Dynamic Channel Allocation Schemes for Overlay Cellular Architectures

by Hazar Akı

EEL6936 - Adv. Top. Wire. Comm. System

OUTLINE

I. *Conventional Cellular Systems*

- Concept of reusing the resource
- Channel allocation methods

II. *Reuse Partitioning*

- Fractional frequency reuse
- Cell radius ratio (CRR)

III. *Adaptive Clustering*

- Maximal dynamic reuse partitioning (MDRP)
- Optimal dynamic reuse partitioning (ODRP)

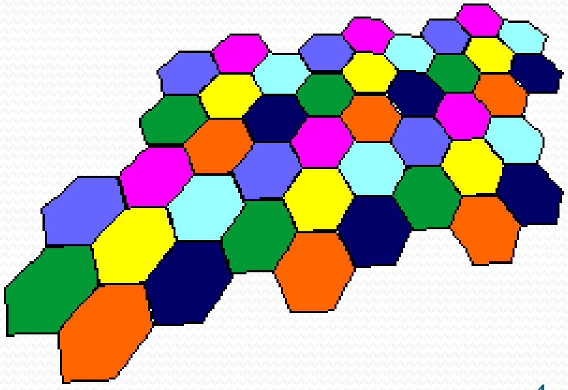
IV. *Grade of Service Perspective*

I. Conventional Cellular Systems

I. Conventional Cellular Systems

The Cellular Concept

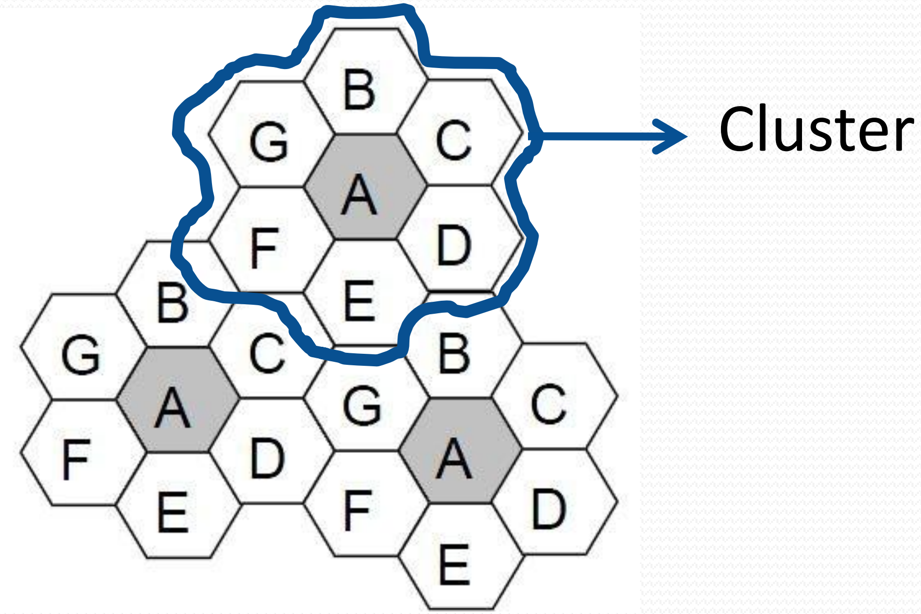
- The main design objective was to achieve a large coverage area by using single transmitter.
- Lack of simultaneous call support.
- High powered transmitters replaced with many low powered transmitters.
- Large coverage areas became small cells.



I. Conventional Cellular Systems

Reusing the Resource

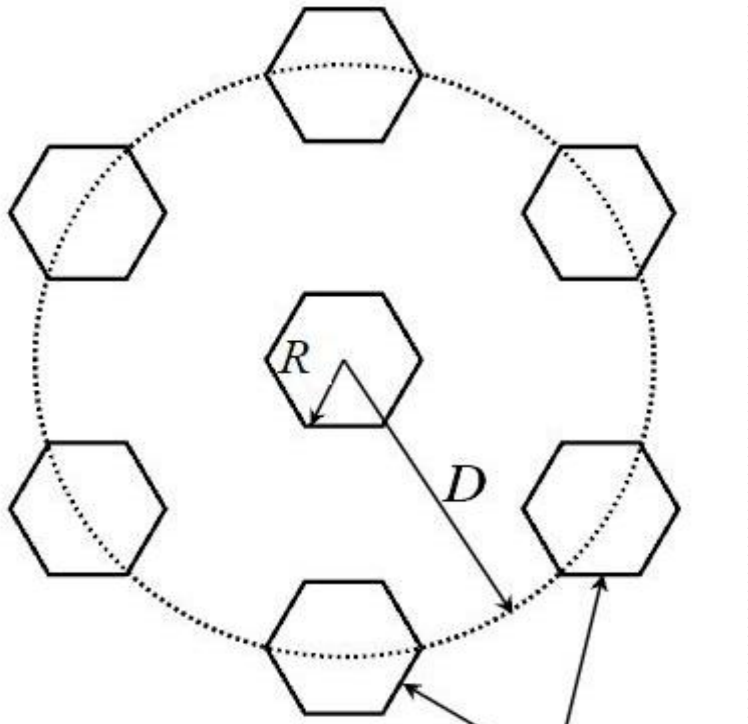
- A group of channels are allocated to each cell.
- Neighboring cells with different set of channels
- Frequency reuse



I. Conventional Cellular Systems

Frequency Reuse

- Symmetric patterns based on hexagonal shape have all co-channel cells located on circles.



R: Radius of the cell
N: Cluster size
D: Reuse distance

$$\frac{D}{R} = \sqrt{3N}$$

- For symmetric reuse patterns; cluster size can be calculated as follows:

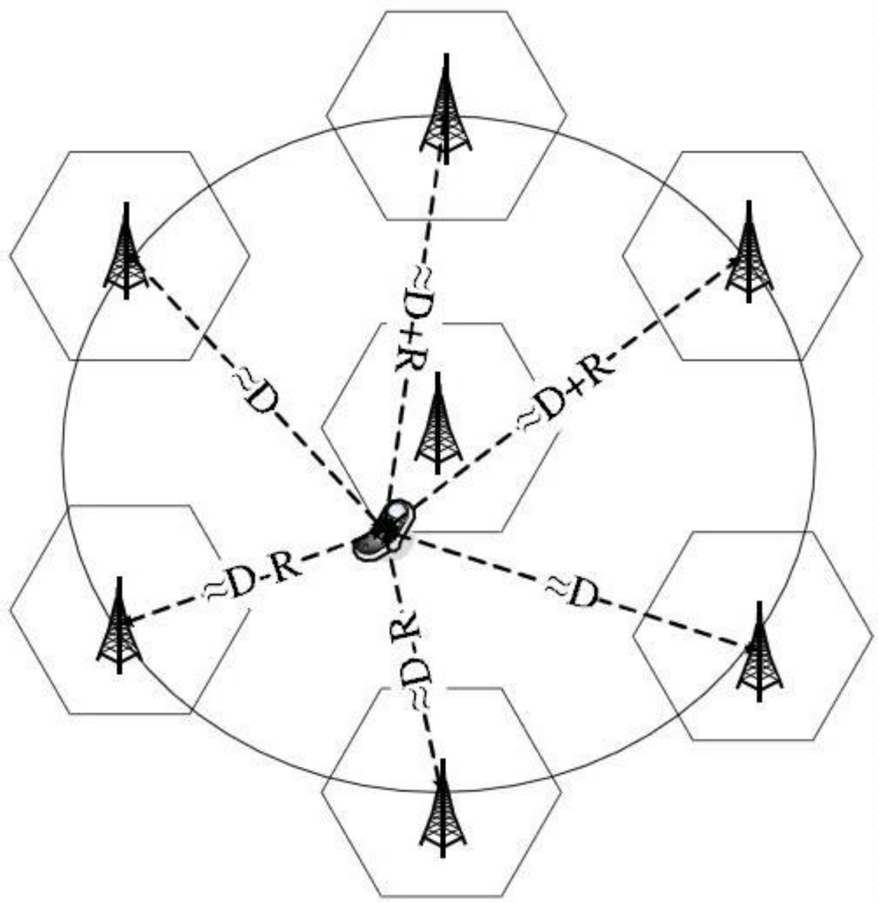
$$N = i^2 + j^2 + ij$$

(N=3,4,7… etc., where both i and j are integers.)

I. Conventional Cellular Systems

Co-channel Interference

- Worst-case scenario: user at the cell edge



$$P = P_T A / (R_C)^n$$

$$I = P_T A \left[\frac{2}{(D - R_C)^n} + \frac{2}{D^n} + \frac{2}{(D + R_C)^n} \right]$$

$$\left(\frac{P}{I}\right) = \frac{1/2}{\left(\frac{R_C}{D - R_C}\right)^n + \left(\frac{R_C}{D}\right)^n + \left(\frac{R_C}{D + R_C}\right)^n}$$

$$= \frac{0.5}{\left(\frac{1}{(D/R_C) - 1}\right)^n + \left(\frac{1}{D/R_C}\right)^n + \left(\frac{1}{(D/R_C) + 1}\right)^n}$$

I. Conventional Cellular Systems

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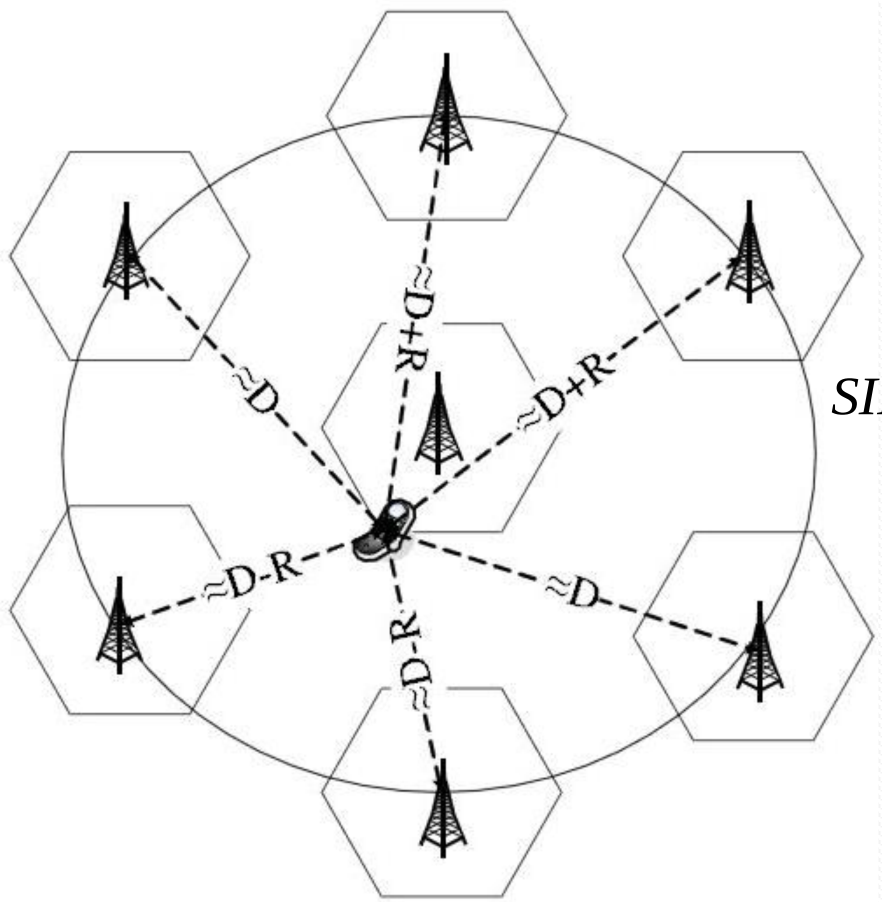

$$\frac{D}{R} = \sqrt{3N}$$

$$SIR_{\min} \leq \frac{0.5}{\left(\frac{1}{\sqrt{3N}-1}\right)^{n} + \left(\frac{1}{\sqrt{3N}+1}\right)^{n} + \left(\frac{1}{\sqrt{3N}}\right)^{n}}$$

II. Reuse Partitioning

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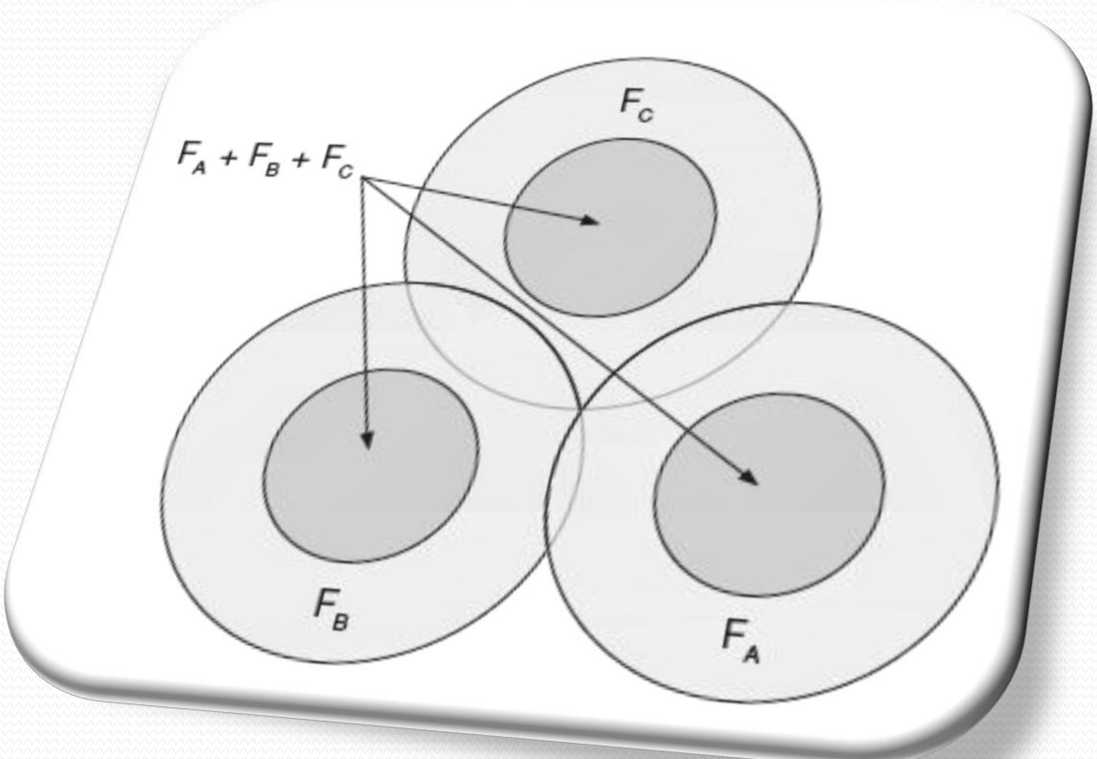
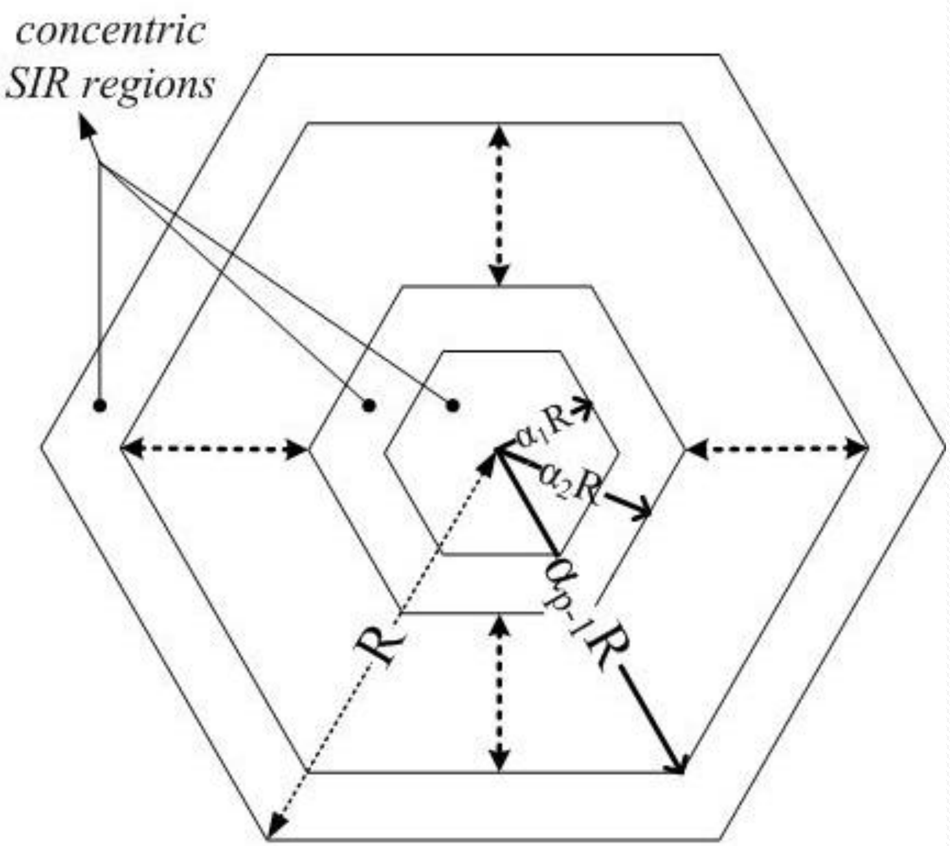
- Each cell is divided into several concentric SIR regions and each region has a different cluster size.
- *Fractional Frequency Reuse:* Hot topic for next generation systems such as Mobile WiMAX and LTE-Advanced.



II. Reuse Partitioning

- User close to its base station is assigned a channel with a smaller cluster size, whereas a user far from its base station with low signal quality is assigned a channel with a larger cluster size.



p^{th} order overlaid cellular system

- ***Cell reuse ratio (CRR):*** α_m

- For example;
innermost concentric SIR region's CRR: $\alpha_1 = R_1/R$

- If the user is at the;
  base station: $\alpha_0 = 0$
  cell edge: $\alpha_p = 1$

I. Conventional Cellular Systems

Co-channel Interference

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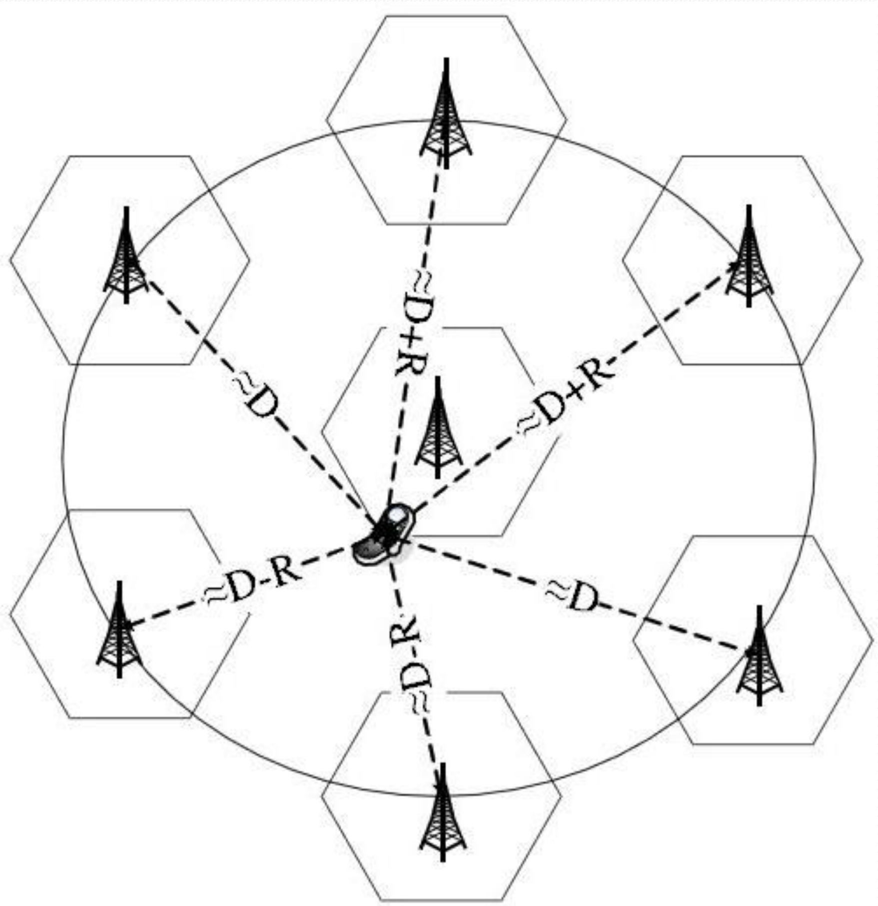

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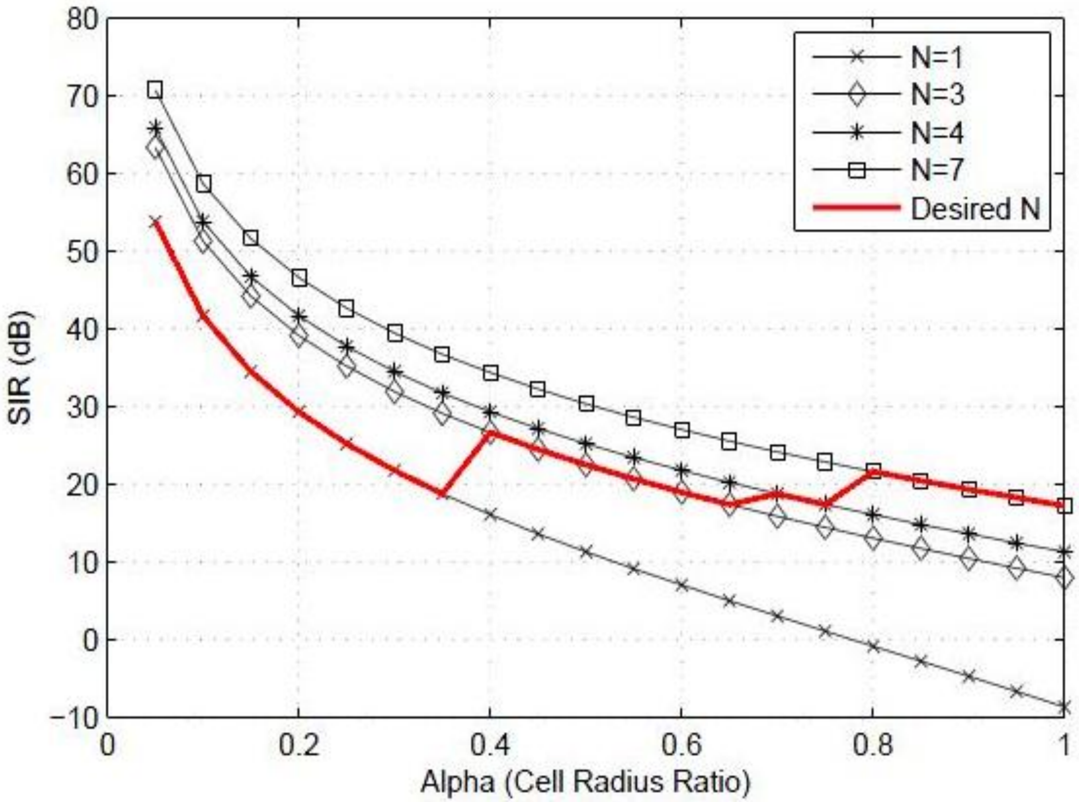
$$= \frac{0.5}{\left(\frac{1}{(D/R_C) - 1}\right)^n + \left(\frac{1}{D/R_C}\right)^n + \left(\frac{1}{(D/R_C) + 1}\right)^n}$$

II. Reuse Partitioning

- Revisiting the conventional system's SIR equation with CRR:

$$SIR(\alpha_m) \le \frac{0.5}{\left(\frac{1}{\sqrt{3N}/\alpha_m - 1}\right)^n + \left(\frac{1}{\sqrt{3N}/\alpha_m + 1}\right)^n + \left(\frac{1}{\sqrt{3N}/\alpha_m}\right)^n}$$



- Users close to the BS are not necessarily needed for fixed cluster size.
- Cluster size can be adaptively changed.

III. Adaptive Clustering Schemes

III. Adaptive Clustering

Maximal Dynamic Reuse Partitioning (MDRP)

- Aims to maximize the capacity by allocating the spare channels to the innermost concentric region

$$C_{Conv} = \frac{C_T}{\tilde{N}}$$

Parameter	Description
C_T	Total number of channels in the system
$\tilde{N}$	Conventional system's fixed cluster size
C_{Conv}	Conventional system's total number of channels in each cell
α	Cell radius ratio
$\tilde{C}_n$	Compulsory number of channels in n^{th} concentric SIR region
N_n	Adaptive cluster size of n^{th} concentric SIR region
C_n	Number of channels in n^{th} concentric SIR region for adaptive clustering scheme
C_{MDRP}	Total effective number of channels for MDRP scheme

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$$C_n = \tilde{C}_n \times N_n \qquad n = 2 \ldots p$$

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$$C_1 = C_T - \sum_{n=2}^{p} C_n$$

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$$C_{MDRP} = C_1 + \sum_{n=2}^{p} \tilde{C}_n$$

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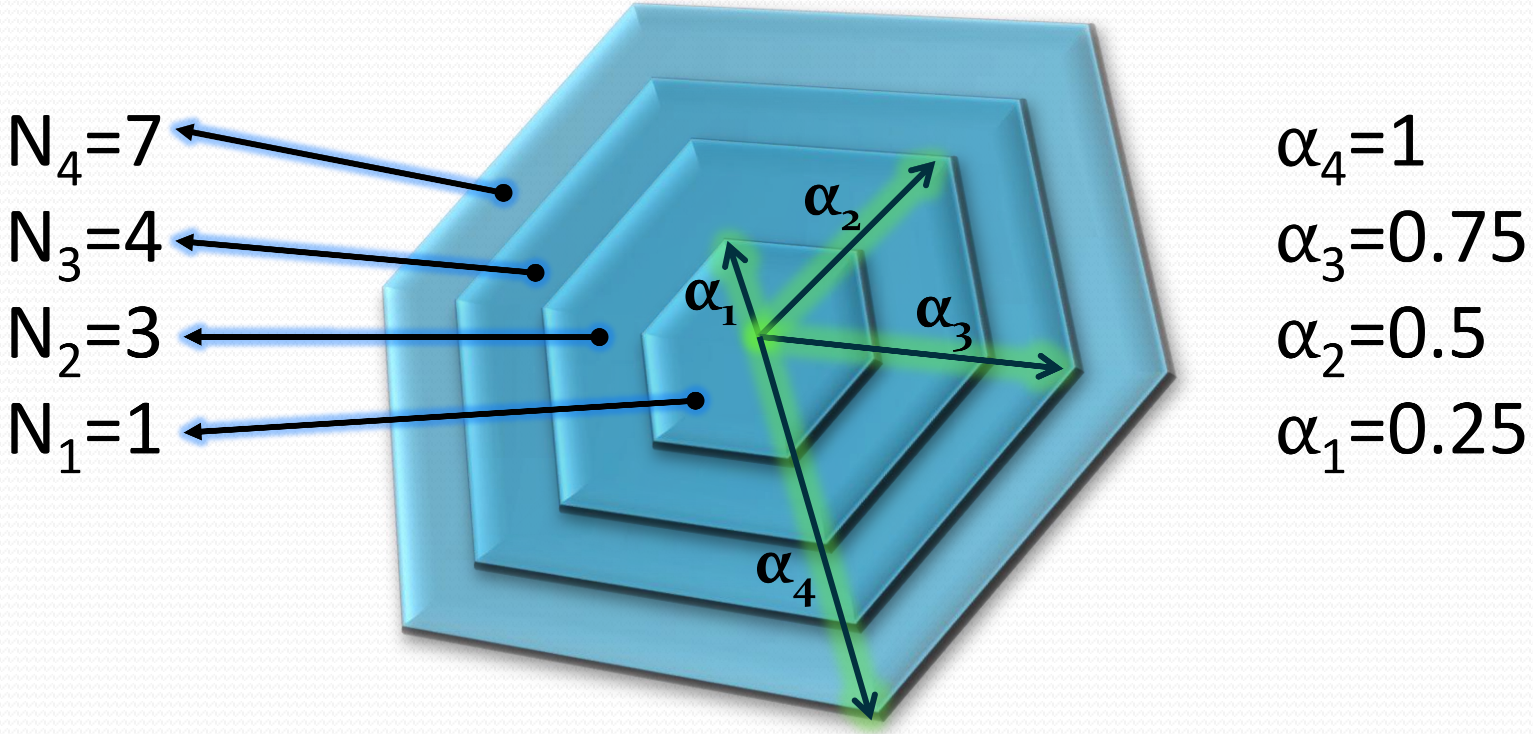
III. Adaptive Clustering

Maximal Dynamic Reuse Partitioning (MDRP)

C_T=84 (total number of channel)

N=7 (conventional cluster size)

C_{conv}=84/7=12 (number of channel in each cell)

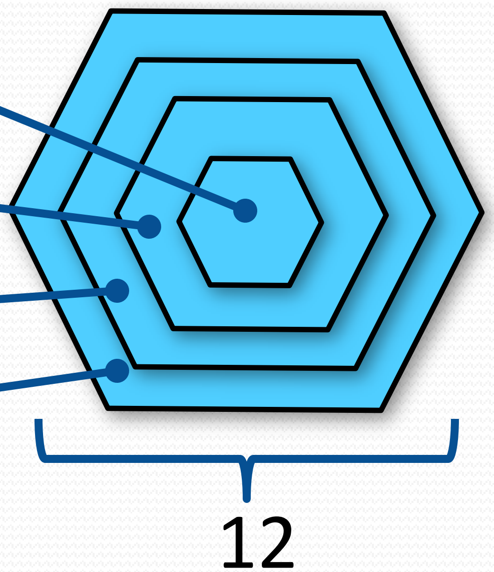


III. Adaptive Clustering

Maximal Dynamic Reuse Partitioning (MDRP)

$\widetilde{C}_n$: compulsory number of channels in each concentric SIR region

N_n	$\widetilde{C}_n$	$\widetilde{C}_n = \left\lfloor C_{Conv}\left(\alpha_n^{\ 2} - \alpha_{n-1}^{\ 2}\right)\right\rfloor$
1	$\widetilde{C}_1$	12 x $(0.25)^2$ = 0.75
3	$\widetilde{C}_2$	12 x $(0.5)^2$-$(0.25)^2$ = 2.25
4	$\widetilde{C}_3$	12 x $(0.75)^2$-$(0.5)^2$ = 3.75
7	$\widetilde{C}_4$	12 x $(1)^2$-$(0.75)^2$ = 5.25
		= 12



III. Adaptive Clustering

Maximal Dynamic Reuse Partitioning (MDRP)

C_{n} : number of channels in n[th] concentric SIR region for adaptive clustering

N_n	C_n	$C_n = \tilde{C}_n \times N_n$
1	C_1	
3	C_2	2.25 x 3 = 6.75
4	C_3	3.75 x 4 = 15
7	C_4	5.75 x 7 = 36.75

III. Adaptive Clustering

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$$C_1 = C_T - \sum_{n=2}^{p} C_n$$

III. Adaptive Clustering

Maximal Dynamic Reuse Partitioning (MDRP)

C_{n} : number of channels in n^{th} concentric SIR region for adaptive clustering

N_n	C_n	$C_n = \tilde{C}_n \times N_n$
1	C_1	84 – 58.5 = 25.5
3	C_2	2.25 x 3 = 6.75
4	C_3	3.75 x 4 = 15
7	C_4	5.75 x 7 = 36.75
		= 84

$$C_1 = C_T - \sum_{n=2}^{p} C_n$$

III. Adaptive Clustering

Maximal Dynamic Reuse Partitioning (MDRP)

- Effective number of channels in each cell:

Conv.

$$C_{Conv} = \frac{C_T}{\tilde{N}}$$

= 84/7

= 12

MDRP

$$C_{MDRP} = C_1 + \sum_{n=2}^{p} \tilde{C}_n$$

= 25.5 + 2.25 + 3.75 + 5.25

= 36.75

III. Adaptive Clustering

Optimal Dynamic Reuse Partitioning (ODRP)

$$C_{Conv} = \frac{C_T}{\tilde{N}}$$

$$\tilde{C}_n = \left\lfloor C_{Conv}\left(\alpha_n^{\ 2} - \alpha_{n-1}^{\ \ 2}\right)\right\rfloor$$

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$C_n^{(2)}$	Allocated number of channel according to the area of regions
C_R	Remaining number of channels
C_{ODRP}	Total effective number of channels for ODRP scheme

III. Adaptive Clustering

Optimal Dynamic Reuse Partitioning (ODRP)

$$C_{Conv} = \frac{C_T}{\tilde{N}}$$

$$\tilde{C}_n = \left\lfloor C_{Conv}\left(\alpha_n{}^2 - \alpha_{n-1}{}^2\right)\right\rfloor$$

$$C_n^{(1)} = \tilde{C}_n \times N_n \quad n = 1 \ldots p$$

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Optimal Dynamic Reuse Partitioning (ODRP)

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$$C_R = C_T - \sum_{n=1}^{p} C_n^{(1)}$$

$$C_n^{(2)} = \left\lfloor C_R\left(\alpha_n^{\ 2} - \alpha_{n-1}^{\ 2}\right)\right\rfloor$$

$$C_{ODRP} = \sum_{n=1}^{p} (\tilde{C}_n + \frac{C_n^{(2)}}{N_n})$$

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III. Adaptive Clustering

Effective number of channels in each cell:

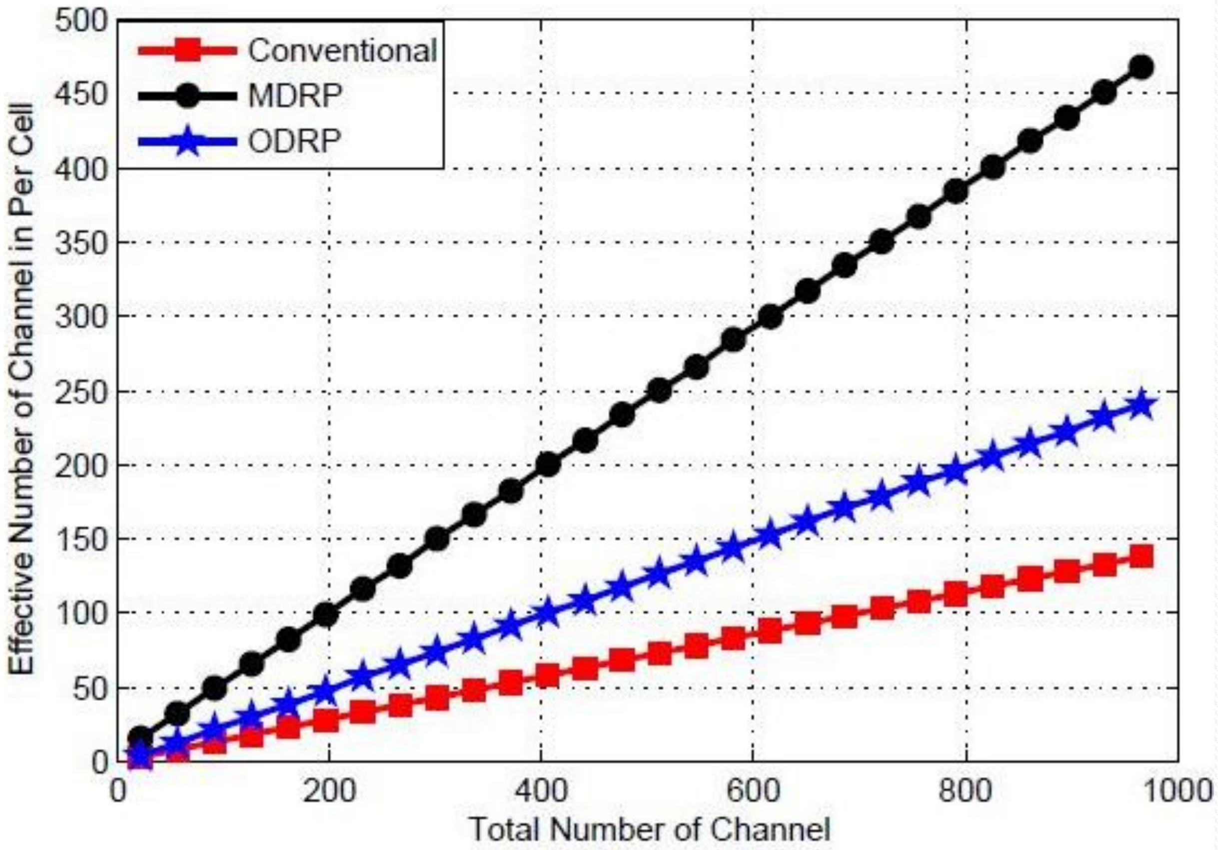
$C_T=84$
$N=7$
$C_{conv}=12$

$\alpha_4=1$ $N_4=7$
$\alpha_3=0.75$ $N_3=4$
$\alpha_2=0.5$ $N_2=3$
$\alpha_1=0.25$ $N_1=1$

Conventional	Optimal	Maximal
$\frac{C_T}{\tilde{N}}$	$\sum_{n=1}^{p}(\tilde{C}_n + \frac{C_n^{(2)}}{N_n})$	$C_1 + \sum_{n=2}^{p} \tilde{C}_n$
12	18.58	36.75

III. Adaptive Clustering

Effective VS Total number of channels



- Maximum capacity: MDRP
- ODRP is still better than Conv.
- Cotangent of the angle: Cluster size

IV. Grade of Service Perspective

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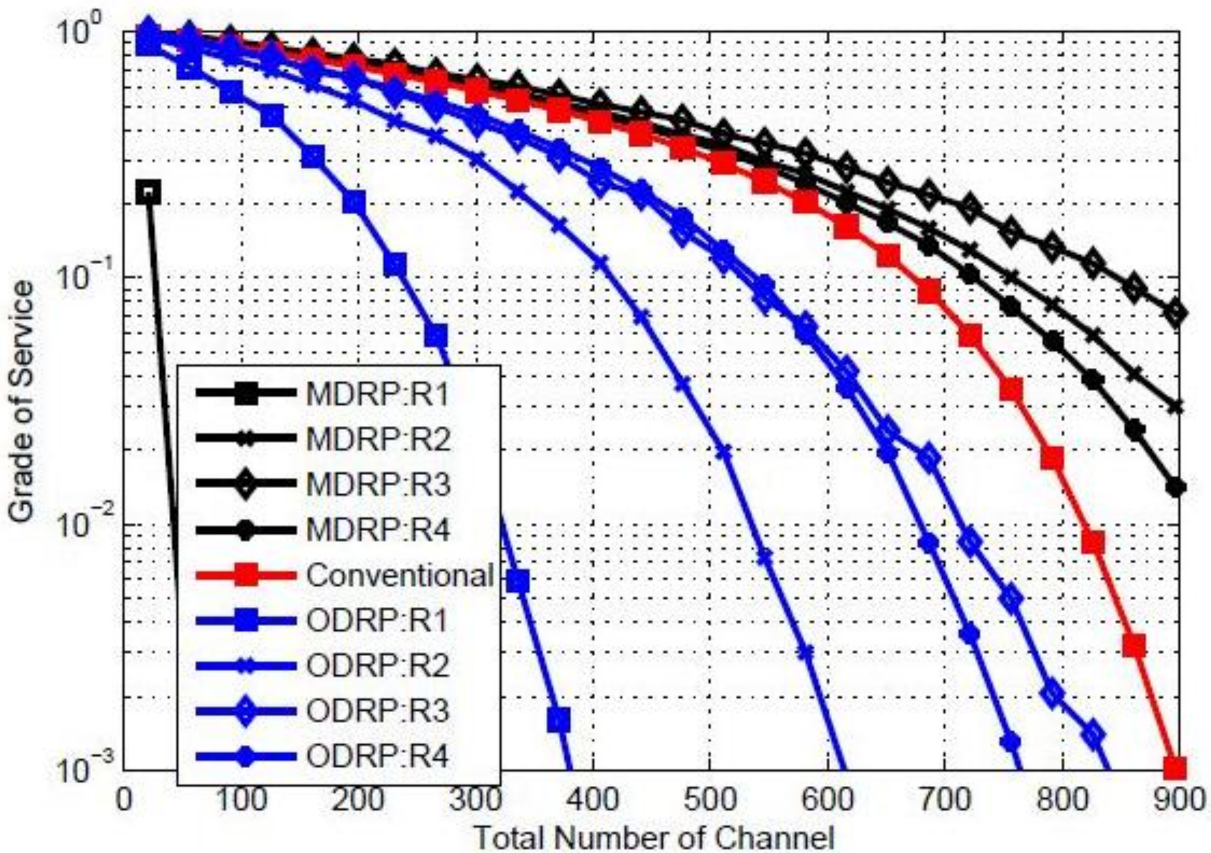
GoS

- The Grade of Service (GOS) is the probability of having a call blocked during busy hour on a regular day.
- In a wireless system, the design target is typically 2% (0.02), or less.
- Erlang B Blocking probability:

$$P_i = \frac{\dfrac{A_i^{C_i}}{C_i!}}{\displaystyle\sum_{k=0}^{C_i} \frac{A_i^k}{k!}}$$

where *i=Conv, MDRP, ODRP*
A_i: *Offered traffic*
C_i: *Total number of channels*

IV. Grade of Service Perspective



- For better GoS, curves should be fallen under the conventional scheme.
- Only region 1 in MDRP scheme offers improved GoS.
- ODRP scheme's four regions provide better GoS.

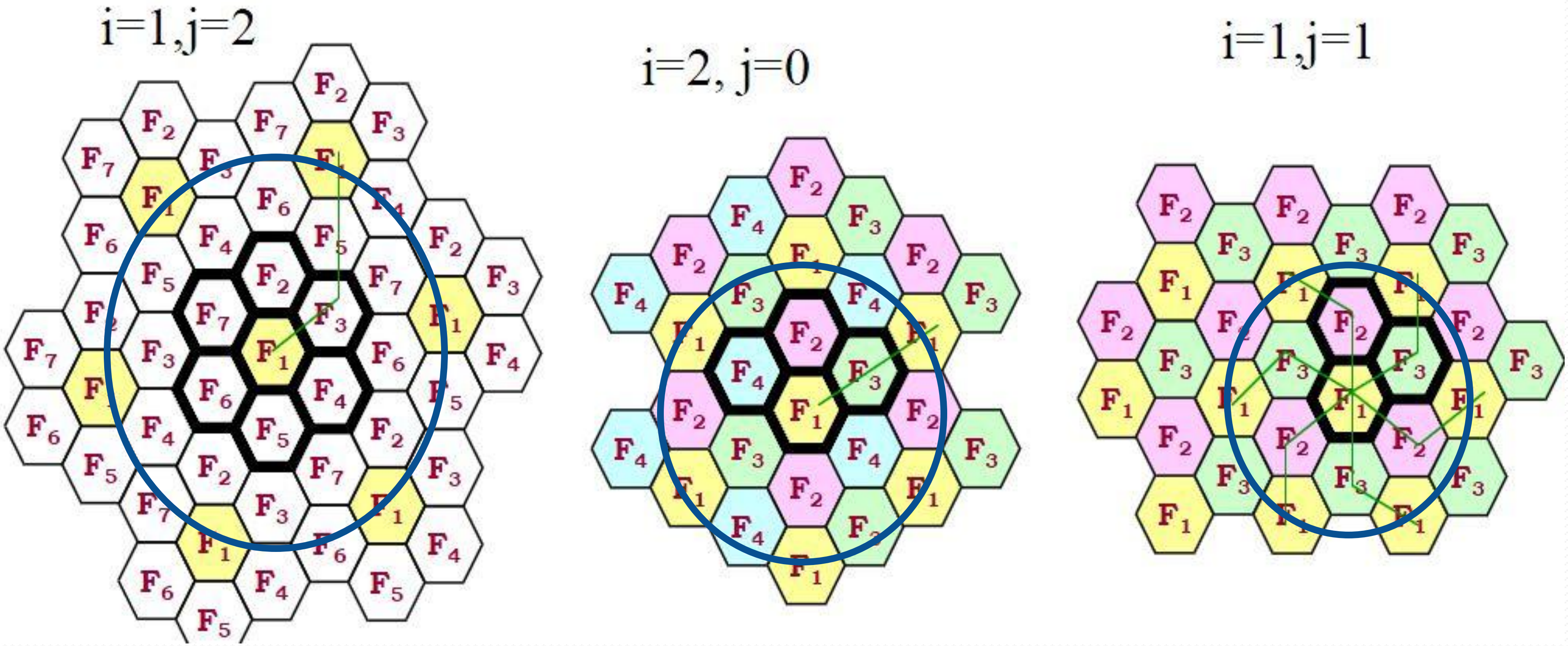
V. Future Work

- Applying the methods to two-tiered networks (femtocell/macrocell)
- Channel numbers can be interpreted as bandwidth or data rates.
- Split and shared spectrum issues.
- Fractional frequency reuse for 4G systems.

THANK YOU!

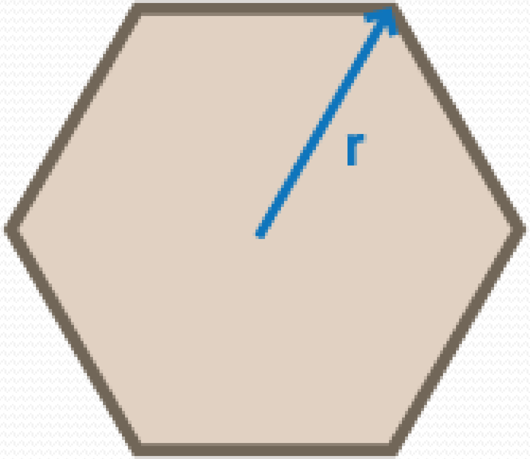
Back-up Slides

- No matter what N is selected; in the first tier, there will always be 6 co-channel cells located on a circle.



N=7 N=4 N=3

- Area of hexagon:



Area = $(3\sqrt{3}/2)r^2$

I. Conventional Cellular Systems

Channel Allocation Methods

- *Fixed Channel Allocation*
  - No adaption for different conditions
- *Dynamic Channel Allocation*
  - Heavy traffic intensity causes inefficiency
- *Hybrid Channel Allocation*
  - High computational complexity