

# 18<sup>th</sup> ComNets-Workshop

## Analytic Capacity Estimation of IMT-Advanced Scenarios

Dipl.-Ing. Maciej Mühleisen

ComNets Research Group  
RWTH Aachen University, Germany

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# Outline

- ITU-R IMT-Advanced Process
  - Motivation & Goals
  - Scenarios
  - Performance Indicators
  - Evaluation
- IMT-A Channel Model
- CIR Calculation for Indoor Hotspot Scenario
- Outlook
- Summary & Conclusion

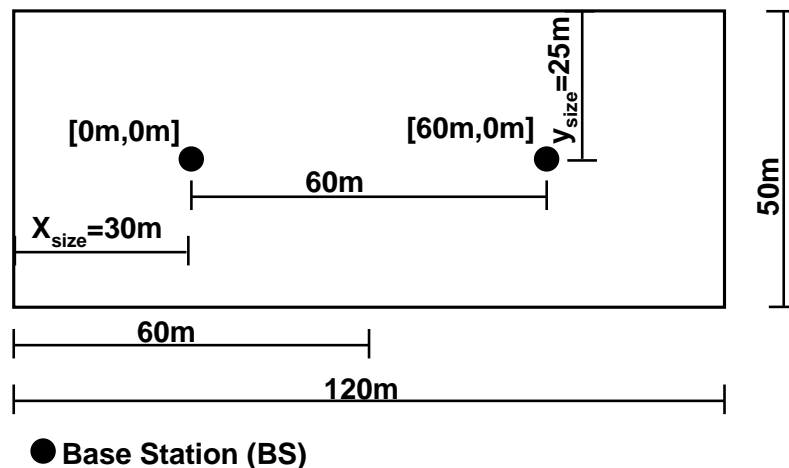
# ITU-R IMT-Advanced Process: Motivation & Goals

- World Radio Conference 2007 (WRC-07) has identified new spectrum for mobile radio communication
- ITU-R controls the allocation of this spectrum
- Issued the IMT-Advanced process to evaluate candidate systems

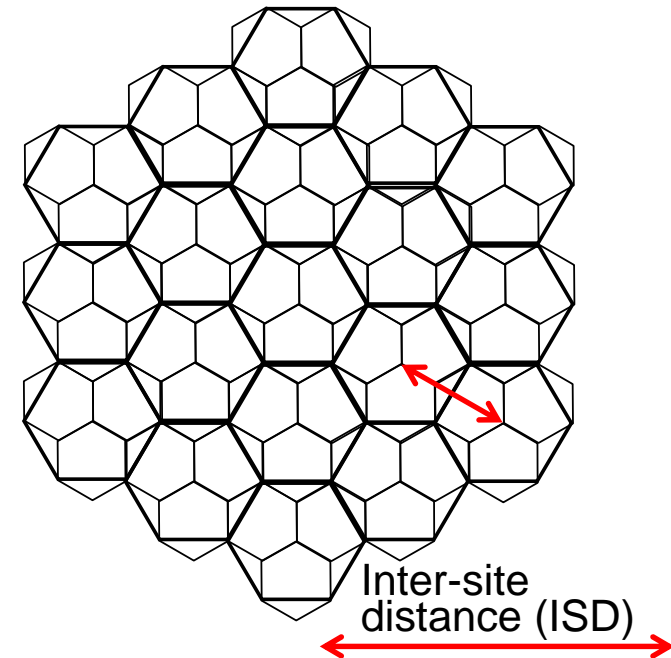
# ITU-R IMT-Advanced Process: Scenarios

- Test environments: Indoor, Microcellular, Base coverage urban, High speed
- Defined by: Cell size (ISD), 3D antenna pattern, channel model, TX power, center frequency, user velocity & class (pedestrian, vehicle, indoor), MIMO scheme

## Indoor



## Cellular



# ITU-R IMT-Advanced Process: Performance Indicators

Performance Indicator	Downlink Indoor / Urban	Uplink Indoor / Urban	Evaluation
Cell spectral efficiency	3 / 2.2 [bit/s/Hz/cell]	2.25 / 1.4 [bit/s/Hz/cell]	<b>System level simulation</b>
Peak spectral efficiency	15 / 15 [bit/s/Hz]	6.75 / 6.75 [bit/s/Hz]	Analytical
Cell edge user spectral efficiency	0.1 / 0.06 [bit/s/Hz/cell]	0.07 / 0.03 [bit/s/Hz/cell]	<b>System level simulation</b>
VoIP capacity	50 / 40 [Active users/cell/MHz]		<b>System level simulation</b>

# ITU-R IMT-Advanced Process: Evaluation

- Self evaluation: Done by bodies behind candidate Radio Access Technologies (RATs) (3GPP, IEEE)
- External evaluation: Done by others ex. WINNER+
  - Problem: How to verify used simulators => calibration

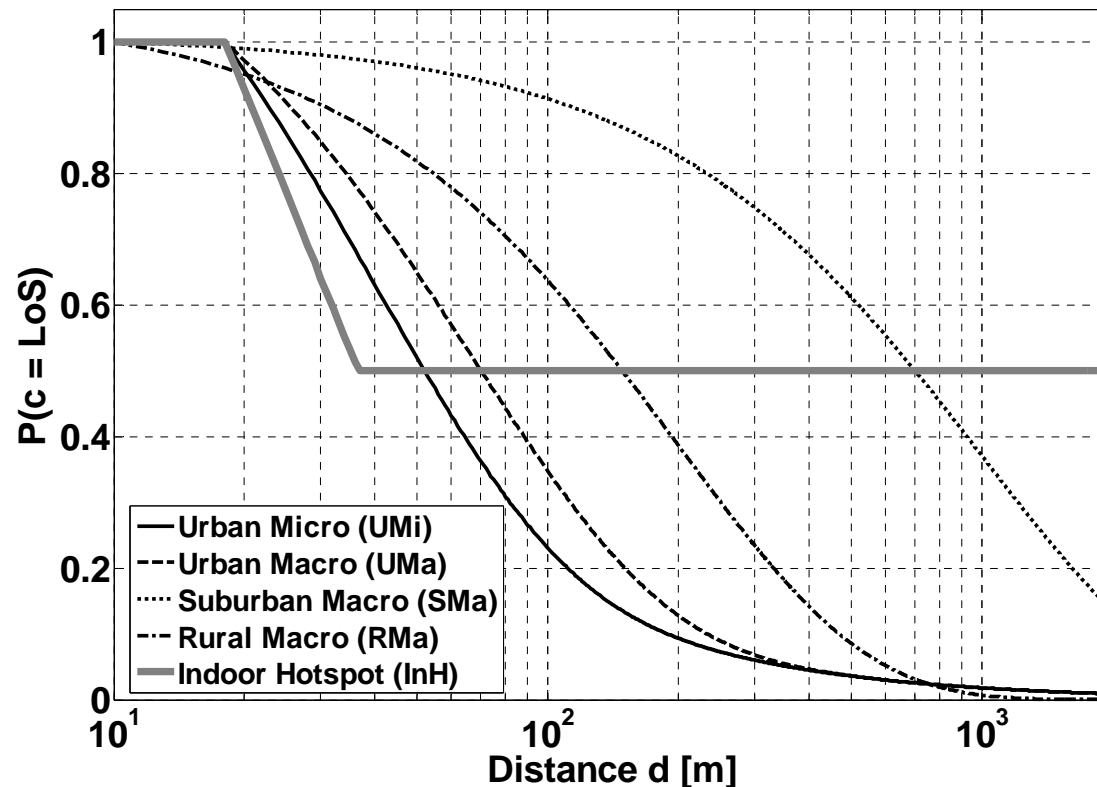
Have a look at: WINNER+ document “Calibration for IMT-Advanced Evaluations” available at

<http://projects.celtic-initiative.org/winner+/WINNER+%20and%20ITU-R%20EG%20documents/Calibration%20for%20IMT-Advanced%20Evaluations.pdf>

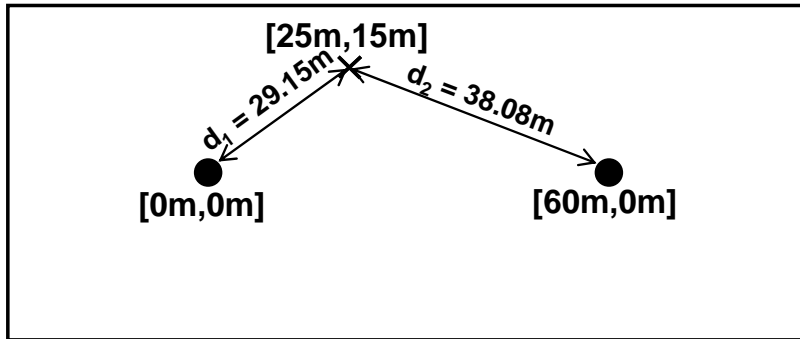
See Figures 1 and 21 to realize how different the results are

# IMT-Advanced Channel Model

- Channel model:
  - Small scale (multi-path fading), varying during simulation run
  - Large scale (path-loss and shadowing), per simulation run
  - Channel condition  $c$  line of sight (LoS) or non line of sight (NLoS) chosen randomly



# IMT-Advanced Channel Model

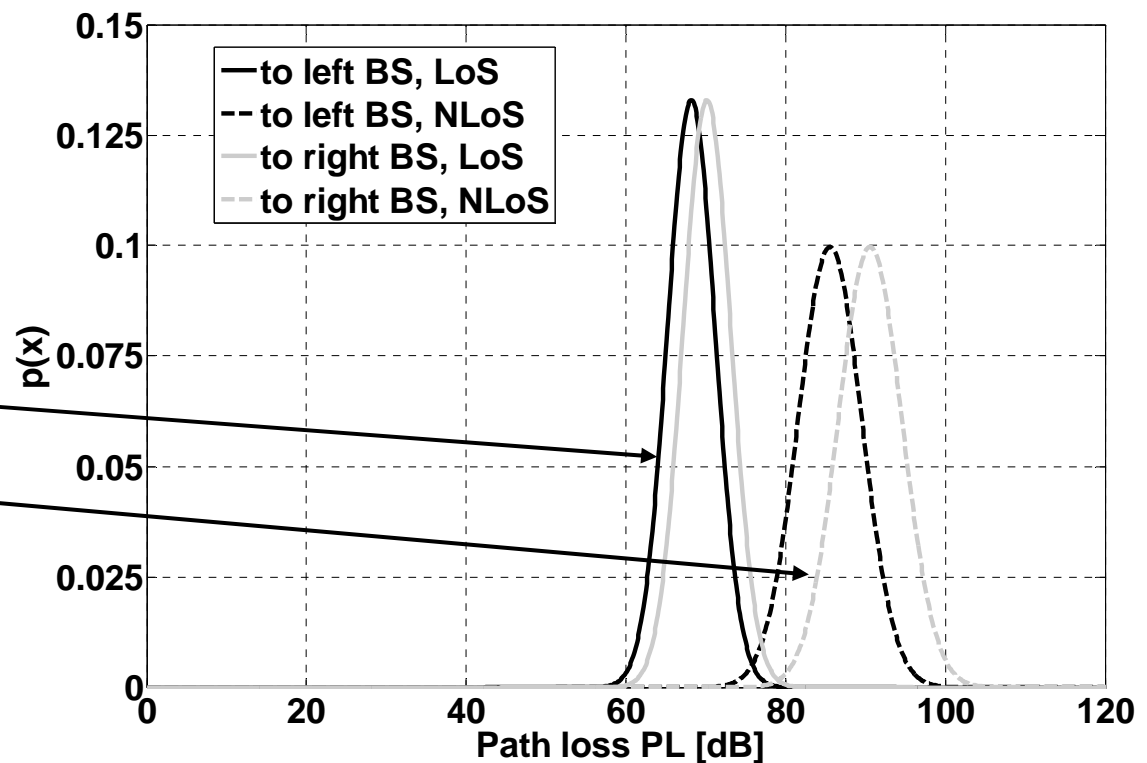


- Four different path loss distributions
- Depends on channel condition  $c$
- Depends on distance to BS  $b$

● Base Station (BS)  
 × User Terminal (UT)

$$p(\text{PL}|c=\text{LoS}, b=1) \\ \sim N(16.9 \log_{10}(d_1) + 43.4, 3) \text{ [dB]}$$

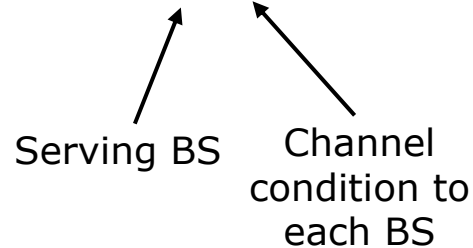
$$p(\text{PL}|c=\text{NLoS}, b=2) \\ \sim N(43.3 \log_{10}(d_2) + 22.1, 4) \text{ [dB]}$$





# CIR Calculation for Indoor Hotspot Scenario

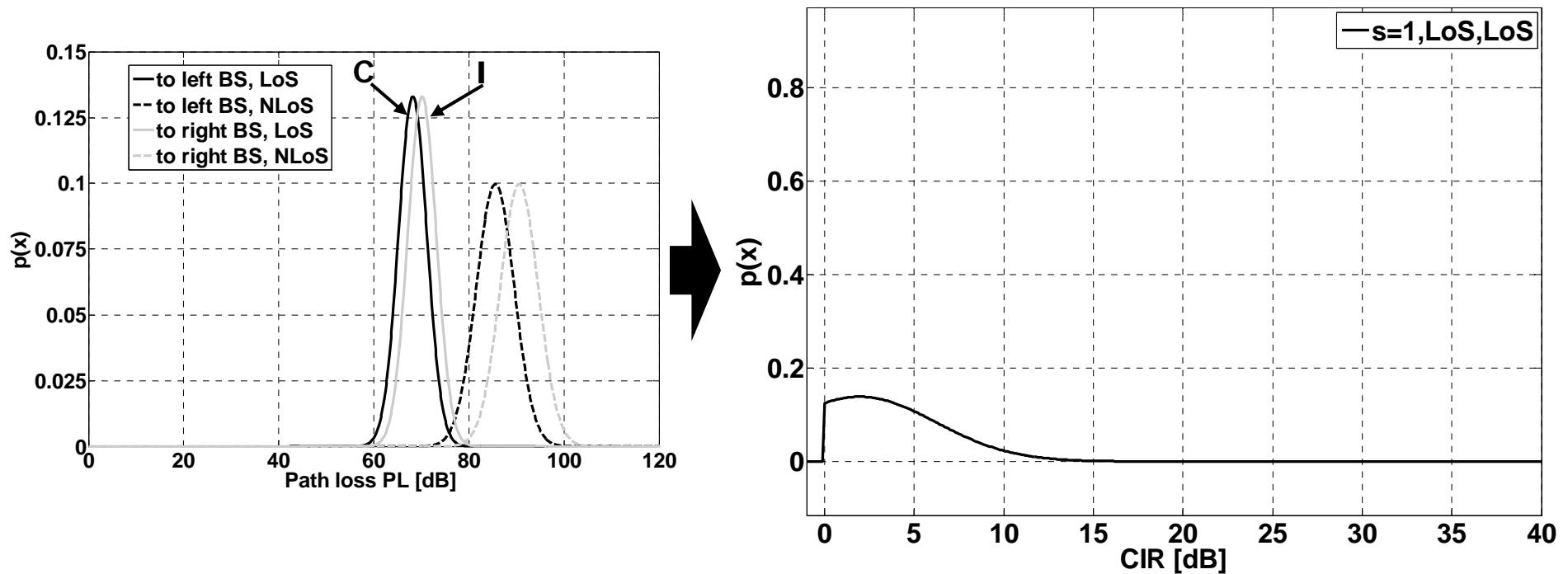
- Which BS is serving? The one with lowest  $PL$  at link
- $PL$  is a random value => Calculate probability for each BS and channel state combination
- $P(\text{serving} = \text{BS1}) = P(PL_{\text{BS1}} < PL_{\text{BS2}}) = P(PL_{\text{BS1}} - PL_{\text{BS2}} > 0)$
- Calculated using error function **erf**
- $n = 2$  BSs:  $n 2^n = 8$  combinations



Serving BS $s$	Channel condition to BS1 $c_1$	Channel condition to BS2 $c_2$
1	LoS	LoS
1	NLoS	LoS
1	LoS	NLoS
1	NLoS	NLoS
2	LoS	LoS
2	NLoS	LoS
2	LoS	NLoS
2	NLoS	NLoS

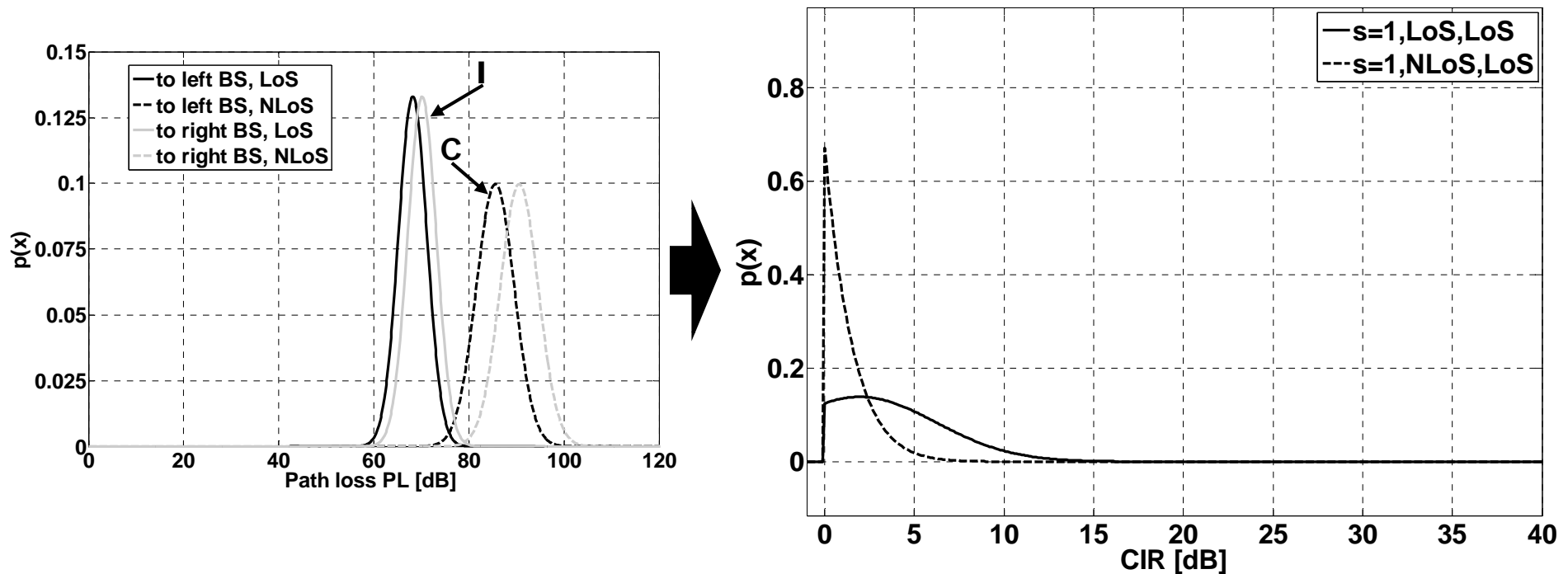
# CIR Calculation for Indoor Hotspot Scenario

$$p(\text{CIR}|s=1, c_1, c_2) \sim N(\mu_{2,c2} - \mu_{1,c1}, \sqrt{\delta_{1,c1}^2 + \delta_{2,c2}^2}) \mathbb{1}_{\{x > 0\}} / P(s=1)$$



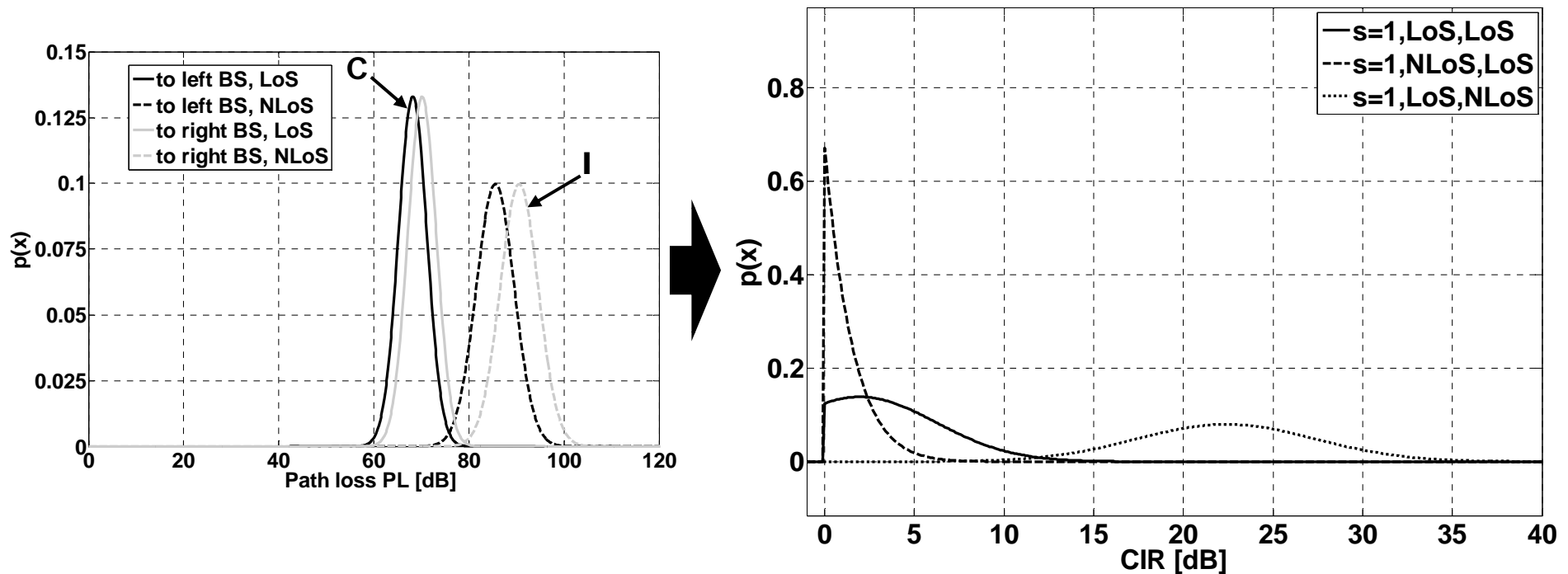
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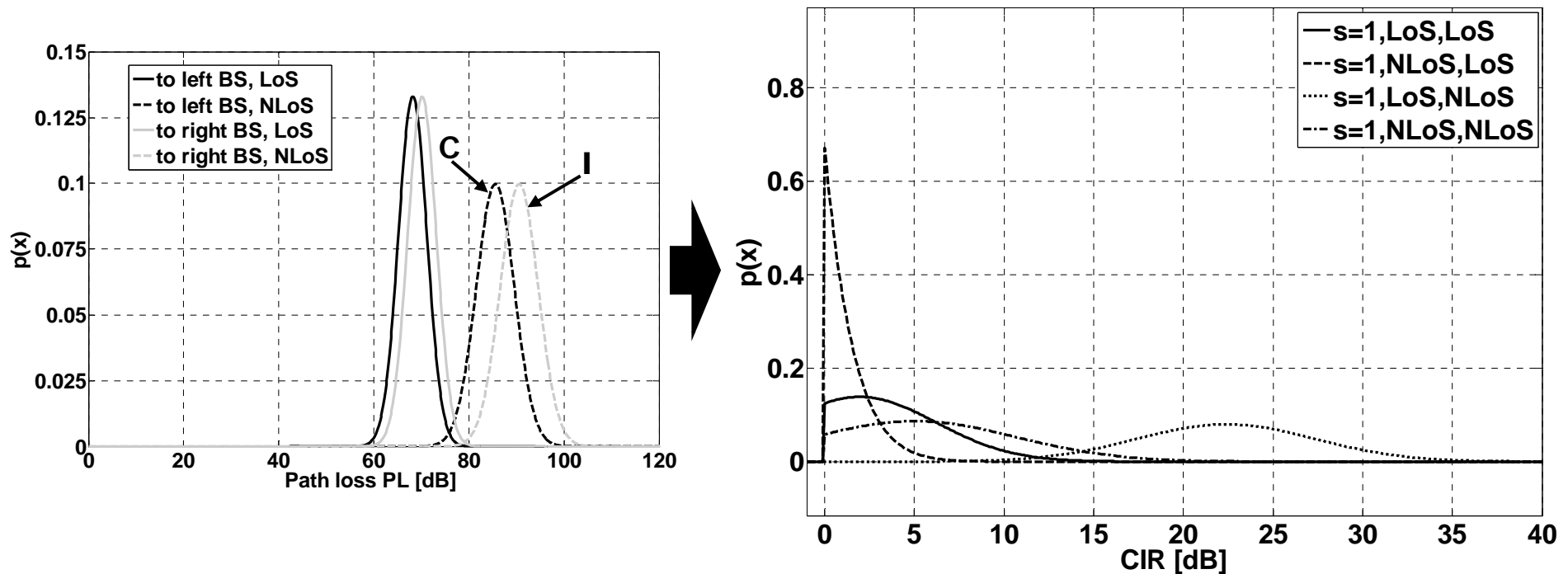
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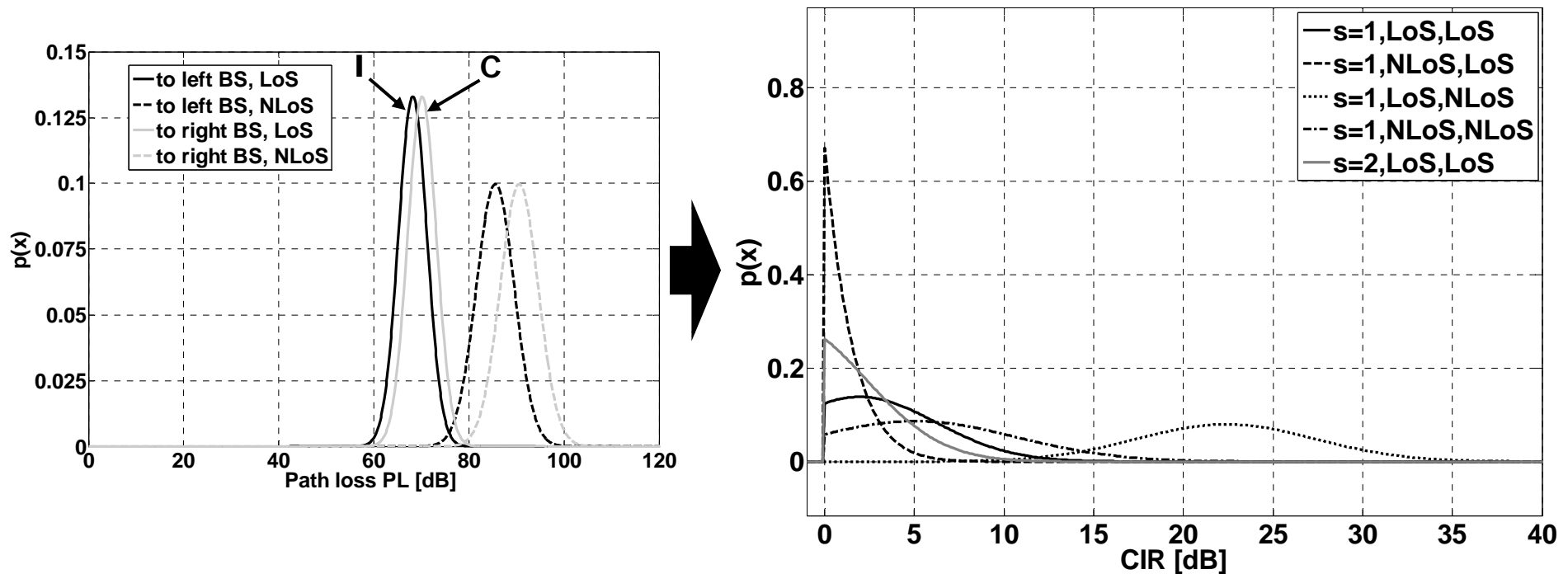
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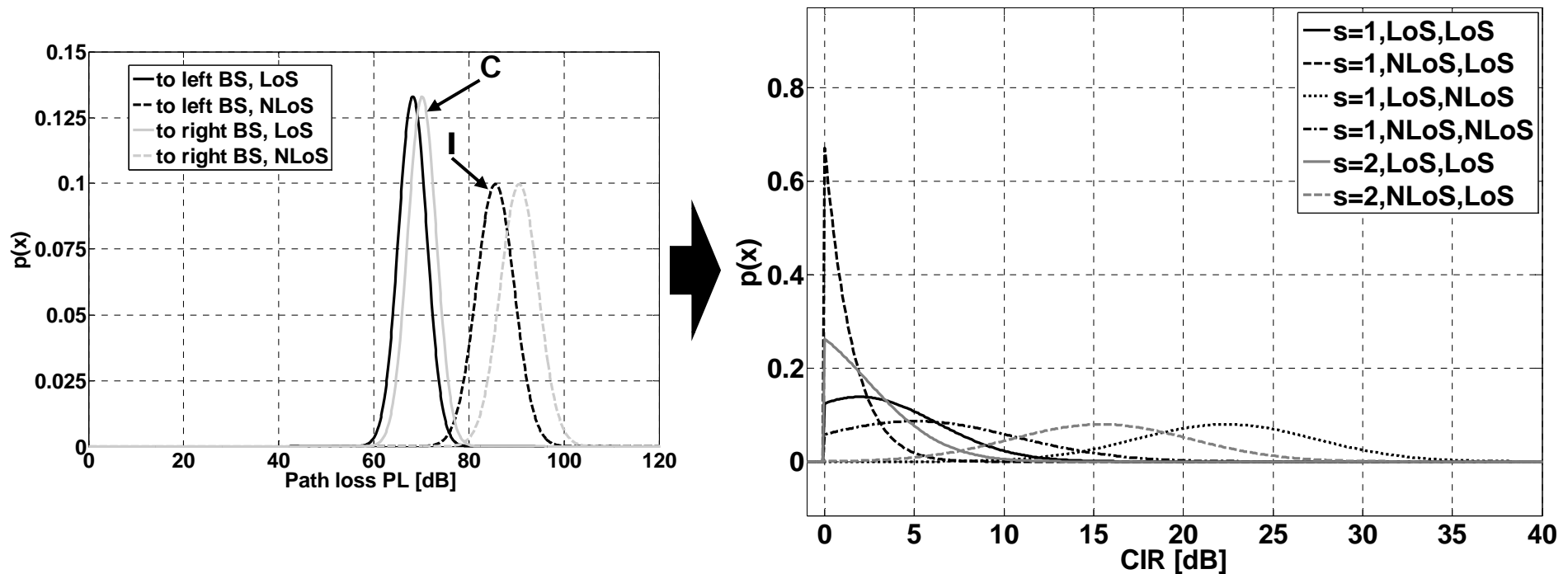
# CIR Calculation for Indoor Hotspot Scenario

$$p(\text{CIR}|s=2, c_1, c_2) \sim N(\mu_{1,c1} - \mu_{2,c2}, \sqrt{\delta_{1,c1}^2 + \delta_{2,c2}^2}) \mathbb{1}_{\{x > 0\}} / P(s=2)$$



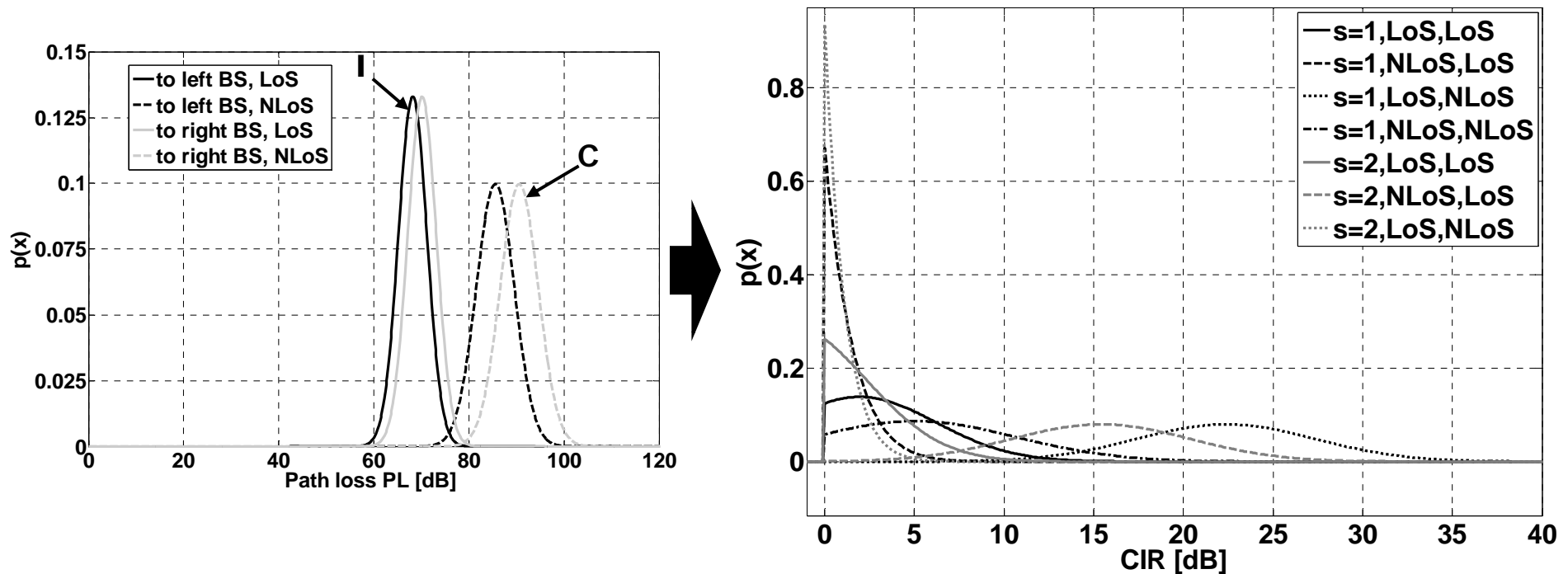
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# CIR Calculation for Indoor Hotspot Scenario

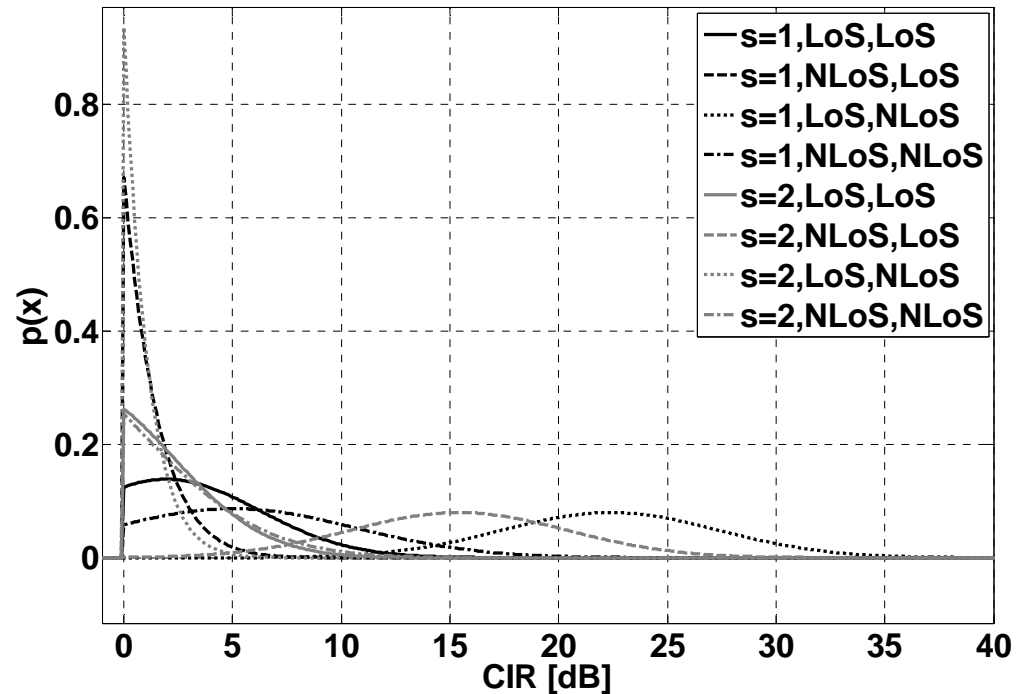
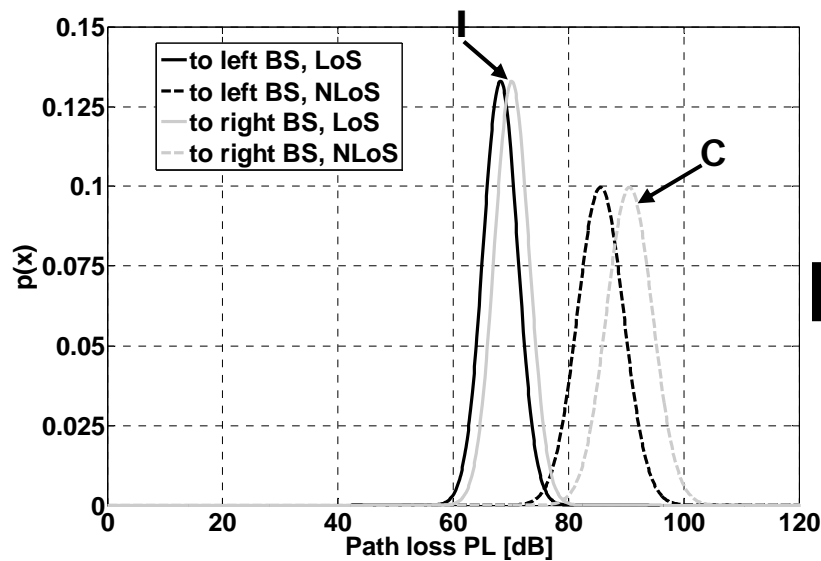
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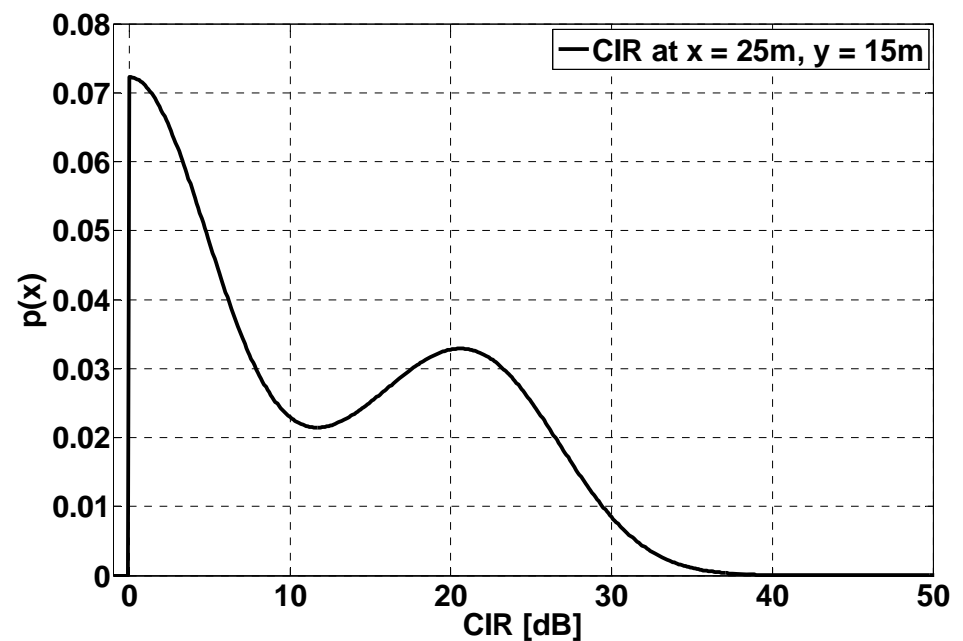
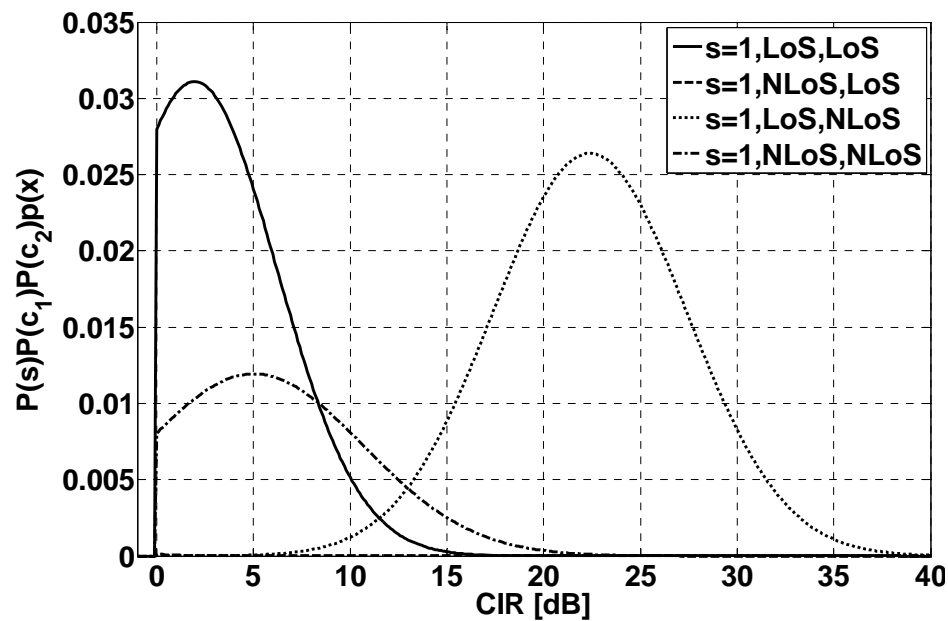
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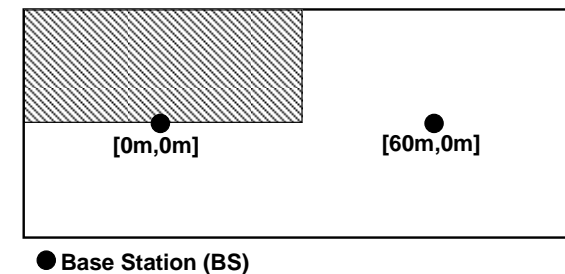
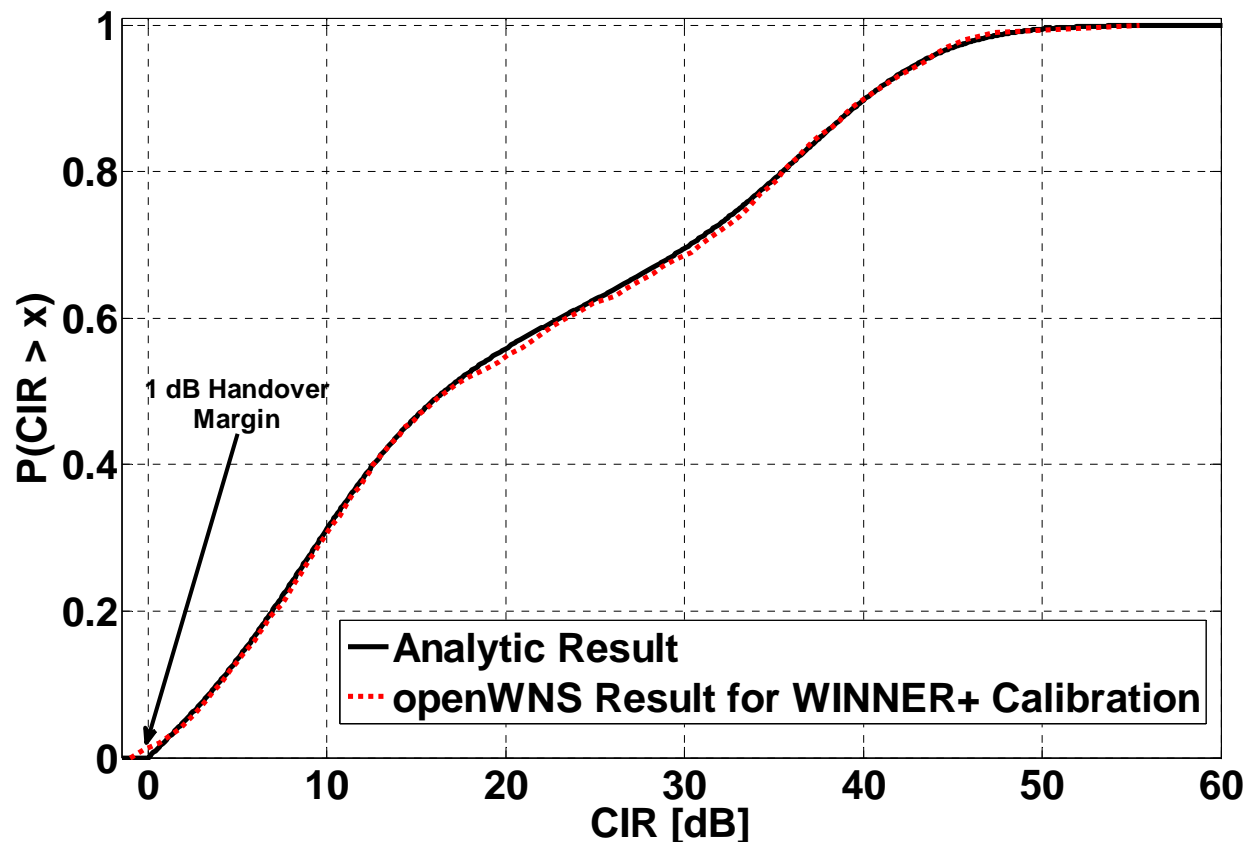
# CIR Calculation for Indoor Hotspot Scenario

$$P(\text{CIR}|x,y) = \sum_{\forall s,c_1,c_2} P(s)P(c_1)P(c_2)p(\text{CIR}|s,c_1,c_2)$$



# CIR Calculation for Indoor Hotspot Scenario

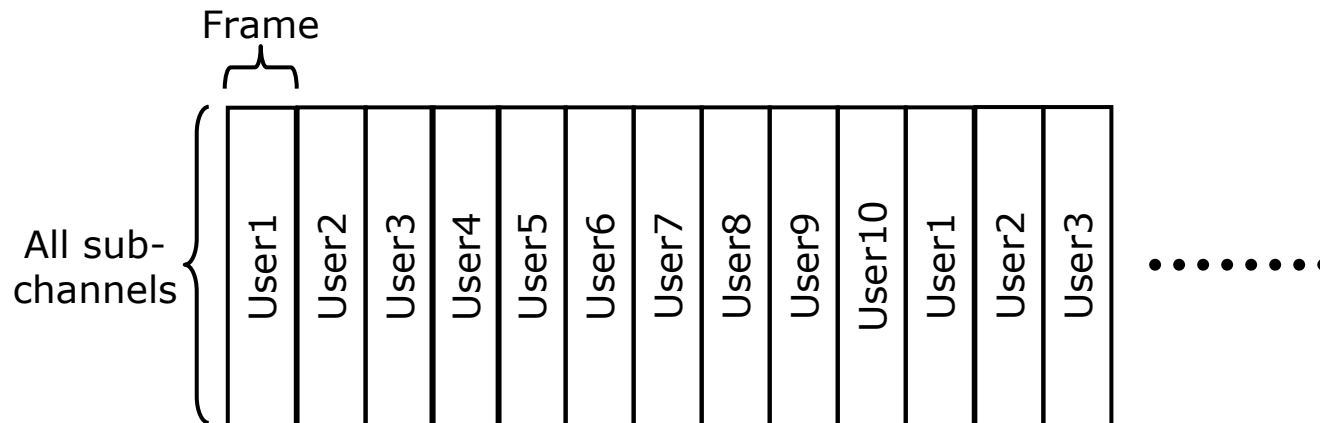
- Integrate over the area and normalize to obtain scenario CIR
- No solution for integral is known => sum up, use symmetry
- Analogous for unlink



# Outlook: Layer 2 Calibration

Influence of layer 2 & small scale fading:

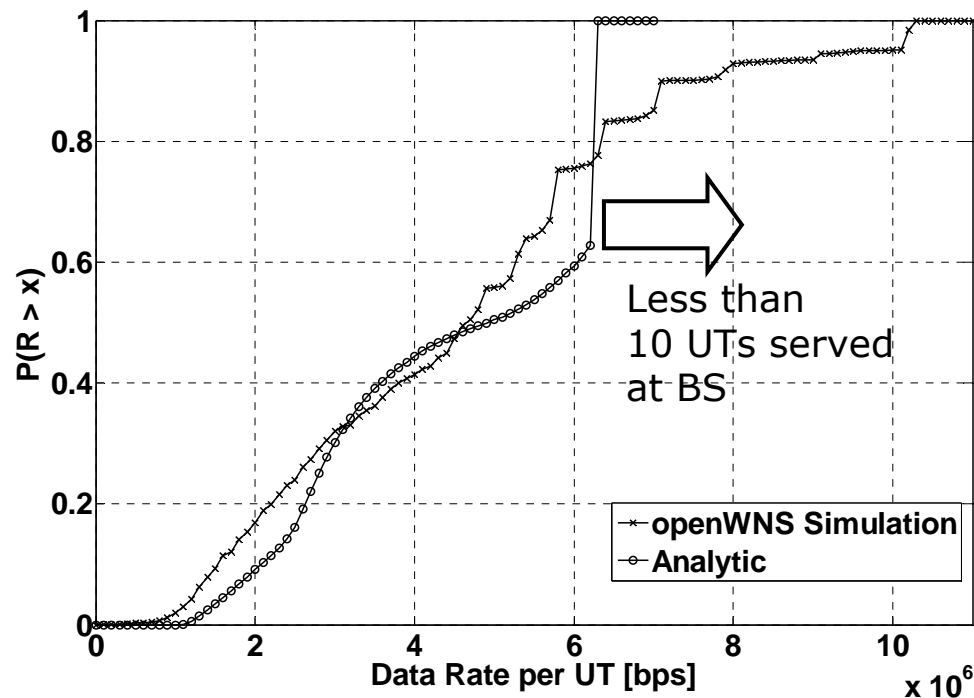
- UTs share capacity
  - 20 UTs, 2 BSs
- Control traffic (eg. MAP & CQI), fixed and extended MAC header
- Per subchannel small scale fading => averaged out
- Hybrid Automatic Repeat Request (HARQ)



Downlink scheduling scheme for LTE R8 calibration

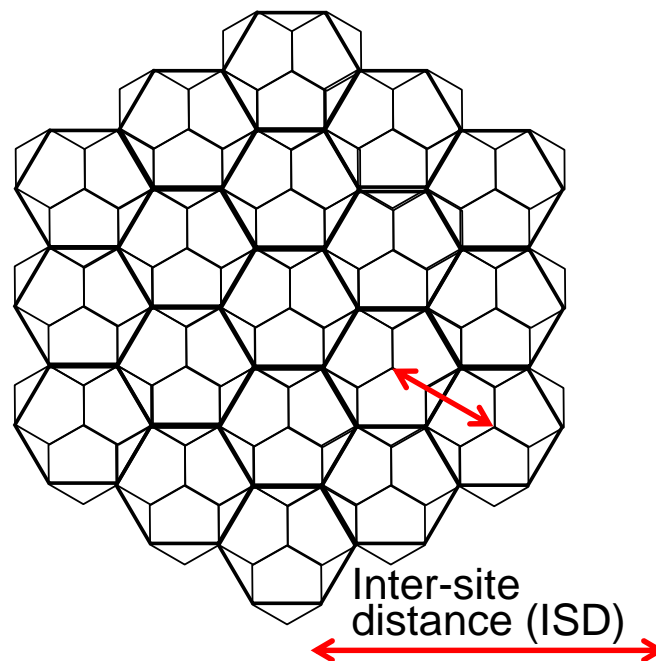
# Outlook: Layer 2 Calibration

- At each position we can calculate eight weighted data rates
  - SINR => data rate
  - 1 / 10 per UT
- Include MAC overhead (3 of 14 symbols for MAP etc.)
- Include fixed and extended MAC headers (not done yet)
- **There can be more / less than 10 UTs associated with a BS**



# Outlook: Cellular Scenario

- $n 2^n \approx 42$  million for 21 sectors
  - Done in [1] without shadowing
- Interference: Approximate sum of log-normally distributed RVs
- Include antenna patterns (additional shift of mean value)



[1] D. Bueltmann, T. Andre, R. Schoenen "Analysis of 3GPP LTE-Advanced Cell Spectral Efficiency" PIMRC 2010

# Summary & Conclusion

- A method to calculate the CIR distribution in the IMT-Advanced indoor hotspot scenario has been presented
- The method can help to verify system level simulation models
- Due to its computational complexity it can hardly substitute results from simulation
- It needs to be further extended to allow layer 2 calibration and more than 2 cells

**Thank you for your attention !**

Maciej Mühleisen

mue@comnets.rwth-aachen.de