Cell Spectral Efficiency of LTE-Advanced Relay-Enhanced Cells

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- Motivation
- Calculation of Spectral Efficiencies
    - Peak Spectral Efficiency
    - Cell Spectral Efficiency
- Results for LTE-Advanced Relaying
- Conclusion & Outlook

Motivation

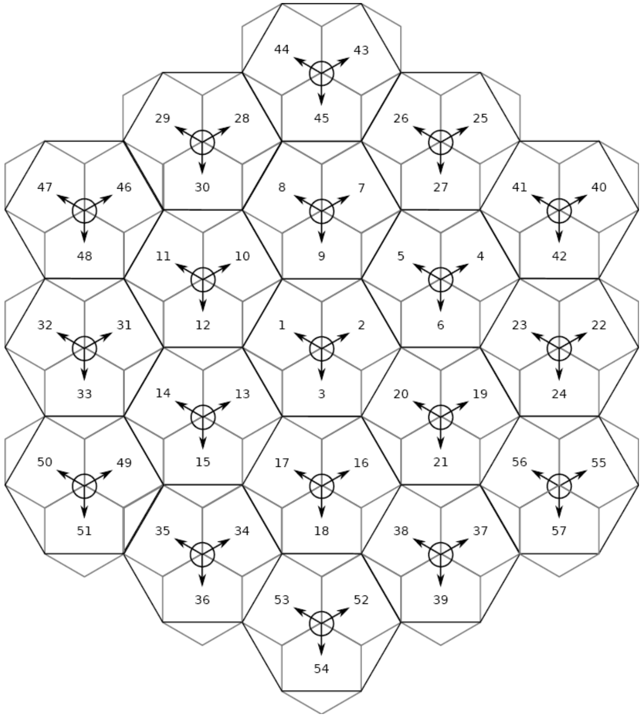
- ITU-R invited organizations to submit 4G (IMT-Advanced) wireless mobile systems to supersede 3G
- 3GPP submitted system proposal *LTE-Advanced* and self-evaluation report
- Independent Evaluation of proposals
  - Evaluated by 13 groups
  - ComNets is part of WINNER+ evaluation group
  - 12 evaluation criteria

Problem Definition

Evaluation of IMT-Advanced criteria

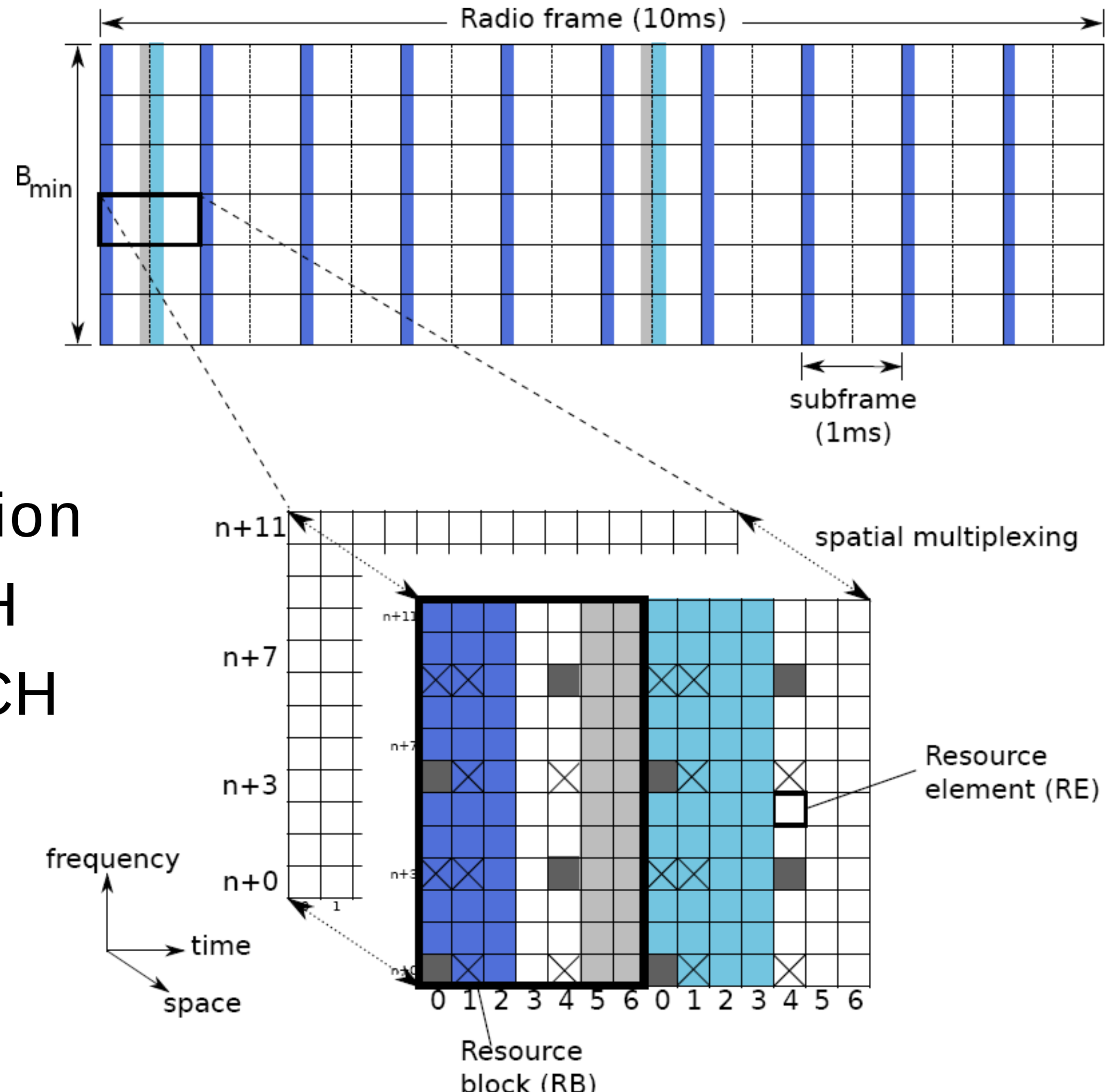
- Peak Spectral Efficiency
  - Foundation for cell spectral efficiency
- Cell Spectral Efficiency
  - Determined by system level simulation
  - Path loss model with randomized LoS/NLoS link conditions

➢ An <u>analytical</u> model for the downlink CSE is developed



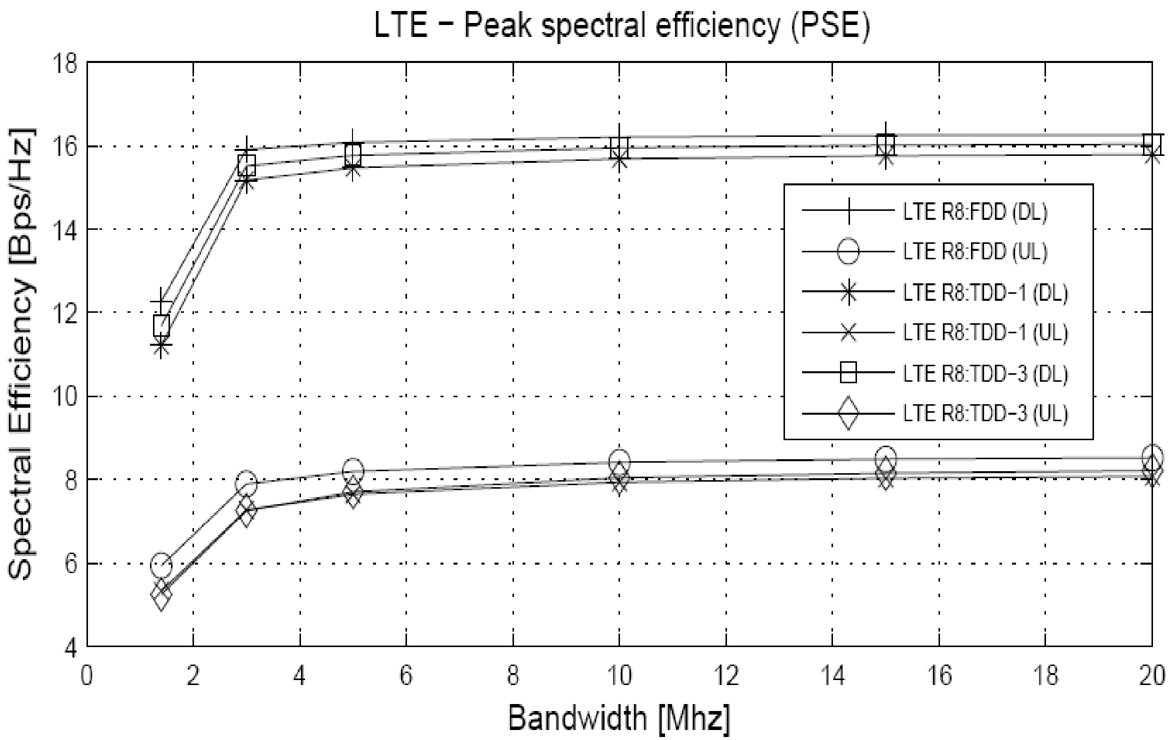
Peak Spectral Efficiency Calculation

- FDD/TDD
- Overhead for
  - Reference Signals, Synchronization
  - PBCH, PDCCH
  - PRACH, PUCCH
- MIMO
  - 4x4 (DL)
  - 2x2 (UL)



Peak Spectral Efficiency

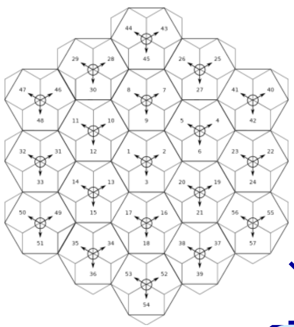
- Minimum overheads, 64QAM-1/1, 4x4 MIMO (DL), 2x2 (UL), perfect channel

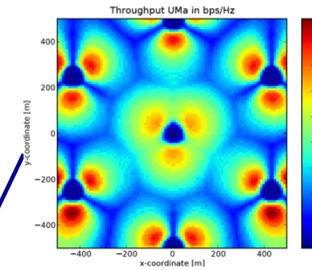


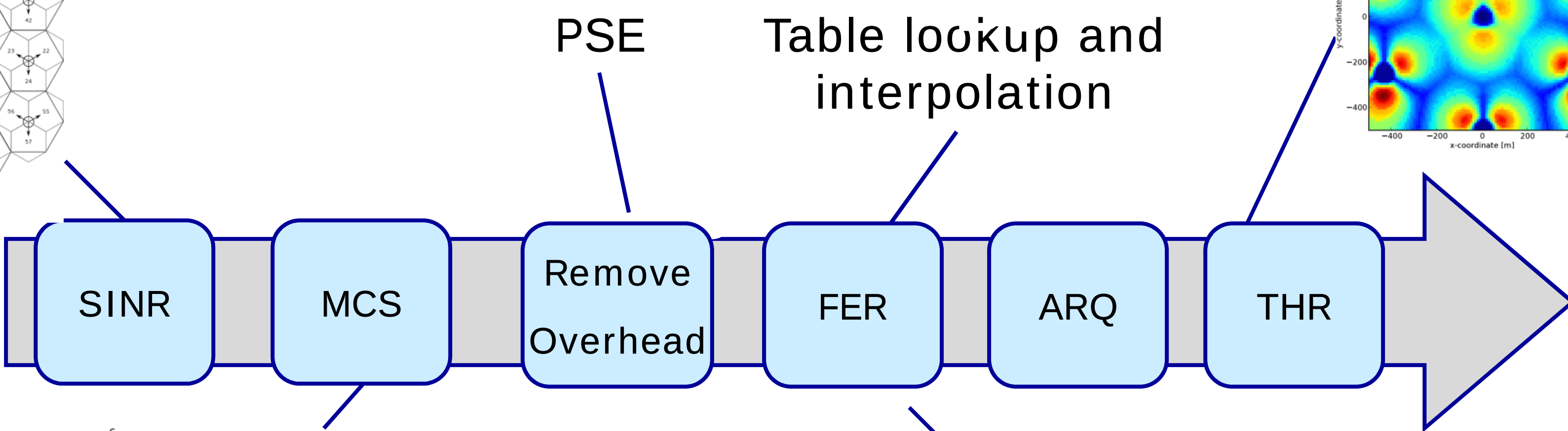
	DL	UL
Required	15.0	6.75
FDD	16.3 ✓	8.5 ✓
TDD	15.8 ✓	8.1 ✓

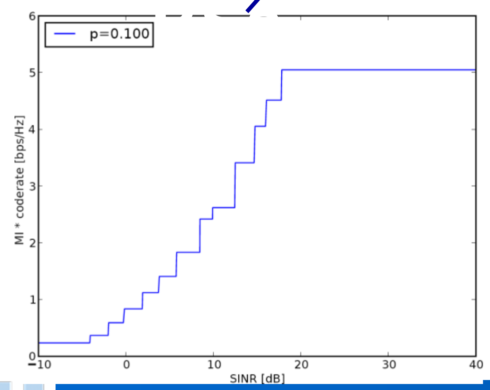
Cell Spectral Efficiency

- CSE depends on achievable SINR; from SINR derive throughput





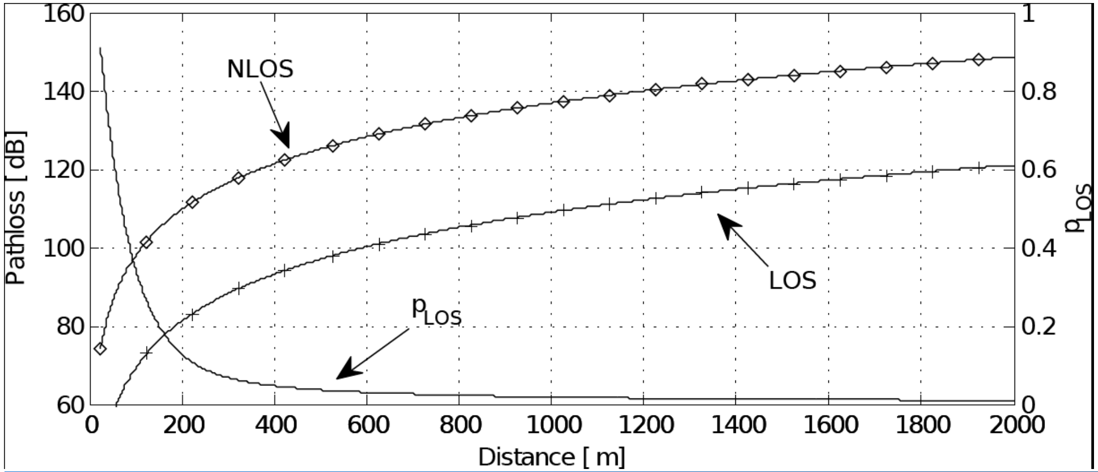




$$THR_{L3} = (1 - FER) THR_{MAC}$$

SINR Calculation including (N)LOS probability

- Downlink SINR depends on received power of serving cell and all interferers
- Pathloss
  - Either LoS or NLoS link depending on probability conditional on distance d
  - Shadowing and Fast-fading effects not taken into count

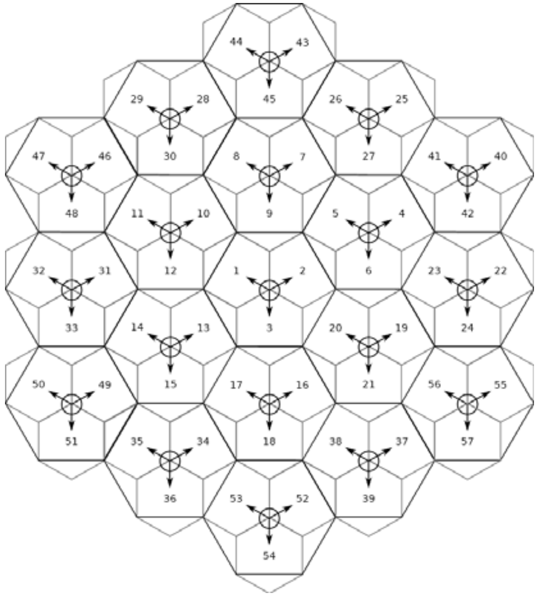


SINR Calculation including (N)LOS probability

- Downlink SINR depends on received power of serving cell and all interferers
- For a given set j of (N)LOS conditions the SINR is given by

$$SINR_j(x,y) = \frac{P_{Rx,LoS}(d_{\mathrm{ServingCell}})}{P_{Rx,NLos}(d_1) + P_{Rx,LoS}(d_2) + \ldots + P_{Rx,LoS}(d_{57}) + \eta}$$

- Random (N)LOS conditions results
    - Random Serving Cell
    - Randomized Interference



Analytical Model

- Idea: compute all permutations and determine exact mean SINR

$$perm_j = (p_{j,1}, p_{j,2}, \ldots, p_{j,M-1}, p_{j,M}), \quad j = 1 \ldots 2^M$$

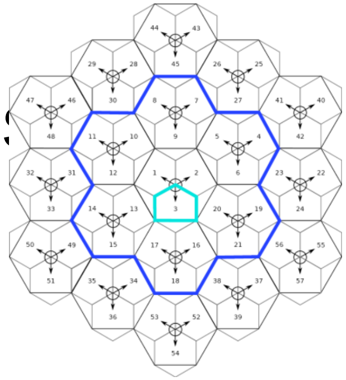
- Necessity to weight the permutation by its occurance probability

$$p_{perm,j} = \prod_{i=1}^{M} p_i \quad \forall j$$

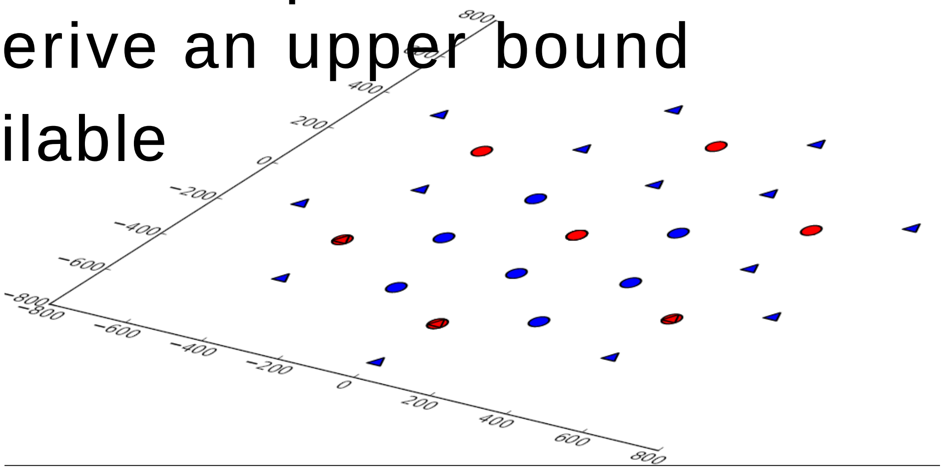
- Mean SINR

$$SINR(x,y) = \sum_{j \in \mathfrak{P}} p_{perm,j} \cdot SINR_j(x,y)$$

Complexity Reduction

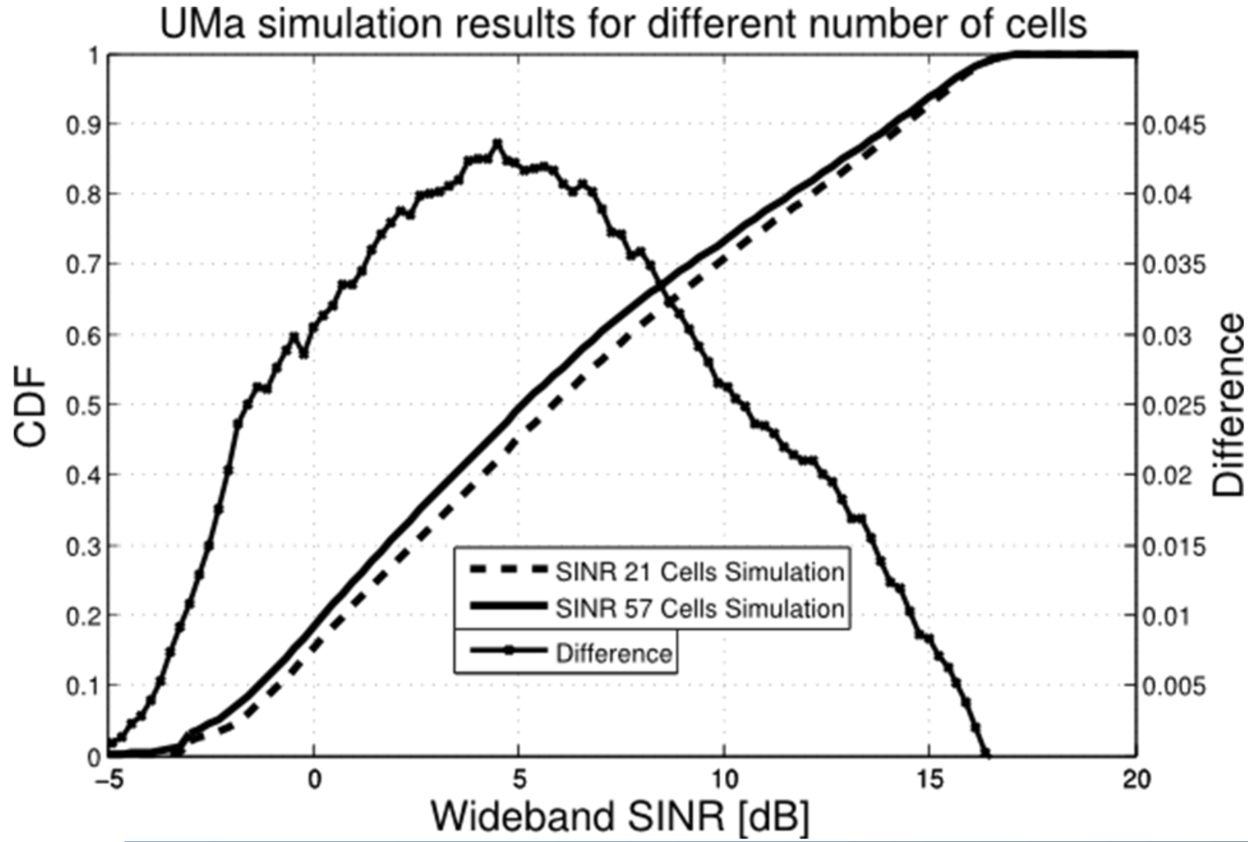


- Consider only one tier of interferers
  - Small impact of second tier on SINR in full load
- Evaluation of one cell in center site
- Reduce number of permutations
  - Assume NLoS link for non-permutable radio access points to derive an upper bound
  - Error analysis available



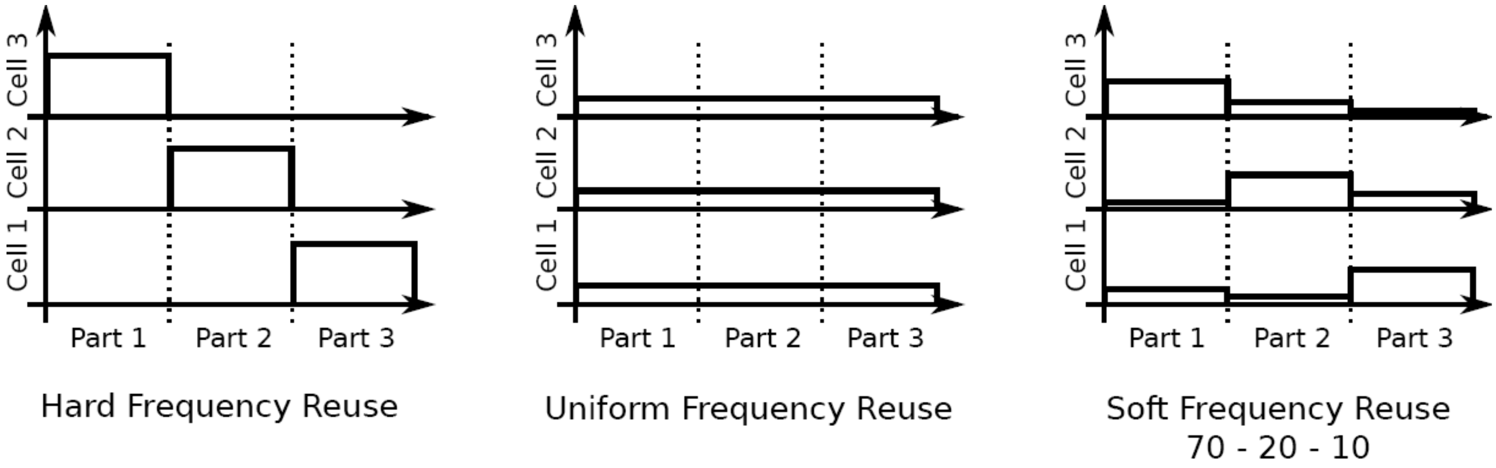
Impact of Reduced Number of Cells

- Simulations show low impact on SINR from reduced number of cells



Frequency Reuse Schemes

- LTE was designed to support reuse-1 power schemes
- Use power mask to alter reuse schemes
  - Split resources in partitions with different power levels



Cell Spectral Efficiency Results

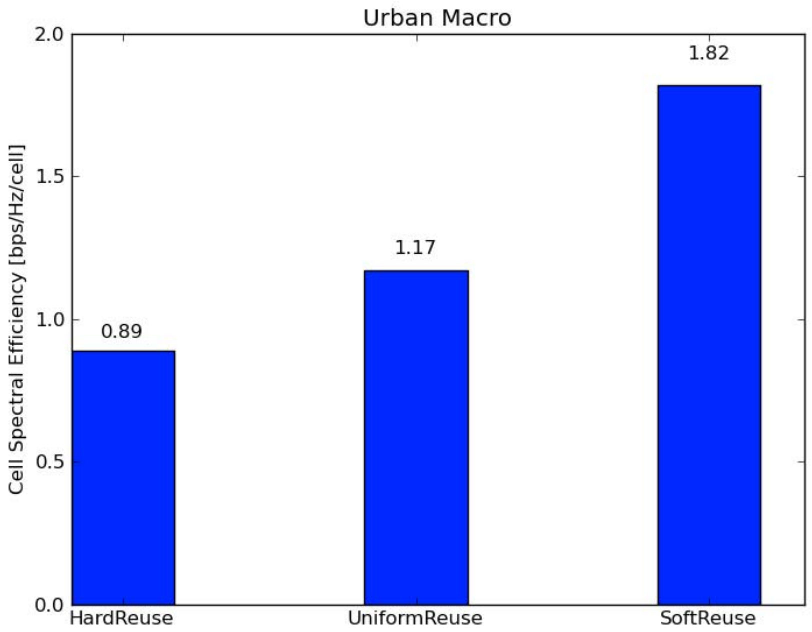
- LTE-R8 SISO, No Relays
- Capacity according to

$$\frac{1}{C_{cell}^{bit}} = \frac{1}{A_{cell}} \sum_{x,y} \frac{1}{bpsym(x,y)}$$

- Spectral Efficiency

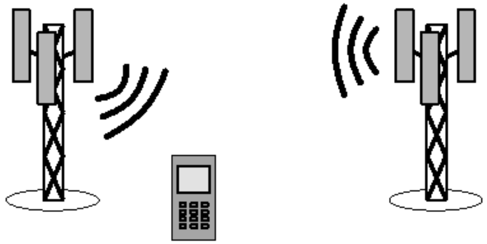
$$CSE = \frac{C_{cell}^{bit} \square C_{net}}{B}$$

- Requirement:
  2.2 bps/Hz/cell



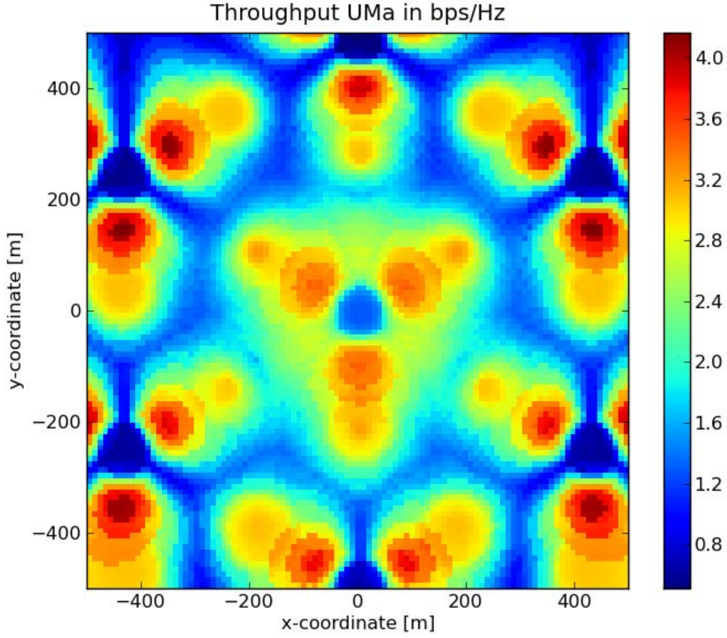
Relay Enhanced Cells

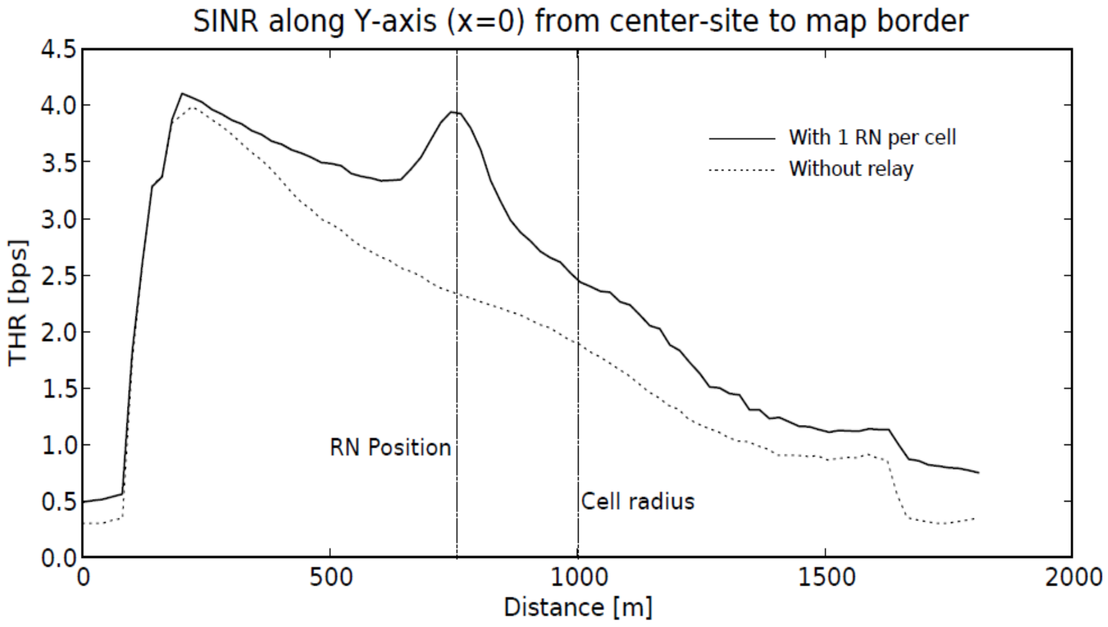
- LTE-Advanced supports Relaying for capacity enhancement and coverage extension
- Include one and three relays per cell to increase spectral efficiency (capacity enhancement)
  - Position at 3/4th of the cell radius
  - 256QAM wireless backhaul, error free conditions
  - Cell capacity according to $\frac{1}{C_{composite}} = \frac{1}{C_{hop1}} + \frac{1}{C_{hop2}}$
- Frequency Reuse applied for relays here
  - Base stations and relays use distinct resources
  - Frequency reuse schemes within set of relays



Throughput in Relay Enhanced Cell

- Uniform frequency reuse, one relay per cell



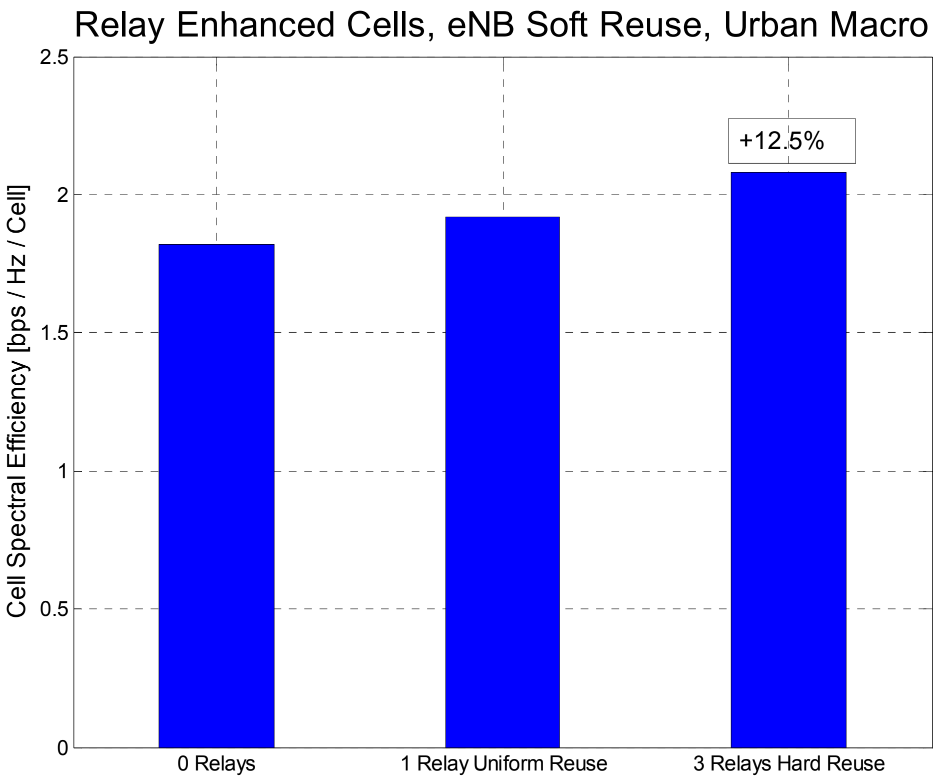


Cell Spectral Capacity for Relay Enhanced Cells

- LTE-A Relaying
- Capacity according to

$$CSE = \frac{C_{RN}^{bit} \cdot C_{RN,net} + C_{BS}^{bit} \cdot C_{BS.net}}{B}$$

- Required: 2.2bps/Hz/cell



Conclusion & Outlook

Conclusions

- Introduction of method to derive cell spectral efficiency analytically
  - Applicable to arbitrary scenarios, not only ITU-R M.2135
  - Supports probabilistic LOS/NLOS links
  - Supports frequency reuse schemes, and antenna patterns
- LTE-Advanced fulfills Peak Spectral Efficiency requirement
- Resource Partitioning between Relays needed if more than 1 Relay per sector is deployed

Outlook

- Include realistic model of the wireless backhaul
- Investigate Cell Edge User performance gains
- Optimize deployments (ISD, downtilt vs. relay distance, etc.)

Thank you for your attention!

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