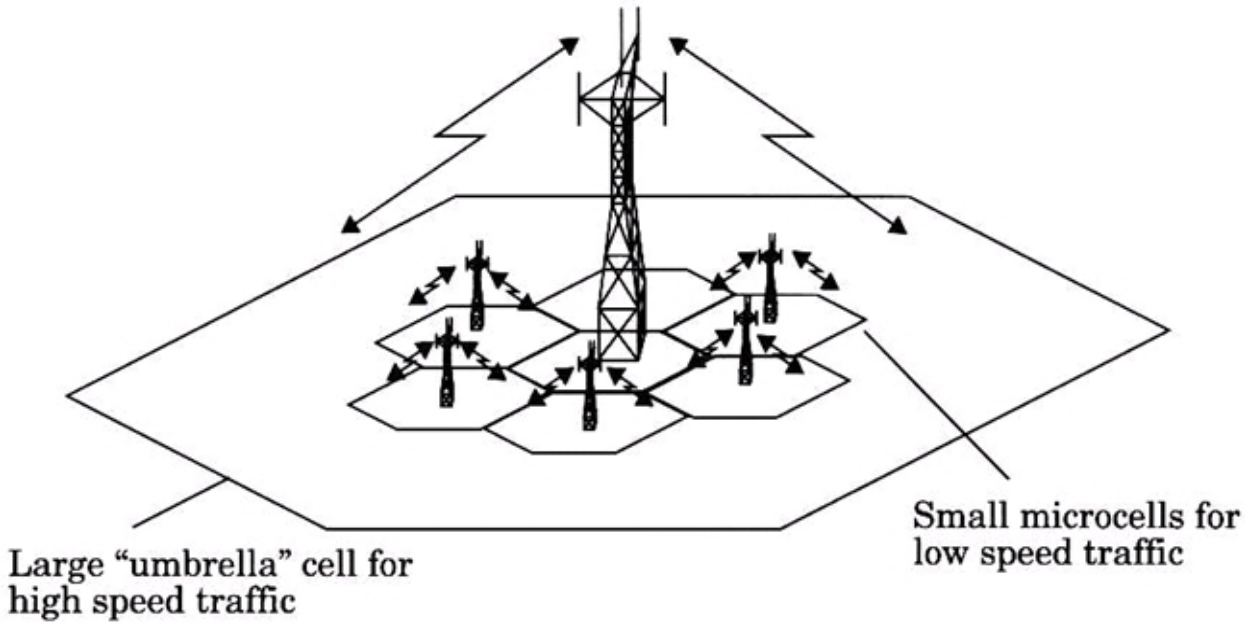


Figure 3.4 The umbrella cell approach.

Improving coverage and capacity in cellular system

- Cell Splitting
- Sectoring

Cell Sectorization

Omni Cells:

Omni Directional Antenna

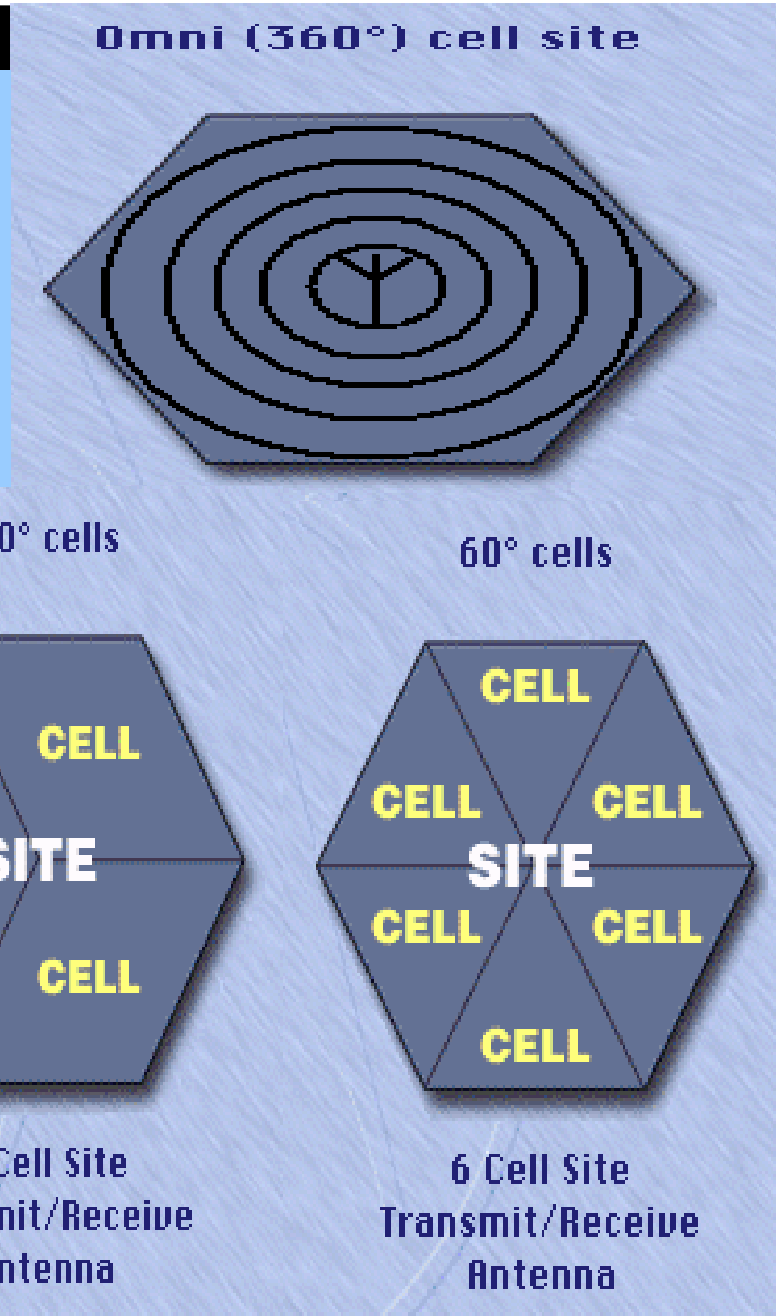
Sectorized Cells:

Directional Antennas.

Advantages:

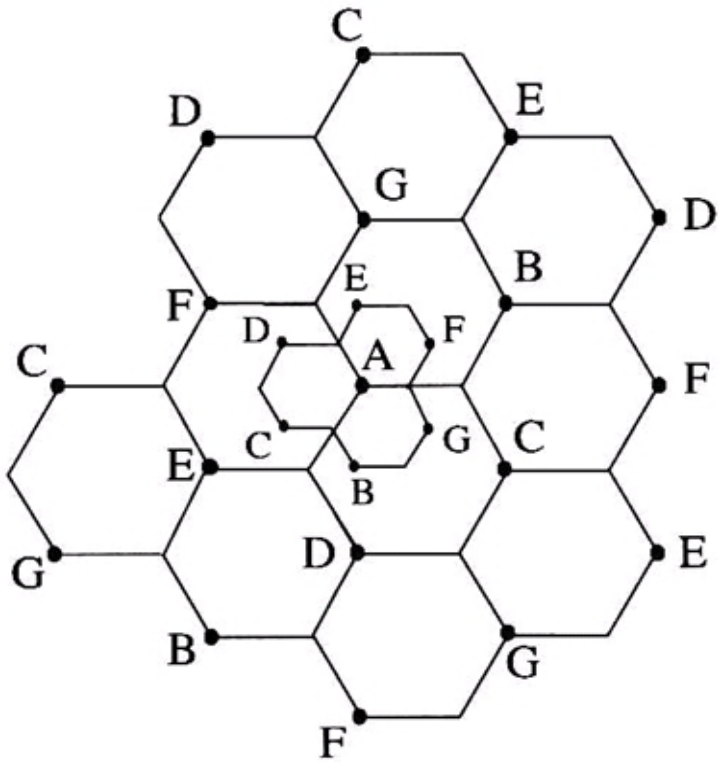
Higher Capacity

Better Coverage

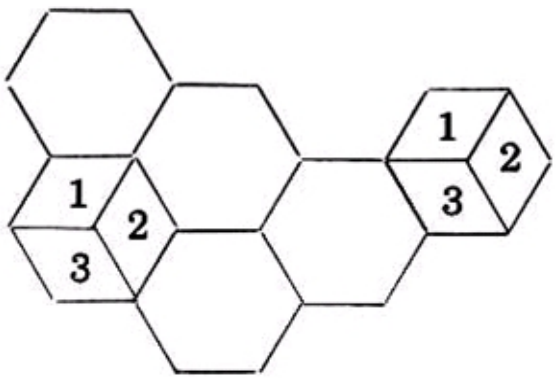


Cell Splitting

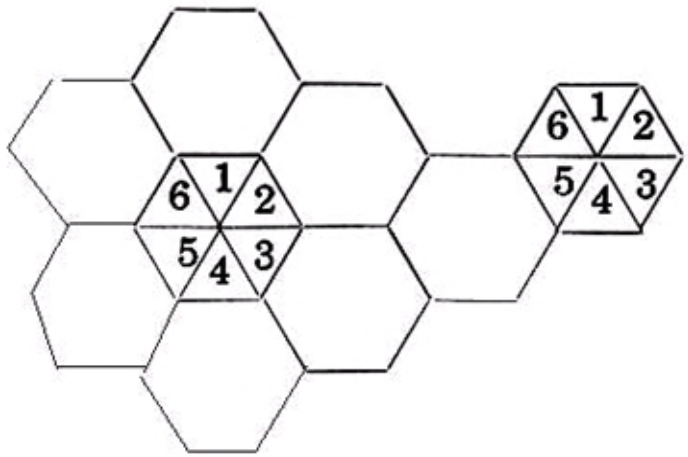
- It is process of dividing a congested cell into smaller cells.
- Transmitting power and antenna height is reduced. • It increases the capacity by increasing the number of times that channels are reused.



Sectoring



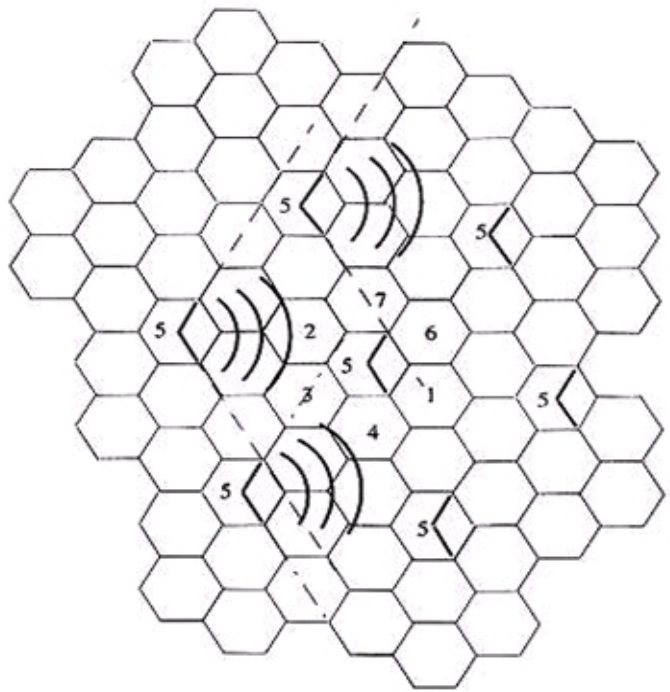
120 degree sectoring



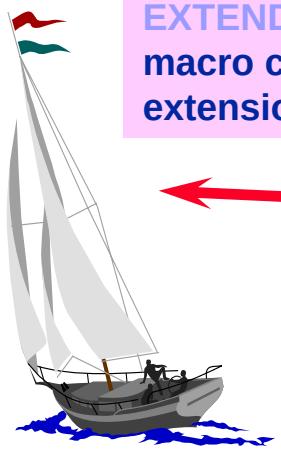
60 degree sectoring

Sectoring

- Sectoring improves S/I.
- In 7 cell reuse we have S/I equal to 10dB, when n=4 and co channels are 6.
- It is improved i,e 23.43dB when co channels are reduced to 2 as in fig.
- It helps reducing N for example to attain S/I of 21 dB we need 12 cell reuse (23.34dB), while sectorizing by 60 degrees we can attain this figure by 7 cell reuse,



Different Types of Cells

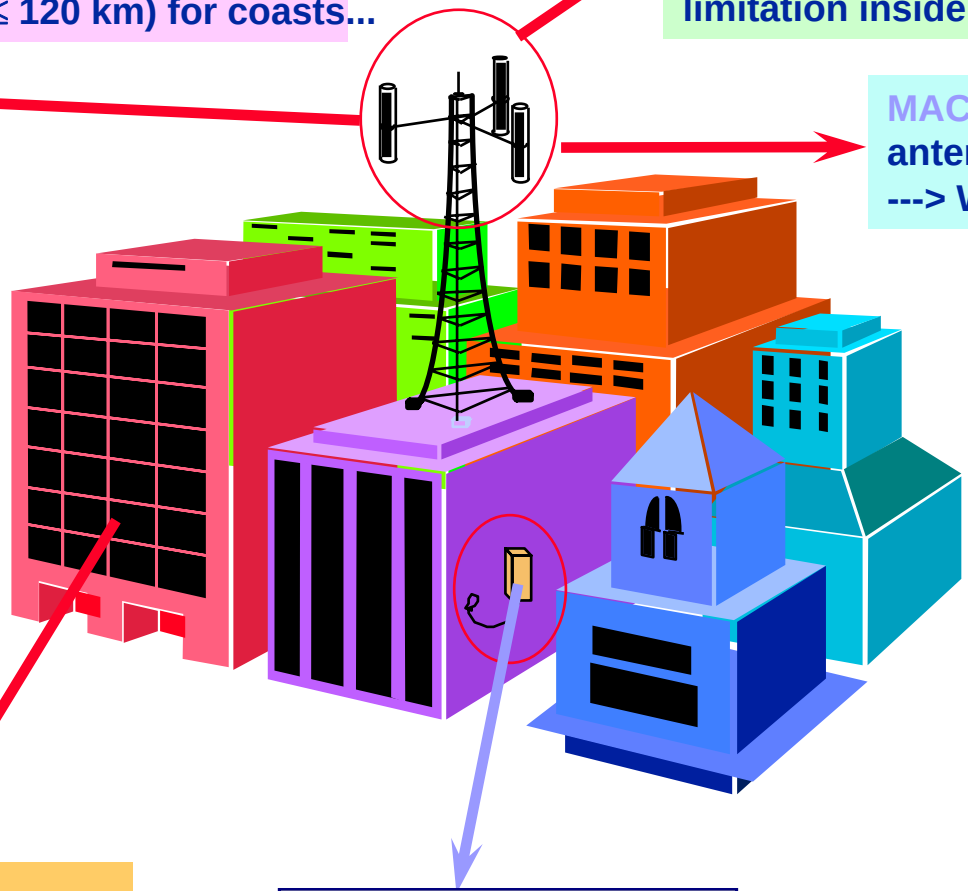


EXTENDED - CELL:
macro cell with system coverage extension (≤ 120 km) for coasts...

CONCENTRIC - CELL:
macro cell with system coverage limitation inside another macro

MACRO - CELL:
antenna radiating 'above' roofs
---> Wide Coverage (≤ 35 km)

- **High sensitivity to interference**
- **Requires "secured" Frequency reuse pattern**

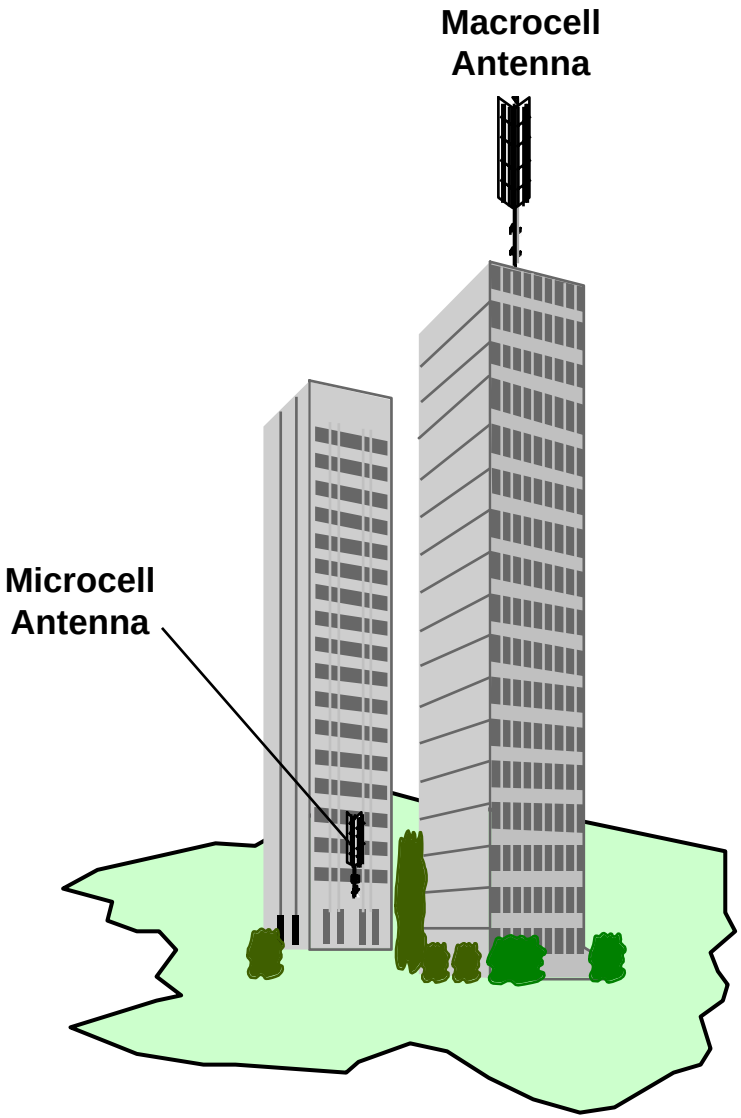


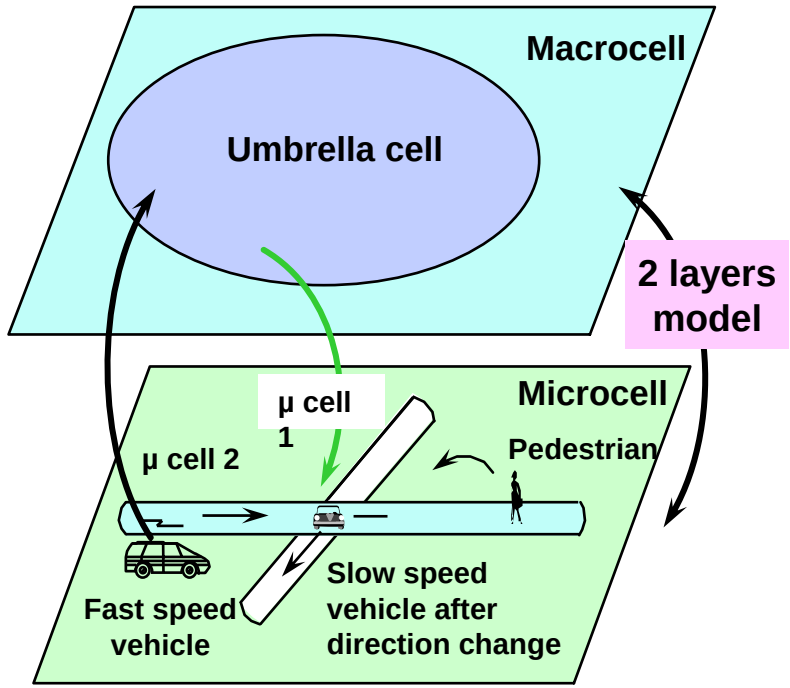
PICO-CELL:
Antenna inside building
---> Very small coverage

MICRO-CELL:
Antenna 'below' the roofs
---> small coverage

- **High isolation from interferences**
- **A few Frequencies intensively reused**

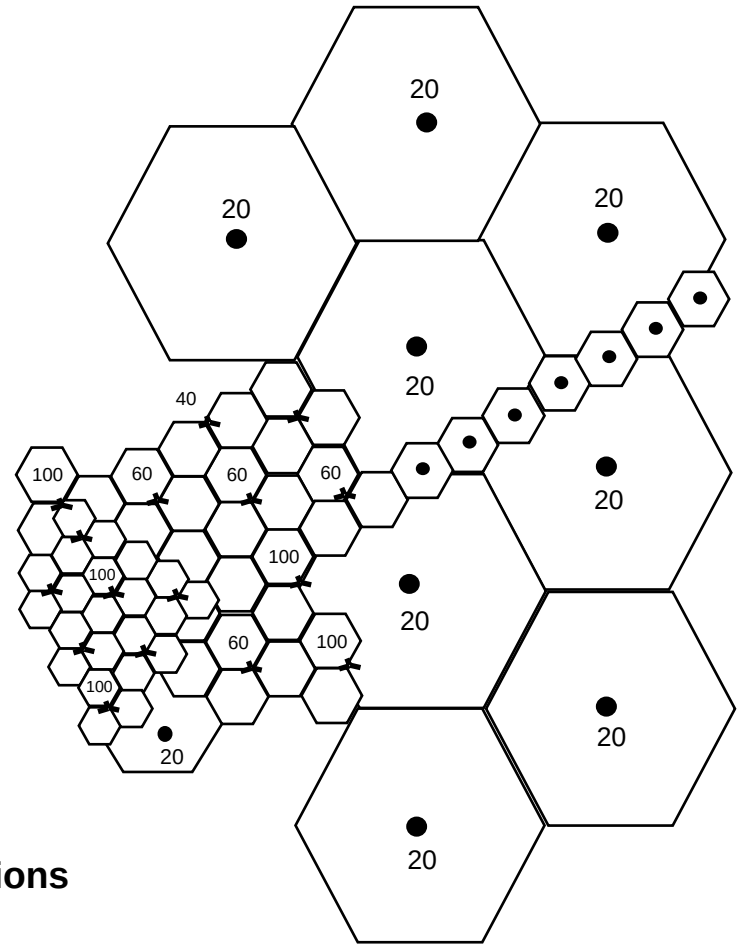
Cell Layering





Exercise

Considering this radio coverage, could you identify the topology of the different areas?



Figures indicates Base Stations Erlang capacity

Solution: Topology of Different Areas