Inter-Cell and Intra-cell Interference Coordination with Multi-Sectored Base Stations

MASc Thesis Defense

Thesis Supervisor: Dr. Halim Yanikomeroglu

Wednesday May 25^{th}, 2011

SCE, Carleton University

Presentation Layout

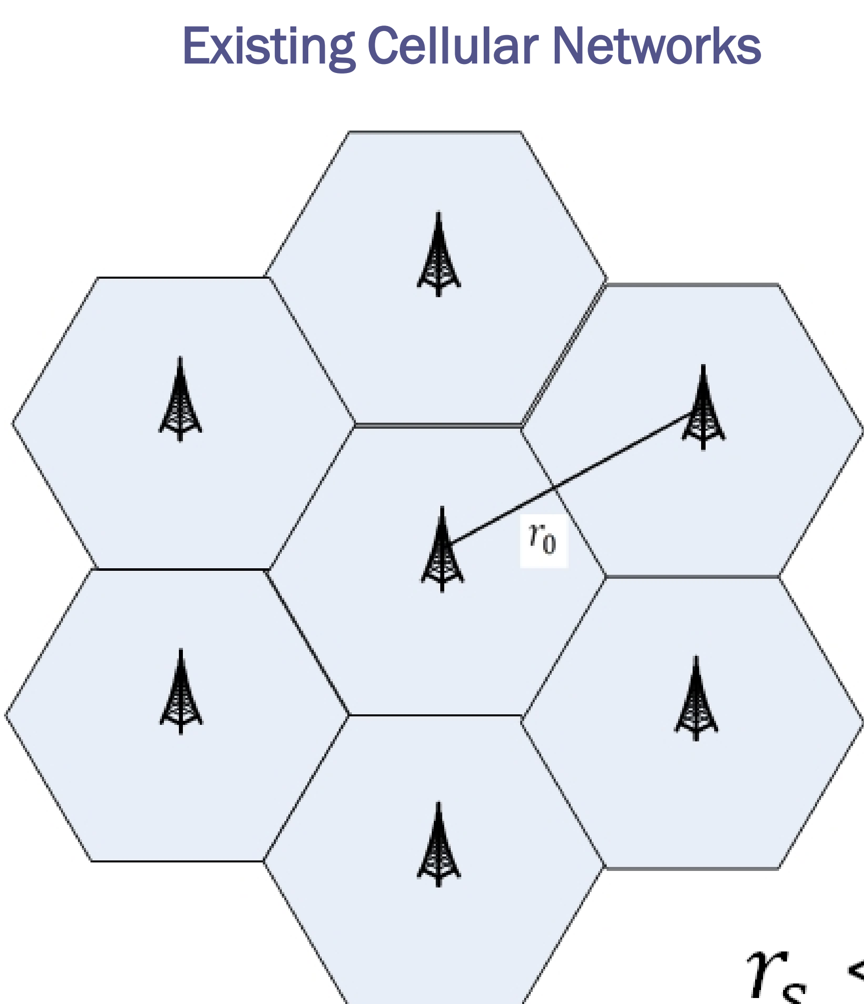
- Background and Motivation
- Problem Statement and Contribution
- Optimization Framework
  - Multi-sectored base station
  - Utilities considered
- Proposed Schemes
  - Inter-cell interference coordination
  - Intra-cell interference coordination
- Simulation Results
- Conclusion

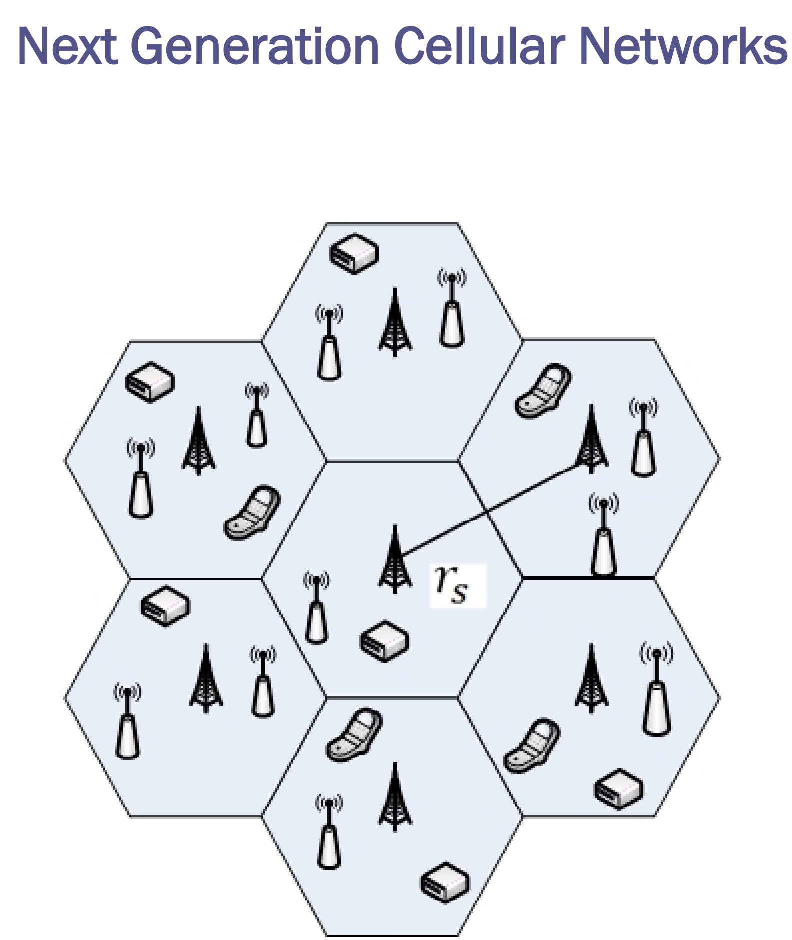
Background and Motivation

Background and Motivation

- Increasing demand on wireless data networks
- Next Generation Networks (LTE, LTE-A)
  - Carrier Aggregation
  - MIMO
  - CoMP
  - Relays
- Orthogonal Frequency Division Multiple Access (OFDMA) is the air-interface technology

Background and Motivation





$$r_s < r_0$$

Inter-cell Interference Coordination (ICIC)

- Inter-cell interference (ICI) can be defined as a collision of resource blocks (RB) (scheduling unit) caused by simultaneous use by several cells.
- Cell-edge users performance degradation due to ICI.
- ICIC techniques aim to minimize collision probabilities and to minimize SINR degradation caused by those collisions by coordinating transmissions between neighbouring base stations.
- Literature focuses mainly on static, semi-static schemes or cluster based schemes.

Problem Statement

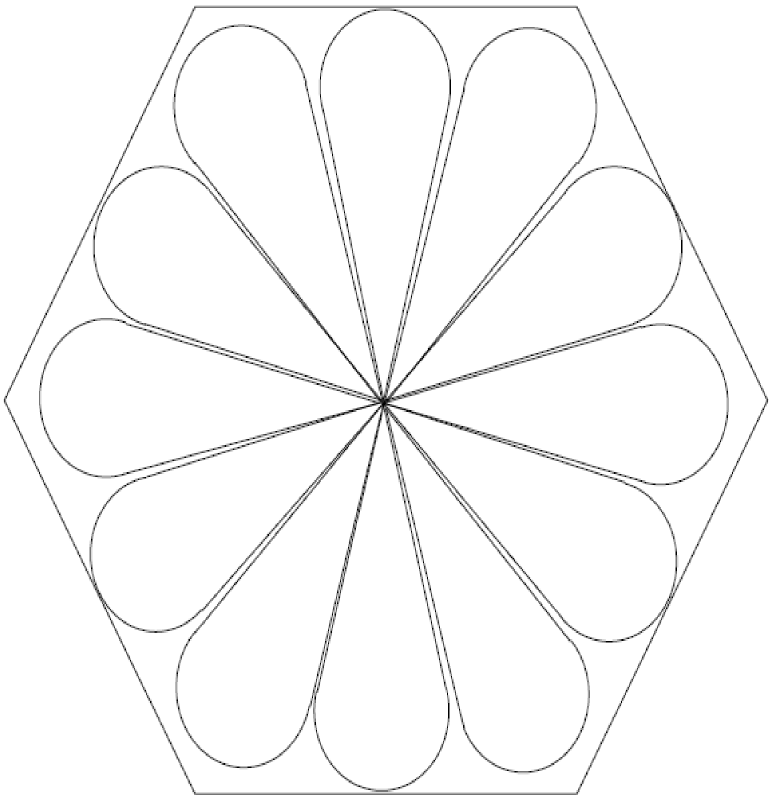
Problem Statement and Contribution

Higher interference levels in NGN, if left unmitigated, will degrade the performance of the network throughput especially to users at cell-edge

We propose an inter-cell and intra-cell interference coordination techniques with multi-sectored base stations.

Optimization Framework

Optimization Framework: Multi-sectored Base Station



- 12 Sectored BS with highly directional antennas.

- Antenna Pattern is given by

$$A(\theta) = -min\left[12\left(\frac{\theta}{17.5}\right)^2, 26\right]. \quad (1)$$

Optimization Framework

Maximize

$$\sum_{i}\sum_{\pi}\left[\sum_{u=1}^{M}\sum_{r=1}^{N} U_{i|\Pi}^{(u,b)} \rho_{i|\Pi}^{(u,b)}\right] \quad (2)$$

subject to

$$\rho_{i|\Pi}^{(u,b)} \in 0, 1; \forall \{u, b\} \quad (3)$$

$$I_i^{(b)} = \sum_{\Pi}\sum_{u=1}^{M} \rho_{i|\Pi}^{(u,b)} = \begin{cases} 0; \text{RB b is restricted in i} \\ 1; \text{otherwise.} \end{cases} \quad (4)$$

Symbols Used

- i → sector (cell),
- u → user,
- b → resource unit,
- M → # of users/sector,
- N → # of resource units,
- $\prod$ → set of transmission possibilities

Optimization Framework: Utilities Considered

- Three different utilities considered:

$$U_i^{(u,b)} = r_i^{(u,b)} \qquad (5)$$

$$U_i^{(u,b)} = r_i^{(u,b)} d_i^{(u)} \qquad (6)$$

$$U_i^{(u,b)} = r_i^{(u,b)} \left[d_i^{(u)}\right]^2 \qquad (7)$$

- Demand Factor:

$$d_i^{(u)} = \frac{\bar{R}_i}{R_i^{(u)}} \qquad (8)$$

where $R_i^{(u)}$ is the average UE u throughput across a certain time frame and $\overline{R}_i$ s given by

$$\frac{\sum_{u=1}^{M} R_i^{(u)}}{M} \qquad (9)$$

Proposed Algorithm

Proposed Algorithm Overview

- Two schemes proposed:
  - **Inter-cell IC:** coordination between sectors in neighbouring base stations.
  - **Intra-cell IC** : coordination among sectors served by a common base station.

Cluster Based Centralized Algorithm

Cluster Group:

- User forms cluster with two dominant interferers , *j* and *k*, respectively.
- User's rates are computed with combinations ($\prod$) of these interferers restrictions
  1. No restrictions $r_{i|\{\}}^{(u,b)}$
  2. Only one restriction takes place, $r_{i|\{k\}}^{(u,b)}$ or $r_{i|\{j\}}^{(u,b)}$
  3. Two interferers are restricted $r_{i|\{j,k\}}^{(u,b)}$
- The rates are computed using the following SINR expression

$$\gamma_i^{(u,b)} = \frac{P_b H_{i,i}^{(u,b)}}{P_b \sum_{\Psi \neq i} H_{i,\psi}^{(u,b)} + P_b \sum_{x} H_{i,x}^{(u,b)} . I_x^{(b)} + P_{TN}}, \quad (10)$$

Inter-cell Interference Coordination: Problem Formulation

- Inter-cell Constraints

$$\rho_{i|j}^{(u,b)} + I_j^{(b)} = \{0,1\}$$

$$\rho_{i|k}^{(u,b)} + I_k^{(b)} = \{0,1\}$$

$$\rho_{i|\{j,k\}}^{(u,b)} + I_k^{(b)} = \{0,1\}$$

$$\rho_{i|\{j,k\}}^{(u,b)} + I_j^{(b)} = \{0,1\} \qquad (11)$$

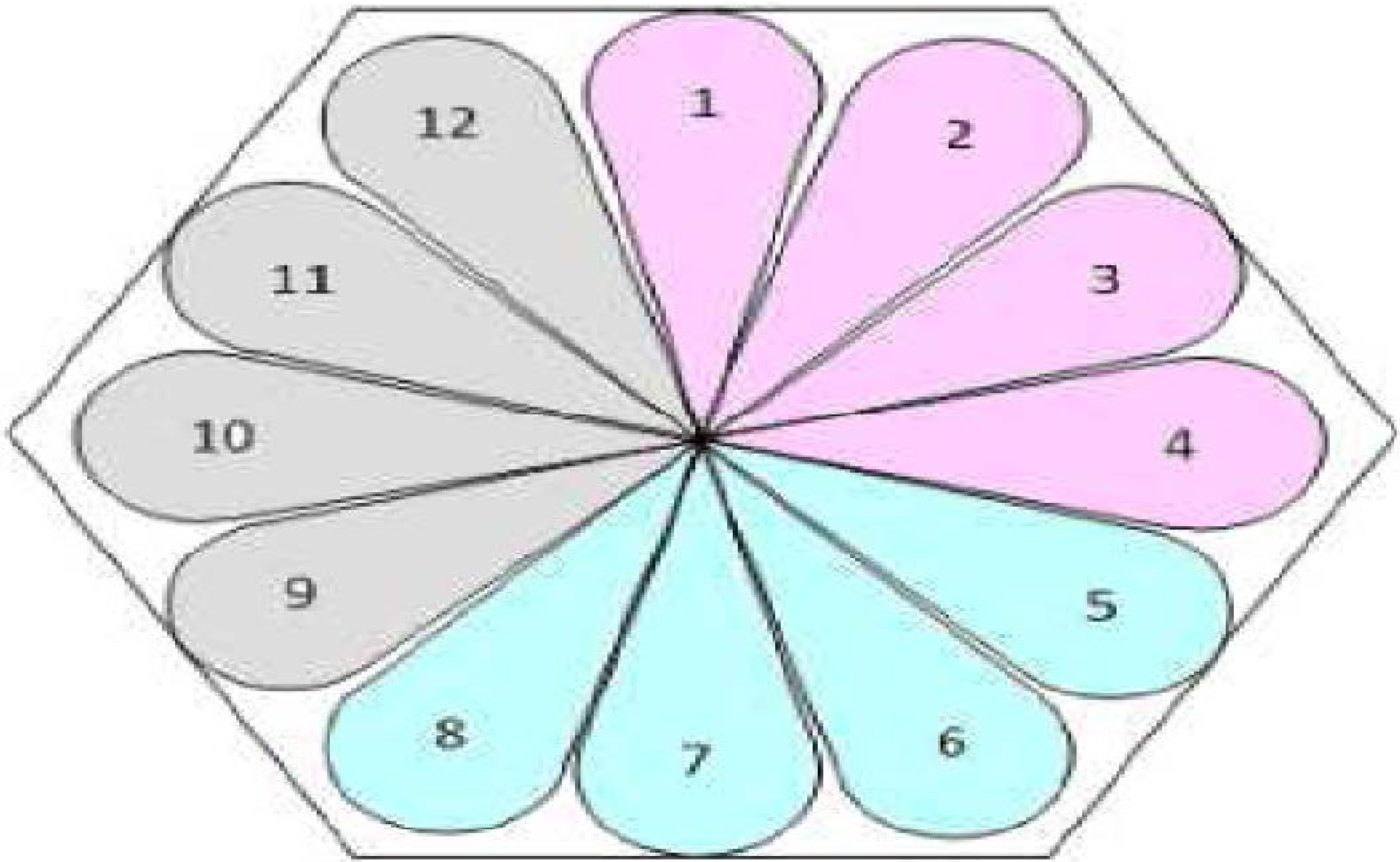
- Due to the complexity of the problem, it is decomposed into smaller sub-problems of size k where k is equal 10

- Scheduling constraints

$$\sum_{\Pi} \sum_{b} \rho_{i|\Pi}^{(u,b)} \leq \beta; \forall \{i,u\} \qquad (12)$$

where β is equal 4

Intra-cell Interference Coordination:



Intra-cell Interference Coordination: Problem Formulation

- SINR Computation:

$$\gamma_i^{(u,b)} = \frac{P_b H_{i,i}^{(u,b)}}{P_{b_{Reduced}} \sum_{\Psi \neq i} H_{i,\psi}^{(u,b)} + P_b \sum_{x} H_{i,x}^{(u,b)} . I_x^{(b)} + P_{TN}} \quad (13)$$

- Intra-cell usage constraint:

$$I_i^{(b)} = \sum_{\Pi} \sum_{u=1}^{M} \sum_{\phi} \rho_{i|\Pi}^{(u,b)} = \begin{cases} 0; & \texttt{RB b is restricted in i} \\ 1; & \texttt{otherwise} \end{cases} \quad (14)$$

Intra-cell Interference Coordination: Problem Formulation

- Inter-cell Constraints

$$\rho_{i|j}^{(u,b)} + I_j^{(b)} = \{0, 1\}$$

$$\rho_{i|k}^{(u,b)} + I_k^{(b)} = \{0, 1\}$$

$$\rho_{i|\{j,k\}}^{(u,b)} + I_k^{(b)} = \{0, 1\}$$

$$\rho_{i|\{j,k\}}^{(u,b)} + I_j^{(b)} = \{0, 1\} \quad (15)$$

- To simplify the problem, it is decomposed into sub-problems of size k where k is equal 16

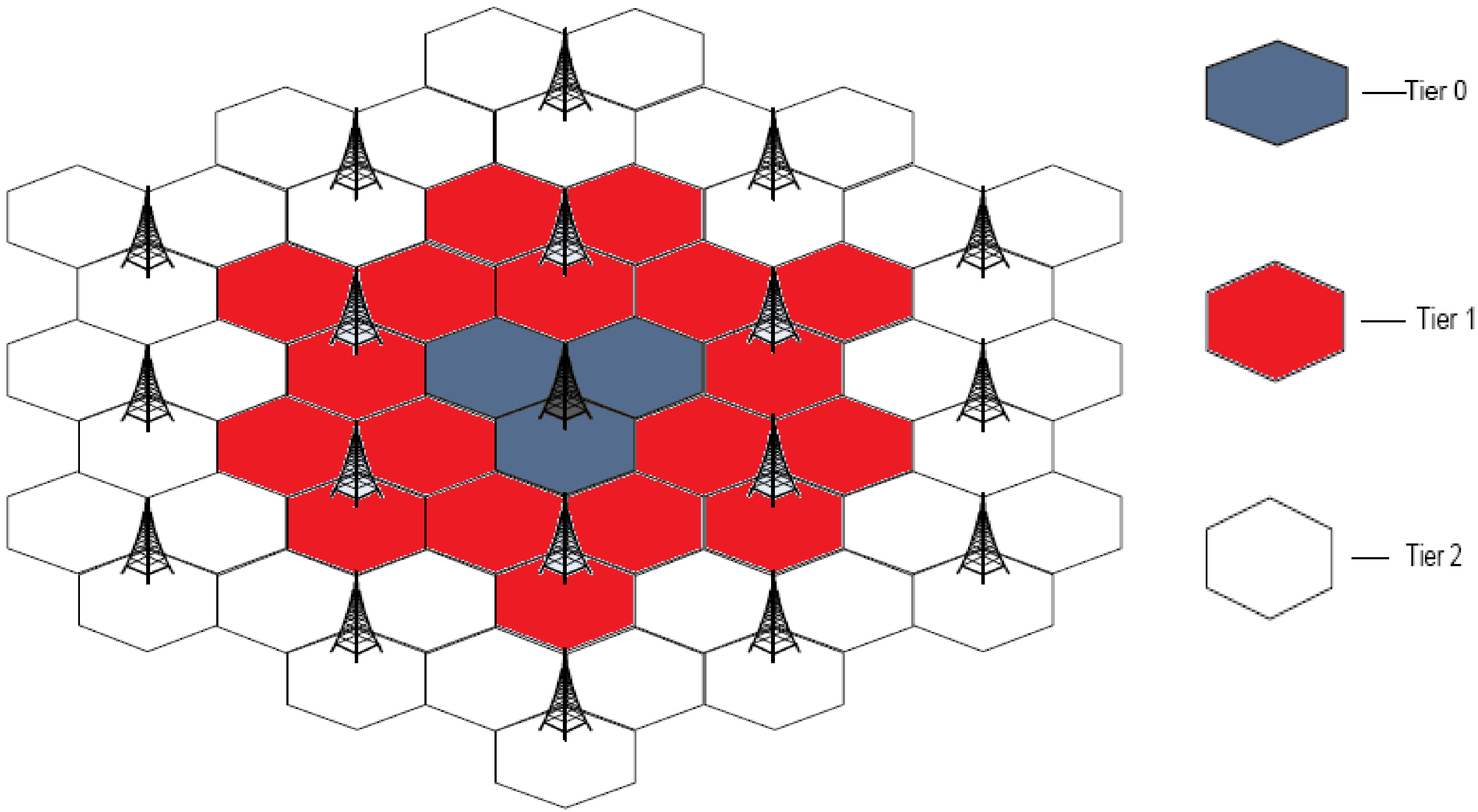
- Scheduling constraints

$$\sum_{\Pi} \sum_{b} \rho_{i|\Pi}^{(u,b)} \leq \beta; \forall \{i, u\} \quad (16)$$

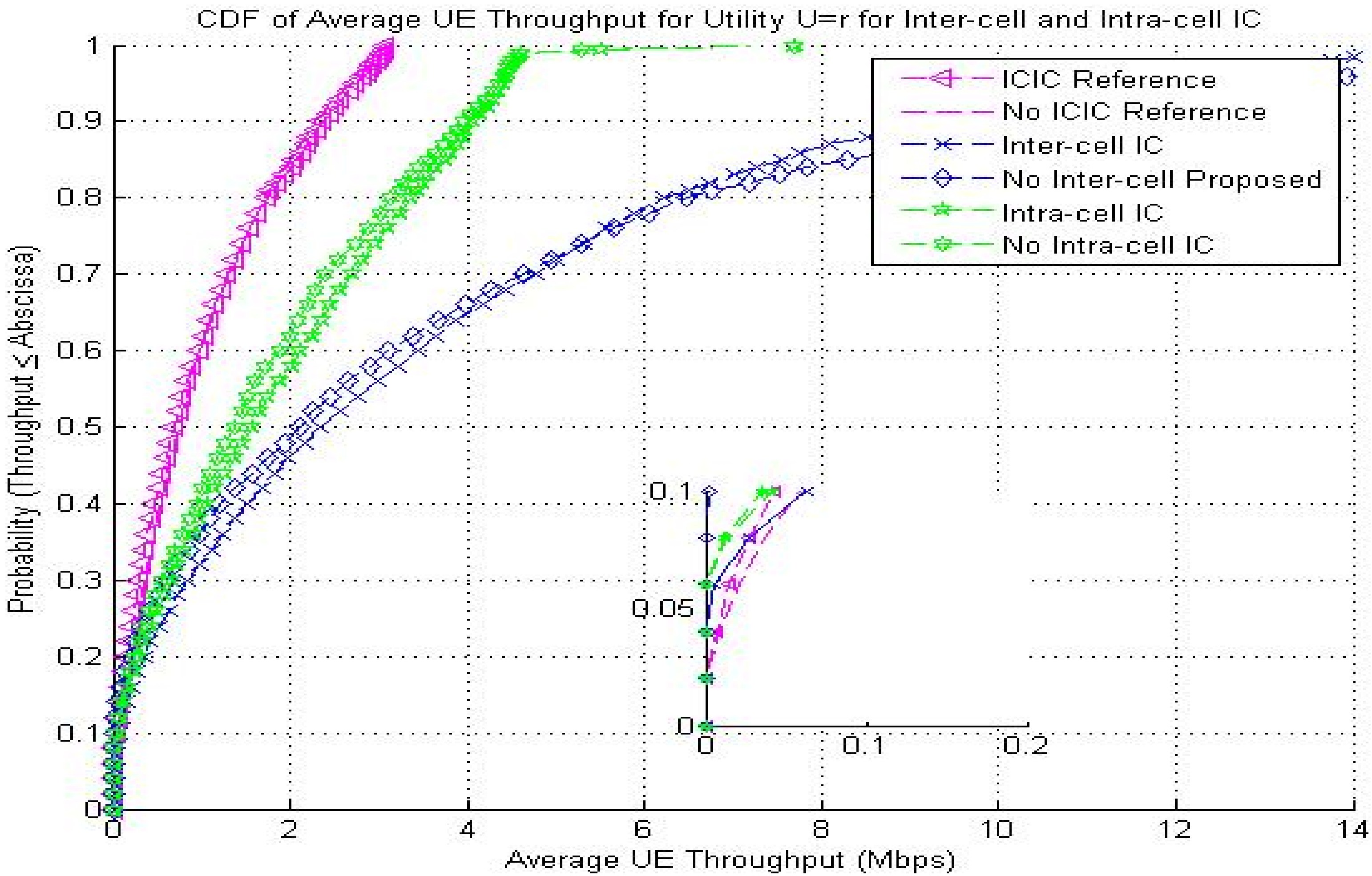
where β is equal 2

Simulation Results

Network Wide Coordination



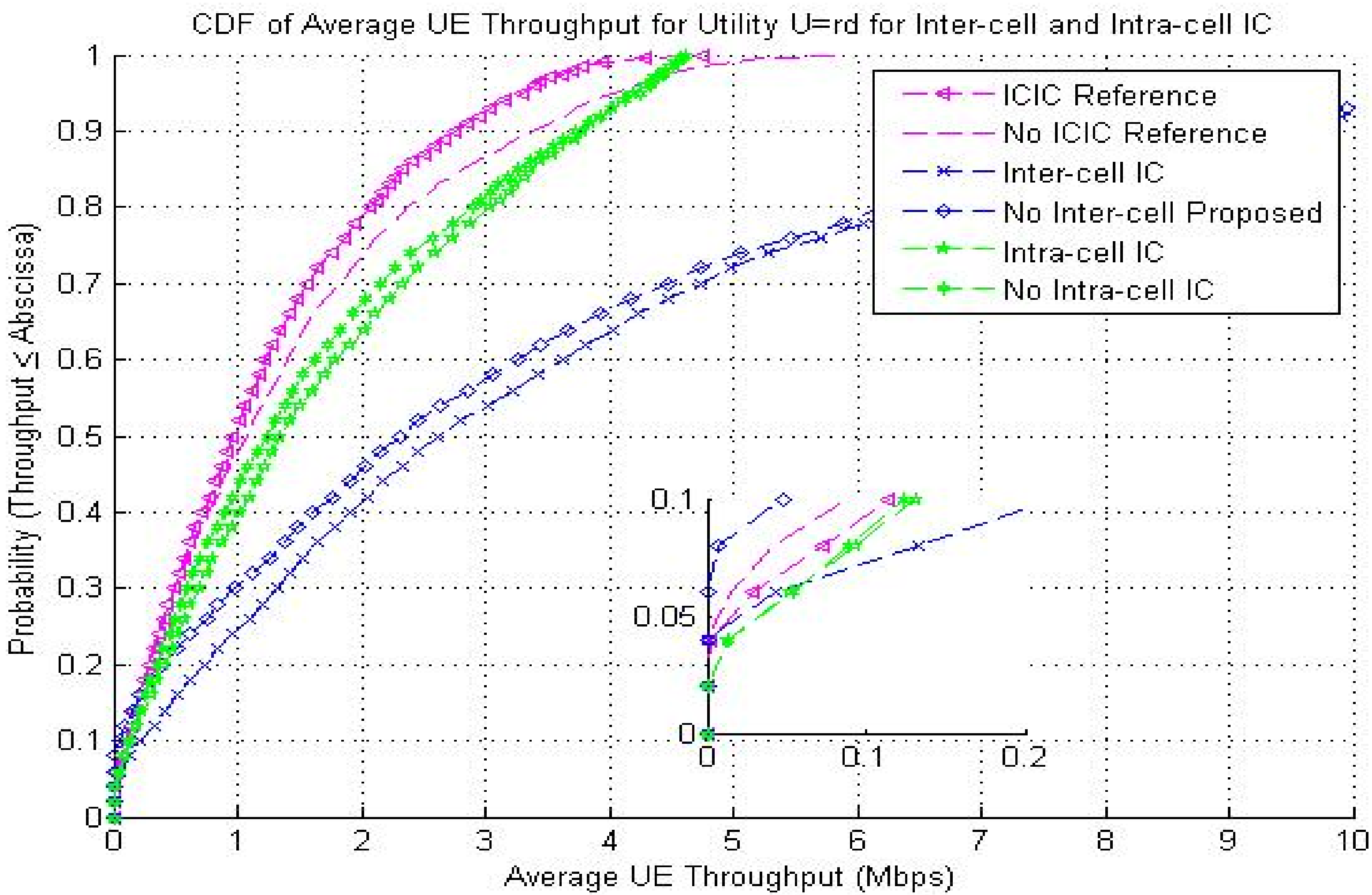
Simulation Results: *U=r*



Simulation Results: $U=r$

Scheme	Cell Throughput (in Mbps)	Cell-Edge Throughput (in Kbps)
Reference Scheme	46.89	40.40
Inter-cell IC	142.11	0.00
Intra-cell IC	66.67	0.00

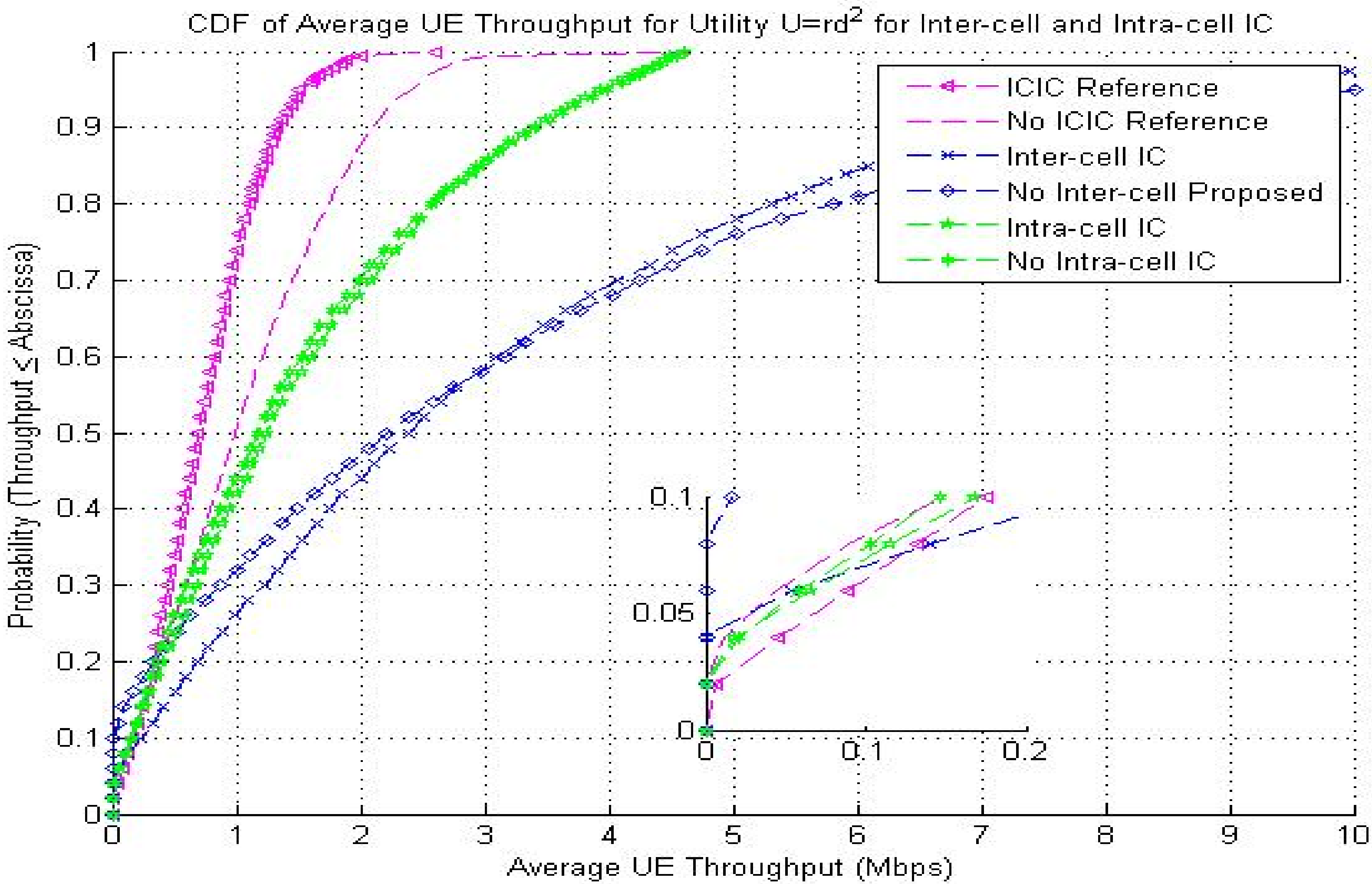
Simulation Results: *U=rd*



Simulation Results: U=rd

Scheme	Cell Throughput (in Mbps)	Cell-Edge Throughput (in kbps)
Reference	42.84	35.45
Inter-cell IC	134.16	149.52
Intra-cell IC	60.45	428.63

Simulation Results $U = rd^2$



Simulation Results $U = rd^2$

Scheme	Cell Throughput (Mbps)	Cell-Edge Throughput (in Kbps)
Reference	40.50	197.56
Inter-cell IC	117.05	262.72
Intra-cell IC	55.08	577.95

Conclusion

Conclusion

- A novel multi-sectored base station with highly directional antennas has been studied with different utilities.
- The use of 12 sectored base station has an enormous impact on cell throughput where the improvement was three times that of the reference scheme.
- Utility $U = rd^2$ shows the most gain in cell-edge throughput.

Conclusion

- Order of cell throughput performance of the three schemes

  Reference scheme $\leq$ Intra-cell IC $\leq$ Inter-cell IC

- Order of cell-edge throughput performance of the three schemes

  Reference scheme $\leq$ Inter-cell IC $\leq$ Intra-cell IC

Questions?

Thank you !! ☺