Christian Doppler Laboratory for
Dependable Wireless Connectivity for the Society in Motion

Three-Dimensional Beamforming

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Bundesministerium für
Wissenschaft, Forschung und Wirtschaft

Studying 3D channel models

- Channel models on system-level tools commonly 2-dimensional (2D)
- 3GPP Spatial Channel Model (SCM)
  - A *geometric stochastic* model
  - Only linear antenna arrays can be inspected with 2D channel models
- Three-Dimensional (3D) channel model enable investigations on
  - Full-dimension MIMO
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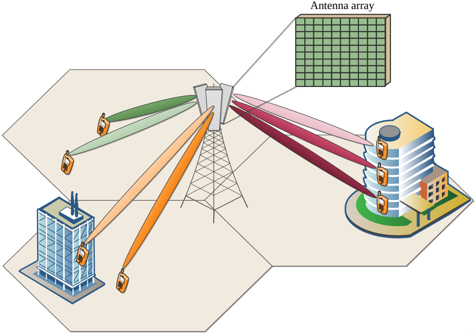

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Modeling the wireless channel in 3-dimensions

Complexity- Simulation run times

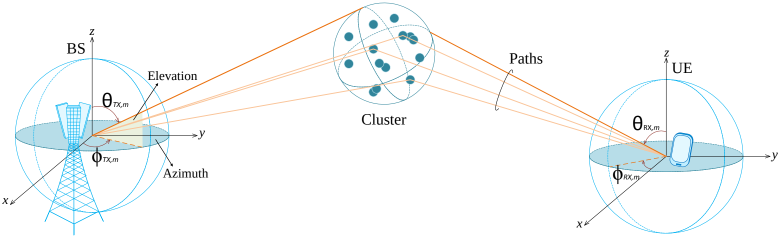
Massive MIMO: Spatial resolution of planar antenna arrays

Conclusion and Outlook

Modeling the wireless channel in 3-dimensions

The 3GPP 3D channel model in Vienna LTE-A system-level simulator

- Considers elevation and azimuth
- Incorporates planar antenna arrays



Reduction in complexity

- The 3GPP 3D model imposes high complexity
- Complexity reduction by:
  - Partition the scenario into equally sized cubes
  - Within a cube UE experiences the same propagation conditions
- Spatial resolution 1 m
- Temporal resolution 1 ms
- UE speed $\mathbf{v} = [7.5, 0, 0]\ \mathrm{km/h}$
- *Change the cube each 36 sub-frames*

Temporal resolution refers to the length of one LTE sub-frame

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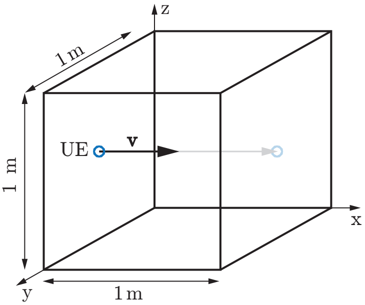

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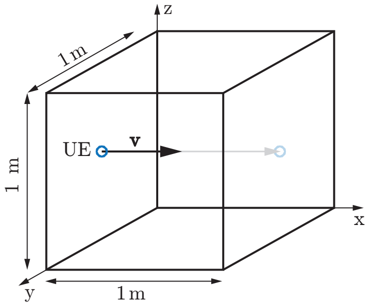

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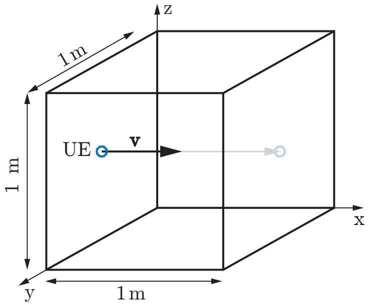

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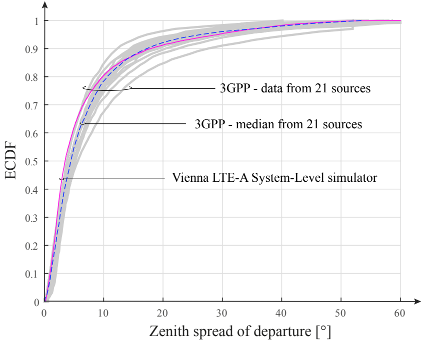
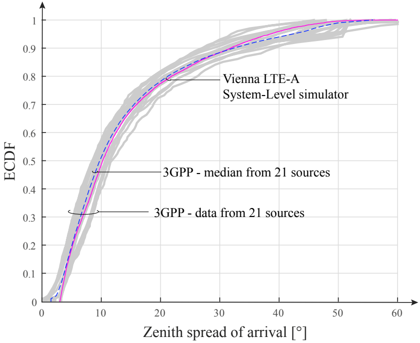
Calibration: Zenith spread

- Comparing system-level simulations and 3GPP TR 36.873 results





Overview

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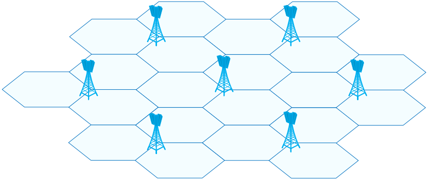
Complexity- Simulation run times

Massive MIMO: Spatial resolution of planar antenna arrays

Conclusion and Outlook

Simulation run times

- A network of seven hexagonally arranged macro-sites, each employing three eNodeB sectors
- Evaluate the simulation complexity [Ademaj et al., a]:
  - Number of interfering links $N_{\mathrm{sector}} = \{2, 8, 14, 20\}$
  - Number of UEs per sector $K = \{2, 20, 50\}$
  - Number of antenna elements $M = \{8, 24, 40, 80\}$
  - Simulation length $N_{\mathrm{TTI}} = \{10, 50, 100\}$



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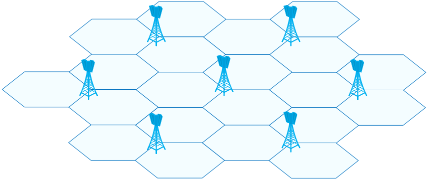

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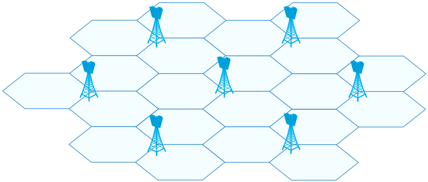

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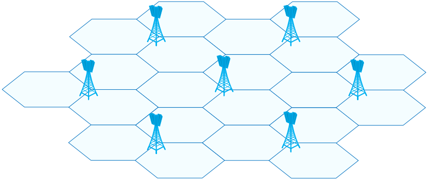

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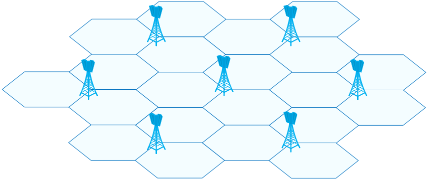

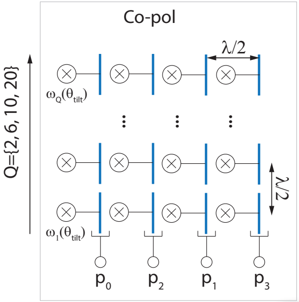

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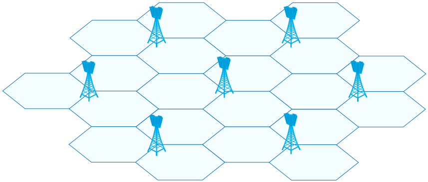

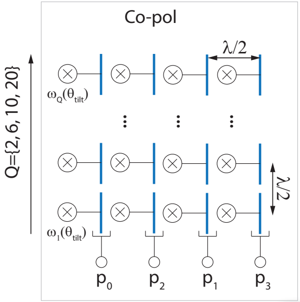

Simulation run times: Varying the size of antenna array

K	Number of UEs
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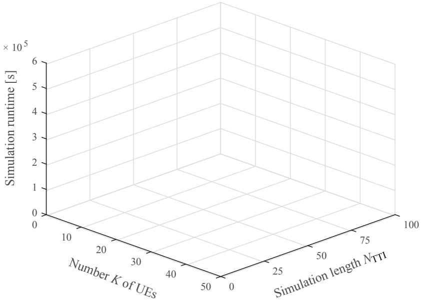

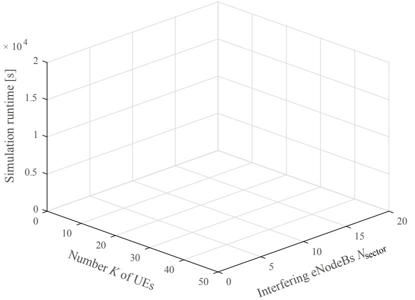

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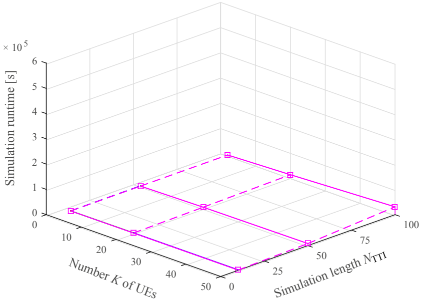

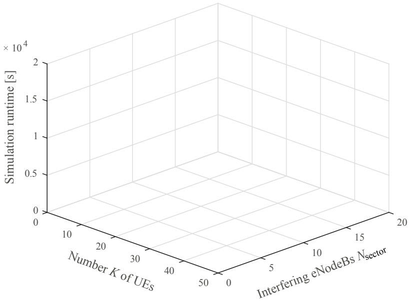

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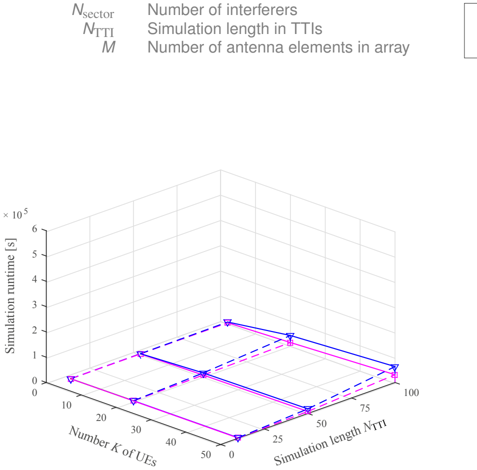

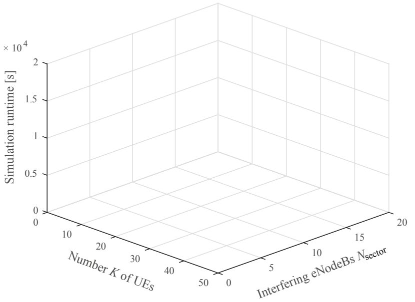

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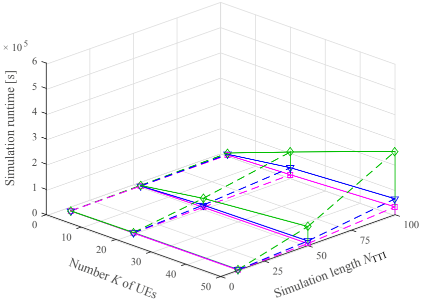

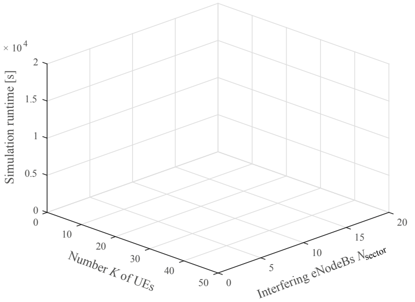

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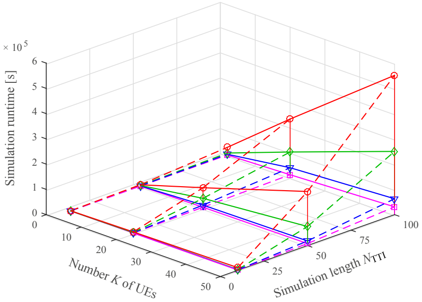
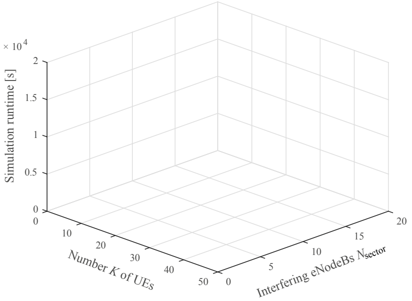
M = 80 M = 40
M = 24 M = 8





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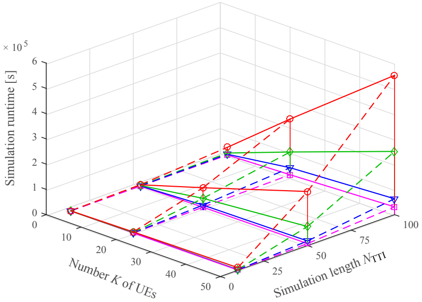

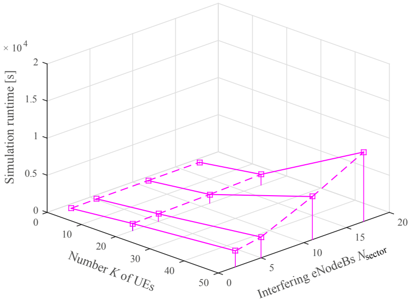

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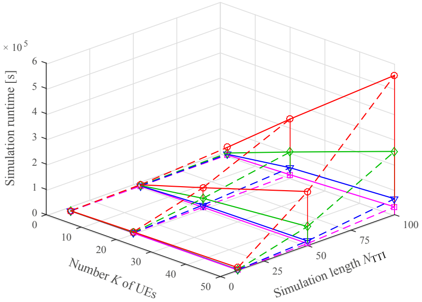

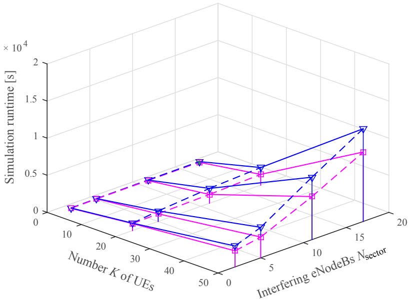

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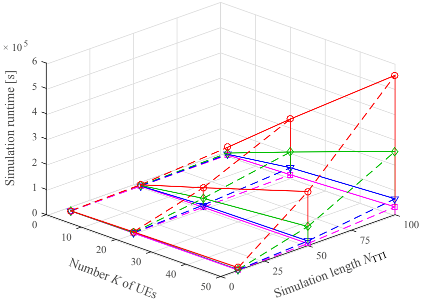

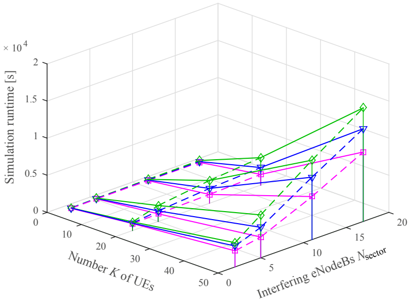

Throughput performance: Rayleigh versus 3GPP 3D model

- Desired channel modeled by 3GPP 3D model
- Interfering channels modeled as
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  - Rayleigh fading
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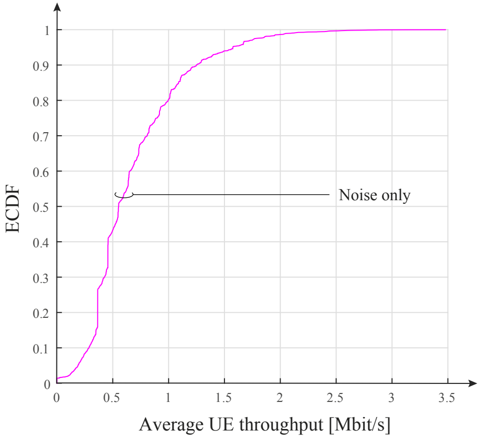

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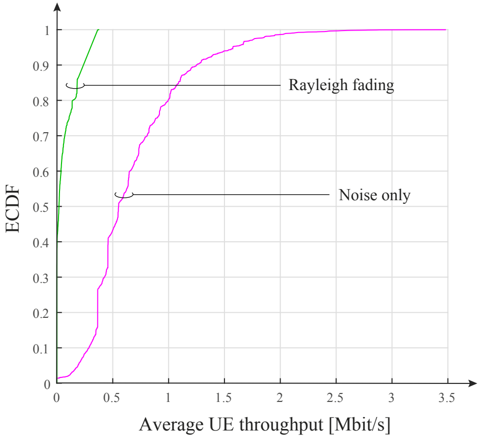

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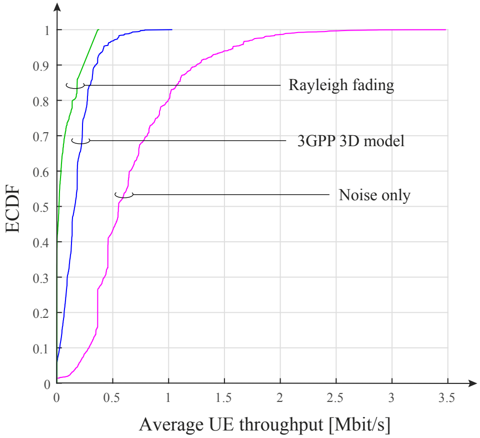


Modeling the wireless channel in 3-dimensions

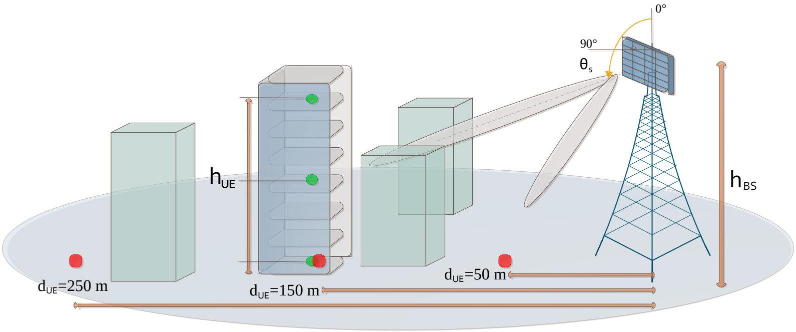
Complexity- Simulation run times

Massive MIMO: Spatial resolution of planar antenna arrays

Conclusion and Outlook

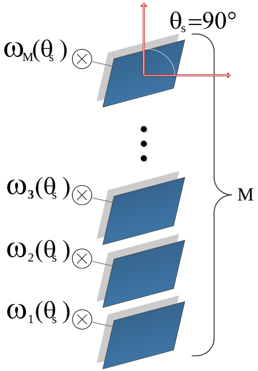
Spatial resolution of planar antenna arrays

- How does the channel impacts the spatial resolution of an antenna array?
- What is the spatial separation of narrow beams in LOS and NLOS, outdoors and indoors [Ademaj et al., b]?



Resolution of a uniform vertical linear array

Antenna array radiation pattern in elevation



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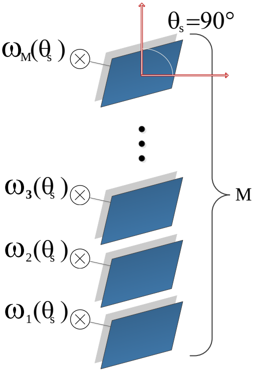

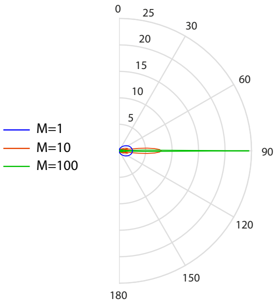

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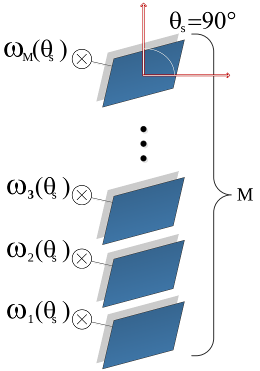
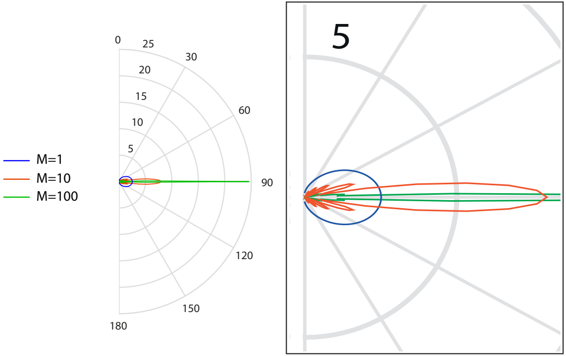
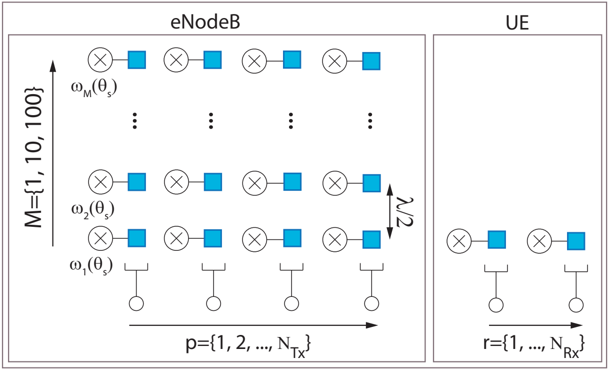




2D Antenna array structure

- Antenna port configuration: $N_{\mathrm{Tx}} \times N_{\mathrm{Rx}} = 4 \times 2$
- Antenna array geometry at eNodeB: $N_{\mathrm{Tx}} \times \mathrm{M}$



Indoor UE: *Channel energy and UE throughput*

- UE height $h_{\mathrm{UE}} = 1.5\,\mathrm{m}$
- UE distance $d_{\mathrm{UE}} = 150\,\mathrm{m}$
- $M = \{1, 10, 100\}$
- Steering angle $\theta_s = \{0^\circ, 10^\circ, 20^\circ, \cdots, 180^\circ\}$
- Target angle $\theta_s = 98.9^\circ$

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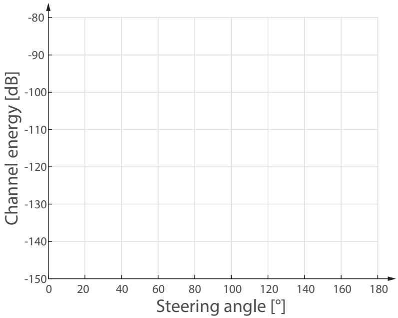
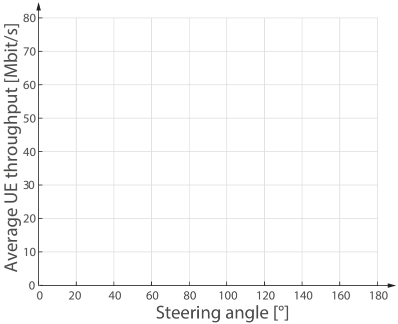
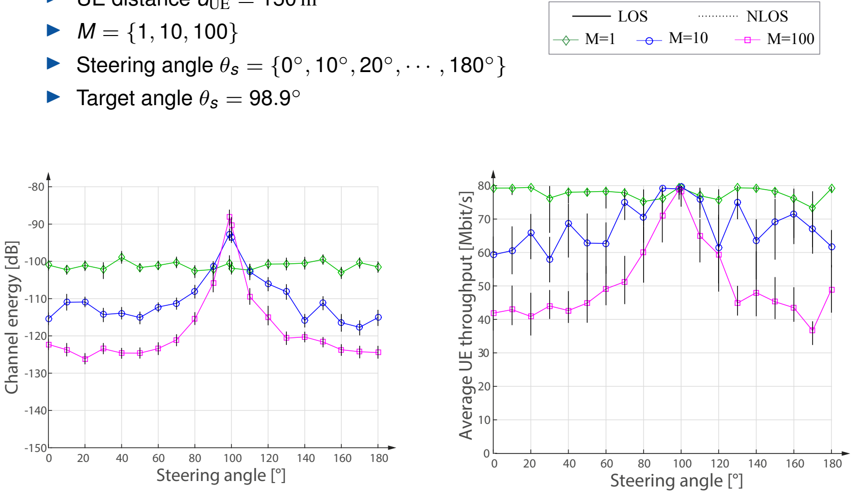




Indoor UE: *Channel energy and UE throughput*

- UE height $h_{\mathrm{UE}} = 1.5\,\mathrm{m}$
- UE distance $d_{\mathrm{UE}} = 150\,\mathrm{m}$
- $M = \{1, 10, 100\}$
- Steering angle $\theta_s = \{0^\circ, 10^\circ, 20^\circ, \cdots, 180^\circ\}$
- Target angle $\theta_s = 98.9^\circ$



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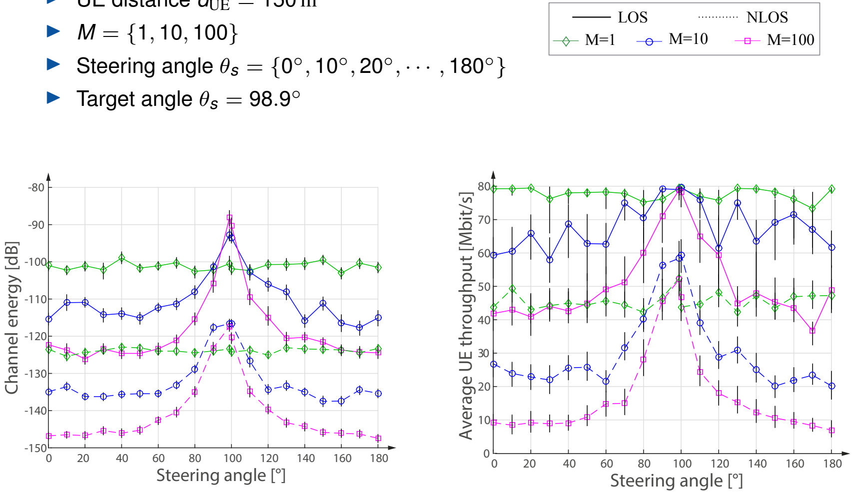


Overview

Modeling the wireless channel in 3-dimensions

Complexity- Simulation run times

Massive MIMO: Spatial resolution of planar antenna arrays

Conclusion and Outlook

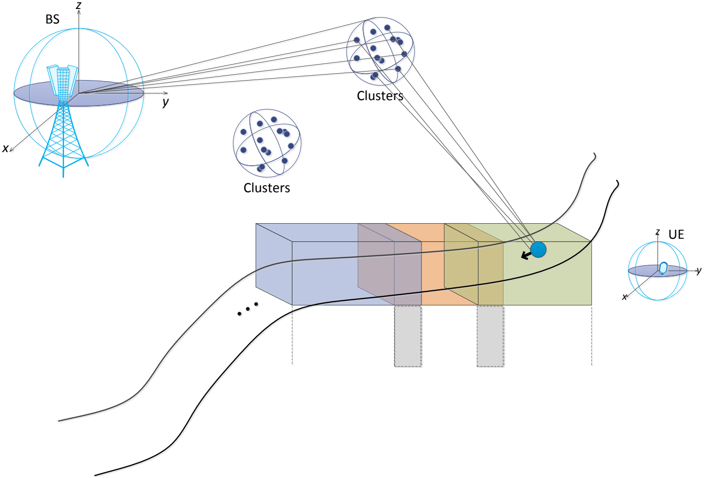
Conclusion

- Incorporation of the elevation dimension increases the computational complexity by more than three times
- The complexity grows roughly linearly with the number of antenna elements per antenna array
- A more optimistic view on performance observed by 3D model: simple channel models may underestimate the achievable performance
- In terms of spatial resolution, doubling the number of antenna elements in elevation does not double the received channel energy
- The optimal number of antenna elements - ?

Outlook: 5G System Level

The 3GPP 3D channel model

- Reduce the model complexity by pruning the multipath components
- Adapt the model for moving scenarios: spatial correlation and channel transitions



Outlook: 5G System Level

3D Channel models $> 6\,\mathrm{GHz}$

- 3GPP TR 38.900: Channel models for carrier frequencies $6\,\mathrm{GHz} - 100\,\mathrm{GHz}$
- Covering many scenarios (rural, urban, street canyons, open area, indoor scenarios, D2D and V2V)
- Three-dimensional beamforming

Outlook: Full-dimension MIMO

- Antenna configurations for 2-dimensional antenna arrays
- New transmitter architectures: TXRU modeling and two-layer mapping
- New precoding strategies to support the element-level antenna structure

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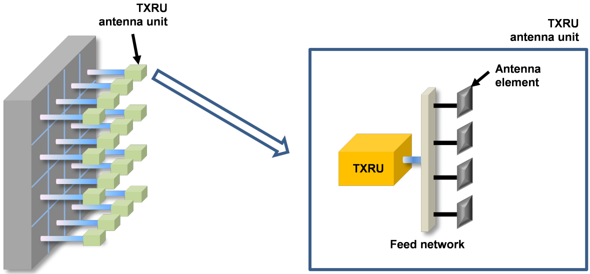

Precoding on 16 TXRU

- New precoding strategies to support the element-level antenna structure

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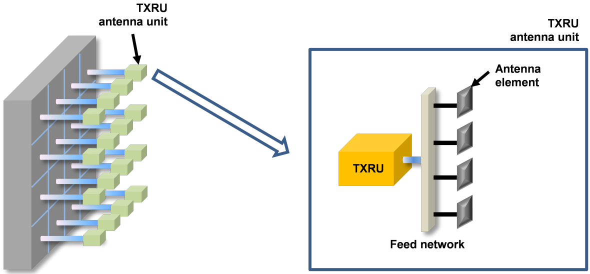

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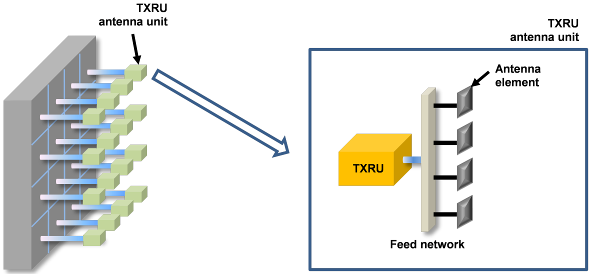


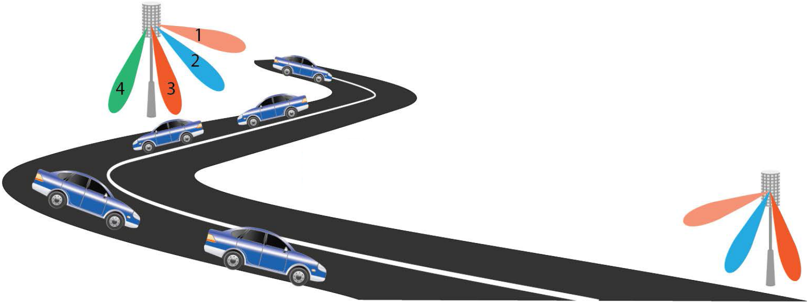
Precoding on 16 TXRU

- New precoding strategies to support the element-level antenna structure

TXRU Transceiver Unit

Outlook: Full-dimension MIMO in moving scenarios

- Beam alignment schemes for efficient UE tracking
  - *Cars and high speed trains*



http://www.profheath.org/research/millimeter-wave-cellular-systems/mmwave-for-vehicular-communications-2/

Christian Doppler Laboratory for
Dependable Wireless Connectivity for the Society in Motion

Three-Dimensional Beamforming

Fjolla Ademaj

15.11.2016

Bundesministerium für
Wissenschaft, Forschung und Wirtschaft

Antennen · Electronic

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