REALISTIC CHANNEL MODELING FOR MOBILE AD-HOC NETWORKS IN THE VHF AND UHF BAND

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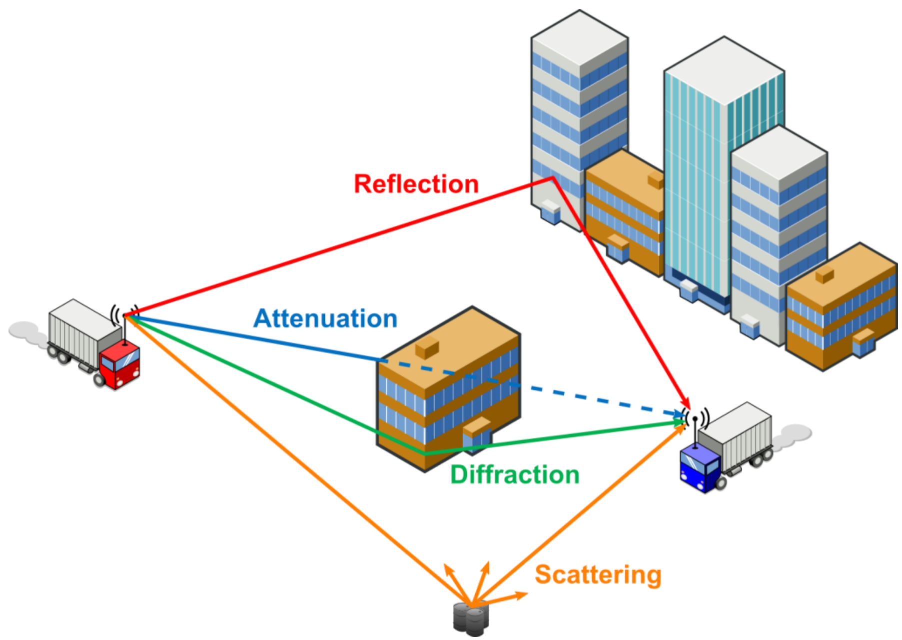

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Channel Modeling for Mobile Ad-Hoc Networks
Testing and Evaluation of CommSystems in the Lab

Application:

Testing and Evaluation of MANETs (Mobile Ad-Hoc Networks) in the VHF and lower UHF band used by military and emergency services (30-400 MHz)

Deficiencies of previous models:

- Are aiming at systems with high antenna towers, not vehicle-mounted antennas
- Assume only the receiver or transmitter is mobile, not both
- Are based on measurements in a different frequency band
- Do not cover all environment classes relevant to the application
- Do not consider the correlation of the links in a network

→ New set of adapted channel models is required to fulfill all demands

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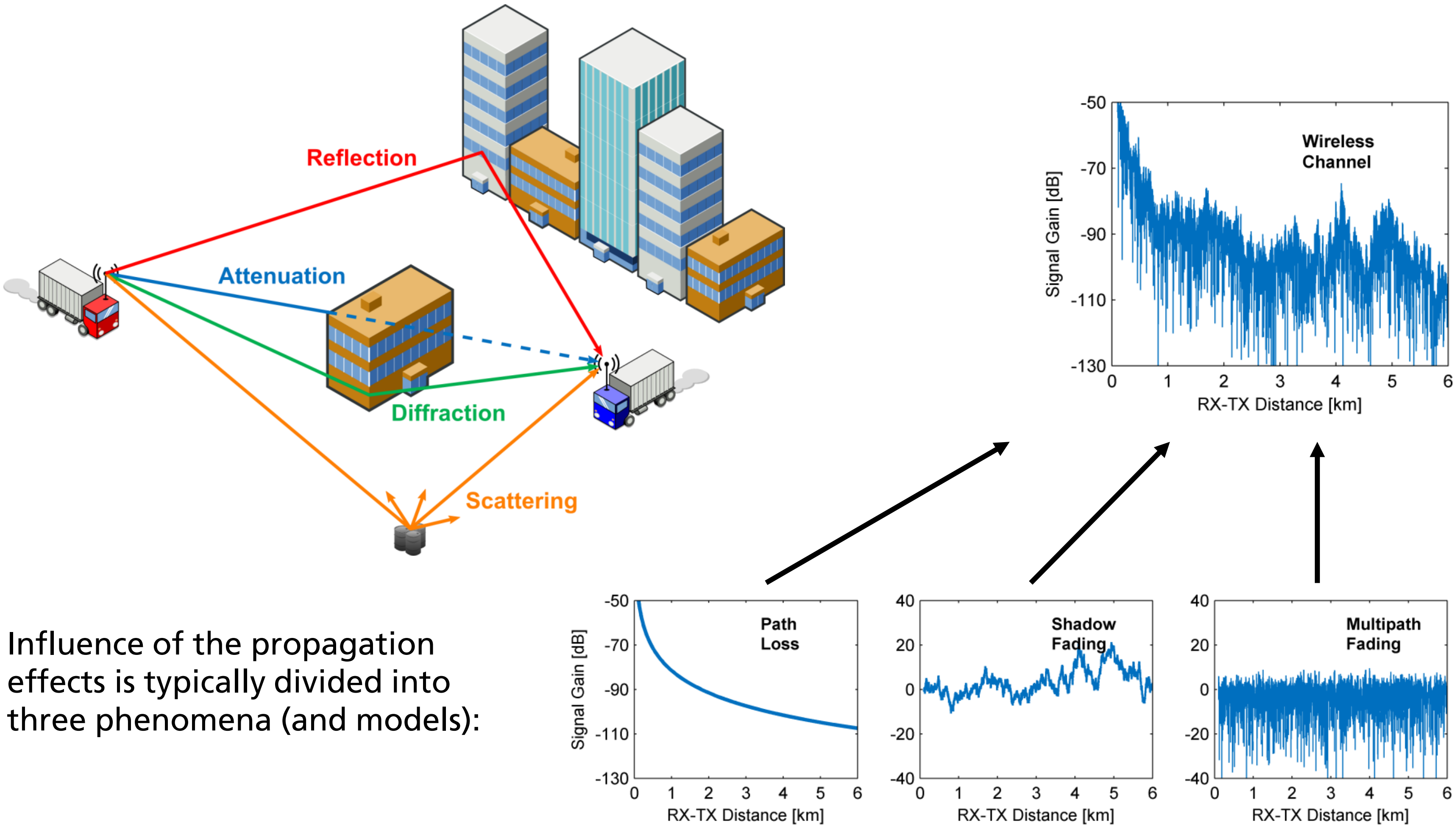
OUTLINE

- Characterization of the Wireless Channel
- Channel Measurement Campaign
- Adaption of Point-to-Point Models for the MANET Application
  - Path Loss
  - Shadow Fading
  - Multipath Fading
- Stochastic Geometry Shadow Fading Model
- Combination & Application of the Presented Models
- Conclusion and Outlook

Characterization of the Wireless Channel
Propagation Effects and Fading Models



Influence of the propagation effects is typically divided into three phenomena (and models):

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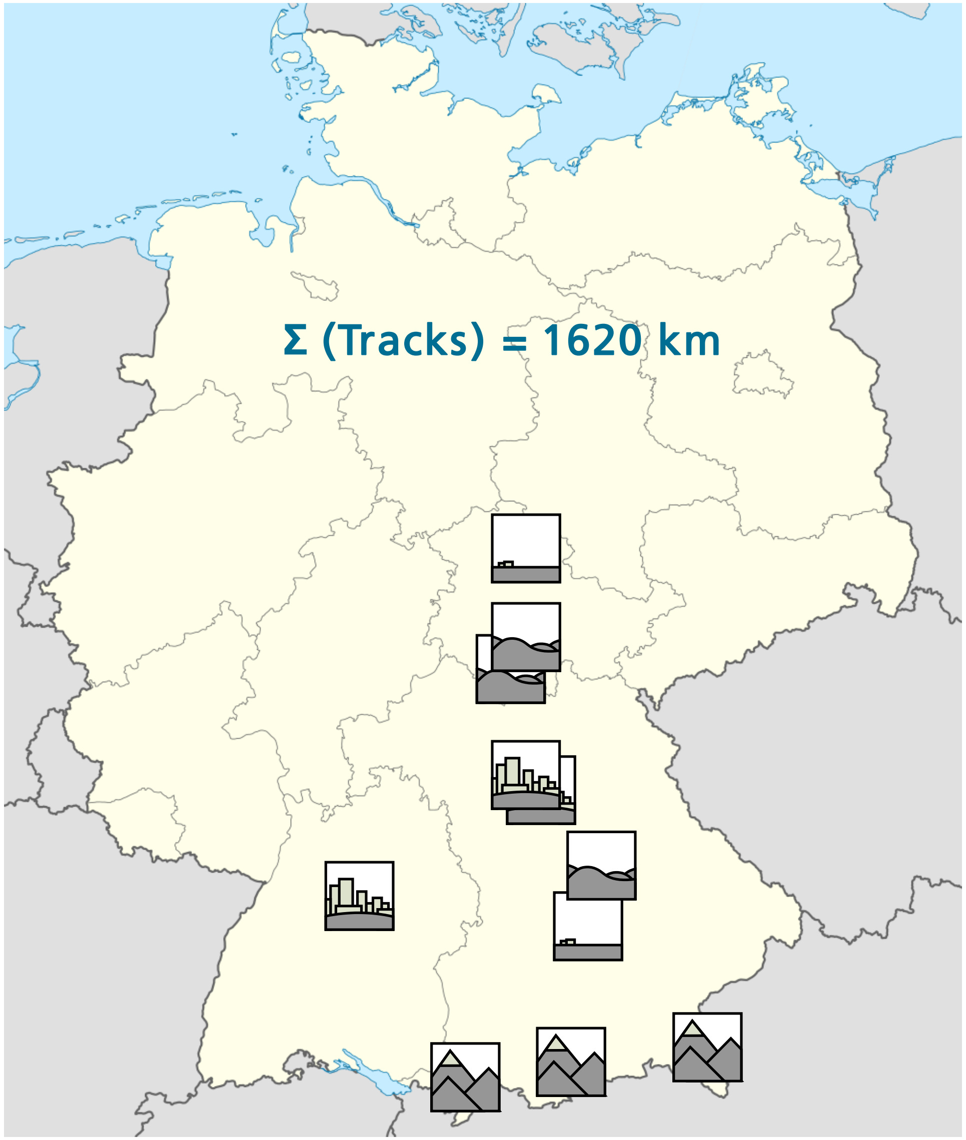
Channel Measurement Campaign



Channel Measurement Campaign
Measurement Setup


Transmitter

- 50 W Signal Power
- VHF: 34.150 MHz
  55.425 MHz
  74.175 MHz
- UHF: 240.000 MHz
  306.000 MHz
  363.750 MHz


Receiver

- IQ Data
- GPS Data
- Distance Transducer

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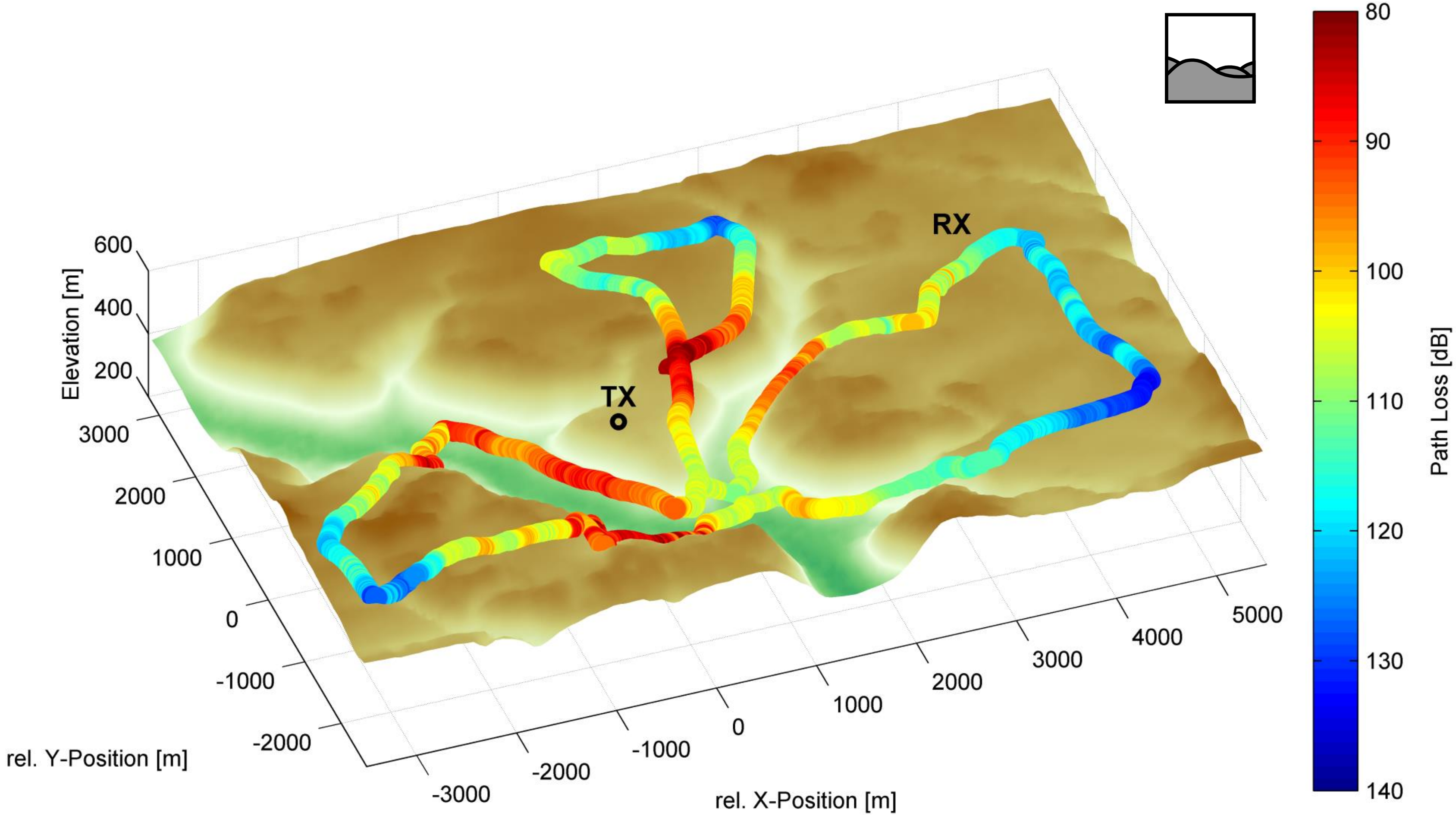
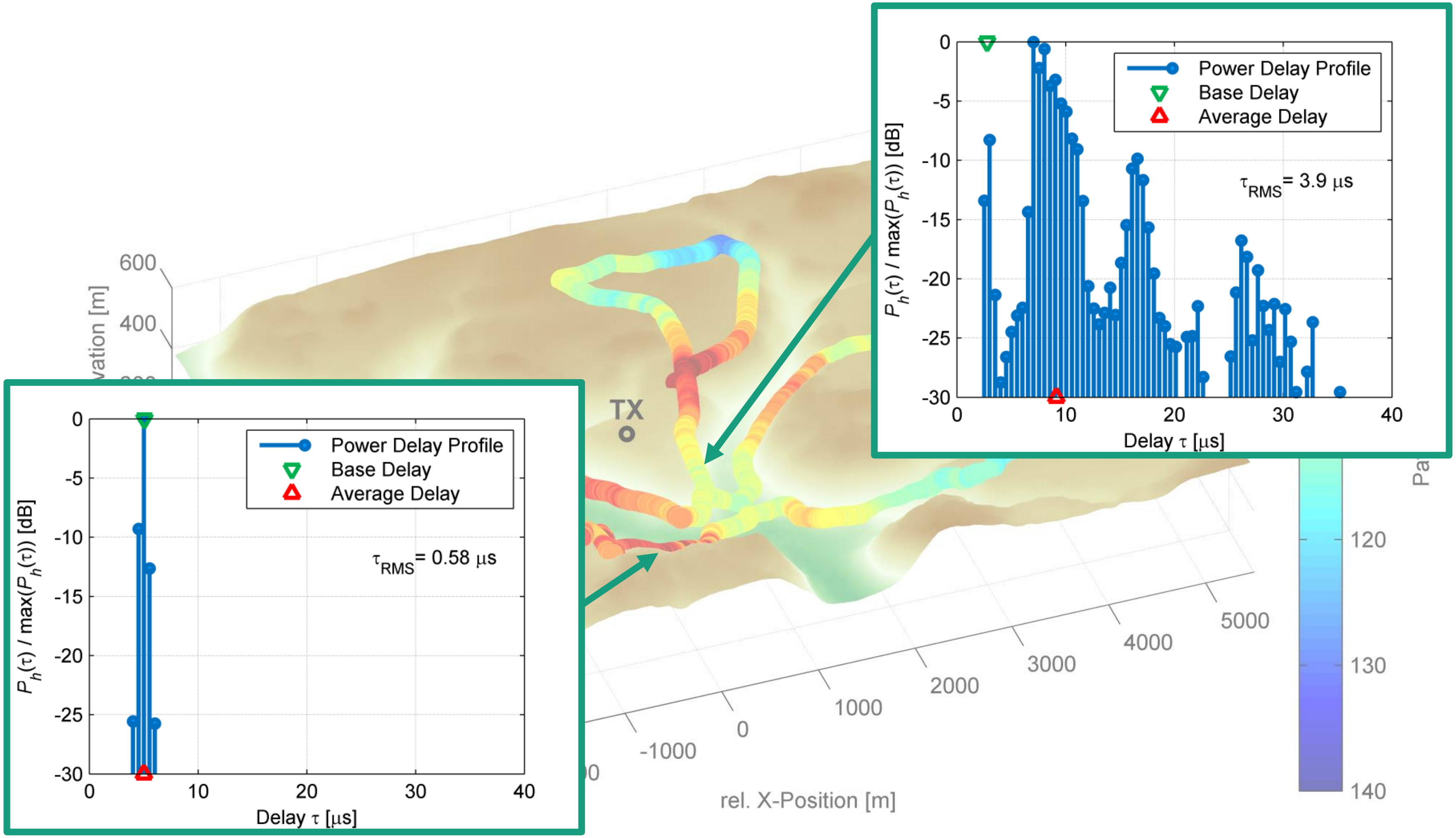
Channel Measurement Campaign

[Hilly] Greding: Path Loss



Channel Measurement Campaign
[Hilly] Greding: Channel Impulse Response



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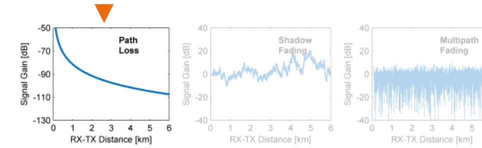
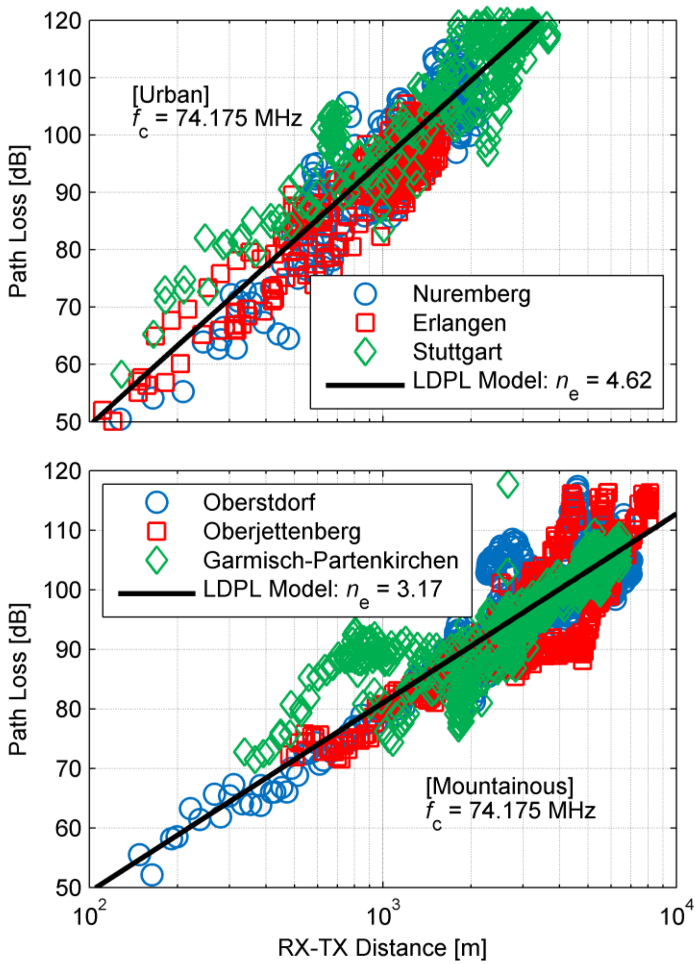
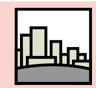
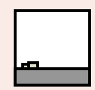
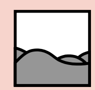
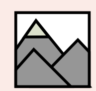
Channel Model I: Path Loss
Measurements and Model Parameters



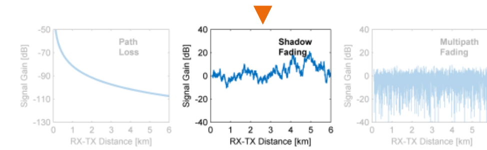


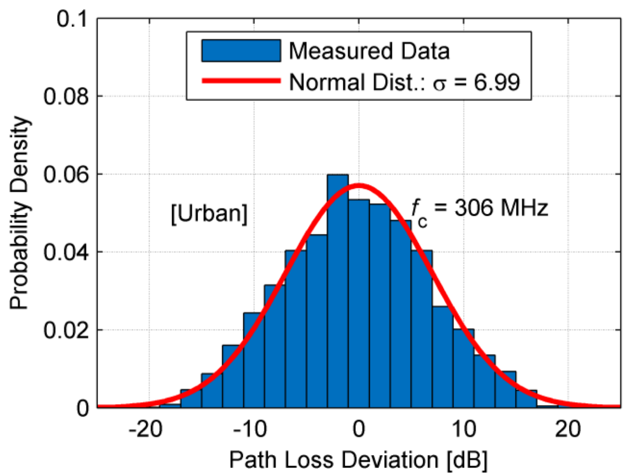
$$\overline{L}(d) = L_{\mathrm{FS}}(d_0, f_c) + A_{\mathrm{E}} + 10 \cdot n_{\mathrm{E}} \cdot \lg\left(\frac{d}{d_0}\right)$$

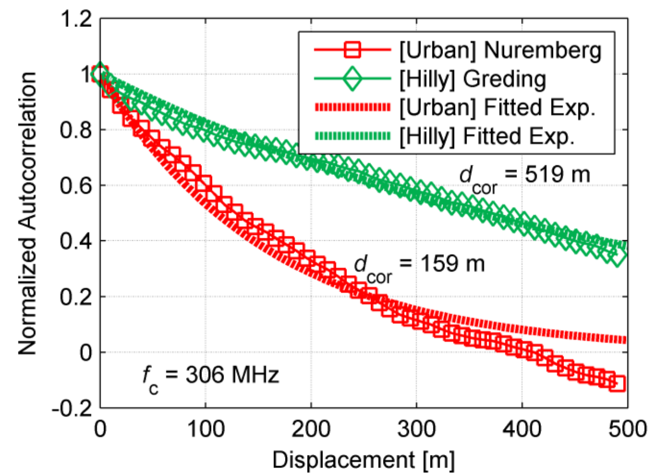
Environment		A_E	n_E
Urban		30.01 dB	4.68
Rural		26.02 dB	3.36
Hilly		19.48 dB	3.34
Mountainous		17.34 dB	3.23

L_{FS}: Free space loss [dB]
d_0 : Reference distance (= 1 km)
f_c : Carrier Frequency [MHz]
A_E : Path loss offset [dB]
n_E : Path loss exponent

Channel Model II: Shadow Fading
Distribution and Autocorrelation







$$L(d) = \overline{L}(d) + X_F \qquad X_F \sim \mathcal{N}(0, {\sigma_F}^2)$$

$$\sigma_F = 0.65 \cdot \log\left(f_c\right)^2 - 1.3 \cdot \log\left(f_c\right) + A_F$$

A_F : Shadow fading offset [dB]

$$R_F\left(\Delta x\right) = e^{-\frac{|\Delta x|}{d_{cor}}}$$

R_F : Normalized autocorrelation function of F
F : Deviation of the local path loss from the mean
d_{cor} : Correlation distance

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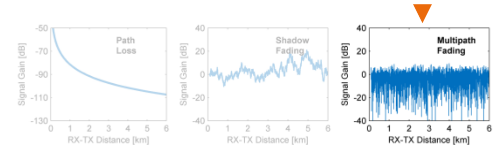
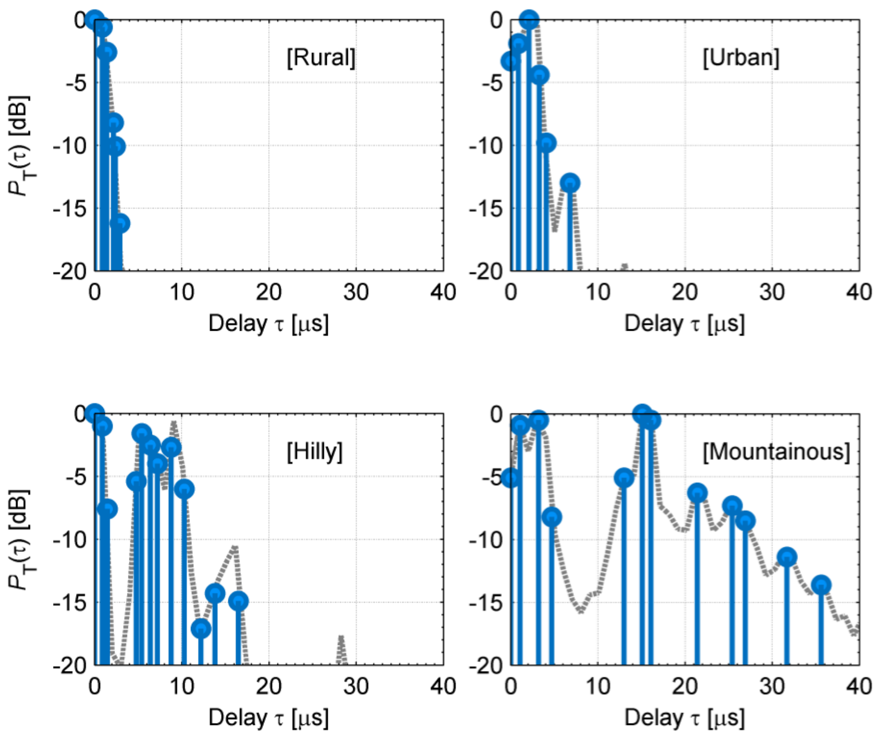
Channel Model III: Multipath Fading
Path Gains, Delays and Doppler Spectra

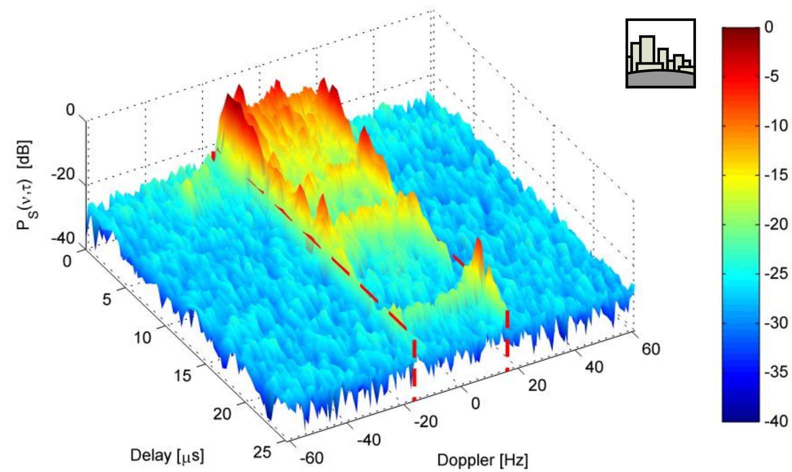


Power Delay Profiles



Scattering Function

Allows analysis of the Doppler spectra dependent on the delay (and environment)



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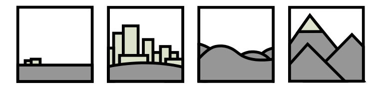
Channel Modeling
Requirements Check

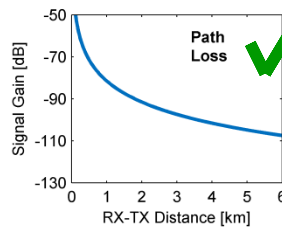
Conditions

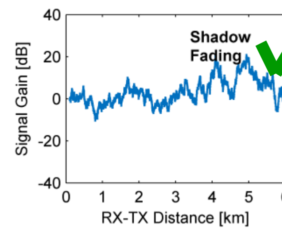
Low Antenna

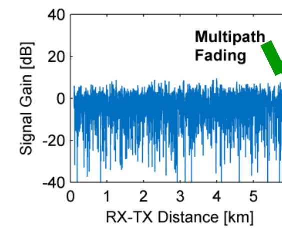
VHF / UHF



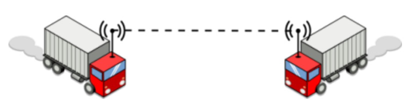
Phenomena



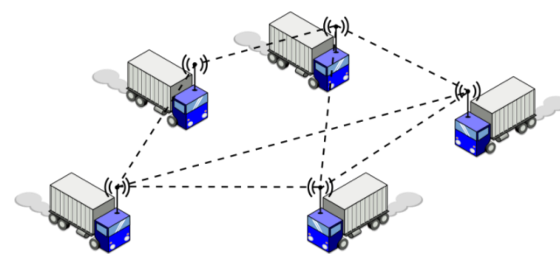




Applications



Point-to-Point



Mobile Ad-Hoc Network

No correlation of links

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- **Stochastic Geometry Shadow Fading Model**
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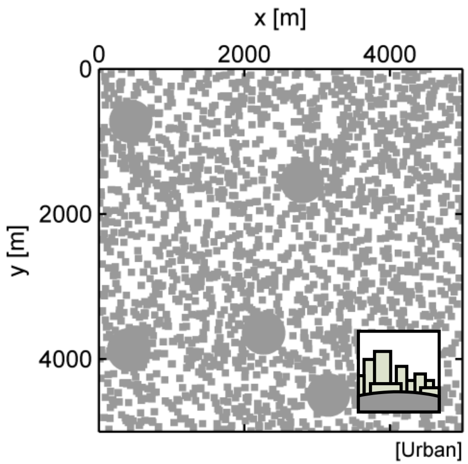
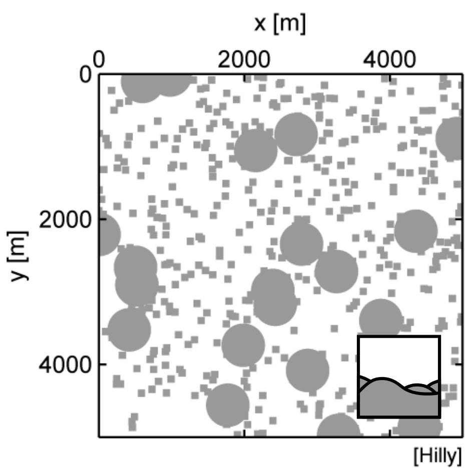
- Conclusion and Outlook

Stochastic Geometry Shadow Fading Model (SGSF)
Approach: Randomly Placed Shadowing Objects





- Squares for small objects like buildings
  ► fast decaying ACF in the range of several tens of meters
- Disks for larger objects like hills / mountains
  ► slowly decaying ACF in the range of several hundreds of meters

Model parameter:

- Size $s_\square$ and density $d_\square$ of the squares
- Radius $\mathrm{r}_\circ$ and density $d_\circ$ of the disks

		Urban	Rural	Hilly	Mount.
$s_\square$	[m]	100	200	100	100
$d_\square$	[1/km²]	80	20	20	40
$r_\circ$	[m]	300	-	300	300
$d_\circ$	[1/km²]	0.2	0	0.8	0.6

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Stochastic Geometry Shadow Fading Model (SGSF)
Implementation

For each evaluation, a series of “drops” is generated and analyzed:

I. Generate „drop“: Create a playground using the parameters for the respective environment

   a) Determine TX and RX position within the playground

   b) Calculate shadow fading factor $\mathbf{A}$ from the tiles intersected by the direct connection between TX and RX:

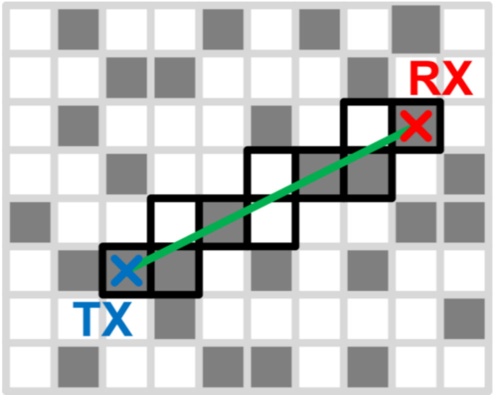
$$\mathbf{A} = \left(\frac{\mathbf{b}_1 + \mathbf{b}_2 + \cdots + \mathbf{b}_n}{n} - \mu_b\right) \cdot \sqrt{n}$$

   c) Calculate shadow fading attenuation $\mathbf{F}$ in dB by scaling $\mathbf{A}$:

$$\mathbf{F} = \frac{\sigma_{\mathbf{F}}}{\sigma_{\mathbf{A}}} \cdot \mathbf{A}$$

   d) Analyze effect on the system under test and return to a)

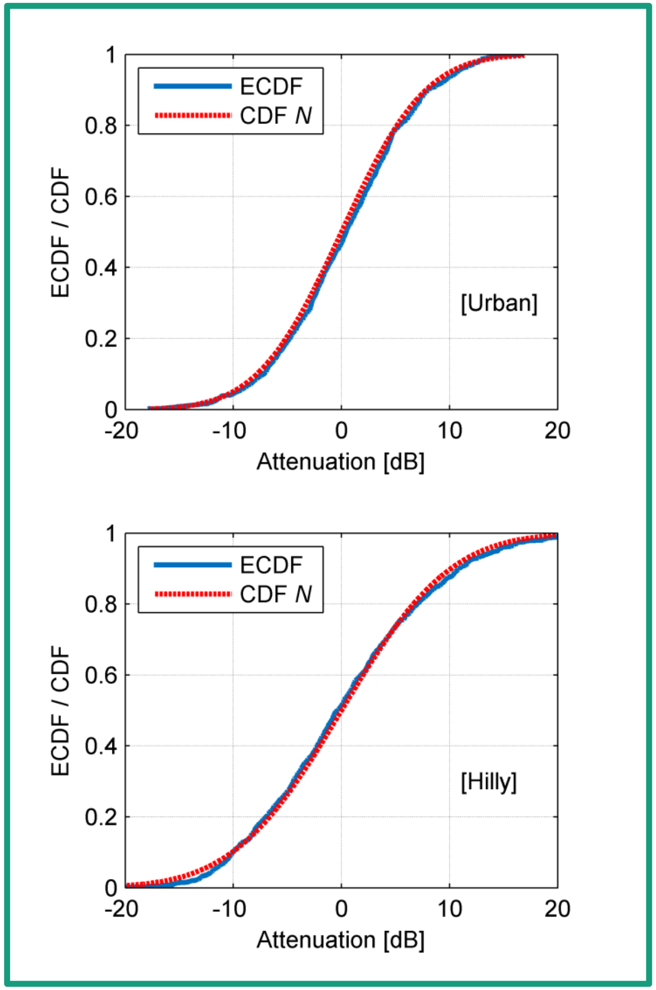
II. Save results and return to I.

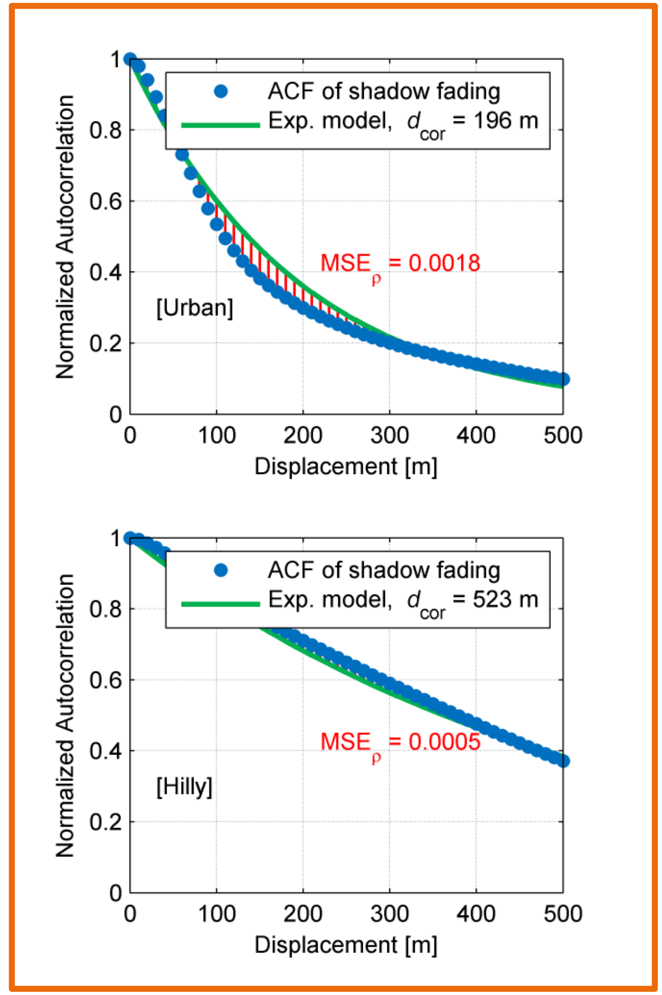


n	: Number of intersected tiles
$\mathbf{b}_1 \ldots \mathbf{b}_n$	: Values of the intersected tiles
μ_b	: Mean value of all tiles
$\sigma_{\mathbf{A}}$	: Measured standard dev. of $\mathbf{A}$
$\sigma_{\mathbf{F}}$	: Target standard dev. of $\mathbf{F}$

Stochastic Geometry Shadow Fading Model (SGSF)

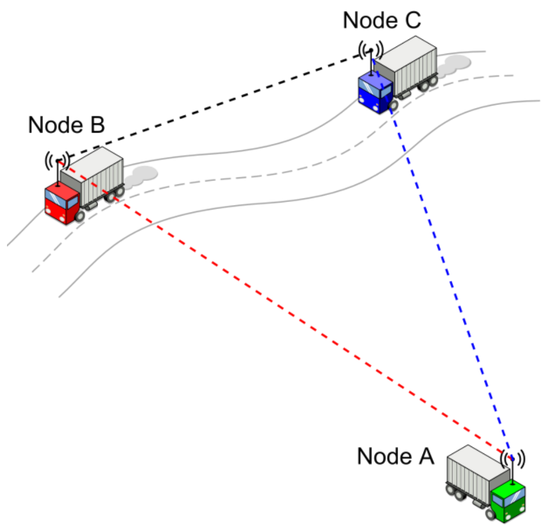
Validation: Distribution & Autocorrelation

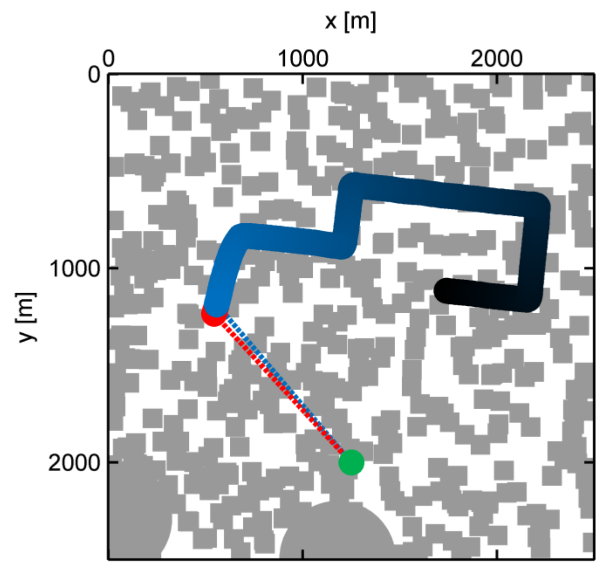




Stochastic Geometry Shadow Fading Model (SGSF)

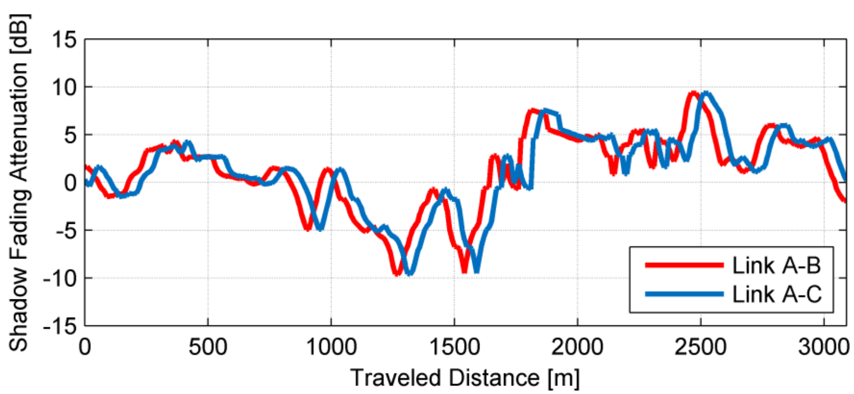
Correlation in a Convoy Scenario





Mobile Ad-Hoc Network

Correlation of Links ✓



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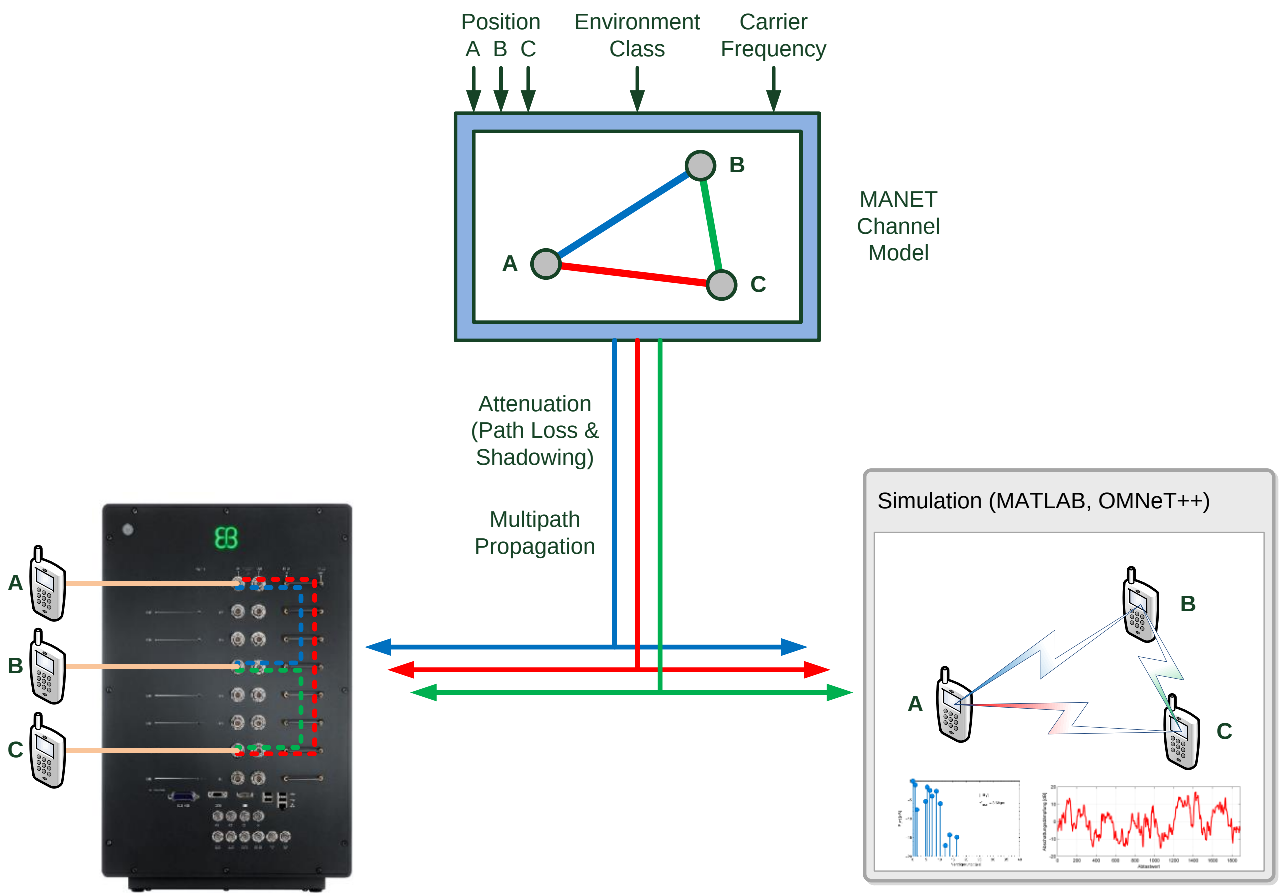
Combination & Application of the Presented Models
Channel Modeling for Mobile Ad-Hoc Networks



Evaluation of Available CommSystems **Development of Future Waveforms**

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Conclusion and Outlook
Channel Modeling for Mobile Ad-Hoc Networks

- Testing and Evaluation of MANETs requires adapted channel models
- Measurements for the application were performed in the VHF/UHF band
- Point-to-point channel models for path loss, shadow fading and multipath fading were adapted
- New channel model considering the correlation of the links in a MANET was presented
- MANET channel model combining the individual models was implemented for hardware and software simulators

- Improved Doppler spectra generation for mobile-to-mobile links based on stochastic scatter clusters will be presented at IEEE WiMob (Oct. 20th)

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Thank you for your attention!

Questions? Welcome!