Cell Spectral Efficiency of a 3GPP LTE-Advanced System

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Schedule of IMT-A Process

Steps in radio interface development process:

Step 1: Issuance of the circular letter
Step 2: Development 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
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
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

![Pathloss Graph]

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Cell Spectral Efficiency

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

  \[
  \text{SINR} (d_4) = \frac{P_{Rx,LoS}(d_4)}{P_{Rx,NLoS}(d_1) + P_{Rx,LoS}(d_2) + \ldots + P_{Rx,LoS}(d_{57}) + \eta}
  \]

- **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 occurrence probability

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

• Mean SINR

\[ SINR(x,y) = \sum_{j \in \Psi} p_{perm,j} \cdot SINR_j(x,y) \]
• CSE depends on achievable SINR; from SINR derive possible throughput

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

- Capacity according to proportional fair

\[ \frac{1}{C_{\text{cell}}^{\text{bit}}} = \frac{1}{A_{\text{cell}}} \sum_{x,y} \frac{1}{b p s y m(x,y)} \]

- Spectral Efficiency

\[ CSE = \frac{C_{\text{cell}}^{\text{bit}} \cdot C_{\text{net}}}{B} \]
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 3/4\(^{th}\) of the cell radius
  - 256QAM wireless backhaul, error free conditions
  - Cell capacity according to
    \[
    \frac{1}{C_{\text{composite}}} = \frac{1}{C_{\text{hop1}}} + \frac{1}{C_{\text{hop2}}}
    \]
- 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
  \[ C_{SE} = \frac{C_{RN,\text{net}}^{\text{bit}} \cdot C_{RN,\text{net}} + C_{BS,\text{net}}^{\text{bit}} \cdot C_{BS,\text{net}}}{B} \]
- Required: 2.2bps/Hz/cell
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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