Thesis Presentation

Block Diagonalization Scheme for Canceling Inter-Cell and Inter-Cluster Interference in Clustered Small Cells

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Related Publications

International

- **Joint Coordination Scheme in Clustered Small Cells with Channel Estimation Error** (Journal – under correction, will be submitted to JSAC)
- **Effect Channel Estimation Error in Coordinated Small Cells**. (International journal, Mechatronics Engineering, Computing and Information Technology AAM 2014).
- **Multi Small-Cells Based Block Diagonalization with Imperfect Channel Estimation.** (WIITC 2014)
- **Cooperative Water Filling in Small Cell Network.** (IEEE ICT Convergence 2013)

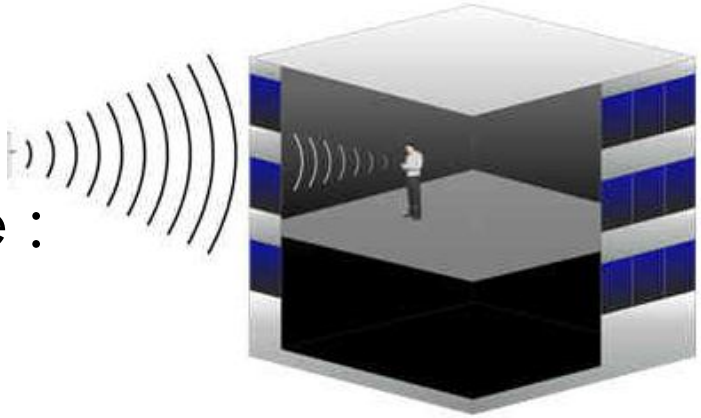
Domestic

- **Inter-Cell Interference Coordination in Heterogeneous Networks with Open Access of Small Cells**", (IEEK Summer Conference July 2014)
- **Cooperative Multi Small Cell with Imperfect CSIT**", (IEEK Fall Conference 2013).
- **Mobility Management in Small Cell Network**, (IEEK Summer Conference 2013)
- **Fractional Frequency Reuse in Femtocell**, (IEEK Fall Conference 2012)

International	Domestic
• 2 - International Journal, 1 under review/writing correction and will be submitted to JSAC • 2 - international conferences	• 4 – Domestic conferences

Motivation

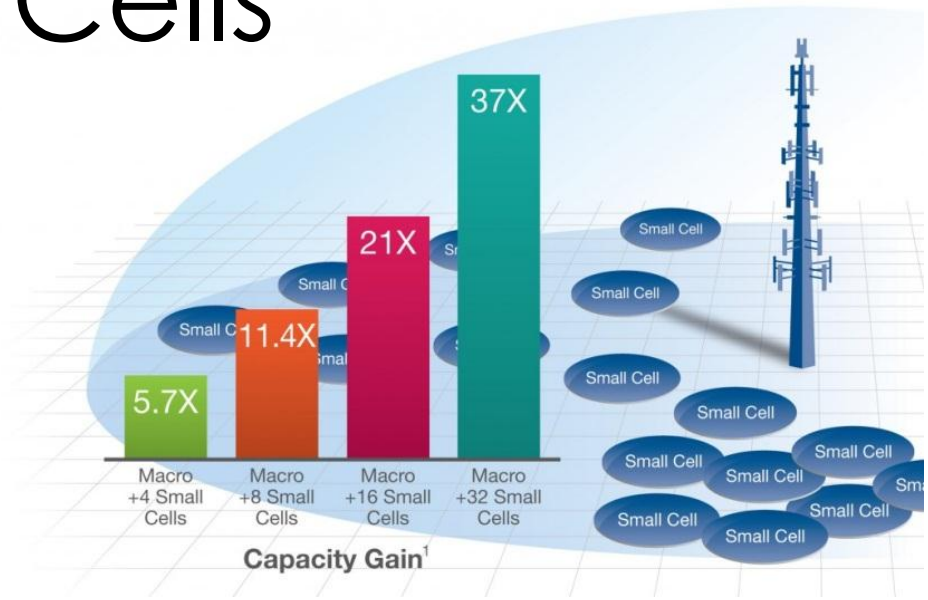
- Shift from voice-only to **voice- & data-based traffic**
- Improved technologies – **smart antennas, MIMO,**
- **Dead zone Problem** – Poor indoor coverage
- Solution – **Small Cells** – (YouTube : http://goo.gl/en8Gc8)



Small Cells

- What is small cells?

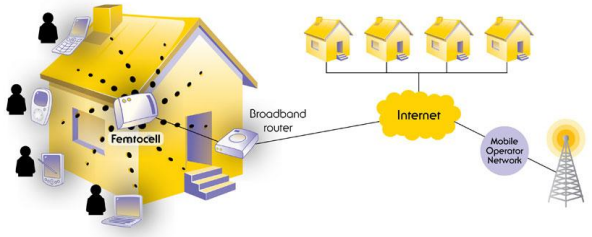
improved cellular/indoor coverage, capacity and applications (ex : SON – Self Organizing Networks, plug and play)



http://taqua.com/solutions

- Type of small cells?

Femtocells, picocells, metrocells and microcells



http://www.smallcellforum.org/

Small Cells - Large Indoor area

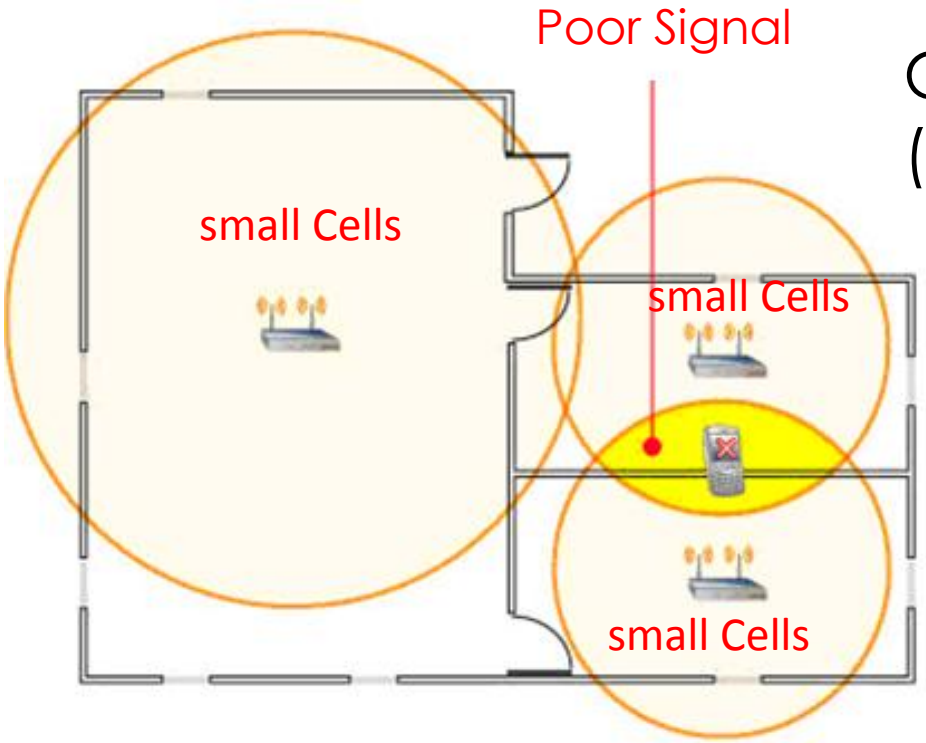
- **High density** of small cells
- **Problems** :

Interference between small cells

- **Solution**

interference management : frequency reuse, preceding technique

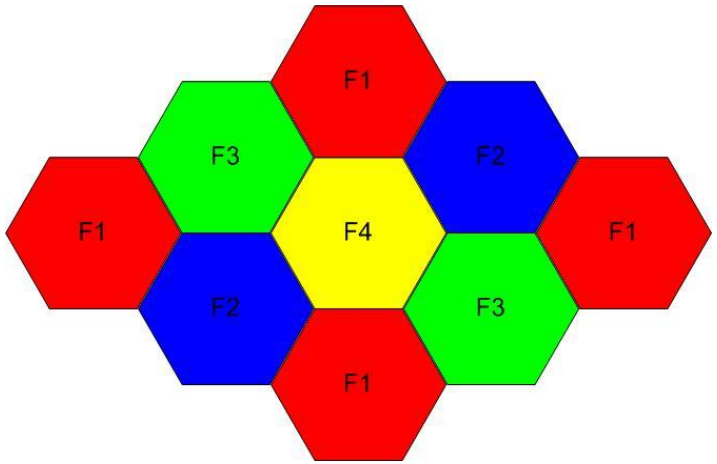
Interference Problem



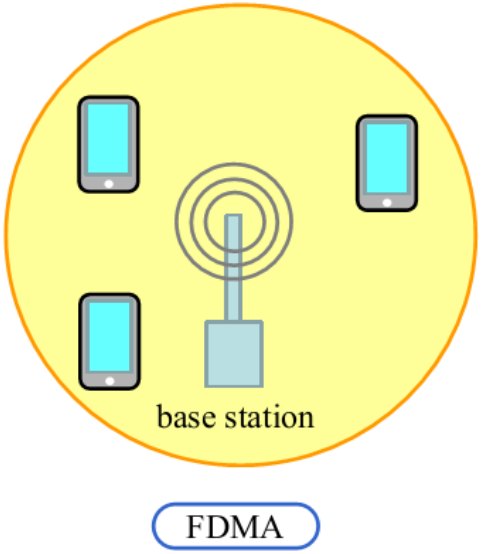
Co-Channel Interference
(same frequency)

Frequency Reuse

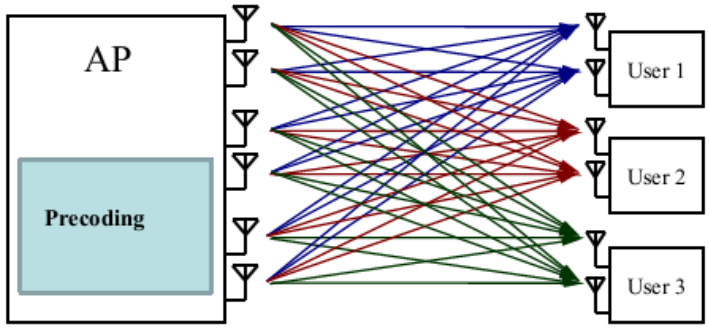
- **FDMA (Frequency Division Multiple Access)**
- **Frequency reuse**, is one of scheme to mitigate inter-cell interference
- Weakness : **waste of frequency bandwidth**



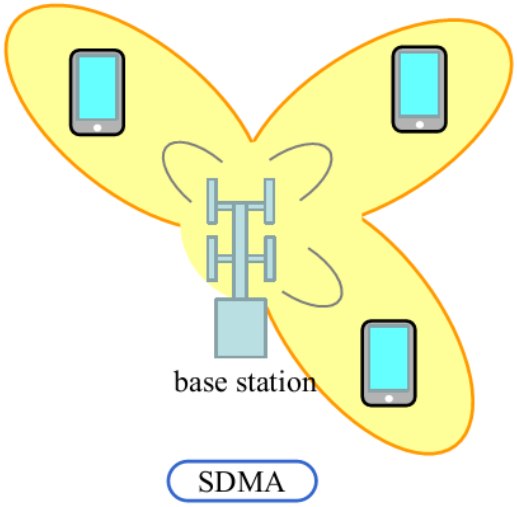
Precoding technique



How to multiple users in the **same time and frequency**?



IUI (Inter User Interference)



FDMA (Frequency Division Multiple Access)

SDMA (Spatial Division Multiple Access)

– precoding technique

Precoding technique

- **Pre define symbol** before transmitting

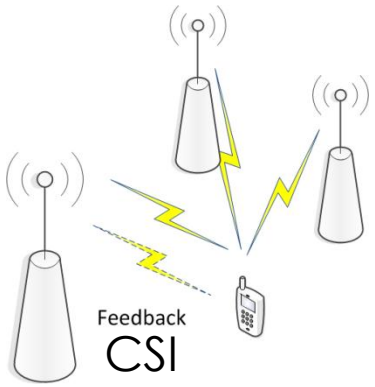
Precoding
$\mathbf{s} = \mathbf{W}\mathbf{u}$

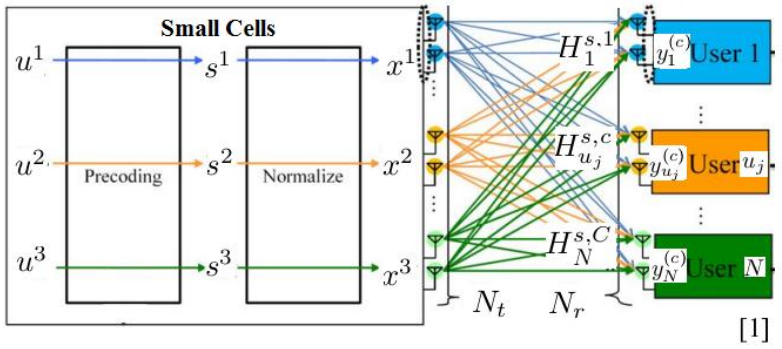
$\mathbf{W}$: Weight matrix

$\mathbf{u}$: Transmission symbol

$\mathbf{H}$: Channel matrix

- $\tilde{V}_{u_j}^{c}$ as channel state information (CSI)
- CSI : to know channel properties of a communication link.





[1]

How to cancel inter user interference?

Precoding technique - MMSE

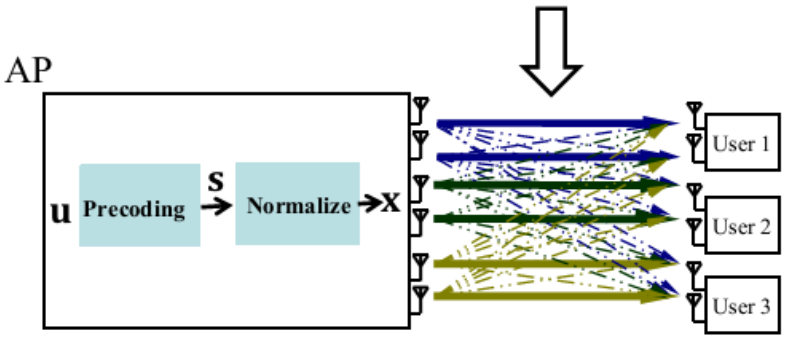
- MMSE (Minimum Mean Square Error), or RCI

$$\mathbf{W_{RCI}} = \mathbf{H}^H(\mathbf{H}\mathbf{H}^H + \sigma^2\mathbf{I})^{-1}$$

Noise power $\rightarrow E[\mathbf{n}\mathbf{n}^{\mathrm{H}}]$

$$\mathbf{s} = \mathbf{W_{RCI}}\mathbf{u} = \mathbf{H}^H(\mathbf{H}\mathbf{H}^H + \sigma^2\mathbf{I})^{-1}\mathbf{u}$$

IUI can not be removed completely



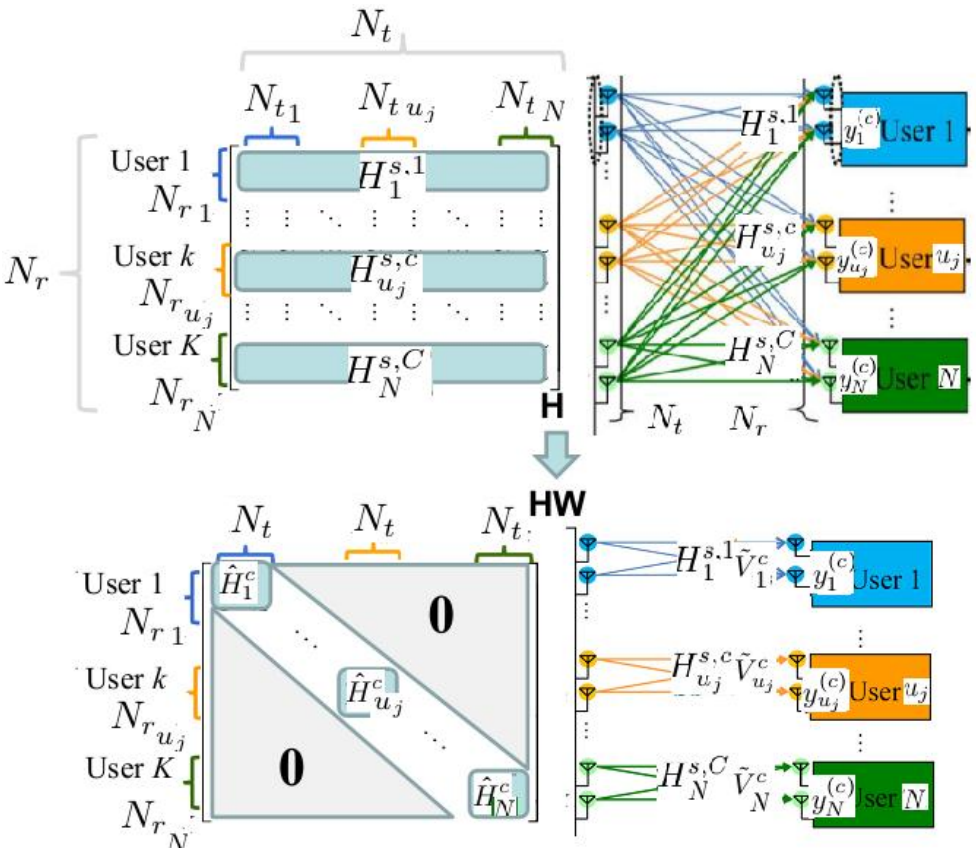
H : Channel matrix

W : Weight matrix

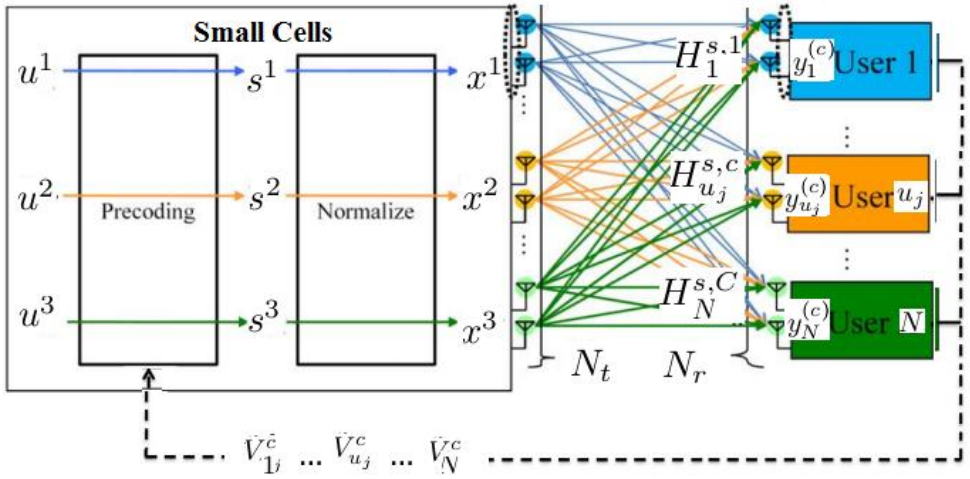
Precoding technique – Block Diagonalization (BD)

Block Diagonalization (BD) need Singular Value Decomposition (SVD) - factorization

$$\hat{H}_{u_j}^{c} w_{u_n}^{c} = 0 \quad if\, j \neq n$$

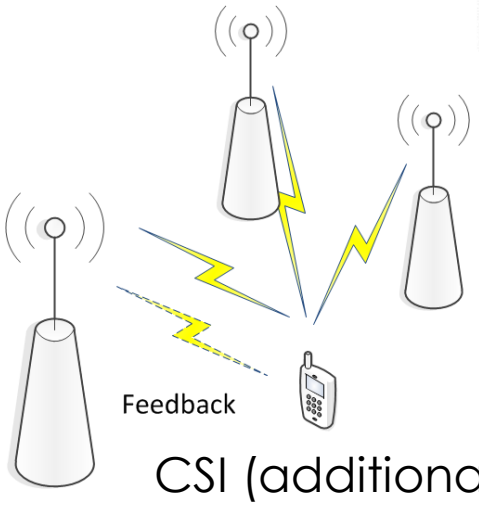


Channel Estimation Error



Error Problem

$$H_{u_j}^e = H_{u_j}^c + \sigma_{err\_u_j}^2$$



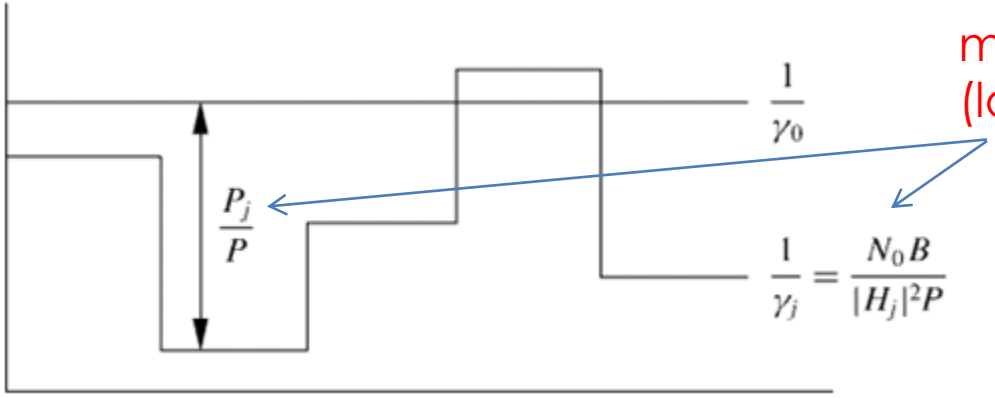
CSI (additional **error**)

Consider : Error Problem $\sigma_{err\_u_j}^2$

$$y_{u_j}^{c,e} = \sum_{c=1}^{C} (H_{u_j}^c + \sigma_{err\_u_j}^2) w_{u_j}^c u_{u_j}^c + n_{u_j}$$

Power Allocation

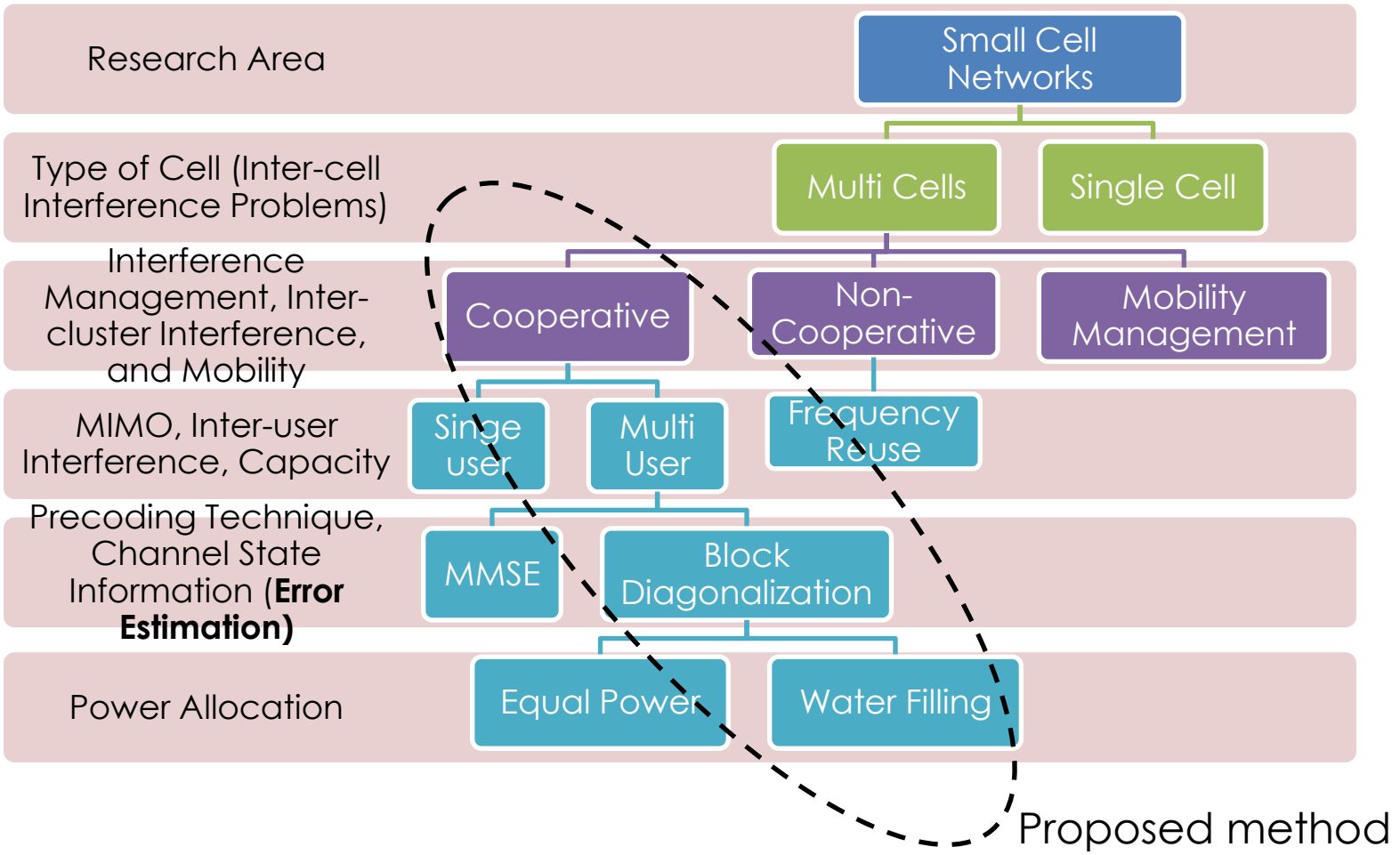
- Power is transmitted to each user by using **water filling power allocation**
- To give the **more power when the channel is good**



$$\Omega_{u_j,l} = \max_{S=c,\ldots,C} \left(\sum_{l=1}^{L} \left| w_{u_j,l}^{C} \right|^2 \right)$$

$$P_{u_j,l} = \left[K \frac{\alpha_{u_j}}{\Omega_{u_j,l}} - \frac{1}{\tilde{\lambda}_{u_j,l}} \right]^{+}$$

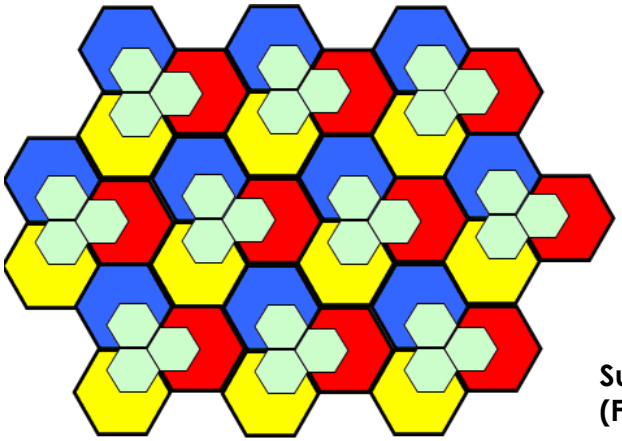
Research Diagram



Related Works

Related Works

- **Interference Management :** Fractional Frequency Reuse [1]
- **A Non-Cooperative** Method in **Femtocell Networks** (with **MMSE)** [2].
- A **Block Diagonalization** for **MIMO Femtocell Networks. (non cooperative and equal power allocation**) [3]
- Single-cell vs. **multicell mimo** downlink signaling strategies with **imperfect csi** (**equal power and MMSE**) [4]



Subcarrier FFR (Frequency Reuse)

Interference Management in Small cells

Proposed Solution

- Interference management in cooperative small cell networks with coordination strategy.

Salient features/contribution

- Coordination strategy in cooperative small cells (**clustered small cells**) with consider :
  - Applied **MIMO** antennas
  - **Water filling** power Allocation
  - Extended **Block Diagonalization** scheme (Applied In clustered small cells)
  - Investigated **channel estimation error** and **closed access** method (CAM)

System Model

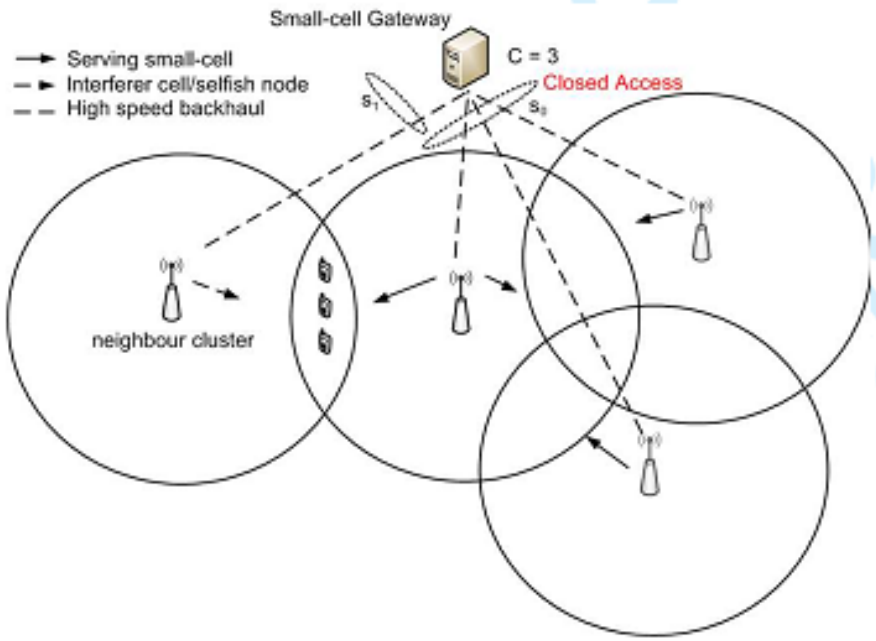


Fig. 1. Clustering in small cell networks, C=3 small cells (c_0) with Closed Access (c_1)

Parameter	Value
Number of small cells in cluster	2, 3, 4, 7
Number of neighbor cluster	1
Transmit Power of small cell	20 dBm/100 mW
Propagation	Indoor propagation Model

System Model

Received signal

$$y_{u_j}^{(s)} = \underbrace{\sum_{c=1}^{C} H_{u_j}^{s,c} w_{u_j}^{s,c} u_{u_j}^{s}}_{serving} + \underbrace{\sum_{c=1}^{C} H_{u_j}^{s,c} \sum_{u_n=1, u_n \neq u_j}^{N} w_{u_n}^{s,c} u_{u_n}^{s}}_{neighbour\ cells}$$

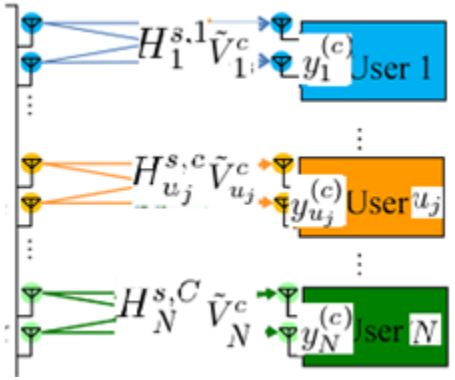
$$+ \underbrace{\sum_{\hat{s}=1, \hat{s} \neq s}^{S} \sum_{\hat{c}=1}^{C} H_{u_j}^{\hat{s},\hat{c}} \sum_{u_x=1}^{N^{\hat{s}}} w_{u_x}^{\hat{s},\hat{c}} u_{u_x}^{\hat{s}}}_{neighbour\ cluster} + n_{u_j}^{s}$$

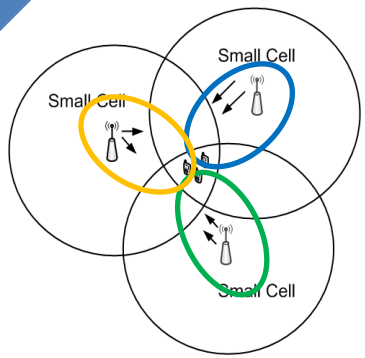
A extended **Block Diagonalization** scheme (Applied In clustered small cells

BD :
cancelling inter-user interference

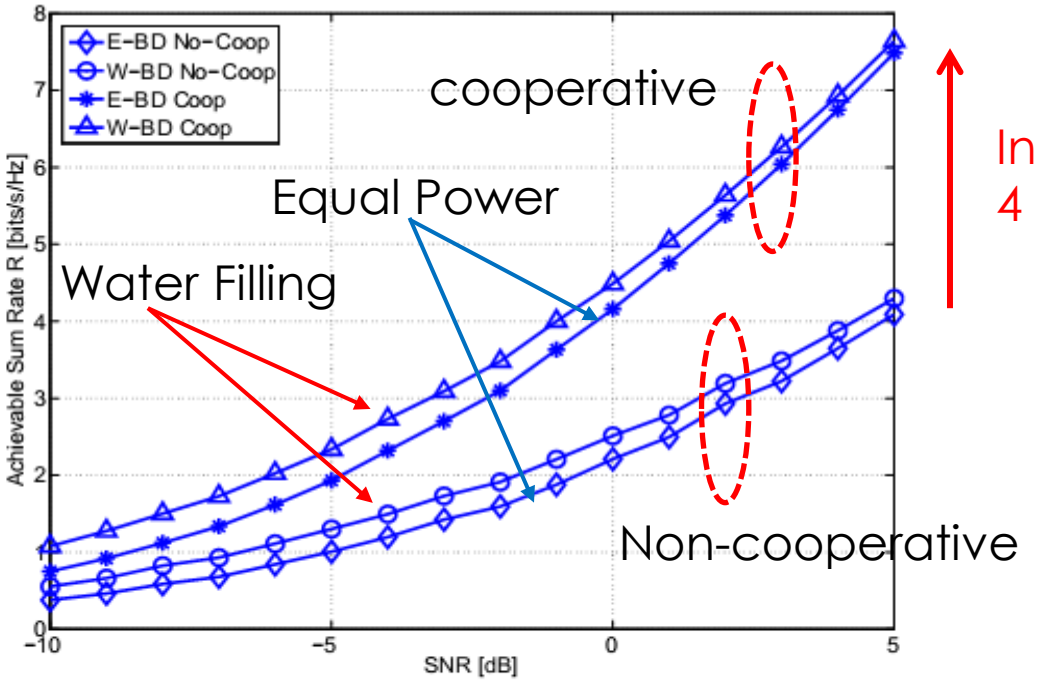
$$y_{u_j}^{c} = \sum_{c=1}^{C} \hat{H}_{u_j}^{c} w_{u_j}^{c} u_{u_j}^{c} + \hat{n}_{u_j} \quad for\ all\ j \neq n$$

$$\hat{H}_{u_j}^{c} w_{u_n}^{c} = 0 \quad if\ j \neq n$$





Simulation Results



Increase about
4 bits/s/Hz

Fig. 2. Non Cooperative and Cooperative Small Cells with number of Cluster $C = 2$, $N_t = 2$ and $N_r = 2$

S. Y. Shin and T. Nugraha, "Cooperative water filling (coopwf) algorithm for small cell networks," in *ICT Convergence (ICTC), 2013 International Conference on*, 2013, pp. 959–961.

Simulation Results

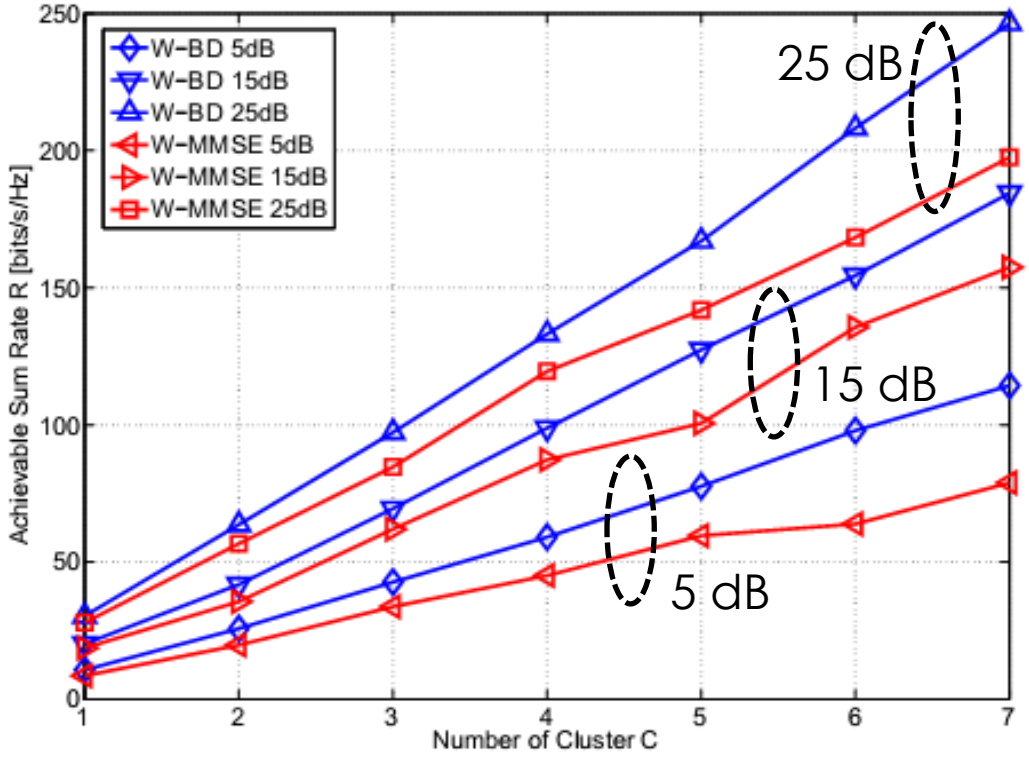
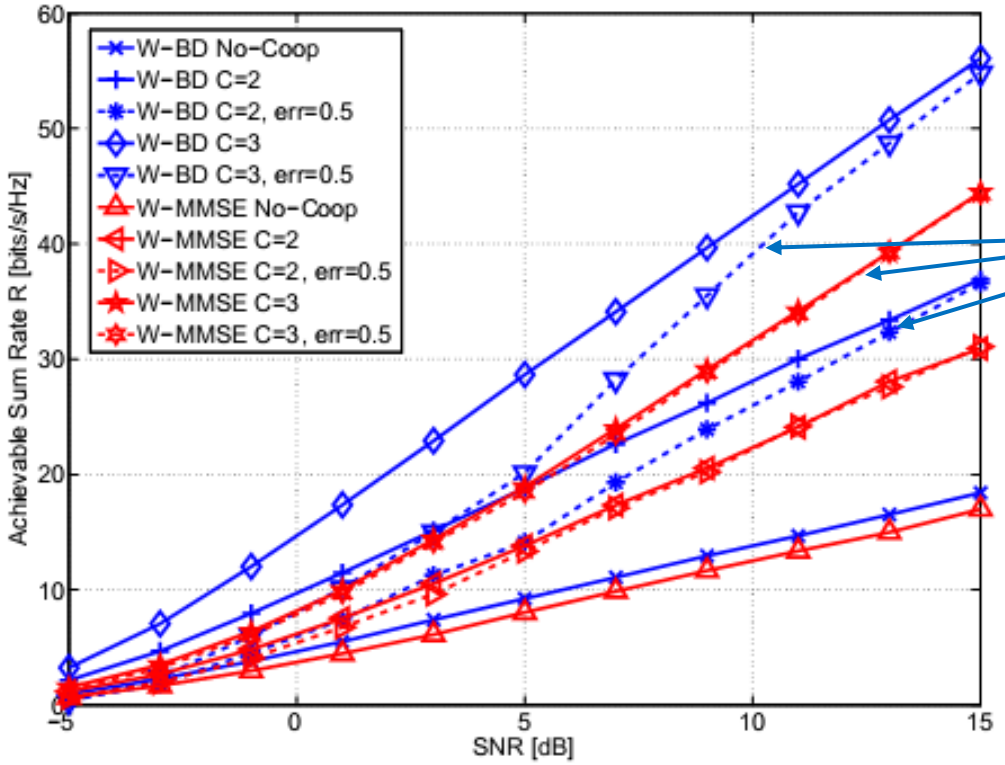


Fig. 4. Coordination strategy with various number of Clustered Small Cells in case of investigation on low SINR (plot 5dB), middle (plot 15dB), and high (plot 25dB).

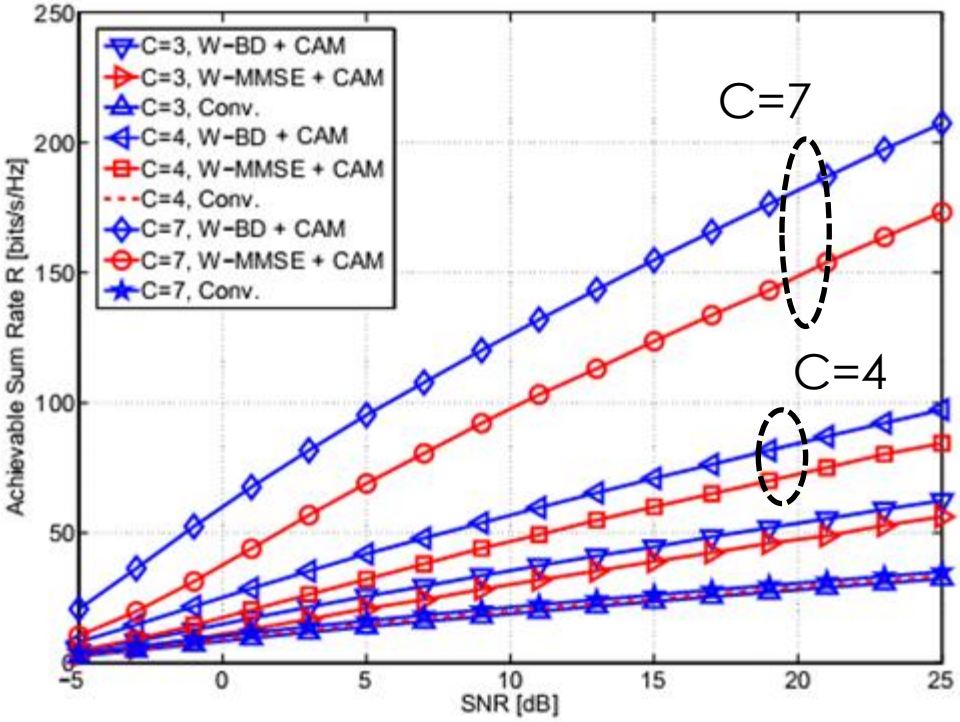
Simulation Results



Channel Error

Fig. 3. Clustered Small Cells under Channel Estimation Error with zero mean and variance of $\sigma^2_{err} = 0.5$ in various number of small cells in clustering system.

Simulation Results



Frequency Reuse

Fig. 5. Comparison between W-BD and W-MMSE, with close access method (CAM) vs conventional scheme, with the number of clustered small cells is set C=3 small cells, 4 small cells, and 7 small cells.

Conclusion and Future Works

Conclusion of this paper:

- **Clustered Small Cells with** applied BD Precoding for **canceling interference**.
- Power based on water filling is better compare to equal power allocation.
- Clustered small cells with BD Is better compare to MMSE in case of same SNR with **Channel Estimation Error**.
- In **Closed Access Mode**, BD is also still better compare with MMSE and Frequency reuse

Future Works

- Investigating small cells with macro cell (**Heterogeneous network**).
- Clustered with **Selfish Small Cells** with consider **SNR Condition**.
- Consider **backhaul problems** for making cooperative cells

Thank You

Question?

Related Works

Related Works

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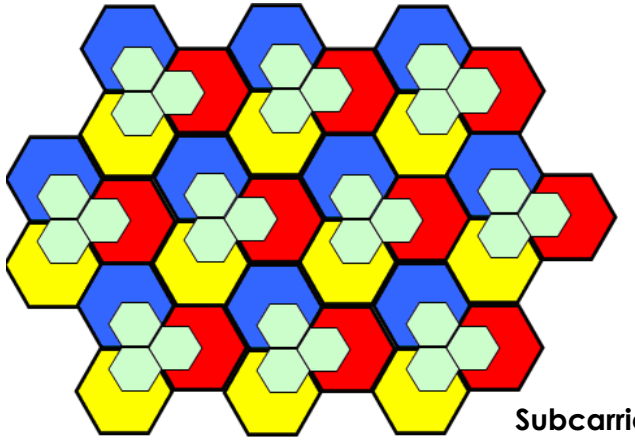
1 F. Jin, R. Zhang, and L. Hanzo, "Fractional frequency reuse aided twin-layer femtocell networks: Analysis, design and optimization," *Communications, IEEE Transactions on*, vol. 61, no. 5, pp. 2074–2085, May 2013.

2 Q. Su, A. Huang, Z. Zhang, K. Xu, and J. Yang, "A non-cooperative method for path loss estimation in femtocell networks," in *GLOBECOM Workshops (GC Wkshps), 2010 IEEE*, Dec 2010, pp. 684–689.

3 M. Khan and M. H. Lee, "A block diagonalization for mimo femtocell networks," in *Ultra Modern Telecommunications and Control Systems and Workshops (ICUMT), 2012 4th International Congress on*, 2012, pp. 510–515.

4 H. Saleh and S. Blostein, "Single-cell vs. multicell mimo downlink signalling strategies with imperfect csi," in *Global Telecommunications Conference (GLOBECOM 2010), 2010 IEEE*, 2010, pp. 1–6.



Subcarrier FFR (Frequency Reuse)