CELLULAR CONCEPT

"Provide additional radio capacity with no additional increase in radio spectrum"

PRABHAKAR.R

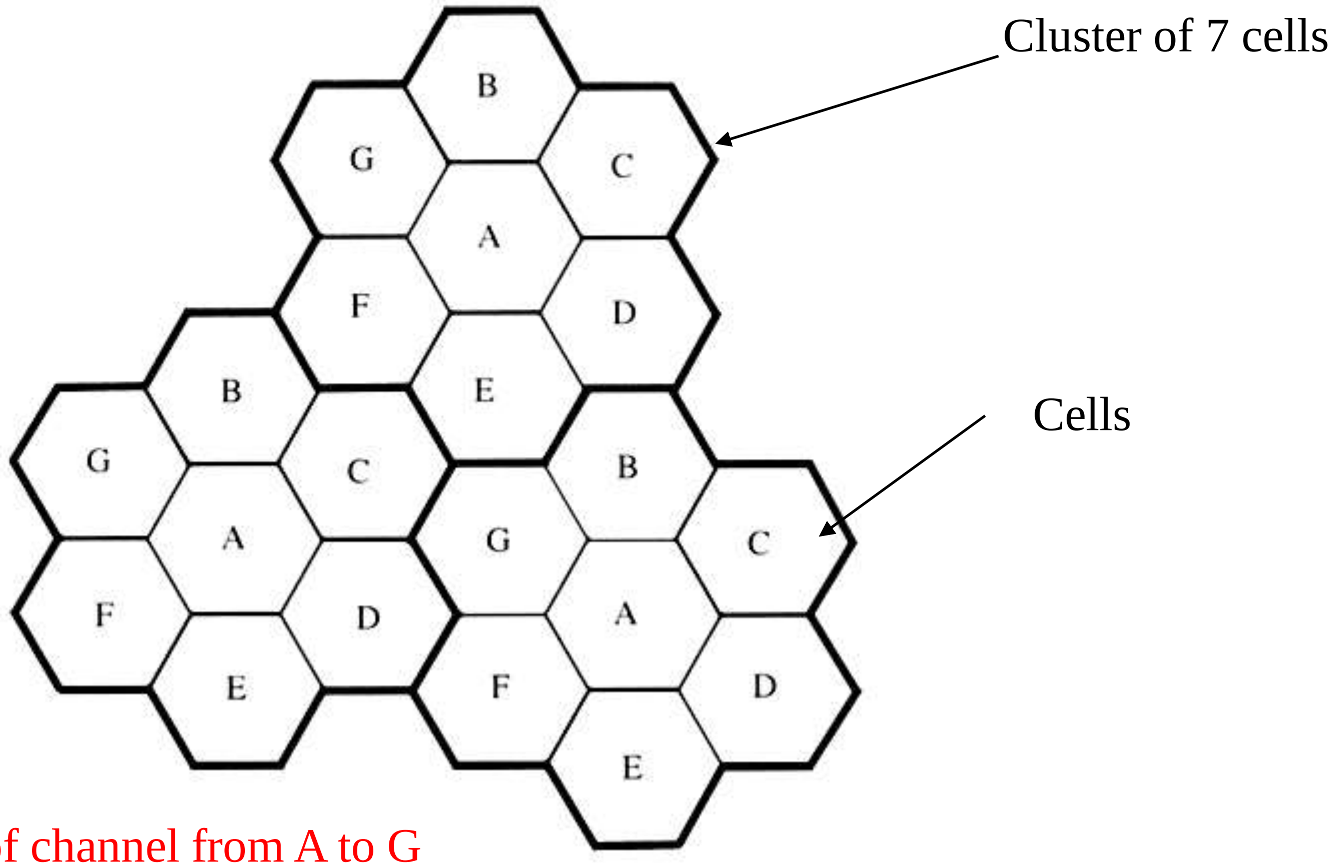
INTRODUCTION

- Early mobile radio system was to achieve a large coverage areas by using high powered transmitter with an antenna mounted on a tall tower
- In this case it is impossible to reuse those same frequencies throughout the system
- Since any attempts to achieve frequency reuse would result in interference

Cont..

- Cellular concept is a system level idea which calls for replacing a single , high power transmitter with low power small transmitters with each providing coverage to only a small portion of service area
- Each base station is allocated a portion of total no of channels available to entire system
- Nearby base station are assigned different groups of channels so that all the available channels are assigned to a relatively small no. of neighboring base stations
- Nearby BSs are assigned different groups of channel so that interference betwwen BS is minimized

THE CELLULAR CONCEPT



- seven groups of channel from A to G
- footprint of a cell - actual radio coverage
- omni-directional antenna v.s. directional antenna

FREQUENCY REUSE

- Each cellular base station is allocated a group of radio channels within a small geographic area called a *cell*.
- Neighboring cells are assigned different channel groups.
- By limiting the coverage area to within the boundary of the cell, the channel groups may be reused to cover different cells.
- Keep interference levels within tolerable limits.
- Frequency reuse or frequency planning

"The design process of selecting and allocating channel groups for all of the cellular base station within a system is FREQUENCY REUSE/PLANNING"

- Consider a cellular system which has a total of ***S*** duplex channels.
- Each cell is allocated a group of ***k*** channels, $k < S$.
- The ***S*** channels are divided among ***N*** cells.
- The total number of available radio channels

$$S = kN$$

- The ***N*** cells which use the complete set of channels is called ***cluster***.
- The cluster can be repeated ***M*** times within the system. The total number of channels, ***C***, is used as a measure of capacity

$$C = MkN = MS$$

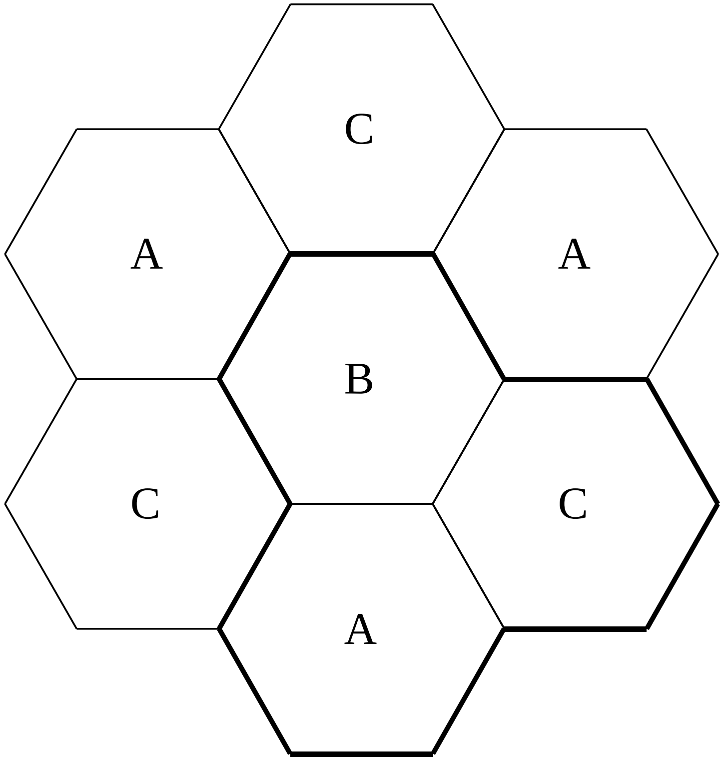
- The capacity is directly proportional to the number of replication ***M***.
- The cluster size, ***N***, is typically equal to 4, 7, or 12.
- Small *N* is desirable to maximize capacity.
- The frequency reuse factor is given by $1/N$

- Hexagonal geometry has
  - exactly six equidistance neighbors
  - the lines joining the centers of any cell and each of its neighbors are separated by multiples of 60 degrees.
- Only certain cluster sizes and cell layout are possible.
- The number of cells per cluster, N, can only have values which satisfy

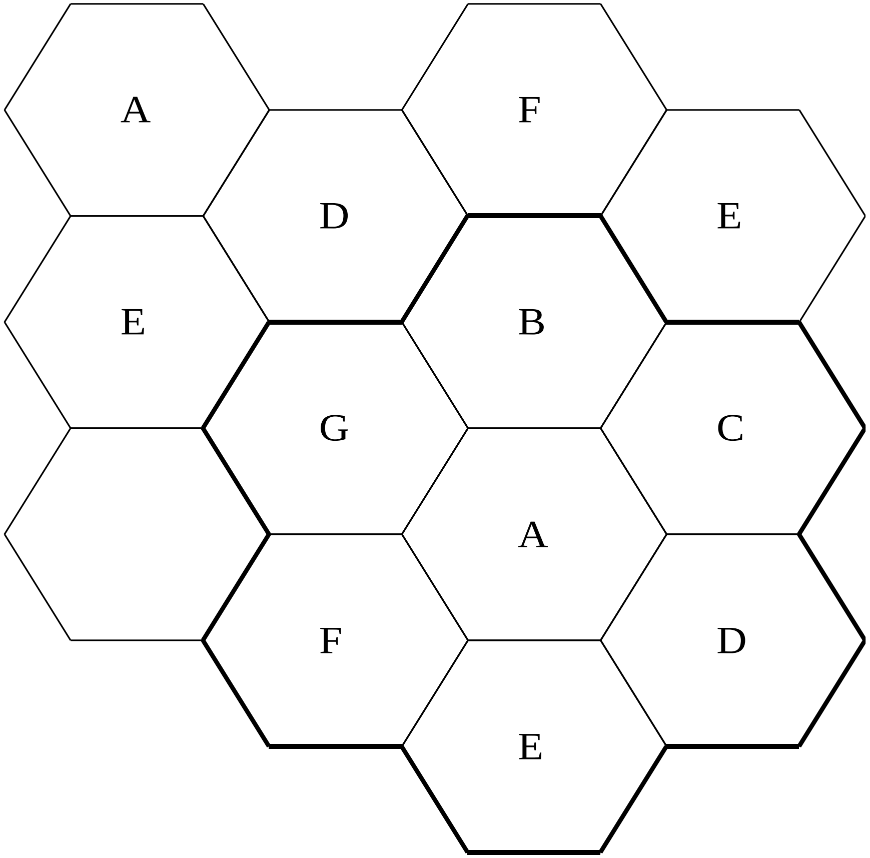
$$N = i^2 + ij + j^2$$

- Co-channel neighbors of a particular cell, ex, $i=3$ and $j=2$.

CLUSTER SIZES AND CELL LAYOUT



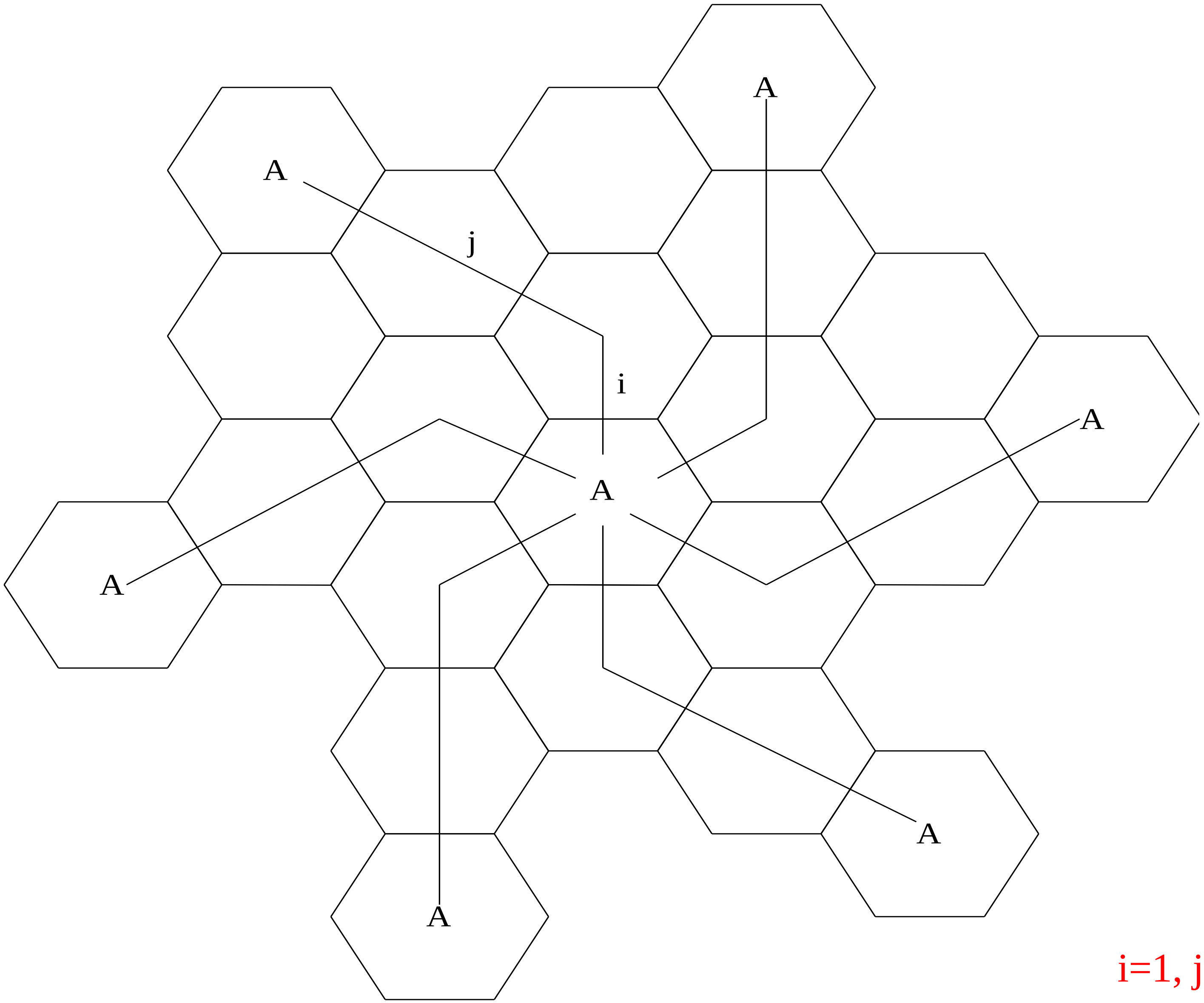
Eg for i=1,j=1



Eg for i=2,j=1

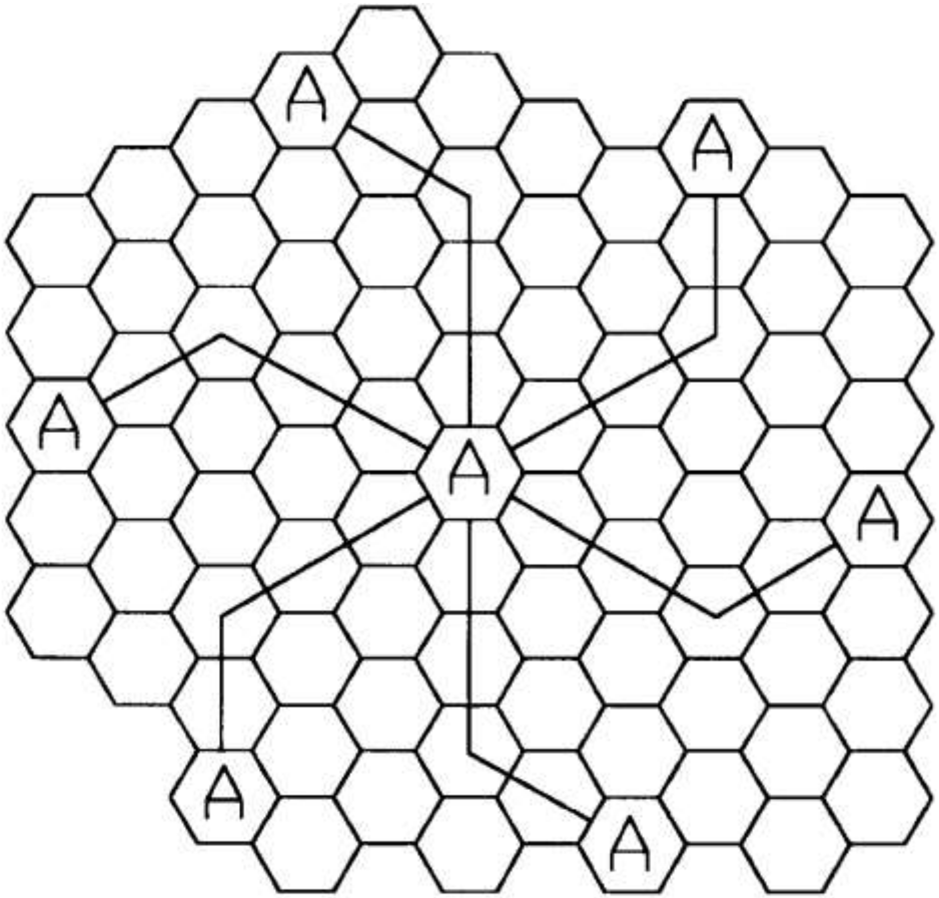
The factor N is called the cluster size and is given $N = i^2 + ij + j^2$

CLUSTER SIZES AND CELL LAYOUT



i=1, j=2 , N=1+2+4=7

CELL REUSE EXAMPLE (N=19)



To find the nearest co-channel neighbor of a particular cell

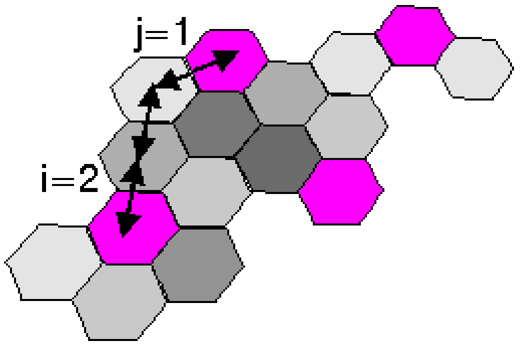
1. Move 'i' cells along any chain of hexagons
2. Then turn 60 degrees counter-clockwise and
3. Move 'j' cells.

Method of locating co-channel cells in a cellular system. In this example, N = 19 (i.e., I = 3, j = 2). (Adapted from [Oet83] © IEEE.)

ADVANTAGES

- Solves the problem of spectral congestion and user capacity.
- Offer very high capacity in a limited spectrum without major technological changes.
- Reuse of radio channel in different cells.
- Enable a fix number of channels to serve an arbitrarily large number of users by reusing the channel throughout the coverage region.

Frequency Reuse



Frequency Reuse is the core concept of cellular mobile radio

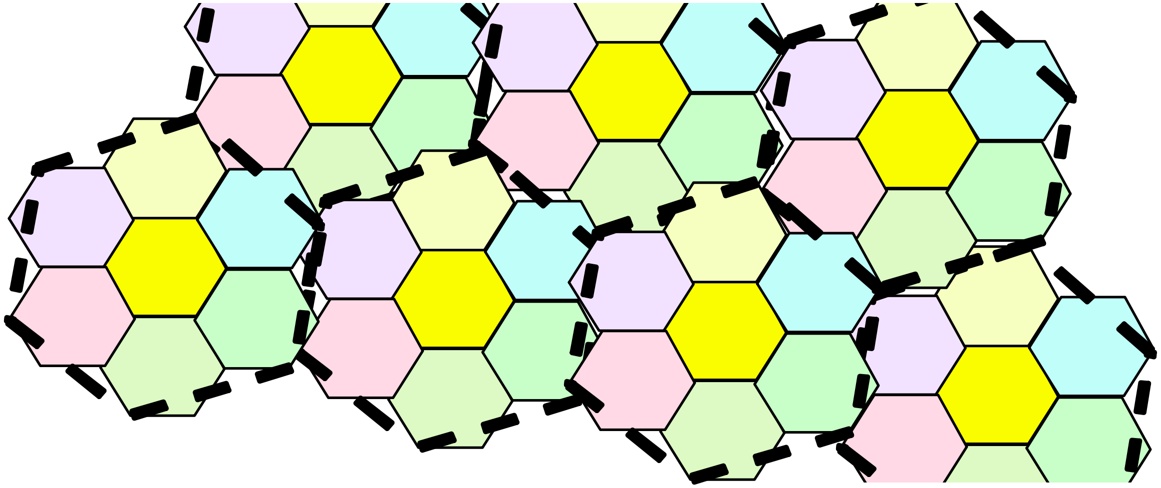
Users in different geographical areas (in different cells) may simultaneously use the same frequency channel

Frequency reuse drastically increases user capacity and spectrum efficiency

Frequency reuse causes mutual interference
(trade off between link quality and subscriber capacity)

Theoretical Network Planning

Honeycomb (hexagonal) cell structure

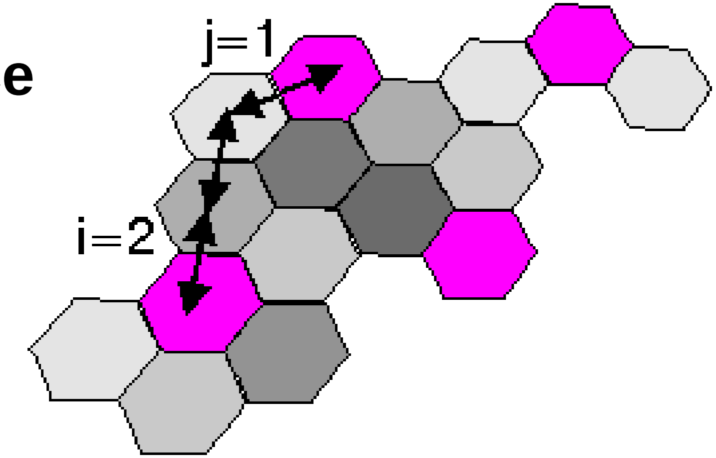


Cluster: set of different frequencies used in group of cells

Cluster is repeated by linear shift
i steps along one direction
j steps in the other direction

How many different frequencies does a cluster contain?

Reuse Distance



Distance between cell centers = $\sqrt{3}$ × Cell Radius

Reuse distance

distance between the centers of two co-channel cells

$$R_u = \sqrt{i^2 + j^2 + 2ij\cos\frac{\pi}{3}}\,\sqrt{3}\,R$$

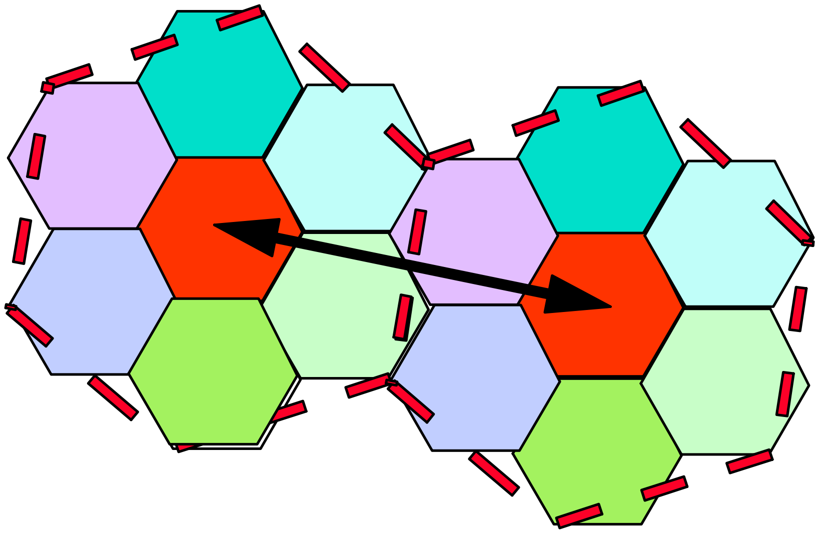
where

R is Cell Radius

R_u is Reuse Distance

and $\cos(\pi/3) = 1/2$

Cluster Radius



Radius of a cluster

$$R_c = \frac{R_u}{\sqrt{3}} = \sqrt{\frac{i^2 + j^2 + ij}{3}}\ R$$

Cluster Size

C: number of channels needed for (i,j) grid

is proportional to surface area of cluster

Surface area of one hexagonal cell is

$$S_R = \frac{3\sqrt{3}}{2} R^2$$

Surface area of a (hexagonal) cluster of C cells is

$$S_{R_u} = C S_R = \frac{3\sqrt{3}}{2} \left\{ \frac{R_u}{\sqrt{3}} \right\}^2$$

Combining these two expressions gives $R_u = R\sqrt{3C}$

Possible Cluster Sizes

We have seen

$$R_u = R\sqrt{3C}$$

and also

$$R_u = \sqrt{i^2 + j^2 + ij}\,\sqrt{3}\,R$$

Thus:

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

with integer i and j .

Cellular Telephony

Chose C to ensure acceptable link quality at cell boundary

Typical Cluster Sizes

Cluster size $C = i^2 + ij + j^2 = 1, 3, 4, 7, 9, \ldots$

$C = 1$	$i = 1, j = 0$	} Cluster size for CDMA net
$C = 3$	$i = 1, j = 1$	
$C = 4$	$i = 2, j = 0$	
$C = 7$	$i = 2, j = 1$	} Usual cluster sizes for TDMA
$C = 9$	$i = 3, j = 0$	} cellular telephone nets
$C = 12$	$i = 2, j = 2$	

.

Design Objectives for Cluster Size

- High spectrum efficiency

  many users per cell

  Small cluster size gives much bandwidth per cell

- High performance

  Little interference

  Large cluster sizes

Spectrum Efficiency

Cable

- bit/s per Hz

Wireless

- Erlang per km^2 per Hz
- Erlang per base station per Hz
- bit/s per Hz per km^2

NMT 450

Sweden

- B = 25 kHz
- C = 9

Total bandwidth needed for one cluster:

B C = 225 kHz

Netherlands

- B = 12.5 kHz
- C = 21 or more

Total bandwidth needed for one cluster:

B C = 262.5 kHz

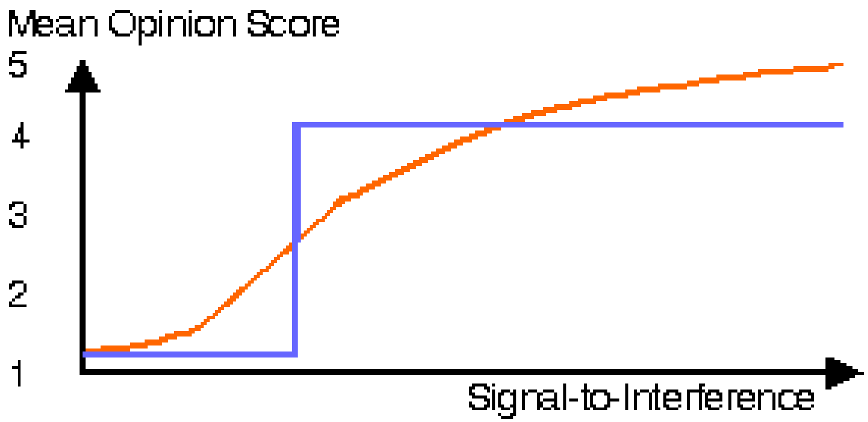
Cell Sizes Decrease with Growth of System

Macro-cellular	1 - 30 km
Micro-cellular	200 - 2000 m
Pico-cellular	4 - 200 meter

The effect of decreasing cell size

- Increased user capacity
- Increased number of handovers per call
- Increased complexity in locating the subscriber
- Lower power consumption in mobile terminal:
  - Longer talk time,
  - Safer operation
- Different propagation environment, shorter delay spreads
- Different cell layout,
  - lower path loss exponent, more interference
  - cells follow street pattern
  - more difficult to predict and plan
  - more flexible, self-organizing system needed (cf. DECT vs. GSM)

Advantages of Digital Transmission



Digital speech transmission reacts differently to changing performance of the radio link

Higher capacity:

1) speech coding
2) smaller protection ratios, denser reuse

Security

1) Privacy
2) Protected against unauthorized use

Additional services