

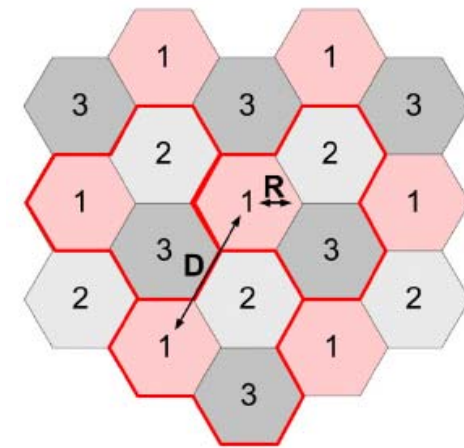
Coverage Extension and Capacity Increase of Cellular Multihop WiMAX Networks

Christian Hoymann

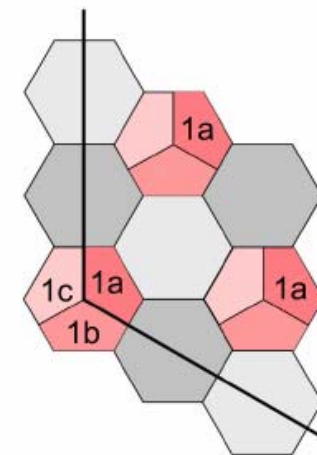
FFV, Aachen, 30.März 2007

Cellular Scenarios

- In OFDM WiMAX preamble / FCH are transmitted
 - with most robust PHY mode BPSK $\frac{1}{2}$
 - without adaptive antenna techniques
 - without subchannelization
- Broadcast phase limits system's range
- Dimensioning approach focuses on worst case scenario (synchronized TDD network)
- Suppression of cellular interference by
 - clustering to increase co-channel distance
 - Sectorization to reduce number of interferer
- IST-WINNER pathloss models in 5 GHz bands
 - Wide area LOS
 - Rural NLOS
 - Manhattan LOS-NLOS
- OFDM-based IEEE 802.16:
 - Bandwidth 20MHz
 - 30 dBm transmit power for all nodes



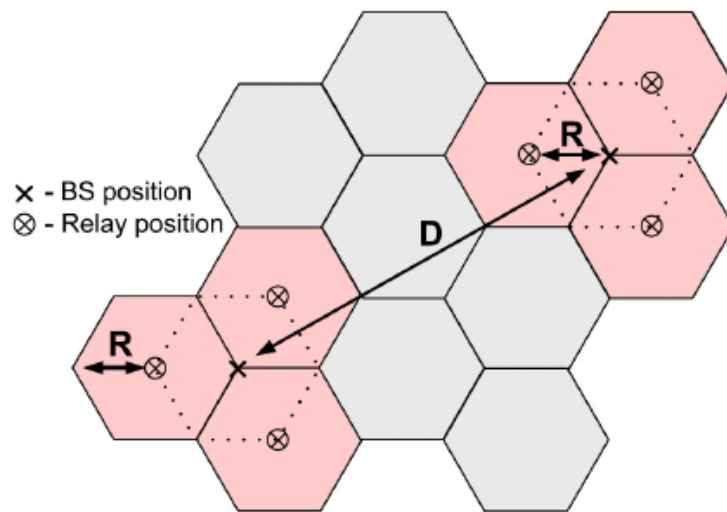
(a) Cell cluster order 3



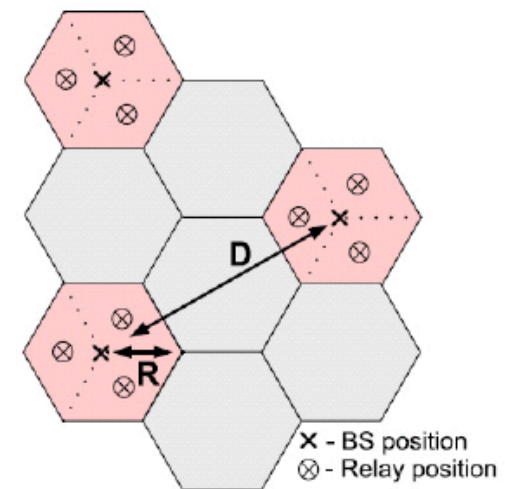
(b) 3-sectored cells using cluster order 3

Cellular Multihop Scenarios

- Coverage scenario extends BS coverage
- Throughput scenario increases cell throughput

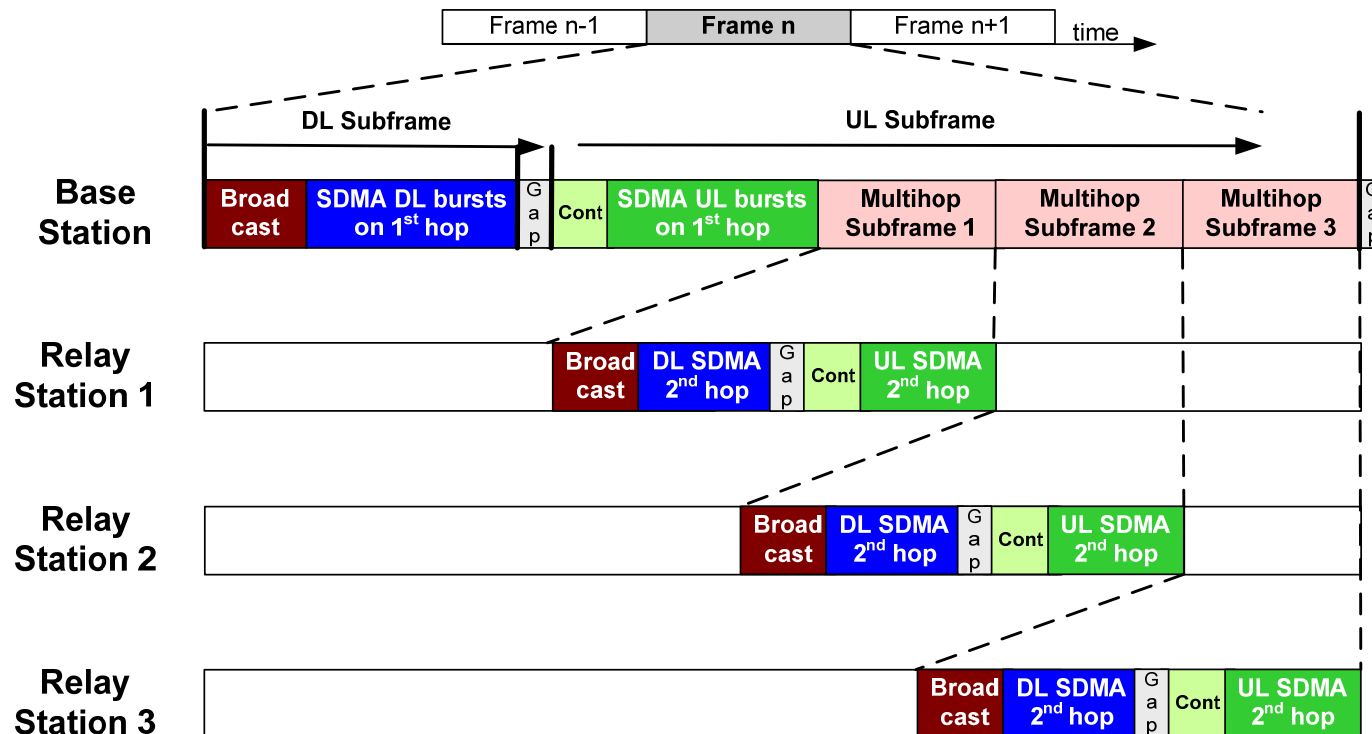


(a) Coverage scenario (cluster order 3)



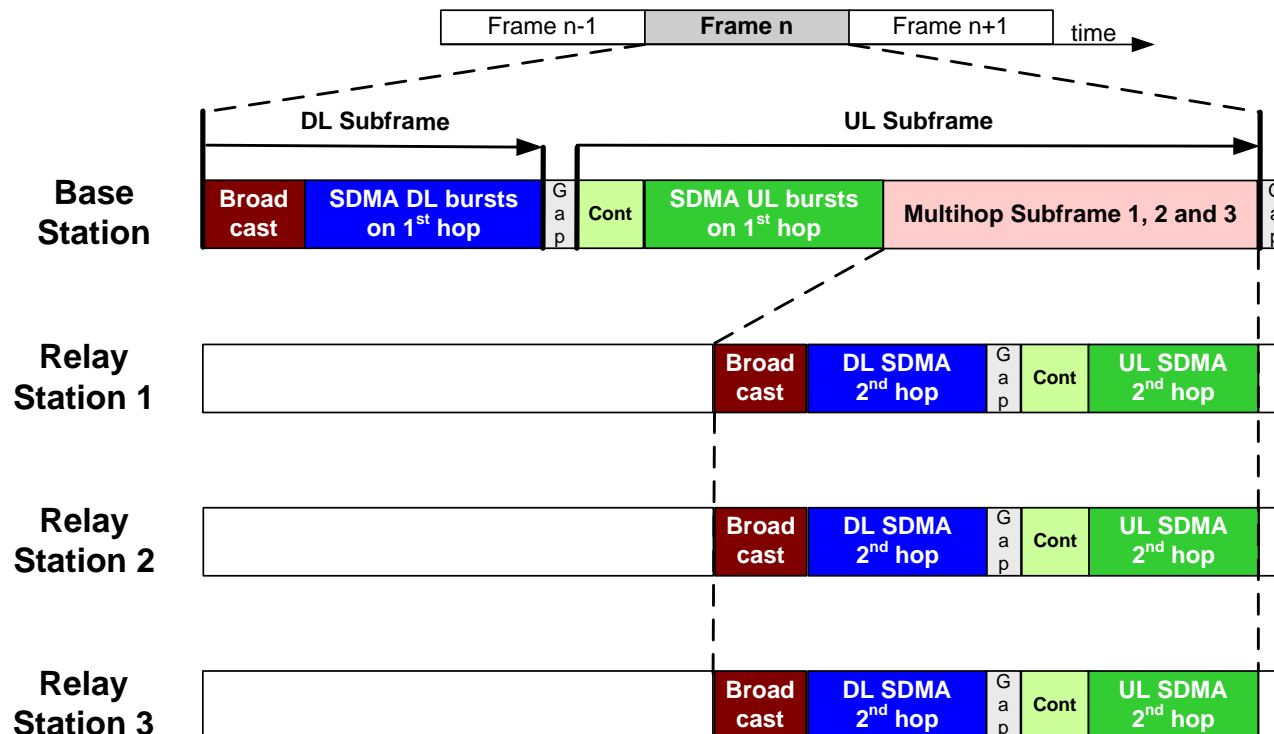
(b) Throughput scenario (cluster order 4)

TDM Operation of Relays



- Only one relay of a cell is active
- One relay of each co-channel cell interferes

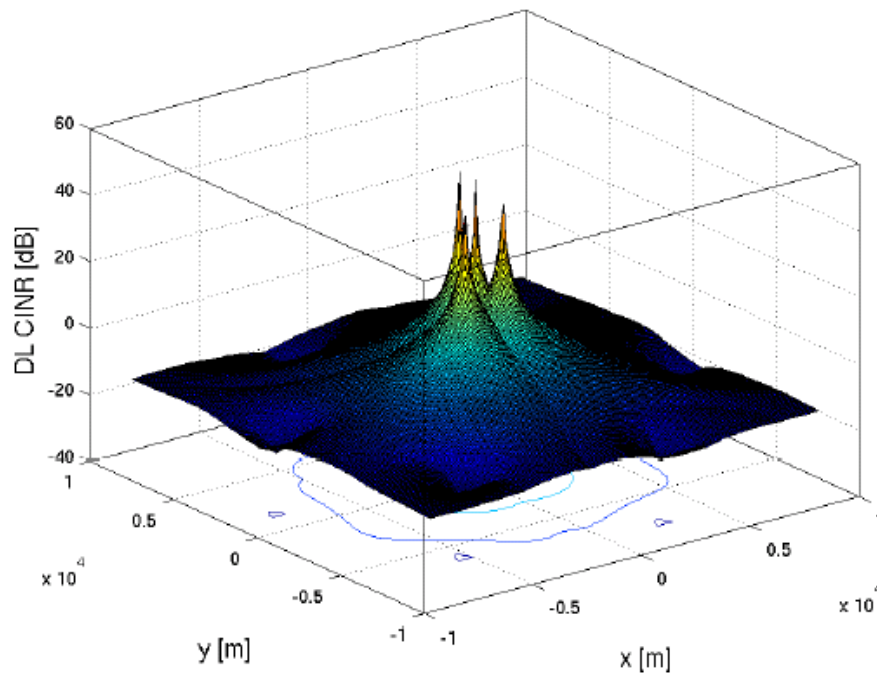
SDM Operation of Relays



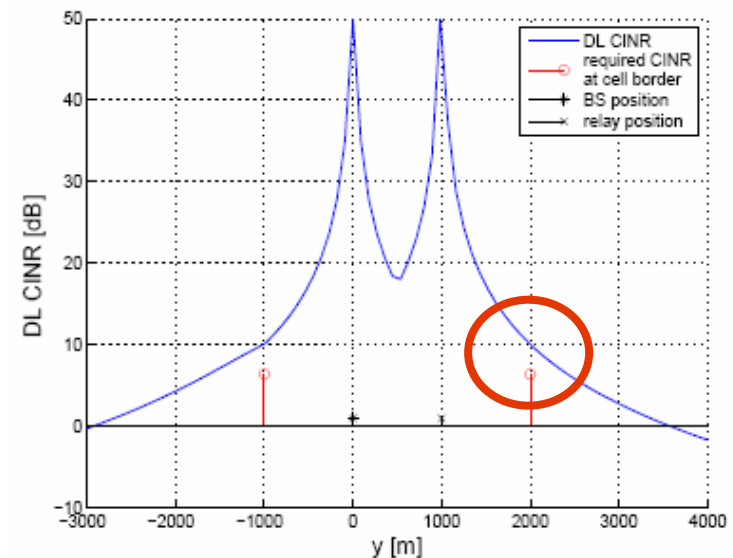
- All relays of a cell are simultaneously active
- Three relays of each co-channel and two relays of the same cell interfere

TDM Operation of Relays

CINR of cellular multihop **coverage** scenario
(BS-to-relay distance 1000m, cluster order 7)



scenario area



traversing the scenario

- Only CINR at (sub)cell border is evaluated in the following
- Dimensioning of multihop throughput (=singlehop) not shown

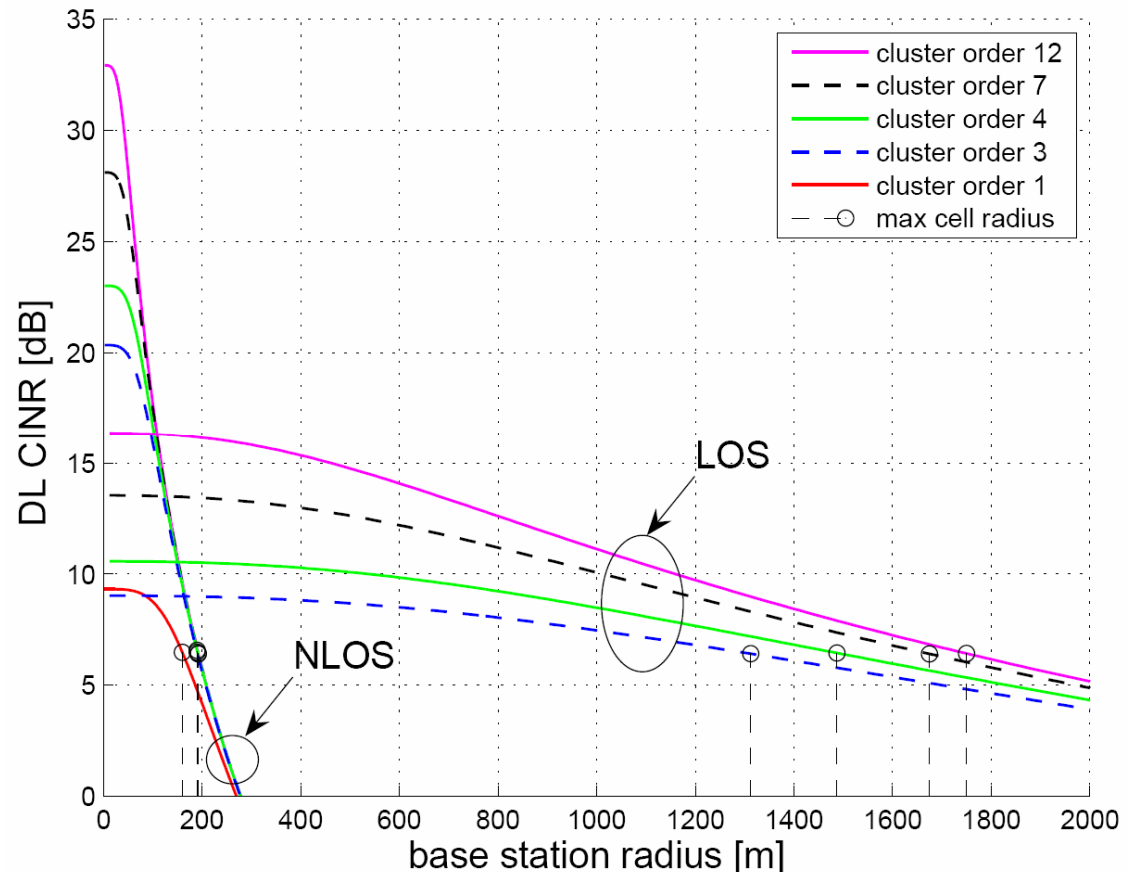
TDM Operation of Relays – Omni Antennas

LOS:

- Cluster order 3 to 7 allow for valid cell radii
- Coverage area extension by factor 8.4 at cluster order 7
- Interference-limited

NLOS

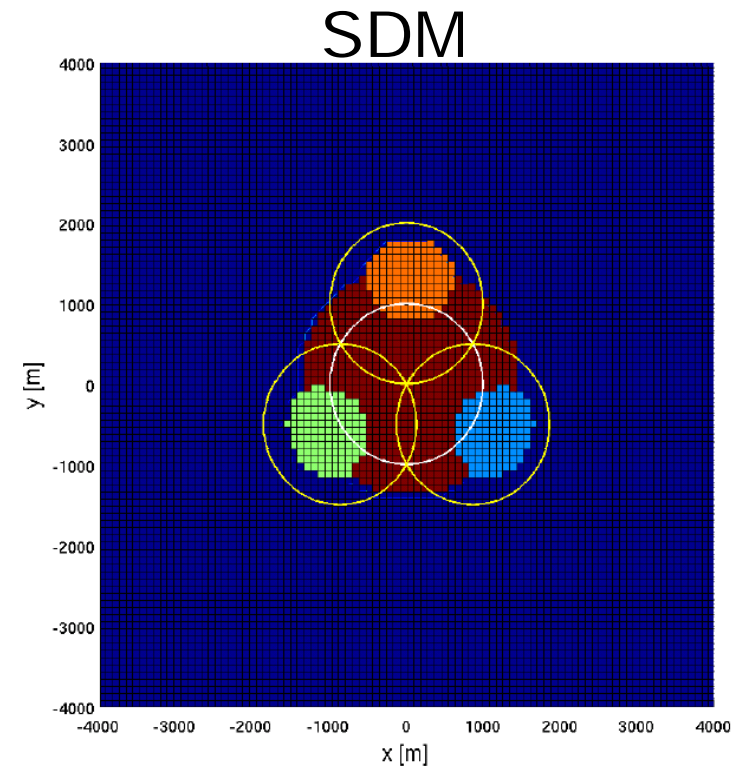
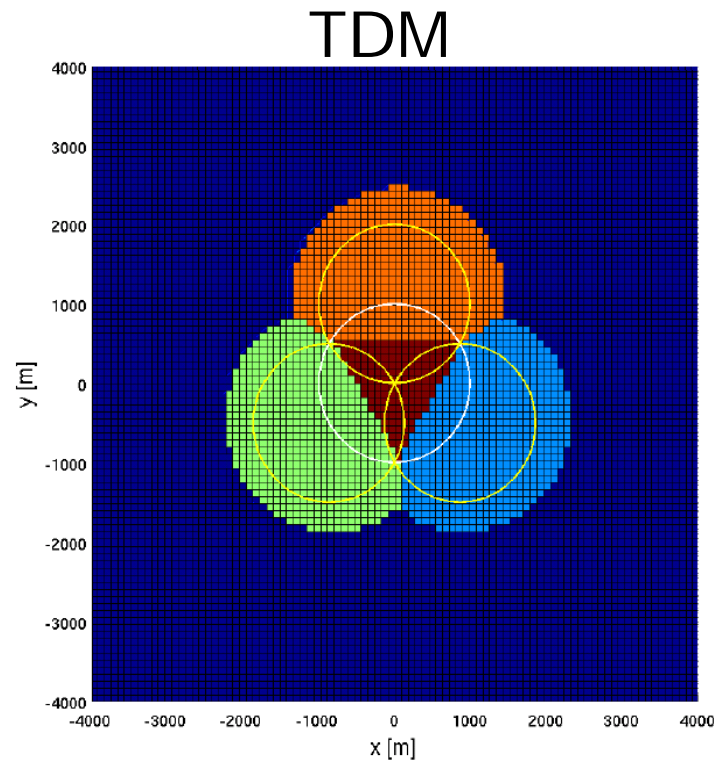
- All cluster order are valid
- Coverage extension by factor 3.2 at cluster order 7
- Noise-limited



→ Multihop deployments extend BS coverage more than three times

SDM Operation of Relays – Omni Antennas

Best server analysis: radius 1000m, cluster order 7, LOS, omni antennas



- Number of interferer more than tripled
- Especially intra-cell interference serious

SDM Operation of Relays – Omni Antennas

LOS:

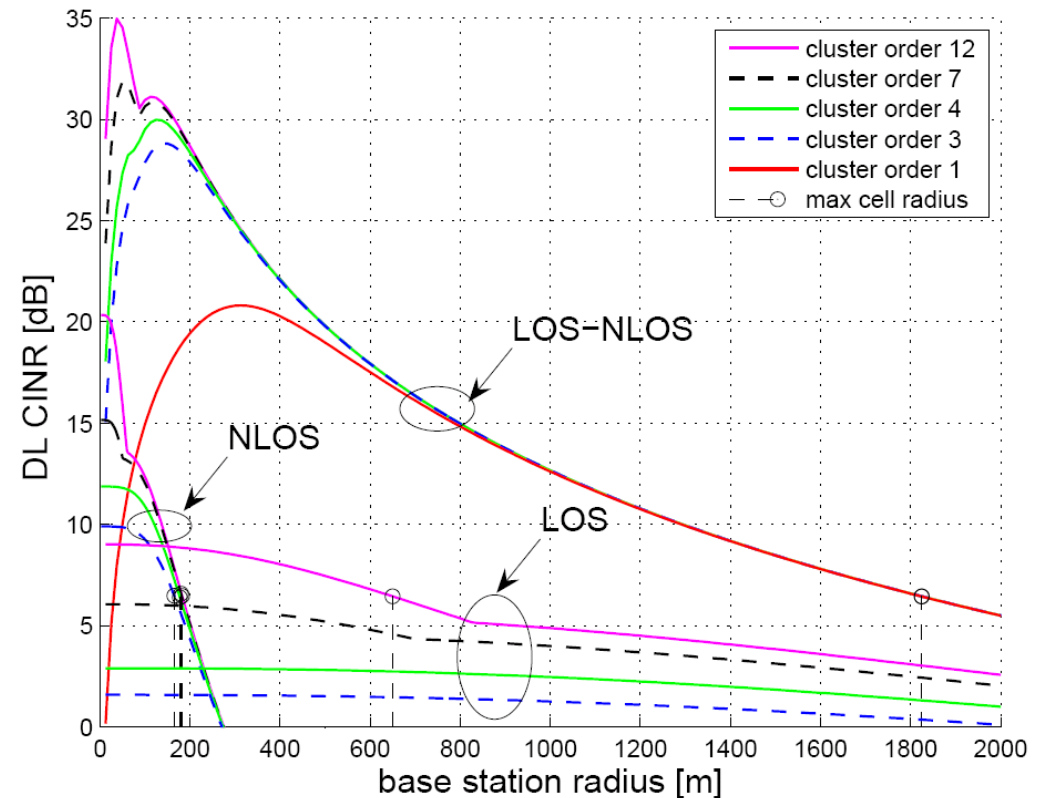
- No valid cell radius possible

NLOS

- Cluster order 3 to 7 valid
- NLOS propagation suppresses fatal interference
- Coverage comparable to TDM

LOS-NLOS

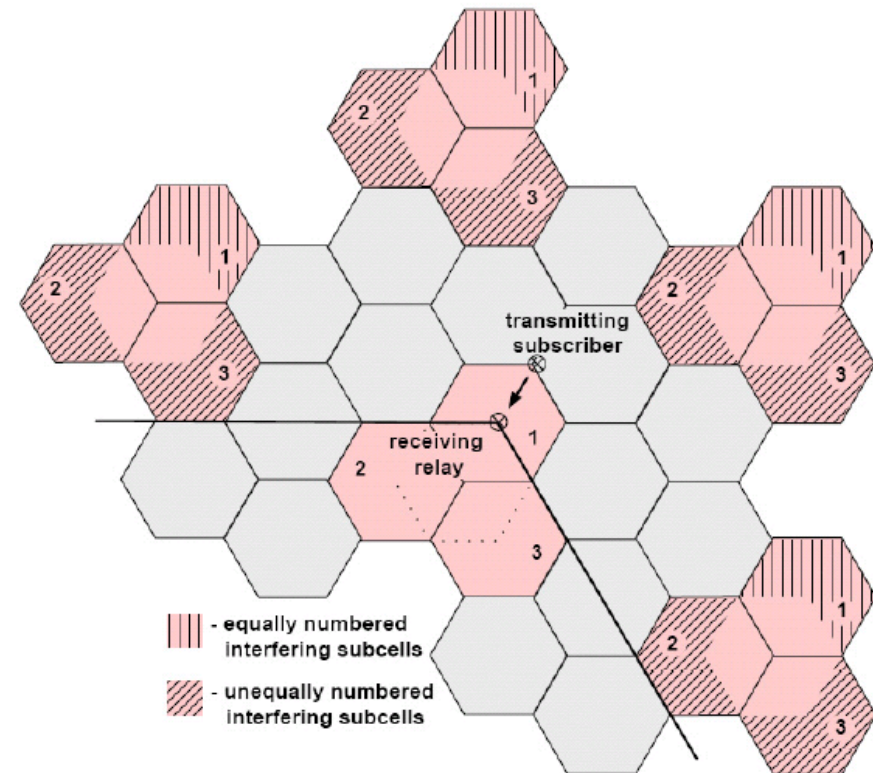
- NLOS shadowing suppresses interference entirely
- System is only noise-limited
→ no clustering, sectorization needed



Directive Antennas

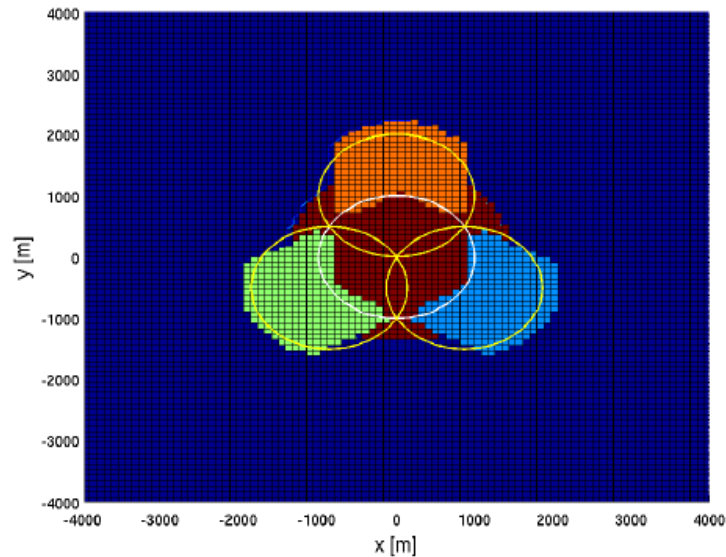
Directive antennas (240° sector antenna)
at relay for 2nd hop

- reduces number of inter-cell interferer by 2/3
- eliminates fatal intra-cell interference

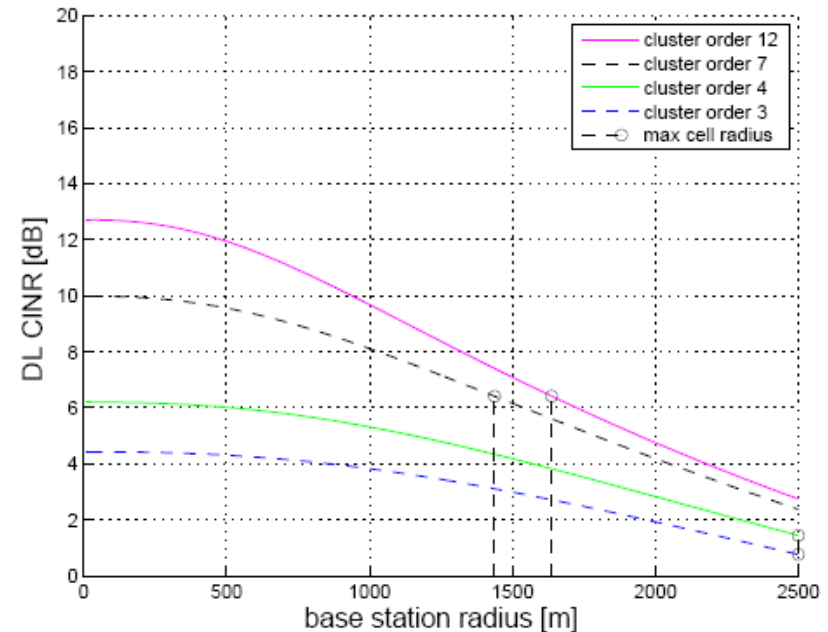


SDM Operation of Relays - Directive Antennas

DL CINR at the cell border (LOS propagation)



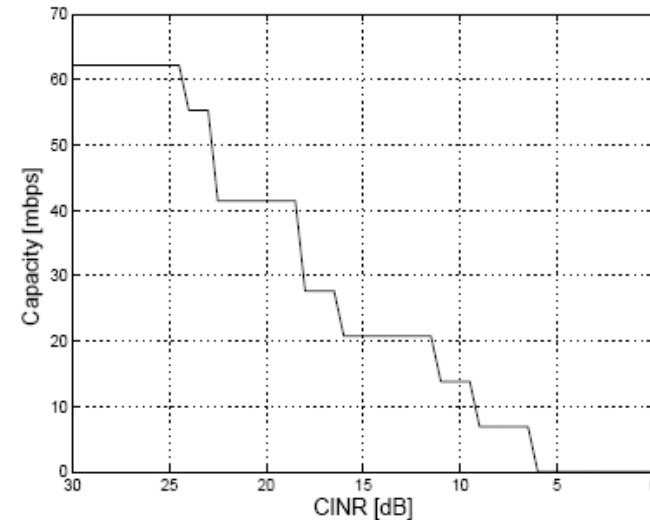
best server analysis



- Directive antennas reduces interference in LOS scenarios significantly
- Only cluster order 7 and 12 allow for valid cell radii
- Radius comparable to TDM, but increased capacity

Capacity of Cellular 802.16 Networks

- CINR [dB] to capacity [Mbps] conversion based on switching points given in 802.16 Std.



- Two hop capacity evaluation, Decode & Forward, optimal slot size
- Cell capacity evaluation assuming equal offered traffic per area element, optimal slot size

$$\frac{1}{Cap_{overall}} = \frac{1}{Cap_{hop1}} + \frac{1}{Cap_{hop2}}$$

$$\frac{1}{Cap_{cell}} = \int_{cell\ area} \frac{1}{Cap(x,y)} dx dy$$

Singlehop and Multihop Throughput Scenarios

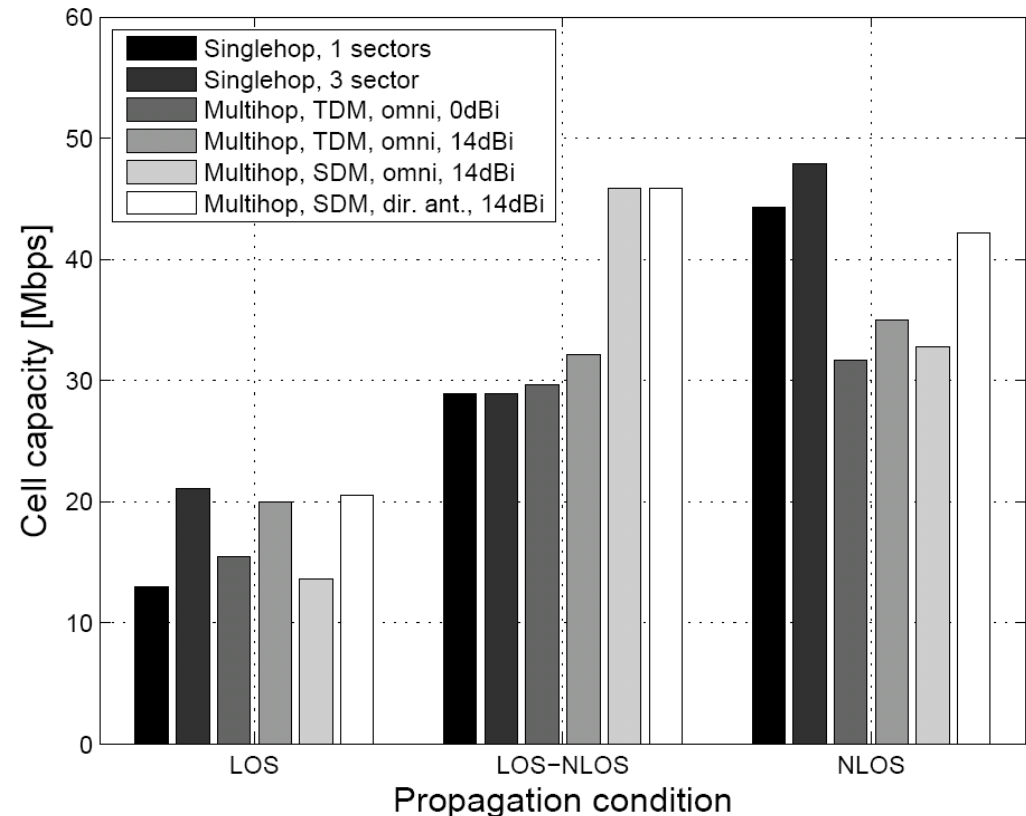
Singlehop:

- Sectorization reduces interference and increases capacity

Multihop Throughput:

- Basic capacity less or equal to singlehop case
- 1st hop receive antenna gain increases capacity
- SDM operation with omni antennas benefits only in Manhattan-like scenario
- SDM operation with directive antennas benefits in NLOS and Manhattan scenario

Radii: 1000m and 150m, DL, cluster order 7



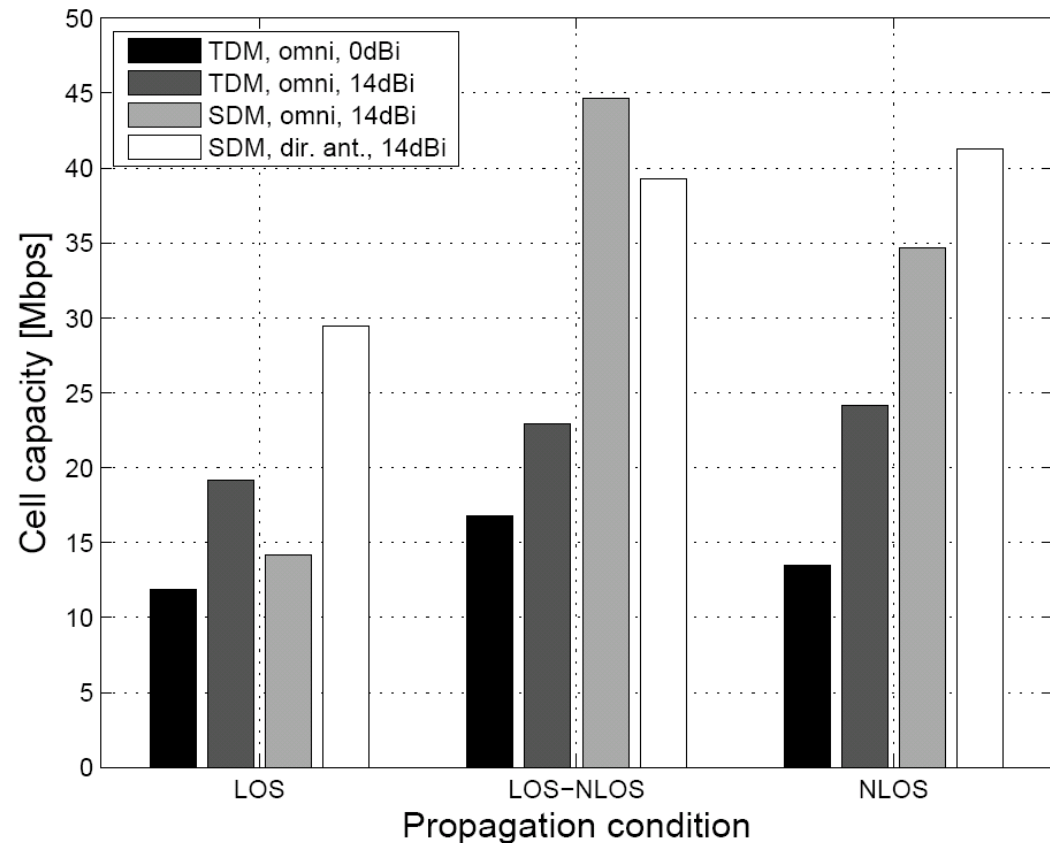
→ Capacity of multihop system exceeds singlehop capacity only in Manhattan-like scenarios

Multihop Coverage Scenario

Multihop Coverage:

- Relay receive antenna gain increases capacity
- SDM operation with omni antennas increases capacity in NLOS and Manhattan scenarios
- SDM operation with directive antennas further increases capacity for LOS and NLOS

Radii: 1000m and 150m, DL, cluster order 7



→ Capacity of multihop systems can be extended by SDM operation and antenna gain

Conclusion

Throughput scenario:

- Conventional relays can increase capacity only in Manhattan scenarios

Coverage scenario:

- Relays can extend the coverage area significantly
- Receive antenna gain increases capacity
- SDM operation of relays further increases capacity if interference can be limited by antennas or shadowing

802.16e / OFDMA benefits:

- Increase range of broadcast phase by
 - Robust FEC, e.g., repetition codes in 802.16e
 - OFDMA with increased spectral density (noise limited)

Future potential:

- Coordination or cooperation of BSs and relays



Any Questions?

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IST-FIREWORKS