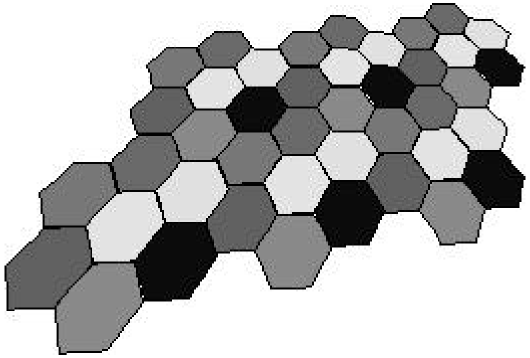
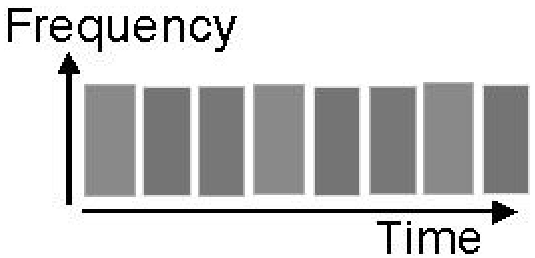
Radio Resource Management



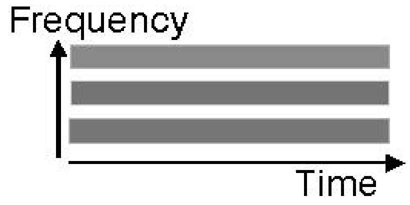
1. Frequency reuse among cells



2. Multiple Access within cells:
   How to share radio resources among multiple users

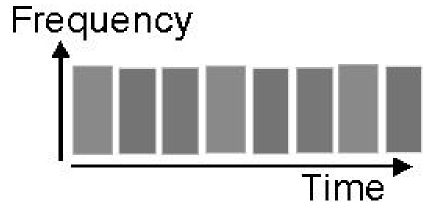
Frequency Division Multple Access: FDMA

Every user has its own frequency channel



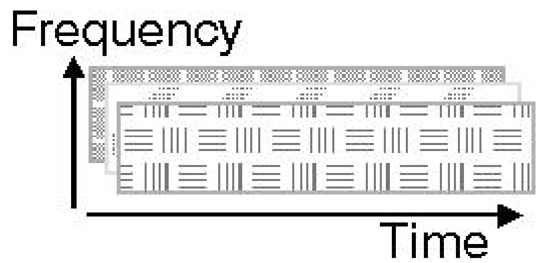
Time Division Multiple Access: TDMA

Users share the same bandwidth but transmit one after the other

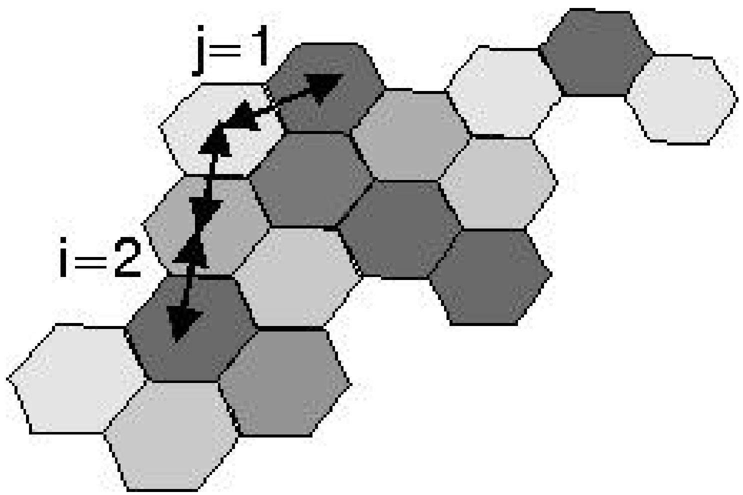


Code Division Multiple Access: CDMA

User signals overlap in frequency and time.
Orthogonality of waveforms is used to separate user signals

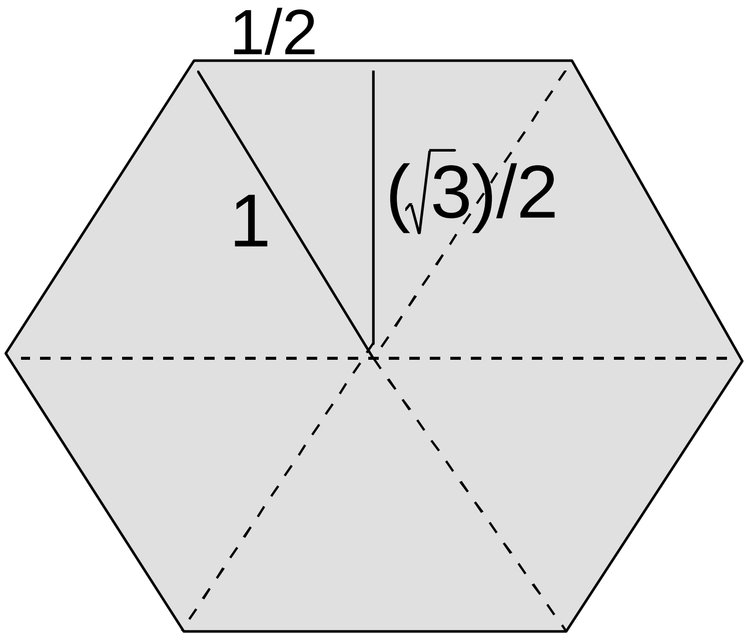


Frequency Reuse



- Frequency Reuse is the core concept of cellular mobile radio
- Users in different geographical areas (in different cells) may simultaneously use the same frequency
- Frequency reuse drastically increases user capacity and spectrum efficiency
- Frequence reuse causes mutual interference (trade off link quality versus subscriber capacity)

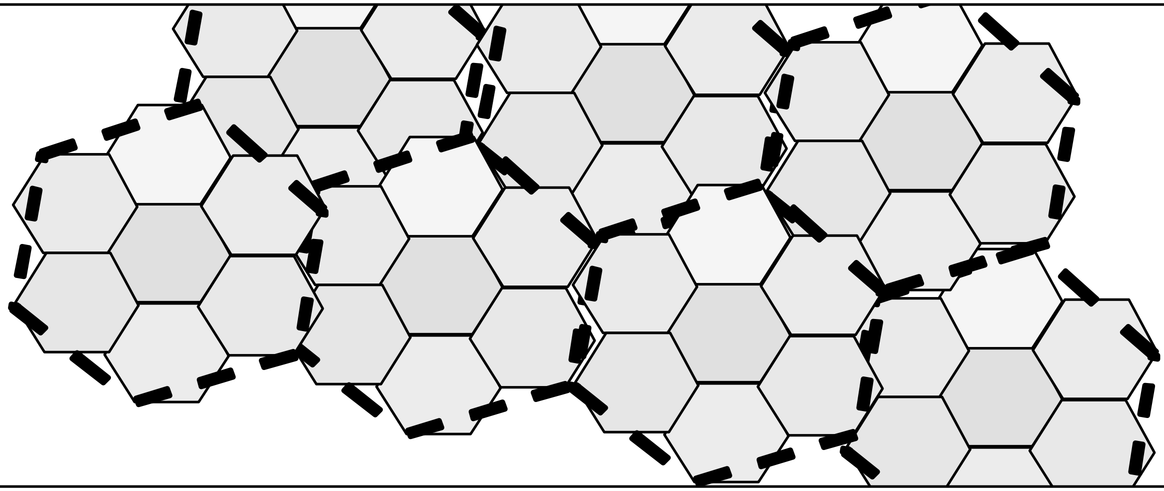
Geometry of a Hexagon



Surface area is 6 R^2 times $(\sqrt{3})/4$

Theoretical Network Planning

Honeycomb (hexagonal) cell structure



Cluster: set of different frequencies used in group of cells

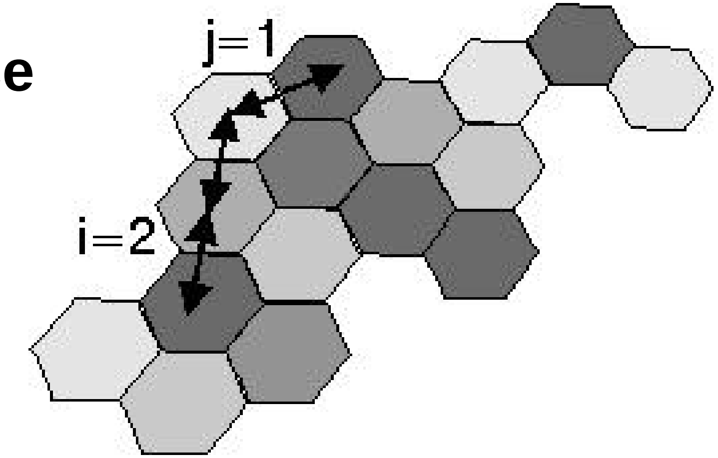
Cluster is repeated by linear shift

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 $= \sqrt{3} \times$ Cell Radius

Reuse distance

distance between the centers of two co-channel cells

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

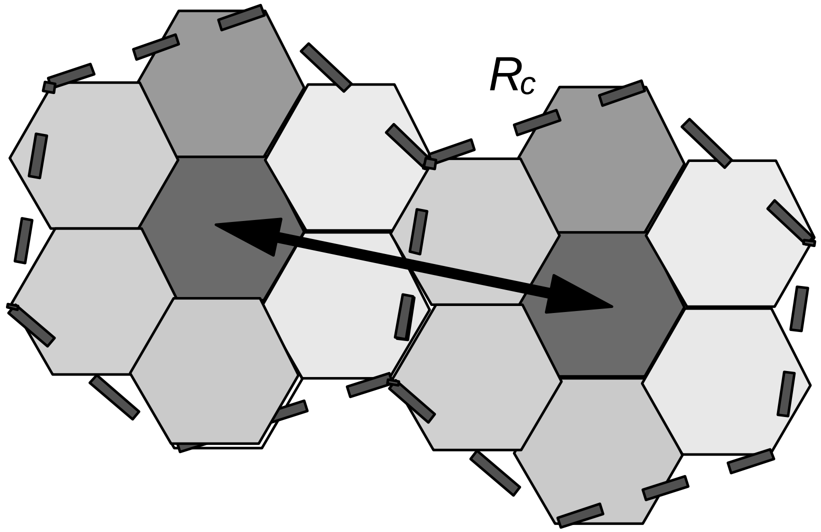
where

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

C: 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

Choose C to ensure acceptable link quality at cell boundary

Typical Cluster Sizes

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

$C = 1$	$i = 1, j = 0$	} 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 analogue
$C = 9$	$i = 3, j = 0$	} 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

Adaptation to growth of system

Decrease Cell Sizes

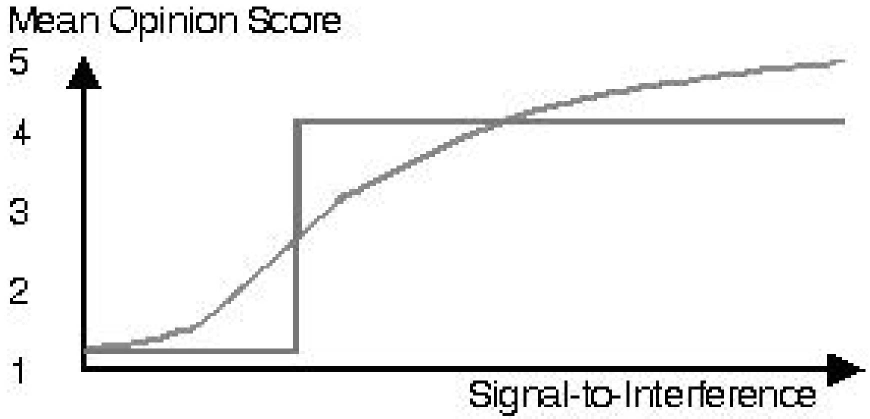
- Macro-cellular 1 - 30 km
- Micro-cellular 200 - 2000 m
- Pico-cellular 4 - 200 meter

Cell Sectorization

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

(NB: same reuse of IS-54 and analog AMPS in US)

Security

1) Privacy
2) Protected against unauthorized use

Additional services