Cell Spectral Efficiency of a 3GPP LTE-Advanced System

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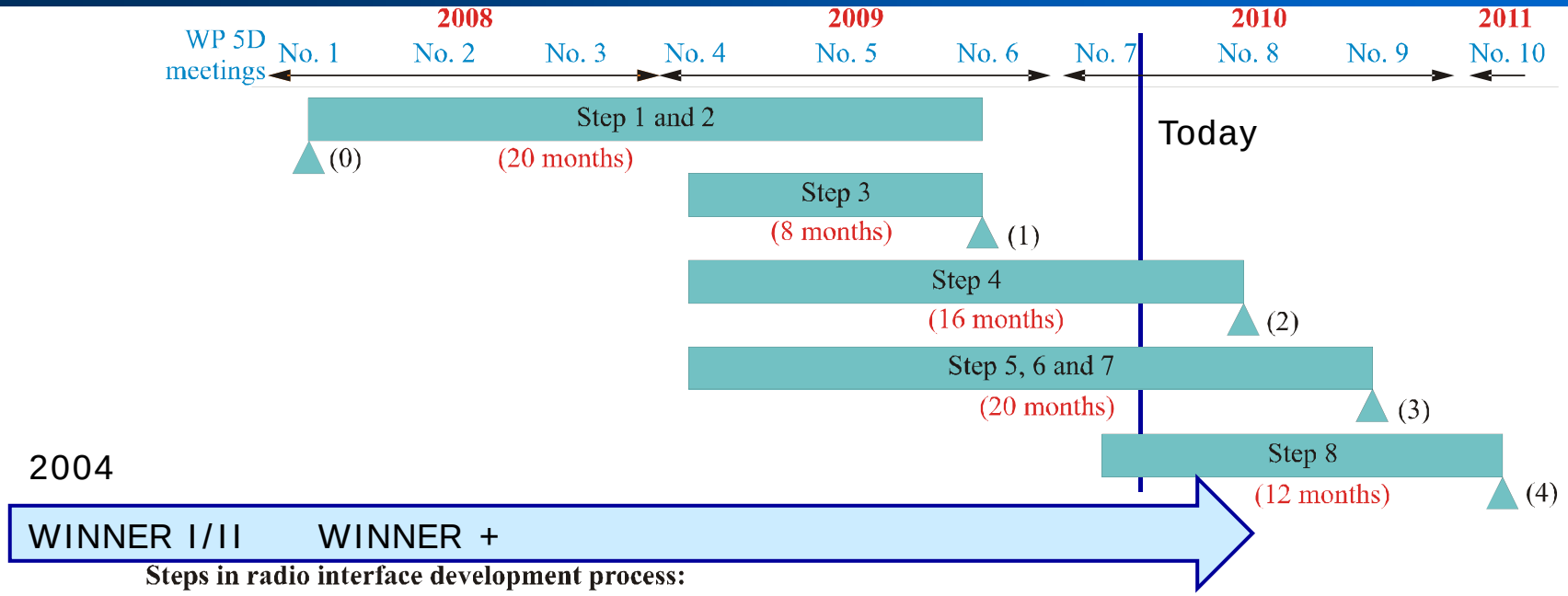
12.03.2010

Schedule of IMT-A Process



Steps in radio interface development process:

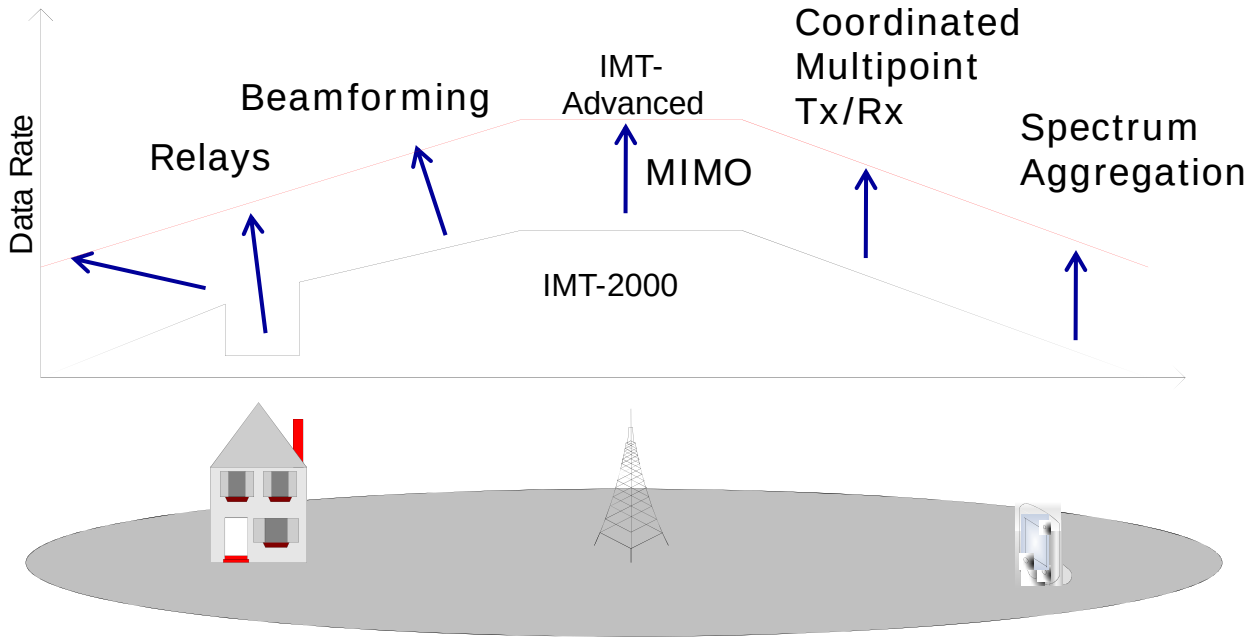
Step 1: Issuance of the circular letter
Step 2: Developement of candidate RITs and SRITs
Step 3: Reception of the RIT and SRIT submissions and acknowledgement of receipt
Step 4: Evaluation of candidate RITs and SRITs by evaluation groups
Step 5: Review and coordination of outside evaluation activities
Step 6: Review to assess compliance with minimum requirements
Step 7: Consideration of evaluation results, consensus building and decision
Step 8: Development of radio interface Recommendation(s)

Critical milestones in radio interface development process:

(0): issue an invitation to propose RITs	March 2008
(1): ITU proposed cut off for submission of candidate RIT proposals	October 2009
(2): Cut off for evaluation report to ITU	June 2010
(3): WP 5D decides framework and key characteristics of IMT-Advanced RITs and SRITs	October 2010
(4): WP 5D completes development of radio interface specification Recommendations	February 2011

IMT-Advanced A2-01

Technologies for IMT-Advanced



Focus on Relays

Compare Deployments

Compare Reuse Schemes

Compare Resource Partitioning

Antenna Patterns

Evaluate IMT-A Scenarios

Apply Method to LTE-A

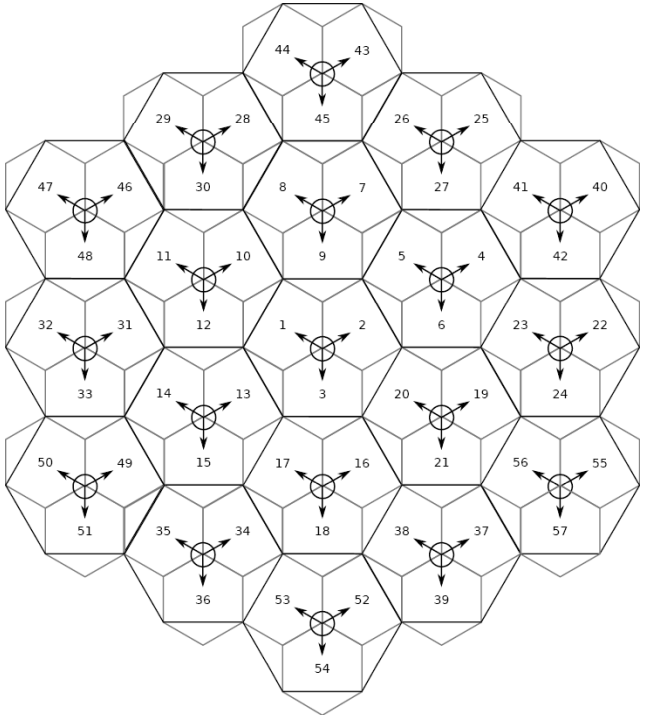
Problem Definition

Evaluation of IMT-Advanced criteria

- Peak Spectral Efficiency
  - Foundation for cell spectral efficiency

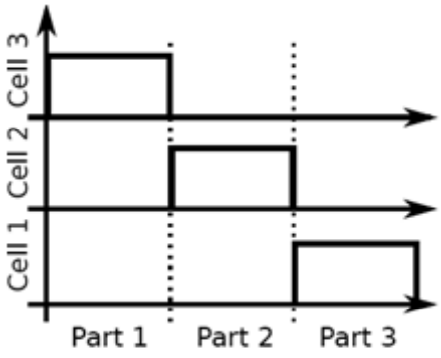
- Cell Spectral Efficiency
  - Determined by system level simulation
  - Path loss model with randomized LoS/NLoS link conditions
  - Frequency Reuse Schemes

➢ An analytical model for the downlink is developed

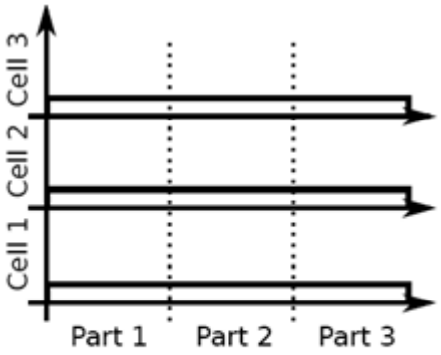


Problem Definition

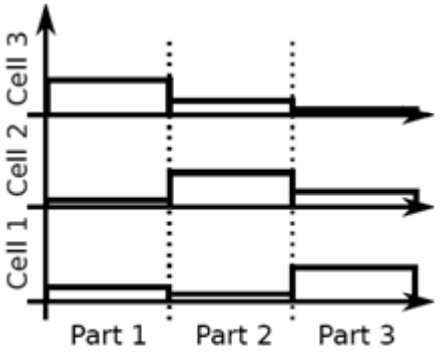
Investigated Frequency Reuse Schemes



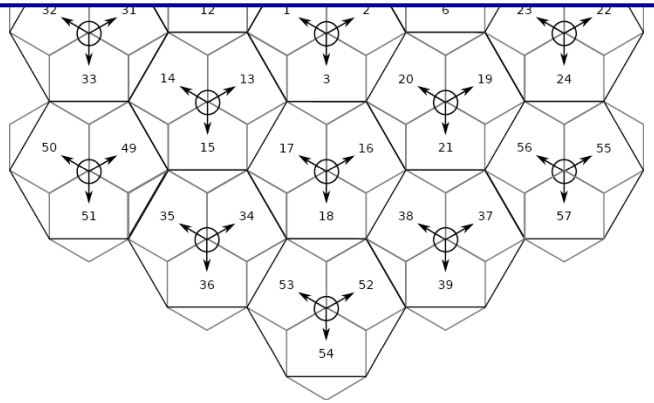
Hard Frequency Reuse



Uniform Frequency Reuse



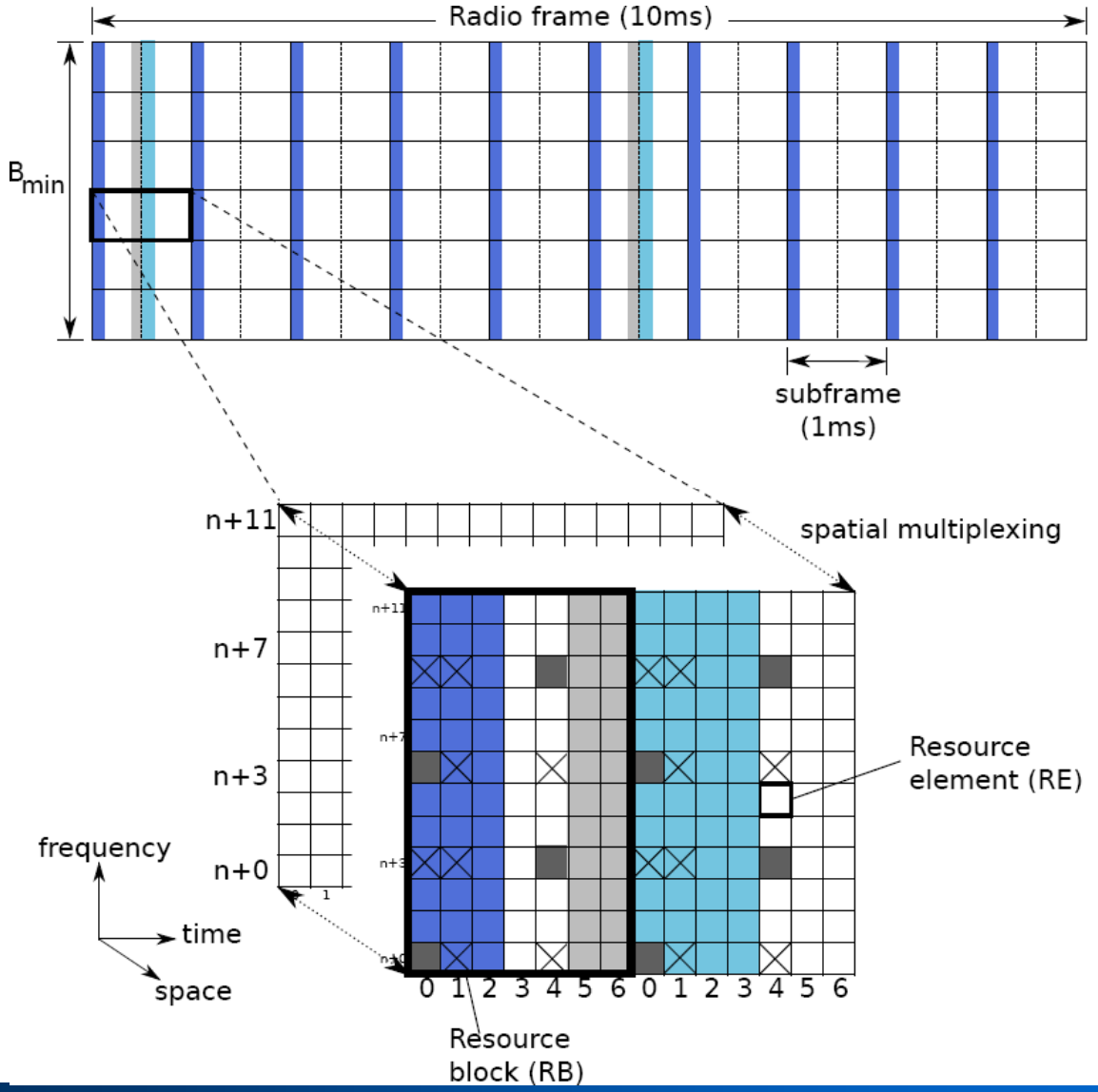
Soft Frequency Reuse
70 - 20 - 10



- An analytical model for the downlink is developed

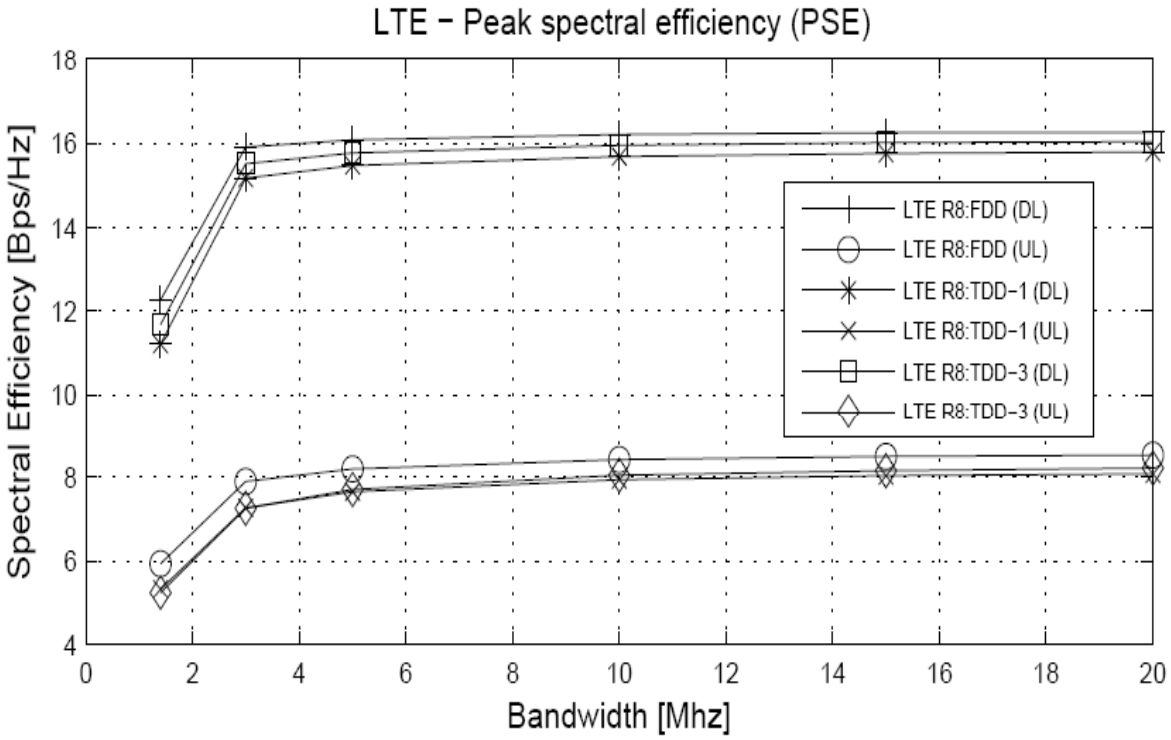
Introduction to Long Term Evolution (LTE)

- OFDMA/ SC-FDMA
- FDD/TDD
- MIMO
  - 4x4 (DL)
  - 2x2 (UL)



Peak Spectral Efficiency

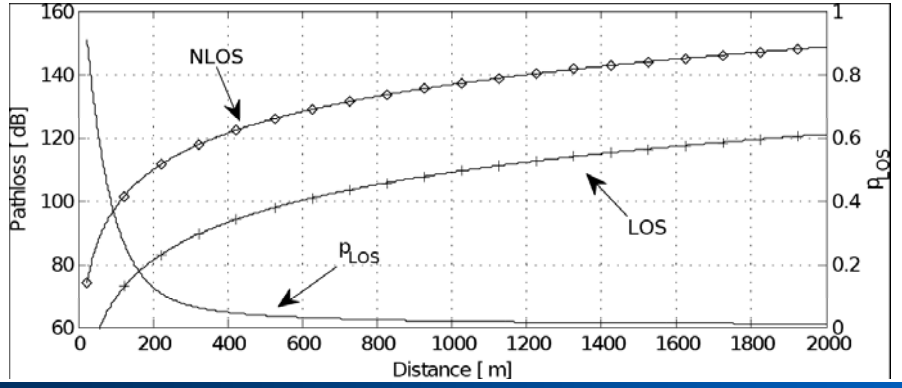
- Minimum overheads, 64QAM-1/1, 4x4 MIMO (DL), 2x2 (UL), perfect channel



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

Cell Spectral Efficiency

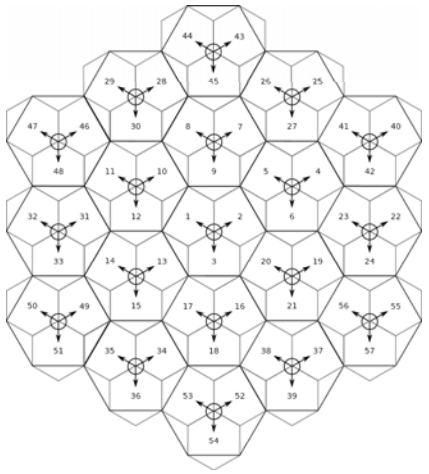
- Definition
  - Scenario net capacity per bandwidth and cell [bps/Hz/Cell]
- Pathloss
  - Either LoS or NLoS link depending on probability conditional on distance d
  - Random SINR depending on distances to all base stations



Cell Spectral Efficiency

- Definition
  - Scenario net capacity per bandwidth and cell [bps/Hz/Cell]

$$SINR\ (d_4) = \frac{P_{Rx,LoS}(d_4)}{P_{Rx,NLos}(d_1) + P_{Rx,LoS}(d_2) + \ldots + P_{Rx,LoS}(d_{57}) + \eta}$$



- Pathloss
  - Either LoS or NLoS link depending on probability conditional on distance d
  - Random SINR depending on distances to all base stations

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

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

Cell Spectral Efficiency

- CSE depends on achievable SINR; from SINR derive possible throughput

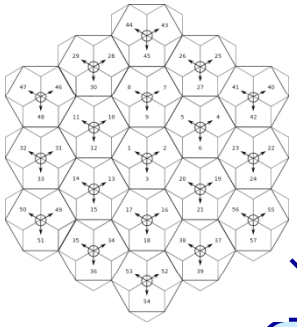
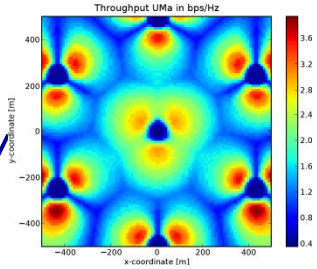
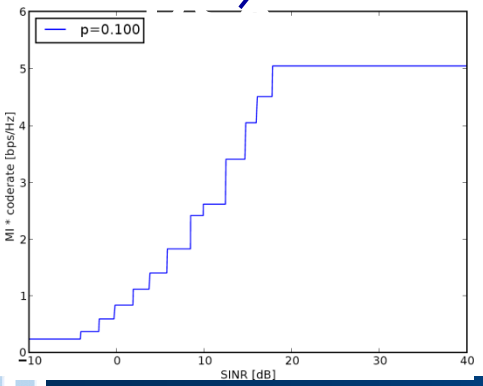


Table lookup and interpolation



SINR → MCS → FER → ARQ → THR



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

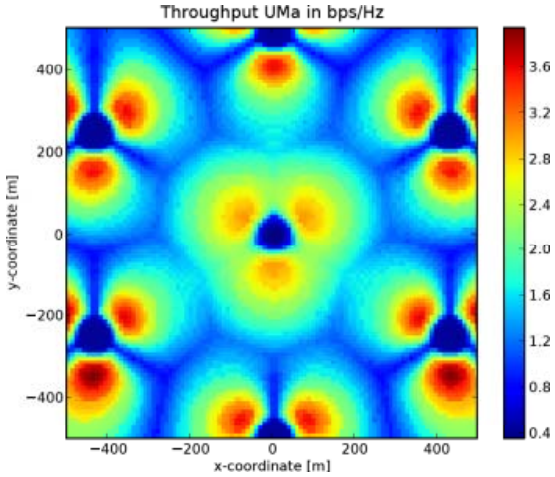
Cell Spectral Efficiency

- Capacity according to proportional fair

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

Gross

Throughput Distribution

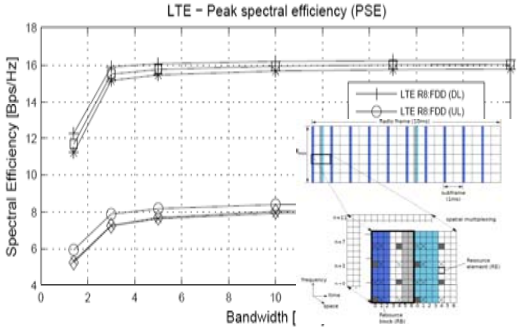


- Spectral Efficiency

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

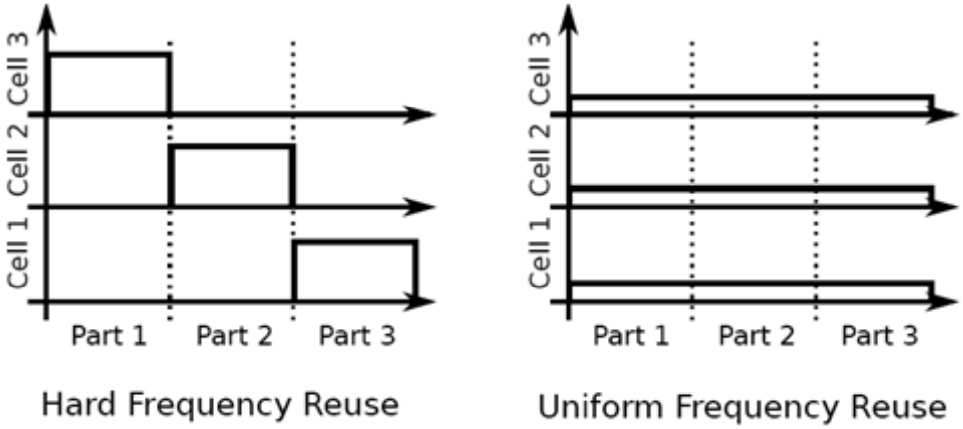
Net

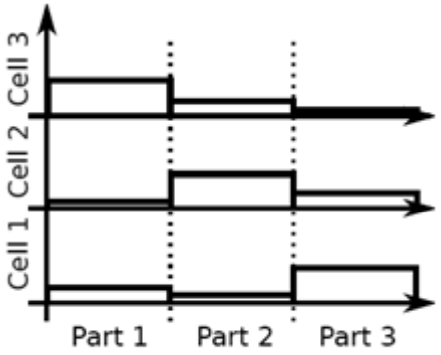
Peak Spectral Efficiency



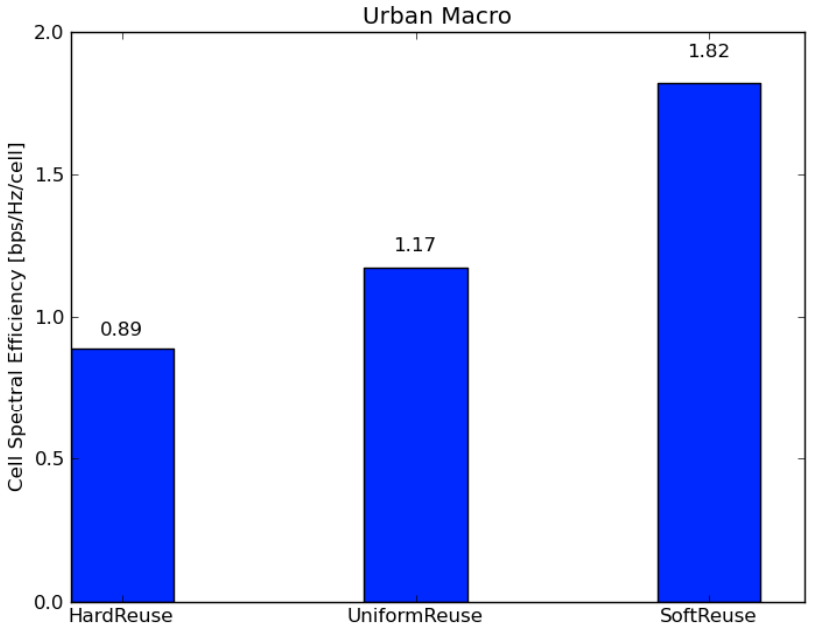
Cell Spectral Efficiency Results

- Reuse Schemes



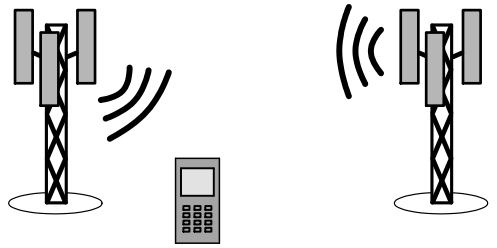


- SISO, 100MHz bandwidth
- Requirement: 2.2 bps/Hz/cell



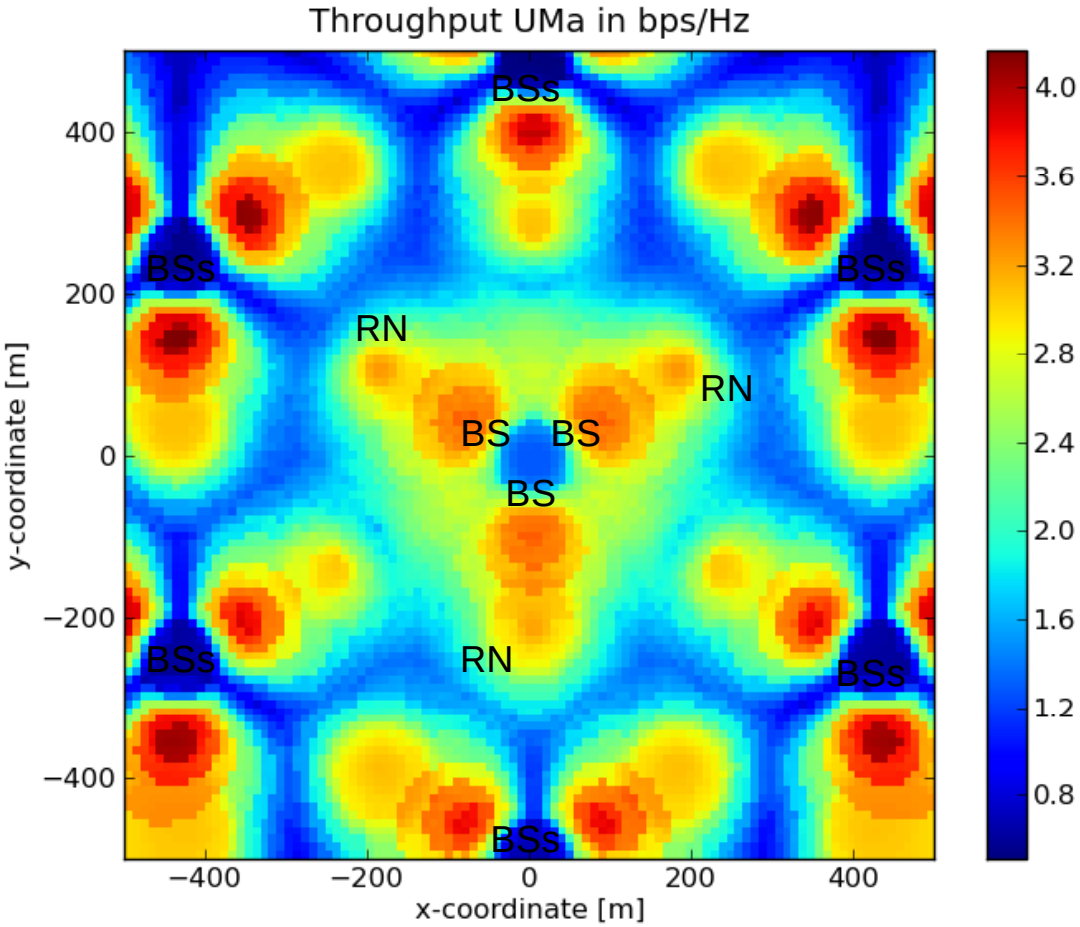
Relay Enhanced Cells

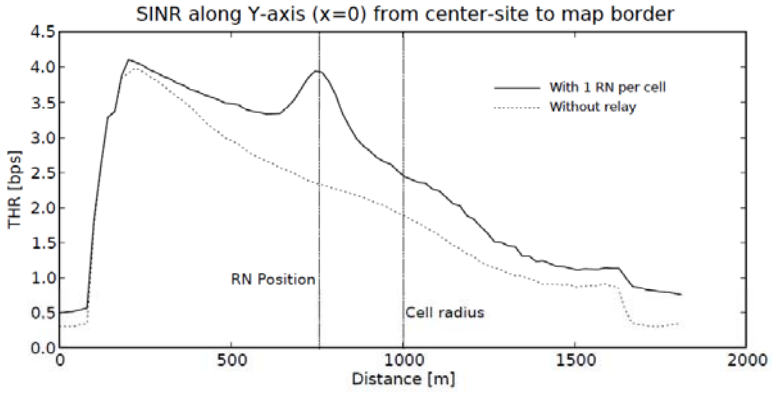
- LTE-Advanced supports Relaying for capacity enhancement and coverage extension
- Include one and three relays per cell to increase spectral efficiency (capacity enhancement)
  - Position at 3/4th of the cell radius
  - 256QAM wireless backhaul, error free conditions
  - Cell capacity according to $\frac{1}{C_{composite}} = \frac{1}{C_{hop1}} + \frac{1}{C_{hop2}}$
- Power mask concept extended to relays
  - 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



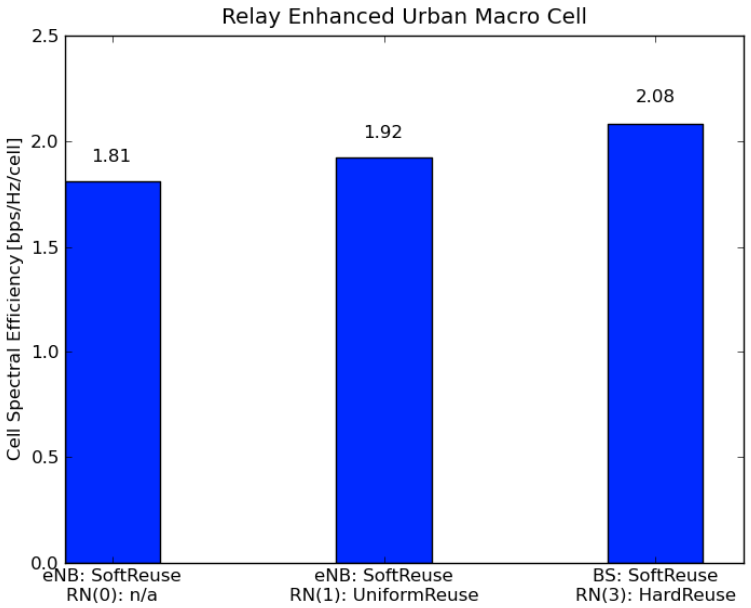


Cell Spectral Capacity for Relay Enhanced Cells

- SISO, 100MHz bandwidth
- 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
  - Can be applied to InH, UMa, RMa scenarios
  - Can be applied to FDD/TDD
  - Allows for investigation of combinations of power masks and RN deployment
- 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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