IMT-A Zellspektraleffizienz bei ratenfairer Betriebsmittelvergabe

19. ComNets-Workshop Mobil- und Telekommunikation

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Outline

Mobile Internet applications are becoming more and more popular

➔ Increasing capacity demands for new mobile radio network standards

How to guarantee that new standards meet the capacity demands?

➔ Performance evaluation and comparison against minimum requirements

- IMT-A evaluation guidelines defined by ITU-R comprising
  - Inspection
  - Analytical investigation
  - System level simulation
- Minimum performance requirements defined by ITU-R
- Key performance indicators
  - Cell spectral efficiency
  - Cell edge user spectral efficiency

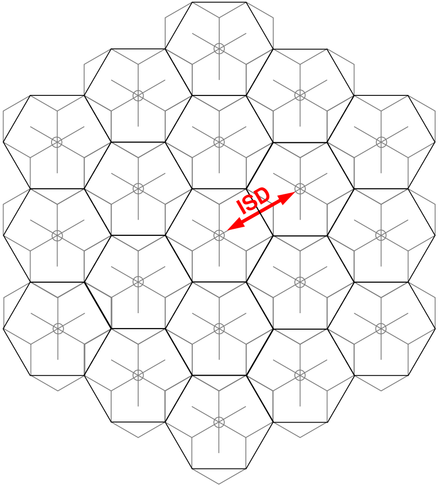
What is the upper bound for the cell spectral efficiency / cell edge user spectral efficiency under optimal (rate fair) resource scheduling?

Features

- Channel model
  - Path loss with distant dependent Line-of-Sight/Non-Line-of-Sight component
  - Spatial correlated shadowing
  - Multiple-Input-Multiple-Ouput (MIMO) transmission
  - Additional attenuation by e.g. walls if applicable
- Deployment setup
  - Indoor (office environment) / outdoor (hexagonal cell setup)
  - Inter-site-distance
  - Distribution of users (uniform and random)
- Station parameter
  - Antenna characteristic
  - Base Station (BS) height
  - BS / Mobile Station (MS) transmit power
  - ...
- Traffic model

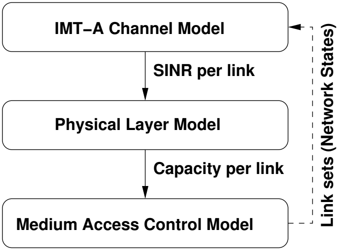
Deployment Scenarios (outdoor)

- Urban Micro (UMi)
  - 50 % of users outdoors (pedestrian users) and 50 % of users indoors
  - Inter-site-distance: 200 m
- Urban Macro (UMa)
  - 100 % of users outdoors in vehicles
  - Inter-site-distance: 500 m
- Suburban Macro (SMa)
  - 50 % of users in vehicles and 50 % of users indoors
  - Inter-site-distance: 1299 m
- Rural Macro (RMa)
  - 100 % of users outdoors in high speed vehicles
  - Inter-site-distance: 1732 m



Sub-Models

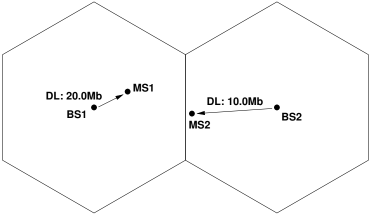
- IMT-A channel model
- Physical layer model
  - Decides under which conditions a transmission is successful according to the Shannon bound
  - Determines the gain for ideal MIMO transmission
- Medium Access Control (MAC) model
  - Coordinates the transmissions between stations considering mutual interference
  - Controls traffic load of stations to account for rate fair scheduling



MAC Model (Example)

- Traffic Vector

$$T = \begin{pmatrix} \text{BS1} \rightarrow \text{MS1} \\ \text{BS2} \rightarrow \text{MS2} \end{pmatrix} = \begin{pmatrix} 20.0 \\ 10.0 \end{pmatrix}$$



- Network States (NSs)

$$NS1 = \begin{pmatrix} \text{BS1} \rightarrow \text{MS1} \\ \text{BS2} \rightarrow \text{MS2} \end{pmatrix} = \begin{pmatrix} 15.0 \\ 0.0 \end{pmatrix}$$

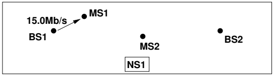
$$NS2 = \begin{pmatrix} 0.0 \\ 5.0 \end{pmatrix}; \qquad NS3 = \begin{pmatrix} 10.0 \\ 2.5 \end{pmatrix}$$

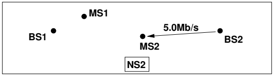
- Optimization problem

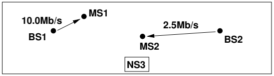
$$\delta_1 \cdot NS1 + \delta_2 \cdot NS2 + \delta_3 \cdot NS3 = T \text{ such that } \sum_{i=1,2,3} \delta_i \text{ is minimal.}$$

- Solution (shortest schedule)

$$\delta_1 = 0.0; \qquad \delta_2 = 1.0; \qquad \delta_3 = 2.0$$







Algorithm

1. Create all feasible network states NS_i
   - Consider which links are feasible (e.g. BS→MS, but not BS→BS)
   - Combine links to sets considering certain contraints (e.g. in a synchronous TDD system BSs and MSs may not transmit simultaneously)
   - Determine the SINRs for all receiving stations in the link sets
   - Map the SINRs to data rates if feasible (e.g. if the SINR for one link is not sufficient for the most robust Modulation and Coding Scheme (MCS), the according NS is assumed to be not feasible)
2. Solve the Linear Programing (LP) problem

$$\sum_i \delta_i \cdot NS_i = T \text{ such that } \sum_i \delta_i \text{ is minimal.}$$

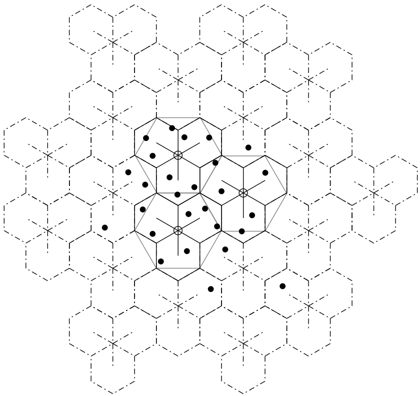
3. Calculate the system capacity C

$$C = \frac{\sum_i t_i}{\sum_j \delta_j} \text{ with } t_i \text{ as entries of } T$$

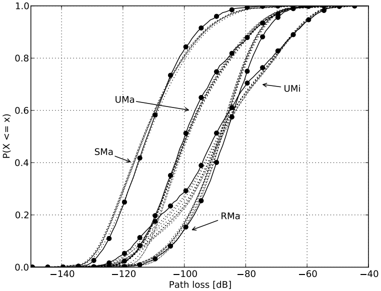
Problem: complexity is increasing exponentially (np-hard)
➔ Maximum size of scenario is limited

Scenario Setup

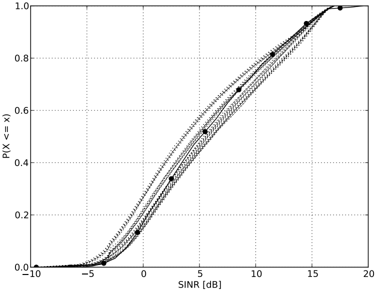
- Simplifications compared to IMT-A scenarios due to complexity
  - Only 3 sites (9 cells) instead of 19 sites (57 cells)
  - Only 3 MSs per BS instead of 10 MSs distributed randomly per cell on average
- Only downlink traffic
- Wrap-around to allow for modeling interference at the edges of the scenario
- Monte-Carlo simulation with 100 independent drops
- Simulation time: ∼53 days on Intel Xeon processor @ 2 GHz



Validation



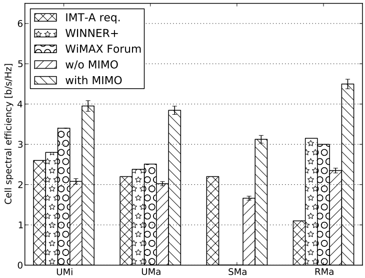
CDFs of path loss



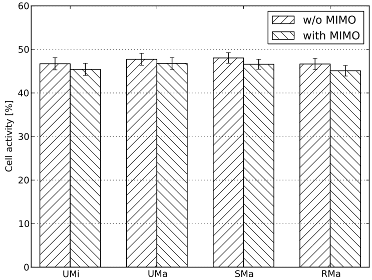
CDFs of SINR (UMa)

- Solid curves represent the results of the capacity model
- Dotted graphs show reference results taken from the WINNER+ project
- The close match of all curves indicate that the
  - channel models are implemented correctly
  - distribution of stations and their associations are correct
  - scenario geometry complies with IMT-A requirements

Evaluation



Cell spectral efficiency



Cell activity

- Only with MIMO transmission for all four scenarios the IMT-A requirements are met
- Results from WINNER+ and WiMAX Forum indicate that capacity improvements seem to be feasible also under rate fair scheduling
- Cell edge user spectral efficiency equals cell spectral efficiency exceeding IMT-A requirements by one order of magnitude
- In an optimal schedule each cell is active only 50 % of time

- A model to calculate the upper bound cell spectral efficiency for IMT-A scenarios assuming rate fair scheduling has been presented
- IMT-A requirements can be met for rate fair scheduling in general, if MIMO transmission is applied
- Under rate fair scheduling the IMT-A requirements for the UMi, UMa and SMa scenario seem to be quite ambitous
- A high degree of coordination between adjacent cells is required to maximize system capacity

Thank you for your attention!

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