Performance Studies on LTE Advanced in the Easy-C Project

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Agenda

1. Introduction
2. EASY C
3. LTE System Simulator
4. Results
5. Conclusions and Outlook

Introduction

- EUTRAN (Evolved Universal Terrestrial Radio Access Network) also called LTE (Long Term Evolution) is the upcoming standard for packet switched based mobile communication
- LTE physical layer is based on OFDMA in the DL and SC-FDMA in the UL
- The scope of EASY C is beyond LTE -> “LTE Advanced”
- EASY C field trials are accompanied by system simulations
- Candidate algorithms shall be evaluated before the real system is implemented
- Accuracy of simulations can be evaluated by comparison with measurements

EASY C
Overview

EASY C Project topics / objectives

- BMBF project
- 3 year project / start Q2/2007
- Preparation of a new Standard: “LTE Advanced”
- Focus on improved spectral efficiency, cell border throughput, fairness, and latency
- Field trials with optimized MIMO algorithms

- Project partners:

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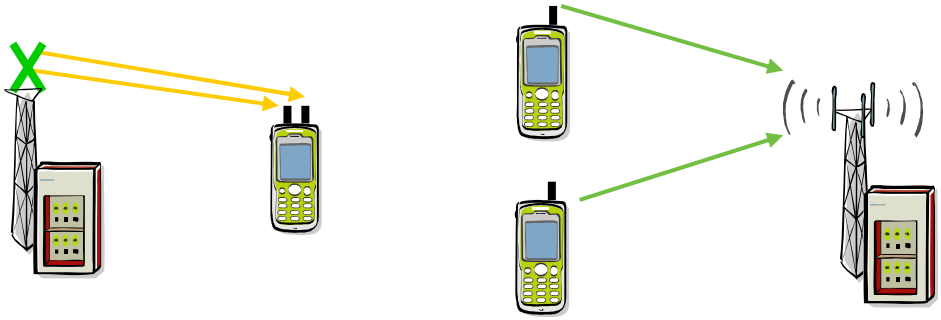
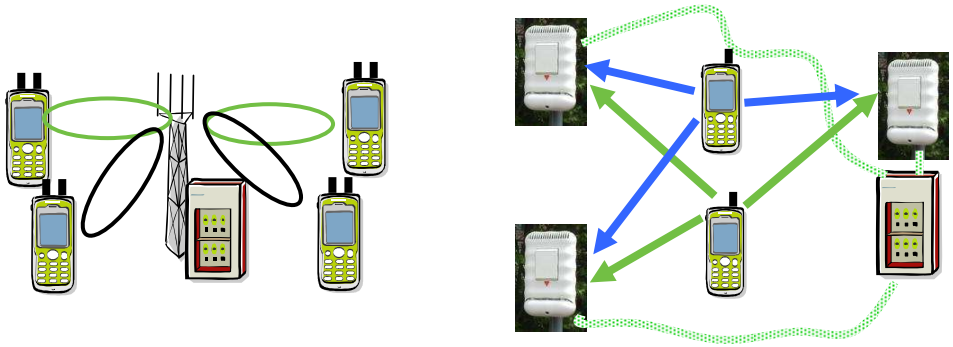
Field Trial Phasing





- Step 1: Basic LTE Release 8 system
  - SU-MIMO
  - MU-MIMO in UL
- Step 2: Enhancements above Release 8
  - Remote Radio Heads
  - Enhanced receivers
  - Optimized codebooks
  - Beam Forming
  - MU-MIMO in DL
- Step 3: Collaborative MIMO Schemes
  - Network MIMO
  - Cooperative scheduling
  - Interference coordination

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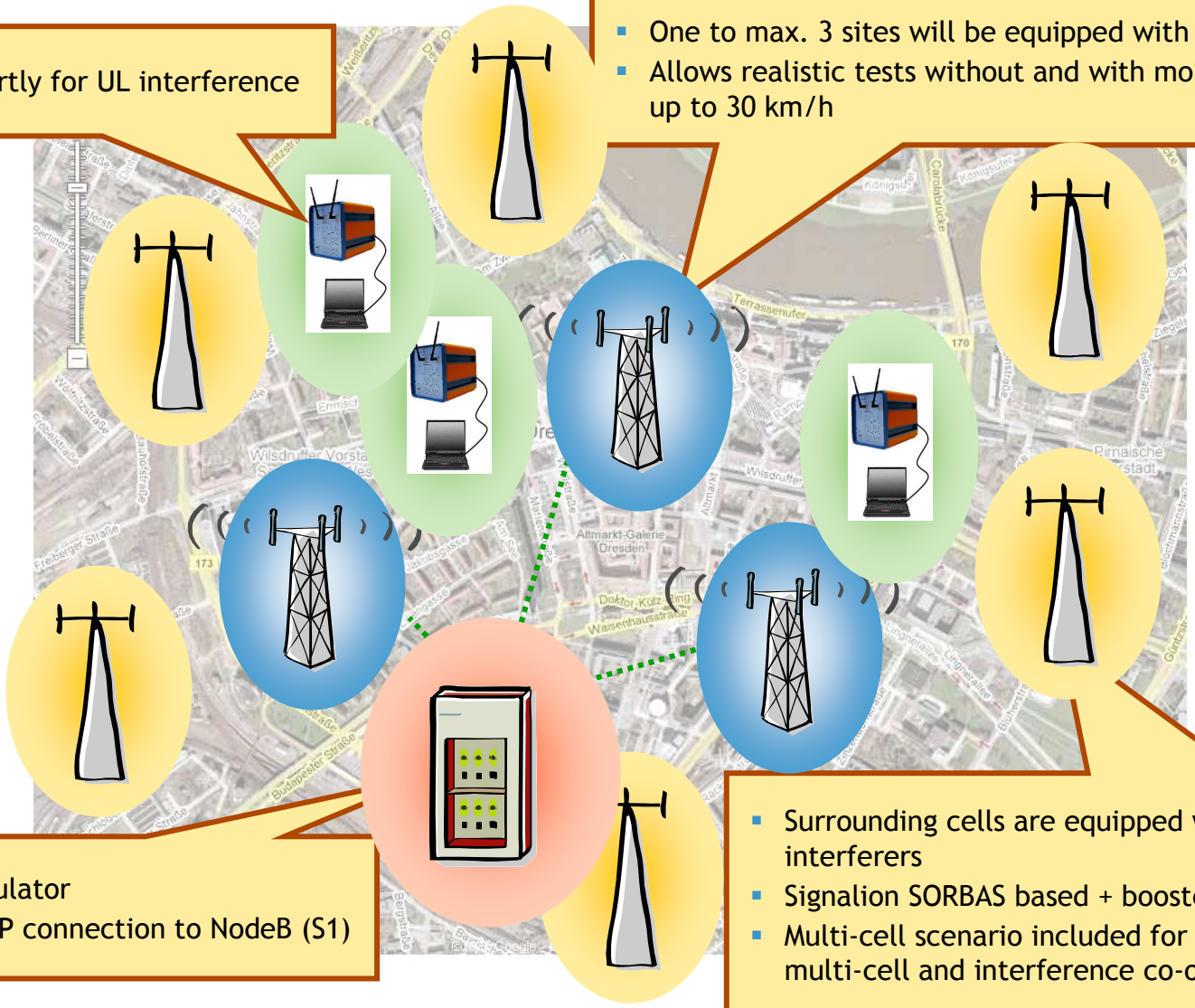
Test Campus Dresden

- Test Ues, partly for UL interference

- One to max. 3 sites will be equipped with eNodeBs
- Allows realistic tests without and with mobility up to 30 km/h



- AGW simulator
- 16 Mb/s IP connection to NodeB (S1)

- Surrounding cells are equipped with interferers
- Signalion SORBAS based + boosters
- Multi-cell scenario included for MIMO/ multi-cell and interference co-ordination

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EASY C
System Simulation Approach

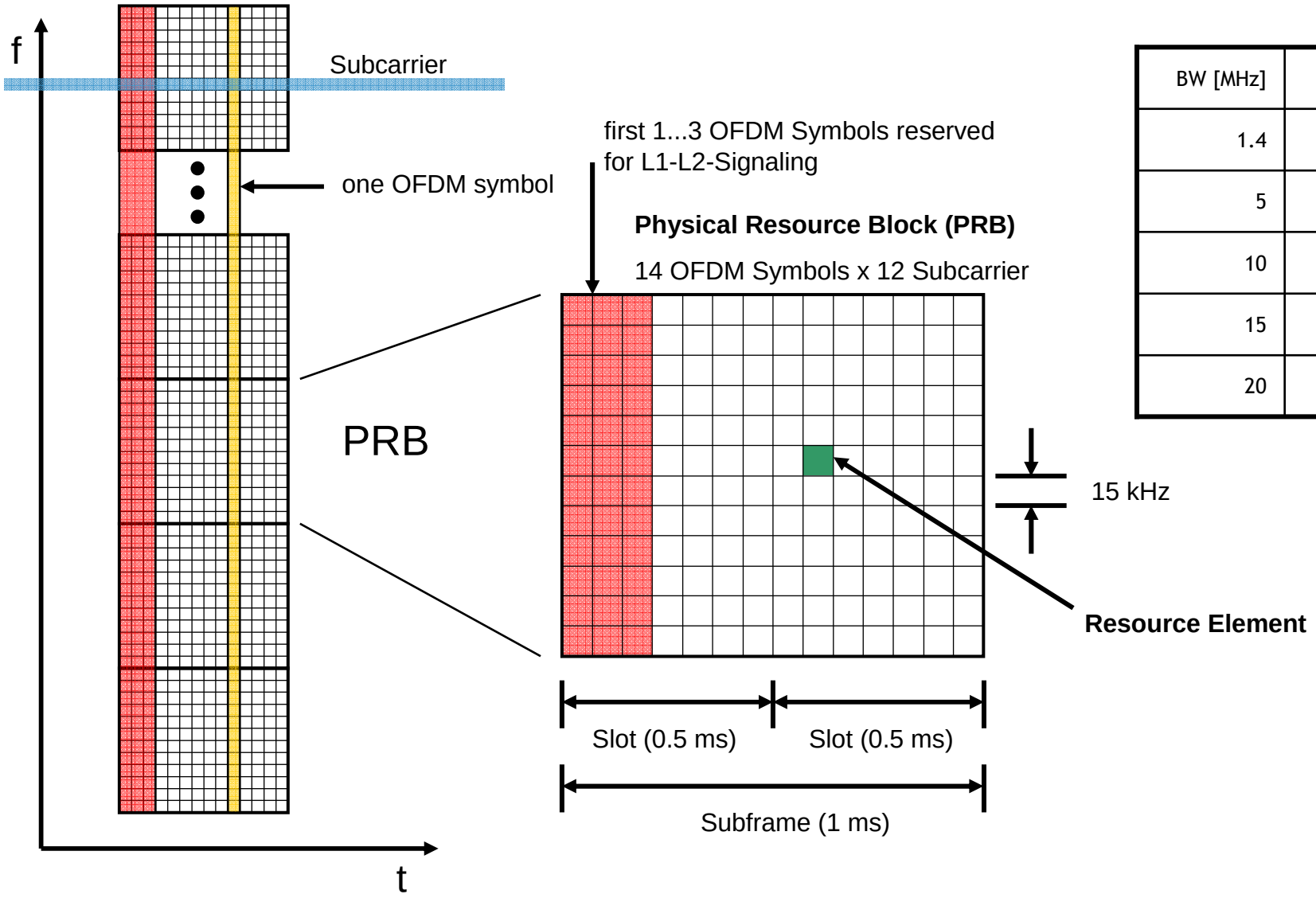
- Field tests shall be accompanied by system simulations
  - Evaluation of candidate algorithms
  - Evaluation of accuracy of simulation models
- System Simulations shall be 3GPP/NGMN compliant (TR 25.814, R1-070674)
  - Full simulation of interference
  - Wrap around
  - Spatial channel model
  - Full buffer simulation
- Results shall be realistic (channel estimation loss model, ...)
- **First phase:** Calibration of simulators of different partners (1x2 in DL and UL)
- **Second phase:** Reference model results (2x2 in DL, 1x2 in UL)
  - Spectral Efficiency
  - User throughput CDF, fairness
  - Cell border throughput
- **Third phase:**
  - Simulation of algorithms
  - Substitution of spatial channel model with
    - ray tracing data
    - channel measurements

LTE System Simulator
Objectives

- Evaluation of LTE system performance in UL and DL
  - Antenna systems
    - 2x2, 4x2, 4x4, ...
    - correlated antennas
    - uncorrelated antennas
    - mixture of correlated and uncorrelated antennas
  - Algorithms
    - Scheduler
    - Link Adaptation
    - Interference Coordination
  - Combination of performance enhancing technologies
- Optimization of algorithms that are impacted by spatial channel behavior

LTE System Simulator

Reminder: DL LTE Channel Structure



BW [MHz]	Nr. PRB
1.4	6
5	25
10	50
15	75
20	100

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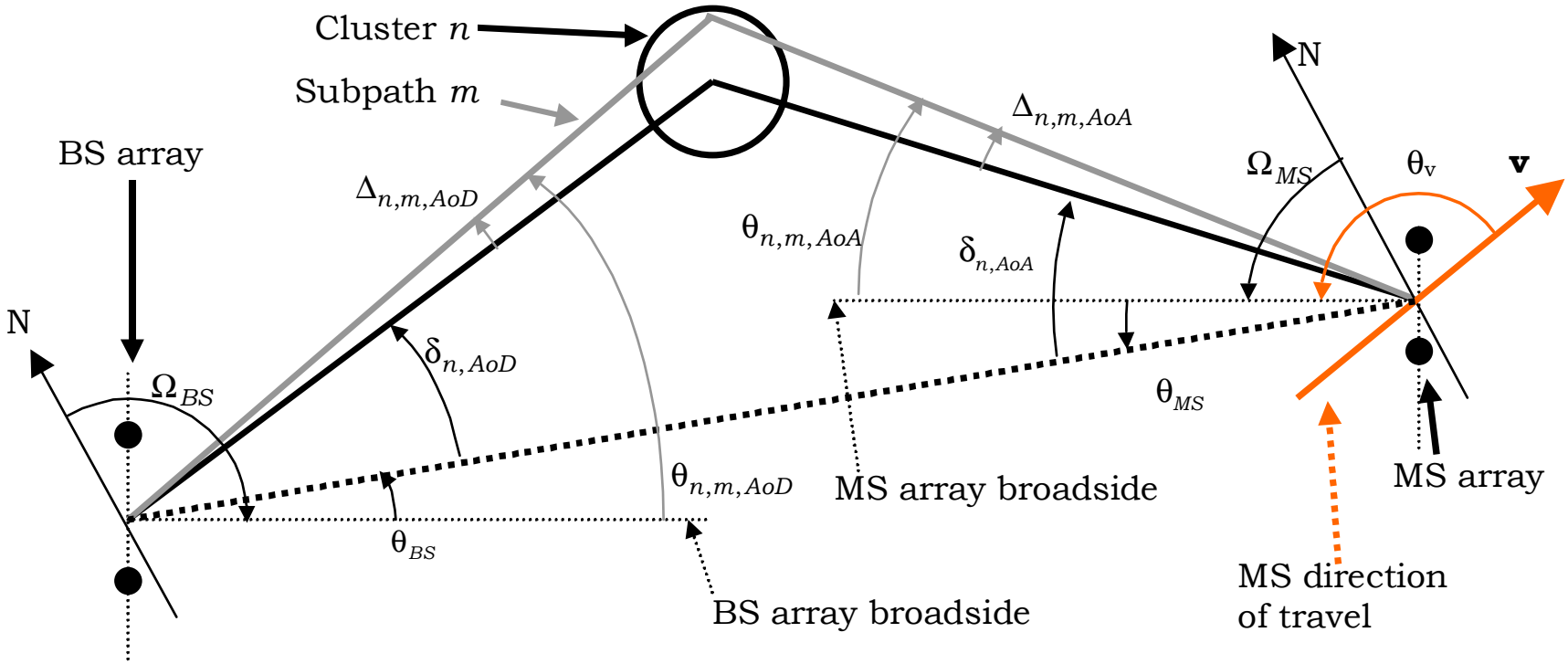
LTE System Simulator
Detailed Features

- Features
  - Spatial channel model (WiM, Winner Model) generates spatial fast fading
  - Full simulation of interference, i.e. SCM is used for all channels
  - Event driven simulation on resource element basis, i.e. per subcarrier (in frequency) and per OFDM symbol (in time), lower granularity possible
  - Monte Carlo drops in order to get a quicker randomization of mobile positions (during drop path loss and shadowing is kept constant)
  - Link to system interface based on MIESM (Mutual Information Effective SINR Mapping)
  - Receiver is explicitly modeled (MMSE or MRC)
  - 1x1, 1x2, 2x2, 4x2, 4x4 TX/RX antennas
  - Single and multiple stream transmissions (e.g. PARC and SDMA)
  - Switching between single stream and multiple stream transmission

LTE System Simulator
Detailed Features

- Features (continued)
  - Frequency selective and diverse allocation
  - Different schedulers
  - CQI generation, CQI reporting delay, CQI reporting period, CQI filtering
  - Ideal and realistic link adaptation
  - Asynchronous, adaptive HARQ (DL) and synchronous HARQ (UL) with feedback delay
  - Transport blocks consisting of an arbitrary number of PRBs
  - BLER calculation on transport block basis (with chase combining and IR)
  - Signaling overhead
  - Pilot symbol patterns (for 1, 2, 3, and 4 antennas)
  - Full and soft fractional frequency reuse
  - Large number of measurement values

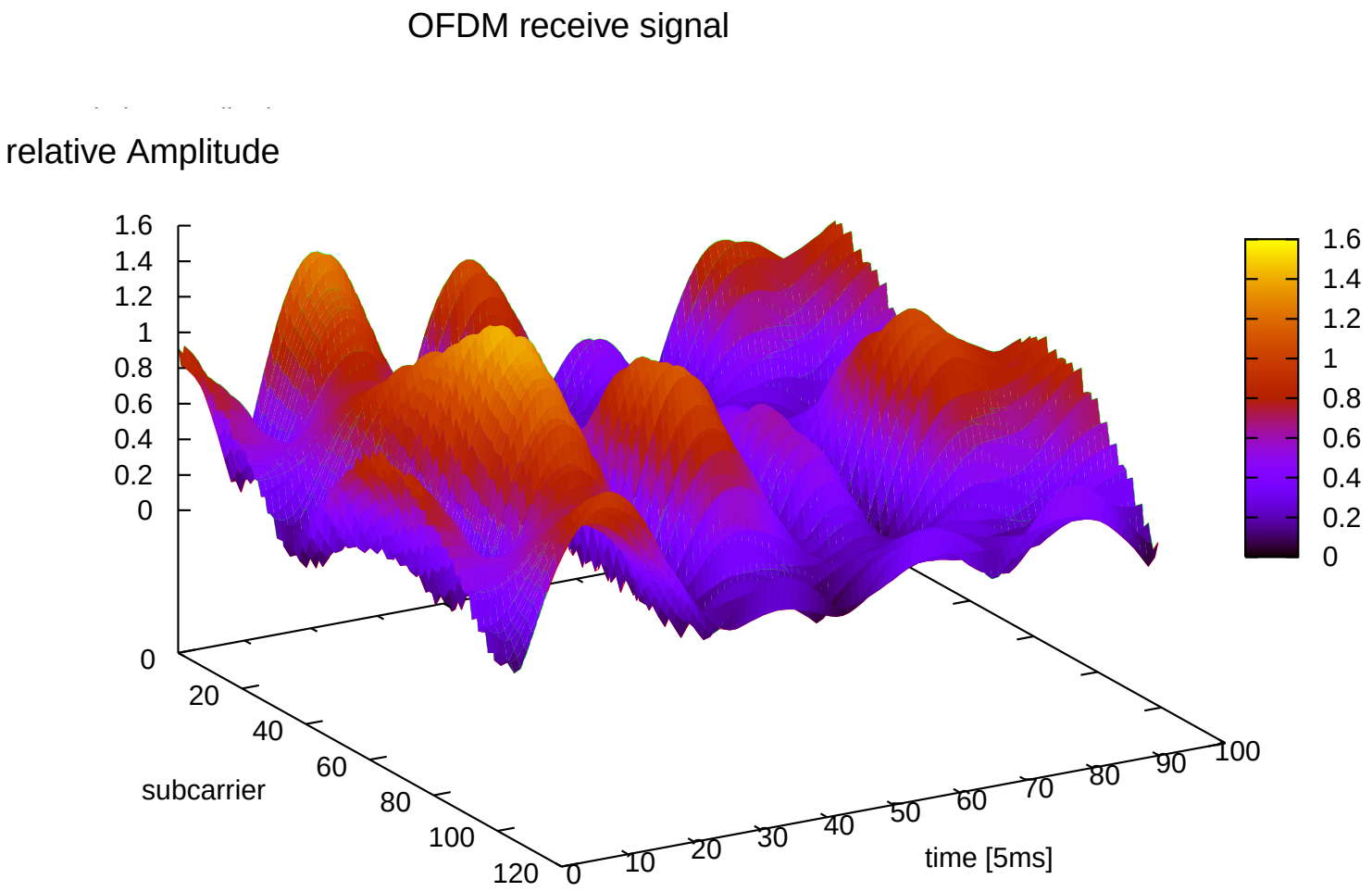
LTE System Simulator
Spatial Channel Model



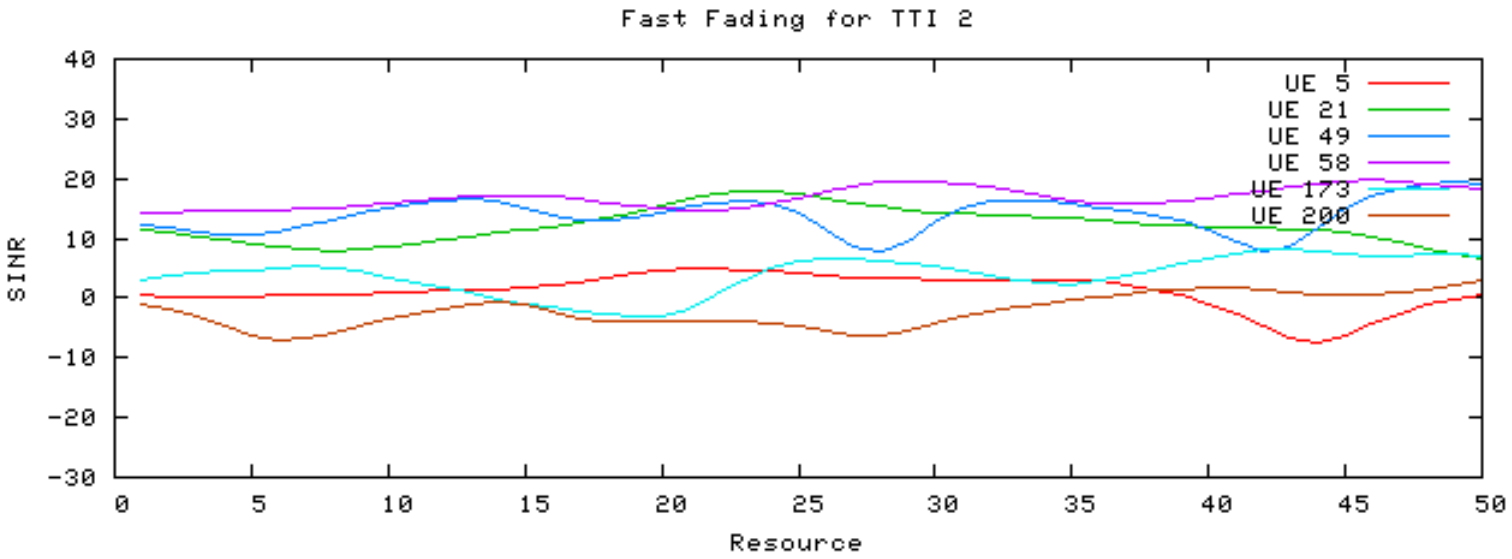
source: 3GPP TR 25.996

Example: urban macro: 6 paths with 20 subpaths each

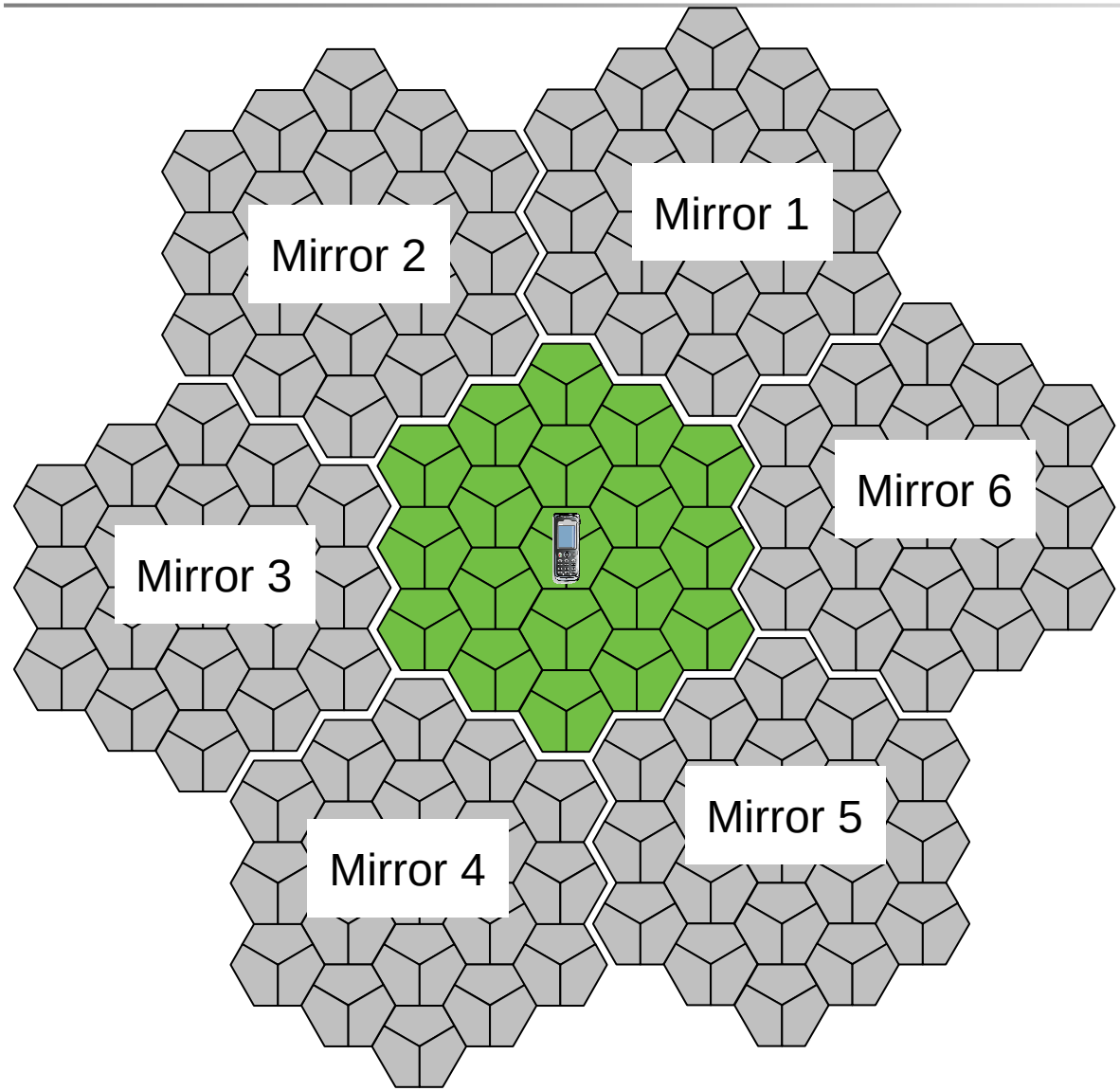
LTE System Simulator
Fast Fading for OFDM



LTE System Simulator
SINR over Frequency and Time

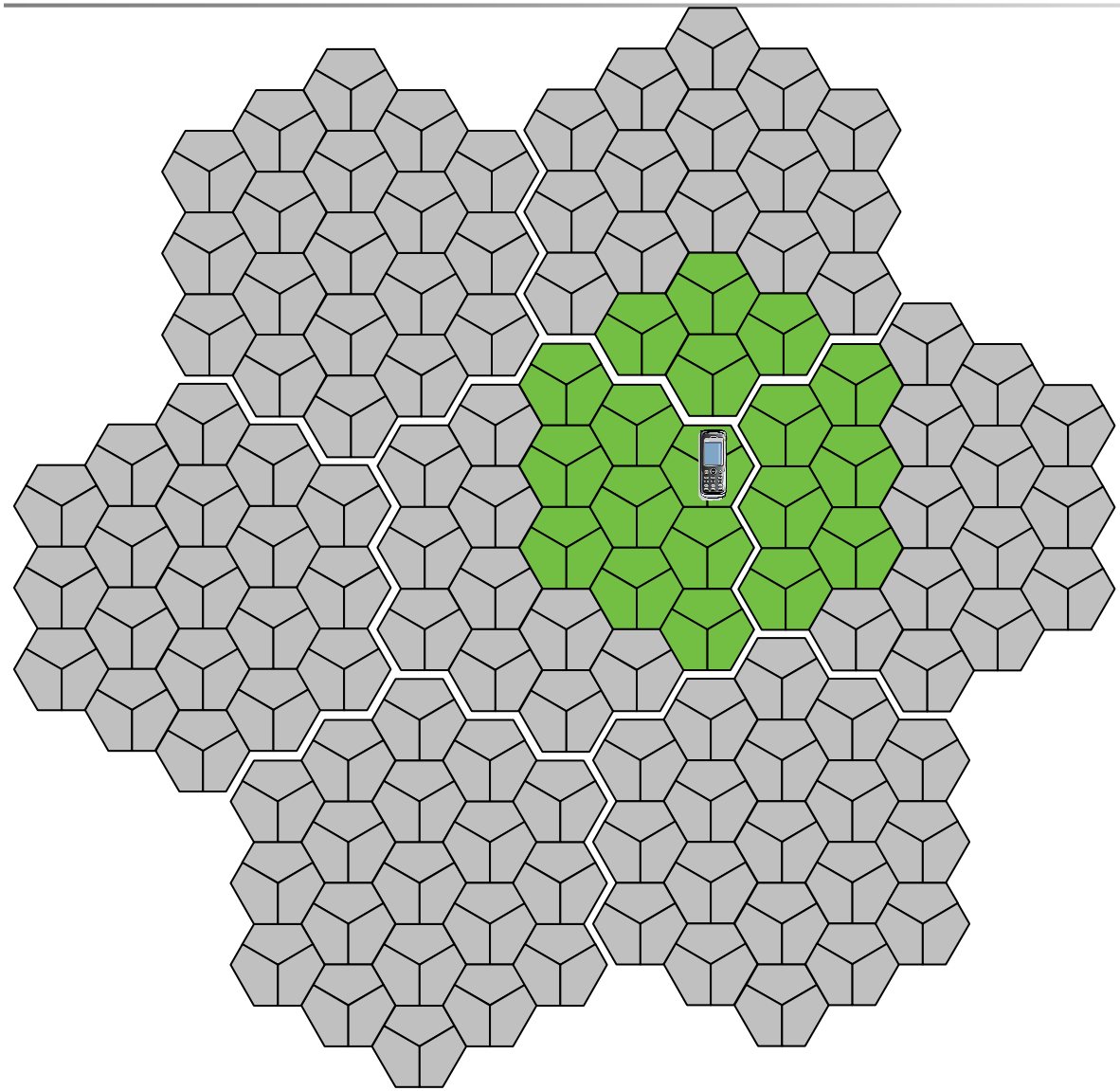


LTE System Simulator
Wrap Around



- Wrap Around avoids border effects
- every BTS has six mirrors
- every mobile claims to be in the middle of 2 rings of BTS sites

LTE System Simulator
Wrap Around



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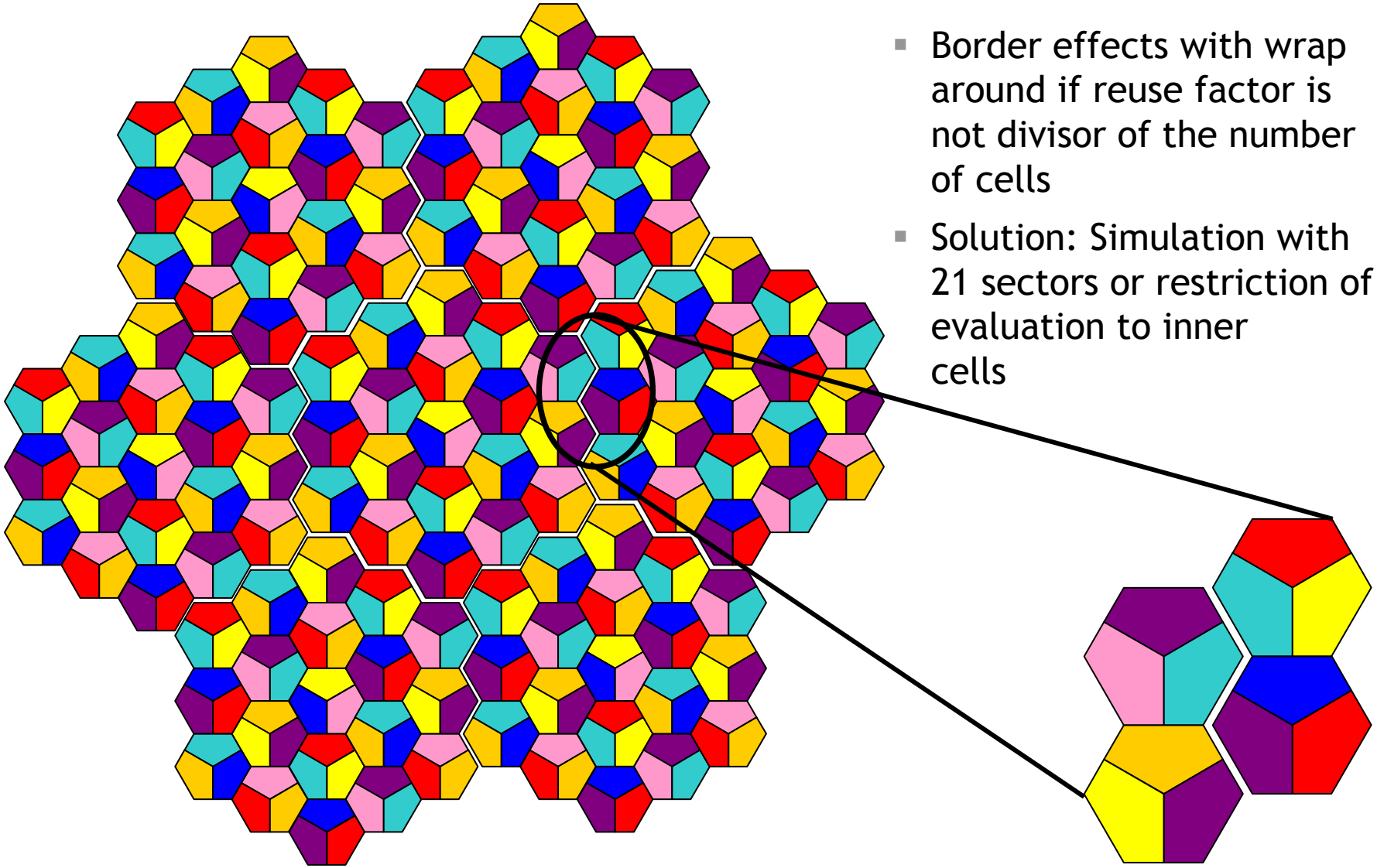
LTE System Simulator

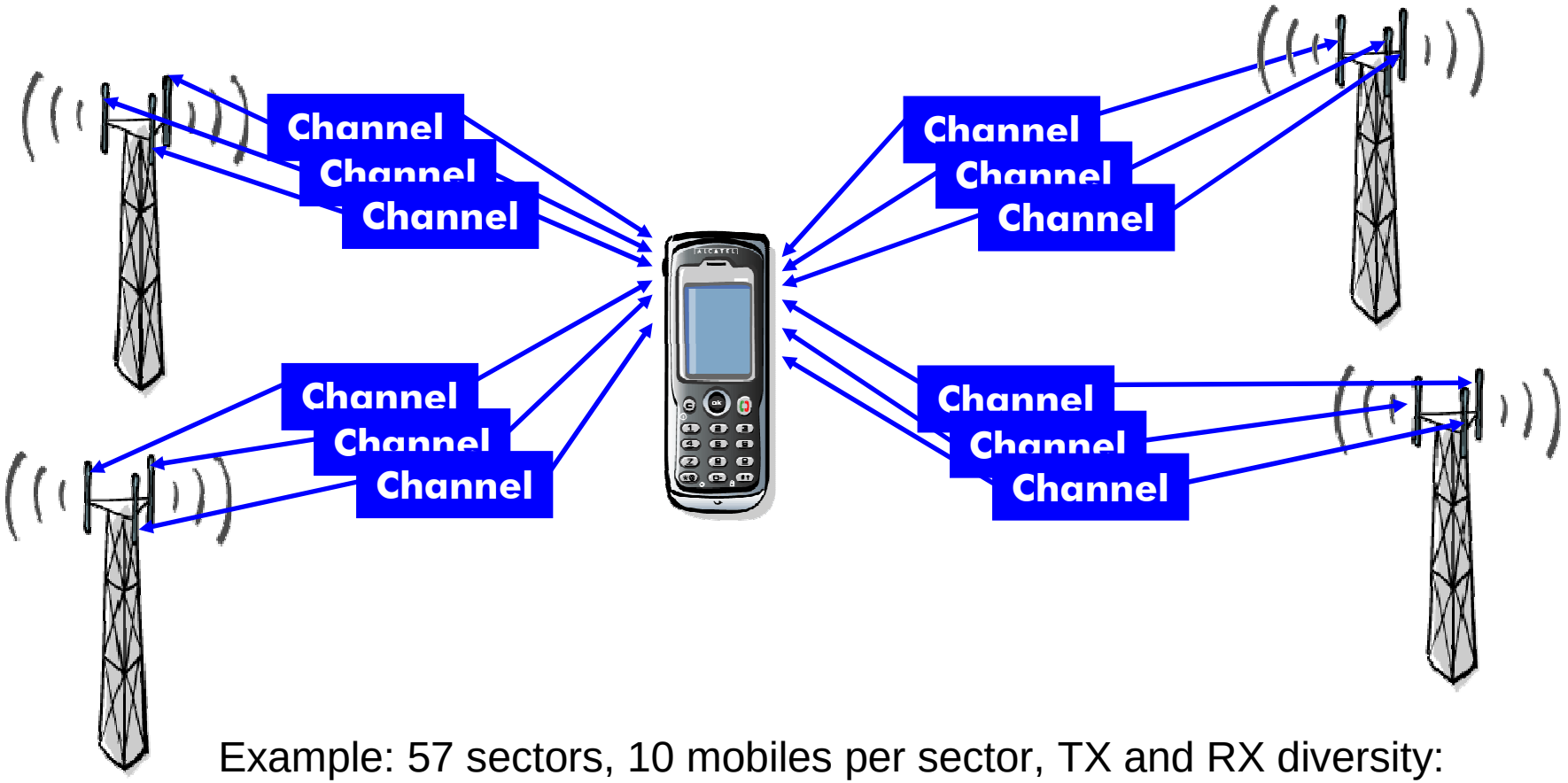
Wrap Around in case of Frequency Reuse



- Border effects with wrap around if reuse factor is not divisor of the number of cells
- Solution: Simulation with 21 sectors or restriction of evaluation to inner cells

LTE System Simulator

Connect all Mobile and Transceiver Antennas

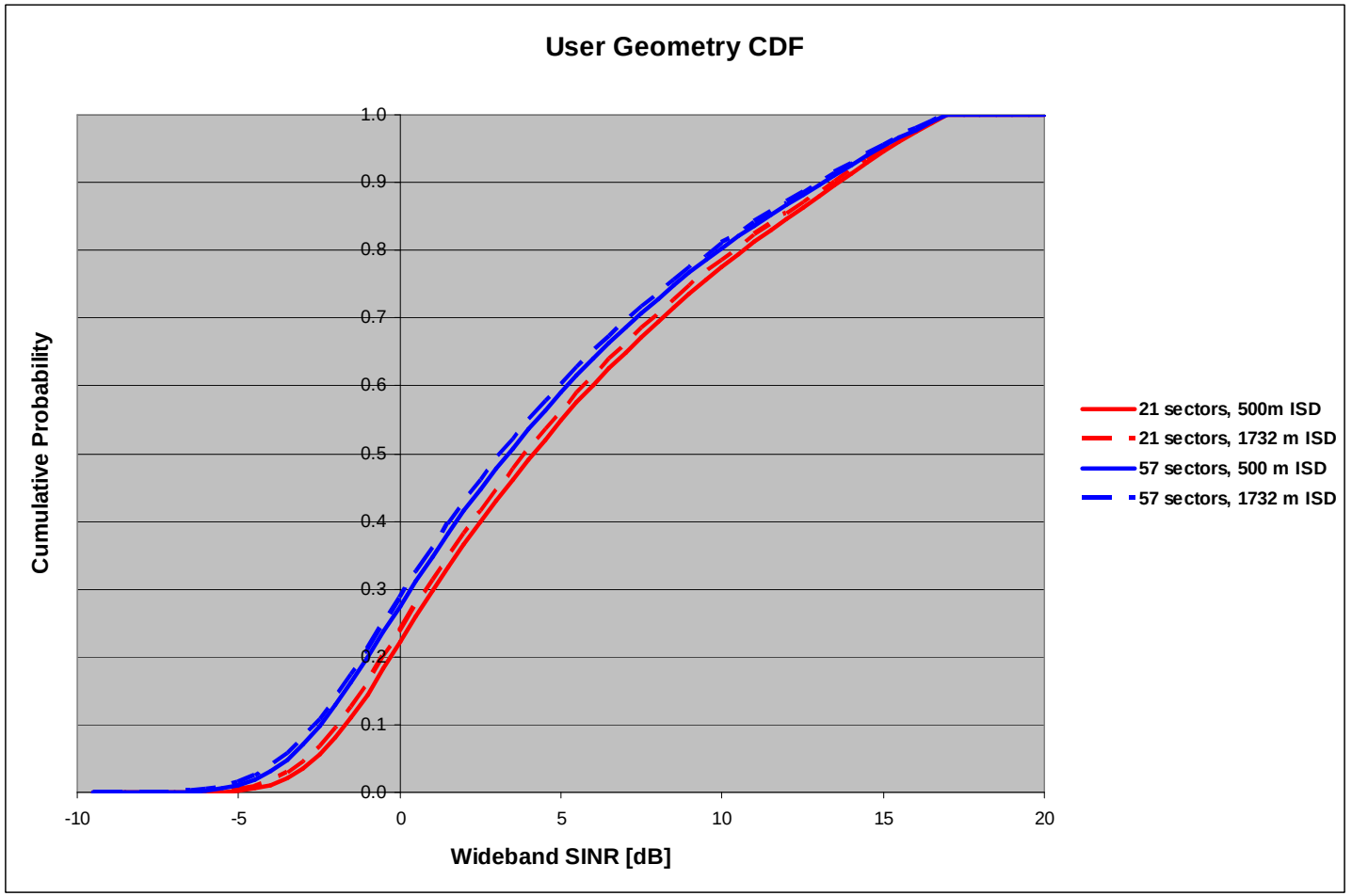


Example: 57 sectors, 10 mobiles per sector, TX and RX diversity:

57 * 2 * 57 * 10 * 2 = 129,960 channels

Results

Calibration: Geometry (exemplary)



User Geometry = E[S]/(E[I] + R*N)

S = Signal Level, I = Interference Level, R = Receiver Noise Figure

Results

Reference Simulations: Exemplary results

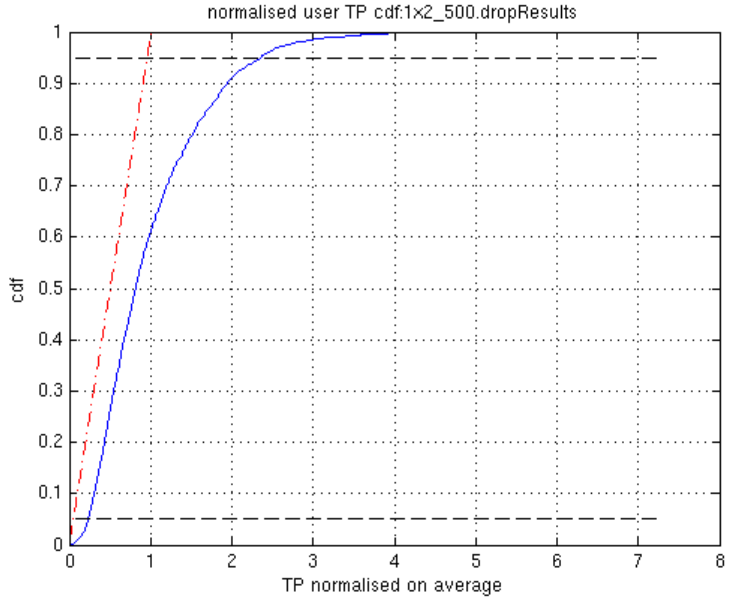
DOWNLINK

Antenna Configuration	Inter Site Distance [m]	Spectral Efficiency [bits/s/Hz]	5-Percentile of UE Throughput [kbit/s]
1x2	1732	1.28	204
1x2	500	1.38	324
2x2	1732	1.37	255
2x2	500	1.46	345

UPLINK*

Antenna Configuration	Inter Site Distance [m]	Spectral Efficiency [bits/s/Hz]	5-Percentile of UE Throughput [kbit/s]
1x2	500	0.97	295
1x2	1732	0.85	57

without IoT control -> high spectral efficiency, low edge user throughput



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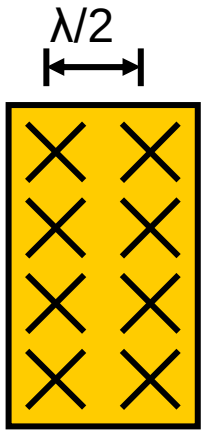
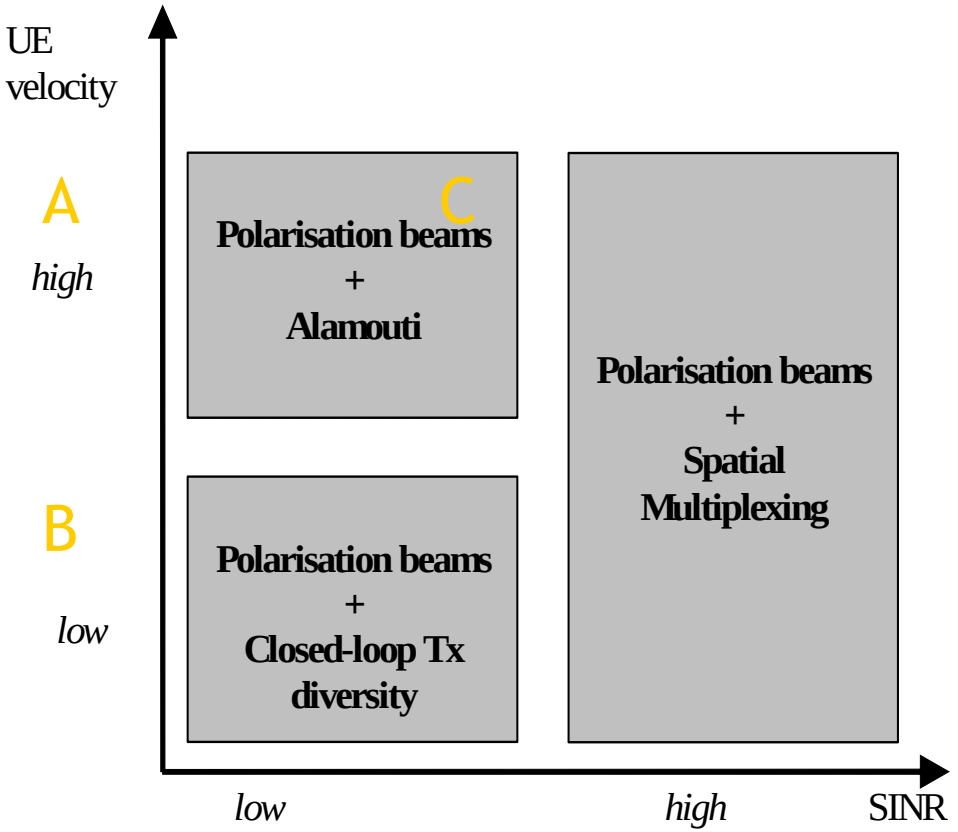
Results

Step 2 Candidate: Adaptive 4x2 SU-MIMO





Results

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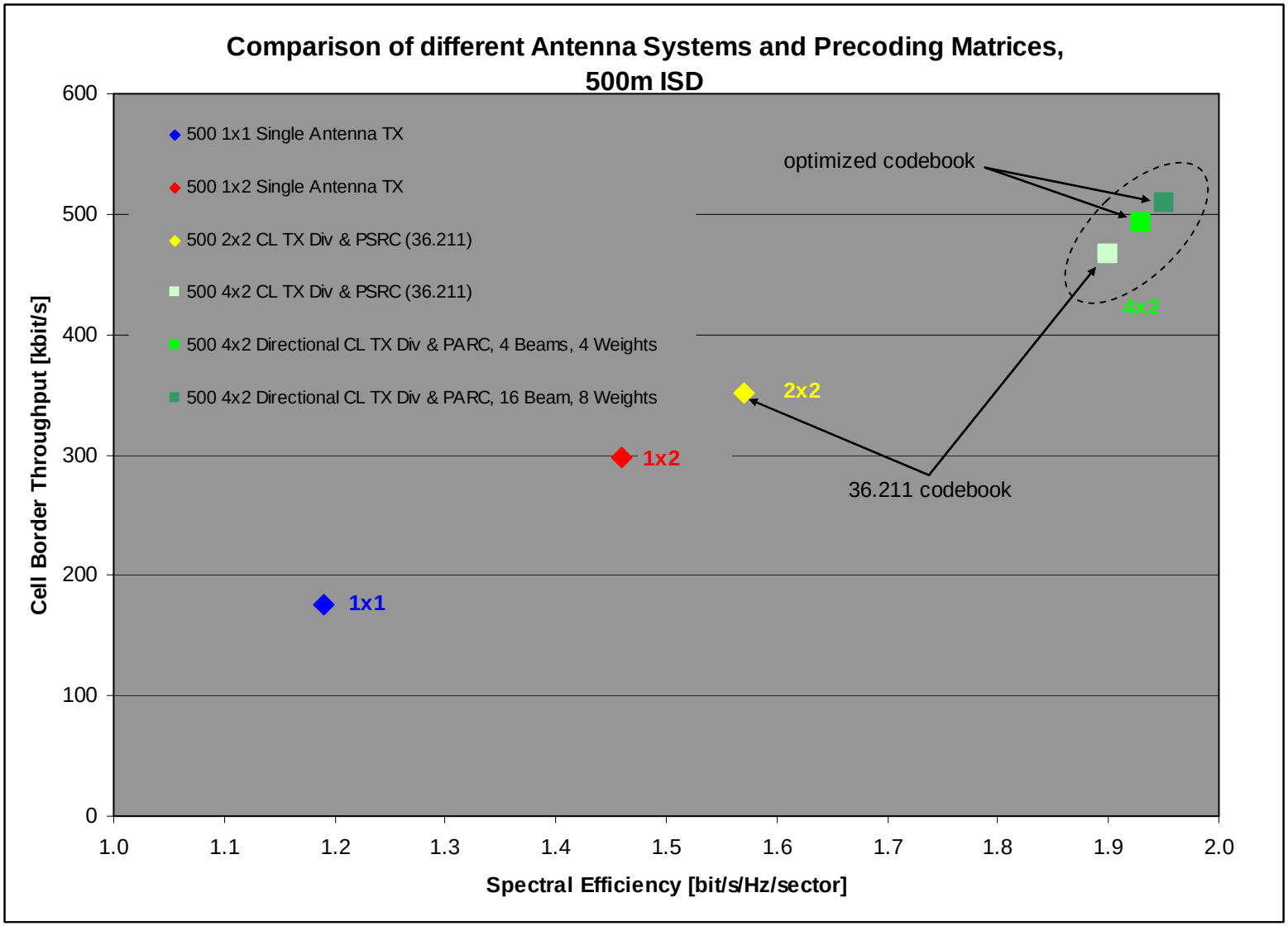

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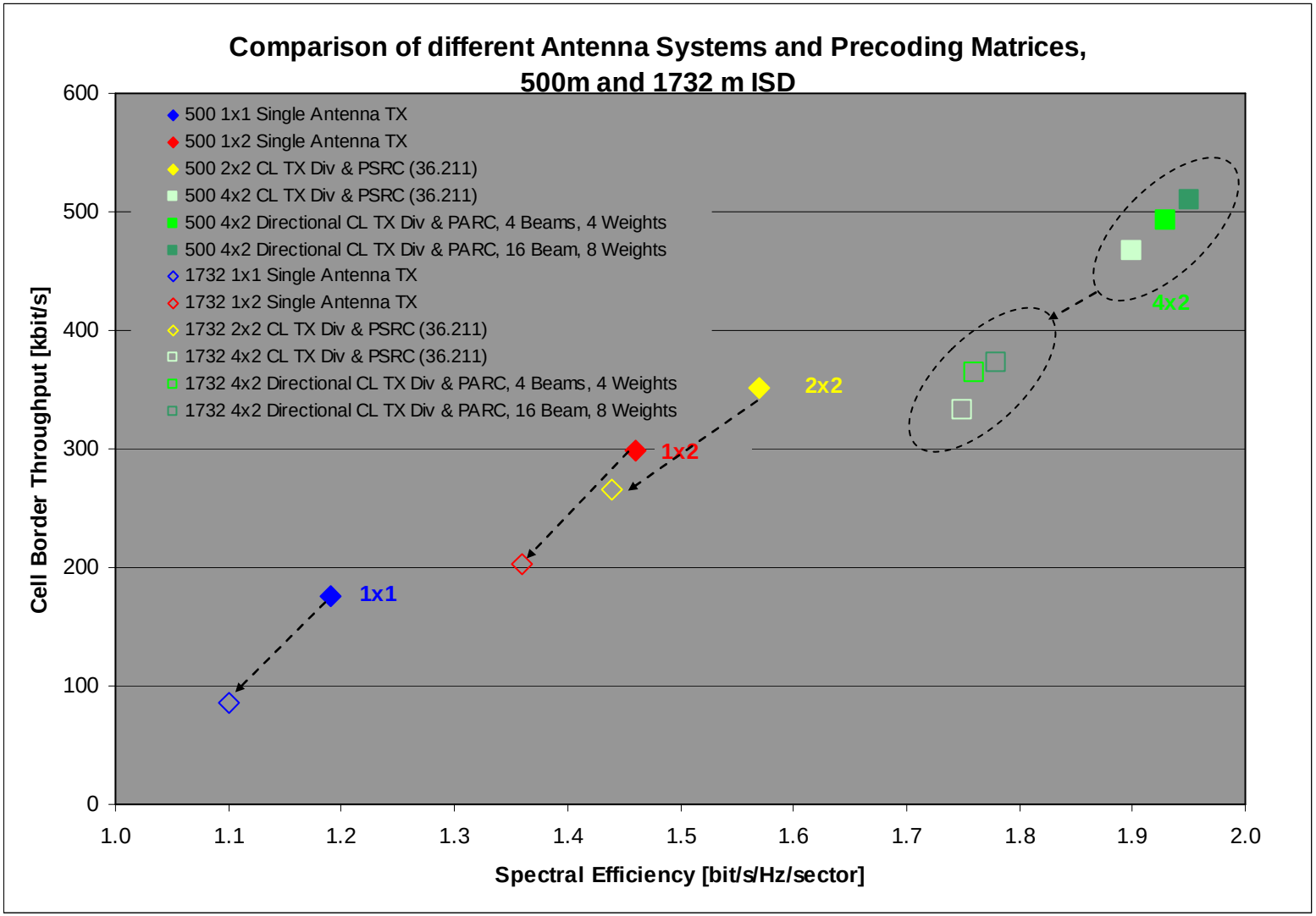
Results

Step 2 Candidate: Adaptive 4x2 SU-MIMO



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Conclusions and Outlook

Conclusions

- System simulations have been performed that show the benefits of candidate algorithms for LTE Advanced
- The results are based on an accurate simulator that includes models for the spatial channel behavior
- Parts of the receiver have to be modeled in the system simulator; a huge number of channels has to be simulated -> computing time saving programming is essential

Outlook

- Many more sophisticated algorithms wait for their simulative evaluation
- Channel measurements allow the evaluation of the accuracy of the ray tracing data and spatial channel models
- System simulations will be based on ray tracing data and channel measurements –> possibility to compare field test and simulation results

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