A Study on Spectrum Sharing for Heterogeneous Networks Using Full 3D Area Model

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1. Introduction

Heterogeneous Networks

- Wireless systems with different cell sizes, which are an Urban Macro cellular system (UMa) and Indoor Hotspot systems (InH), sharing the same spectrum
- Potential advantages
  - Extremely large per-area capacity achieved by the InH systems
  - Wide coverage area supported by the UMa system
- Potential Problem (especially for "closed access" cases)

  : Inter-system interference causes system performance degradation including capacity decrease and outage probability, e.g.
  - Communication quality of UMa MSs are severely degraded by InH BS.
  - Large interference limits the capacities of InH BSs near UMa BSs.

⇨ Appropriate performance evaluation (esp. inter-system interference) of InH and UMa is a tool of great necessity for designing Heterogeneous Networks.

1. Introduction

<u>Conventional estimation methods for system-level simulation</u>

1. System-level simulation based on Statistical propagation model
   A) 2-Dimensional evaluation method; e.g. ITU-R P.1411 and Hata Model
      - A typical outdoor model is applied to all Tx-Rx links.
      - Requires small calculation complexity.
      - Lack of Line-of-Sight/non Line-of-Sight conditions yields non-realistic evaluation results.

   B) Partial 3-Dimensional evaluation method
      - Assume 3D model for partial areas, 2D model for the other areas
      - Selects appropriate statistical propagation models within the 3D area, while a typical outdoor model is applied to all paths lying between 2D-3D areas
      - The problem of 2D-based method remains for the path lying between 2D-3D areas
2. System-level simulation based on Ray tracing
   - Yields realistic results compared to statistical propagation model.
   - Requires tracing many rays including reflections and diffractions even for one Tx-Rx link, which results in unaffordable complexity for large scale system level simulations.

1. Introduction

In this study,

1. Propose an estimation method which yields realistic system performances of heterogeneous networks with moderate calculation complexity.

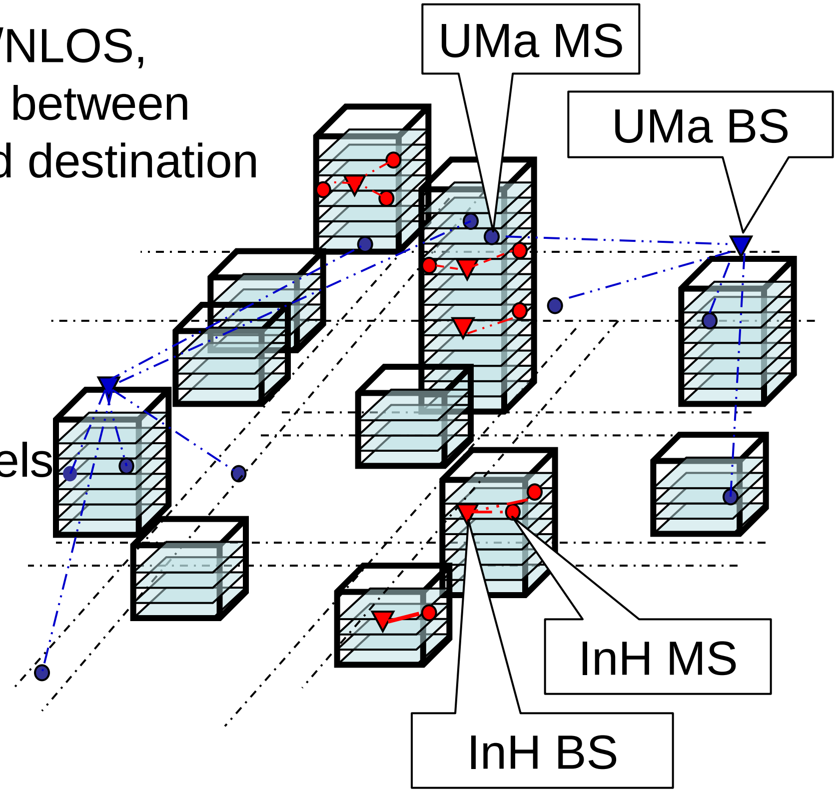
2. Evaluate SINR performance of the UMa system and the InH system under a heterogeneous network environment using 2D-based simulation method and the proposed method to show the necessity of "Full 3D-based system-level simulation".

   The system capacity of the UMa system and the InH system are also evaluated.

2. System Level Evaluation based on 3D

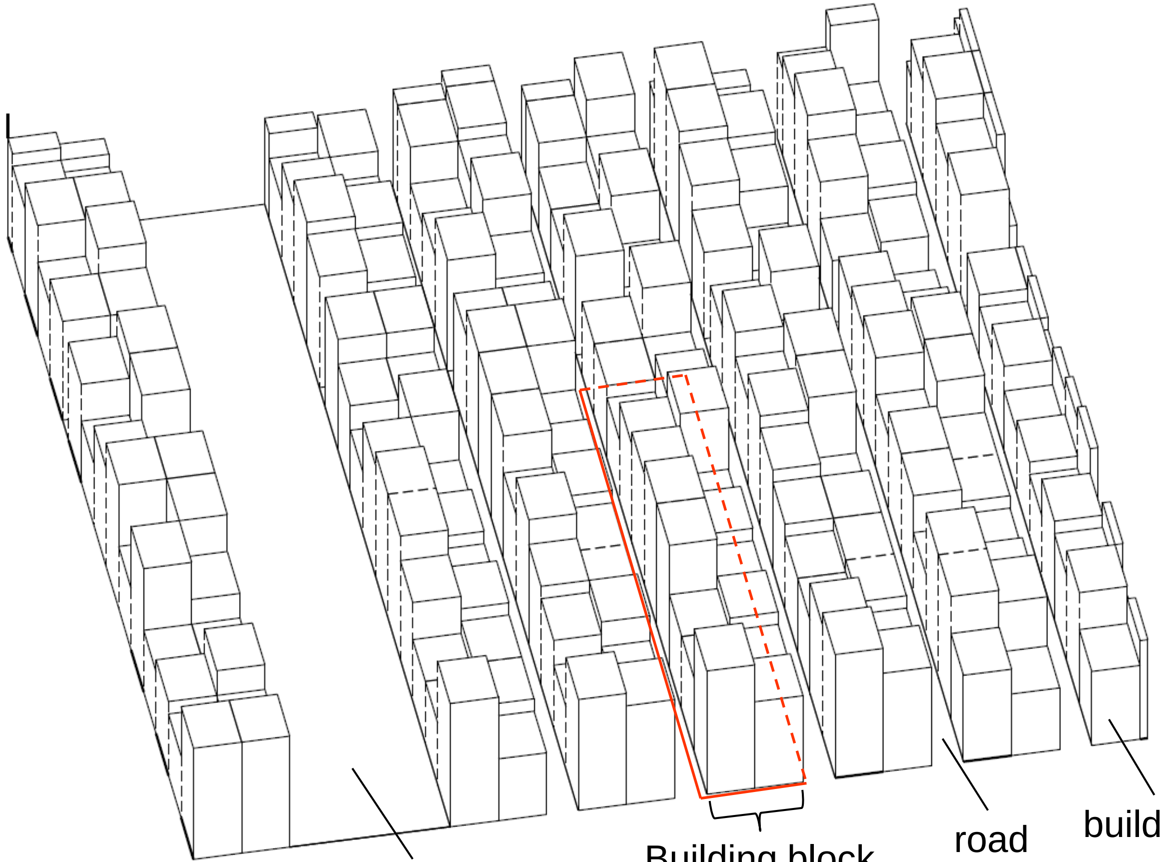
Basic procedure of the proposed method

1. Generate a 3-Dimensional area -> Slide 6
2. Allocate BSs and MSs of UMa and InH
3. Calculate propagation losses between transmitters and receivers for system performance evaluation ->Slide 7,8
   A) Check path conditions such as LOS/NLOS, obstacles by tracing only direct path between Tx-Rx pairs together with source and destination conditions such as indoor/outdoor
   (only for indoor cases)
   located building block ID/
   located building ID/ located floor.
   B) Select appropriate propagation models and take account of
   additional losses according to the direct path conditions.



2.1 3D Area Model

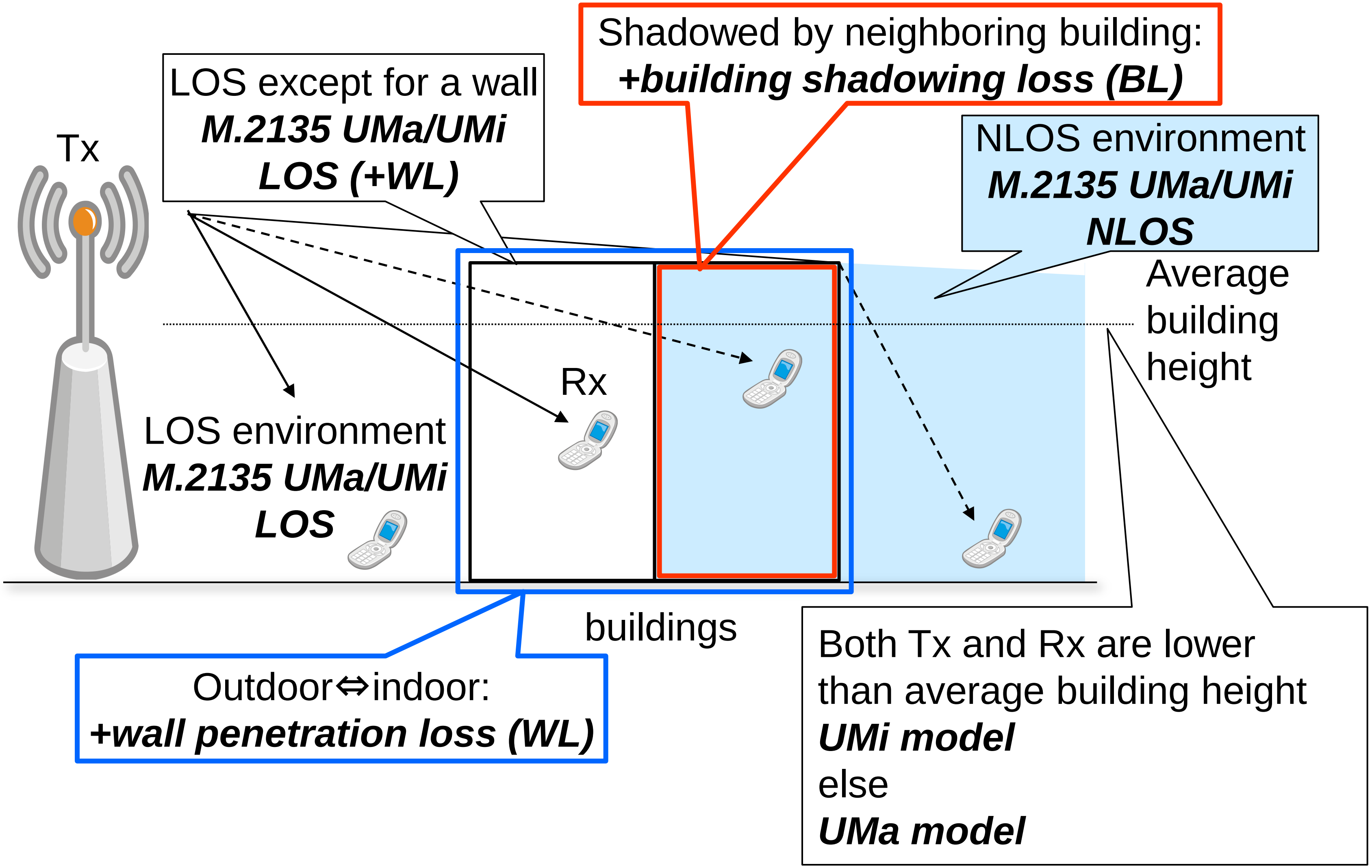
Example of the assumed 3D area model



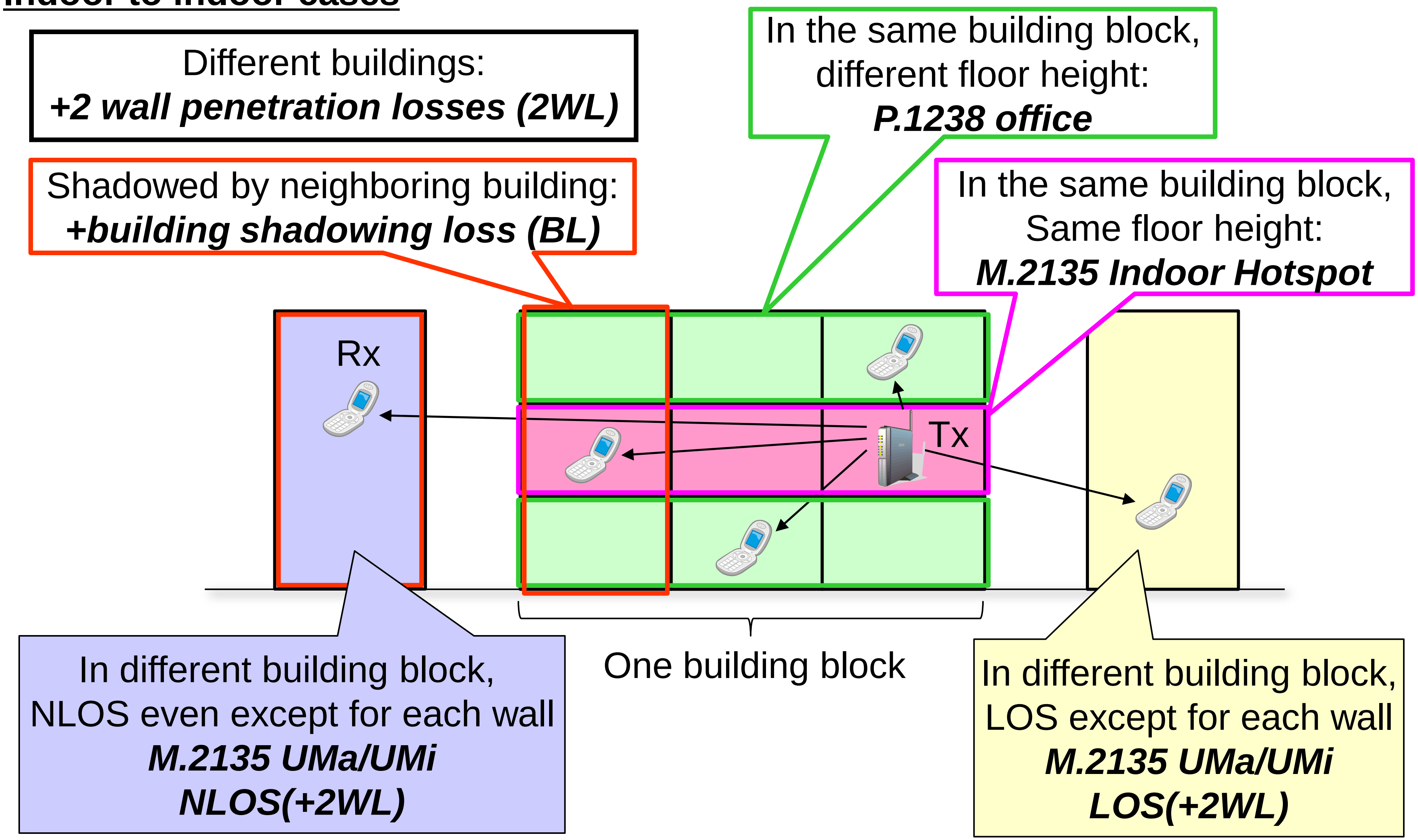
Note: Only a part of the whole assumed area is shown.

2.2 Key Procedures for Propagation Model Selections

Outdoor to outdoor cases & Outdoor to indoor cases



Indoor to indoor cases



3. Performance Evaluation

Overall Parameters

Frequency	2100MHz
Thermal noise density	-174dBm/Hz
Bandwidth	5MHz
Wall penetration loss (WL)	12dB
Building shadowing loss (BL)	12dB

UMa/InH MS parameters

Antenna	Isotropic 0dBi
Noise figure	6dB
MS height	1.5m above floor or ground

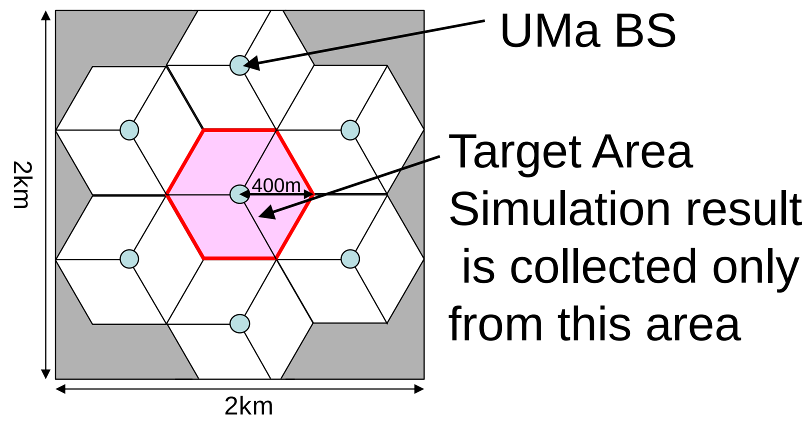
UMa BS Parameters

Antenna	F.1336 3-sectors14dBi
Transmission power	5W
Cell radius	400m
BS height	50m

InH BS parameters

Antenna	F.1336 Omnidirectional 3dBi
Transmission power	20mW
Location	Center of each floor
BS height	3m above floor

UMa BS Location



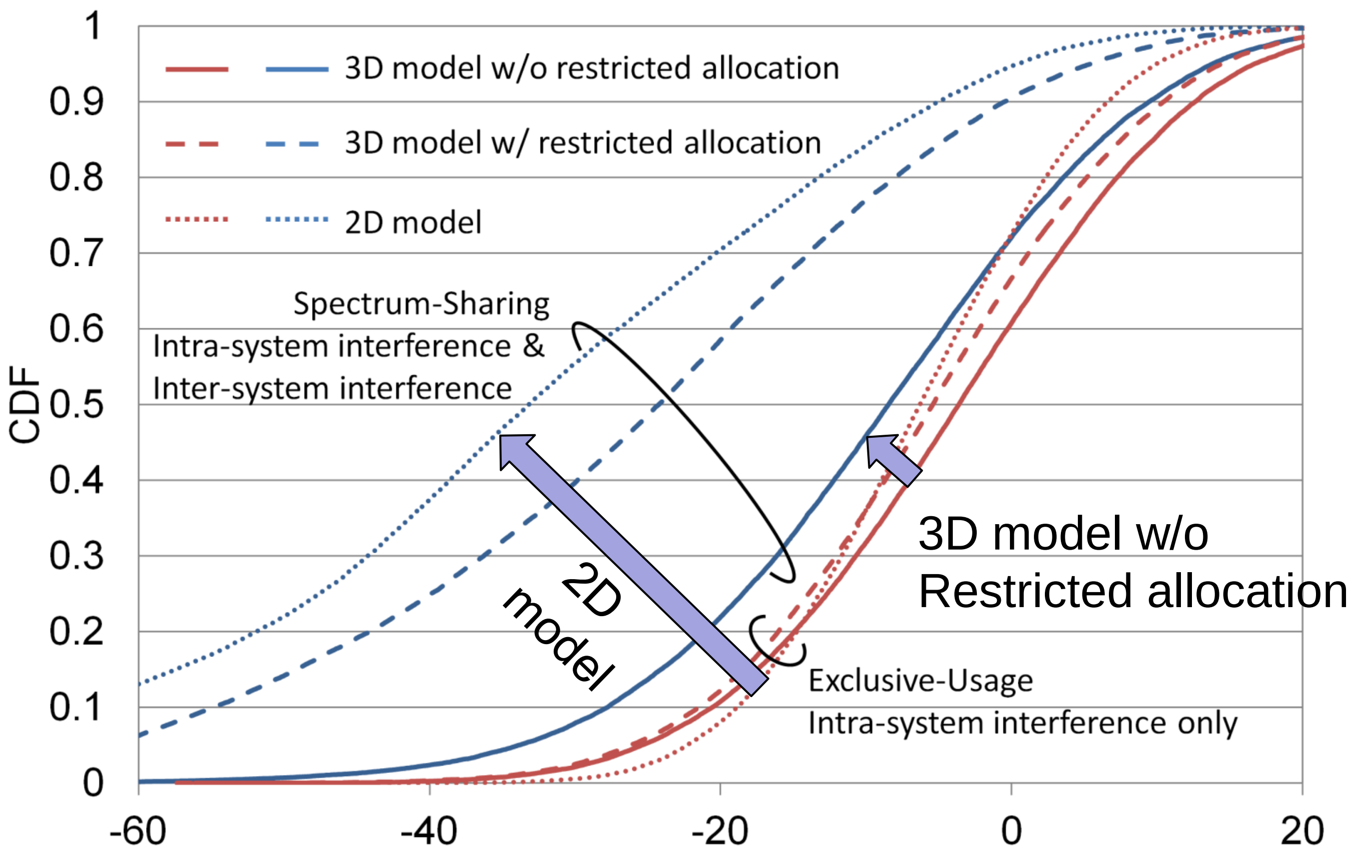
UMa MSs and InH BS/MS Allocation

•Uma MSs: Uniformly located on floor or ground.
•InH BSs: Uniformly located on each building floor. (No more than 2 BSs are installed on any 1 floor).
•InH MSs: Uniformly located on the same floor of registered InH BSs.

Other assumptions

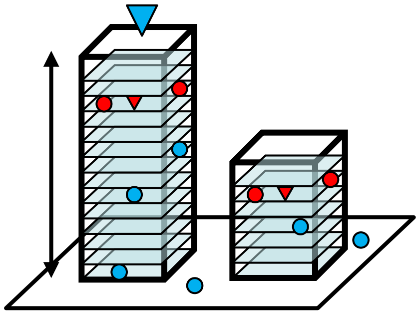
• Downlink only
• UMa BSs accept only UMa MSs, InH BSs accept only registered InH MSs.
• Shadow-fading factors are generated using shadow-fading parameters defined by applied channel models.
• Frequency reuse factor: 1
• Traffic model: Full buffer

3.1 SINR distribution at UMa MSs

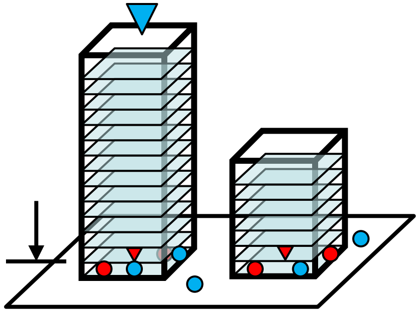


Geographical Density of InH BS: 400[stations/km^2]

3D model w/o restricted allocation: Uniformly distributed

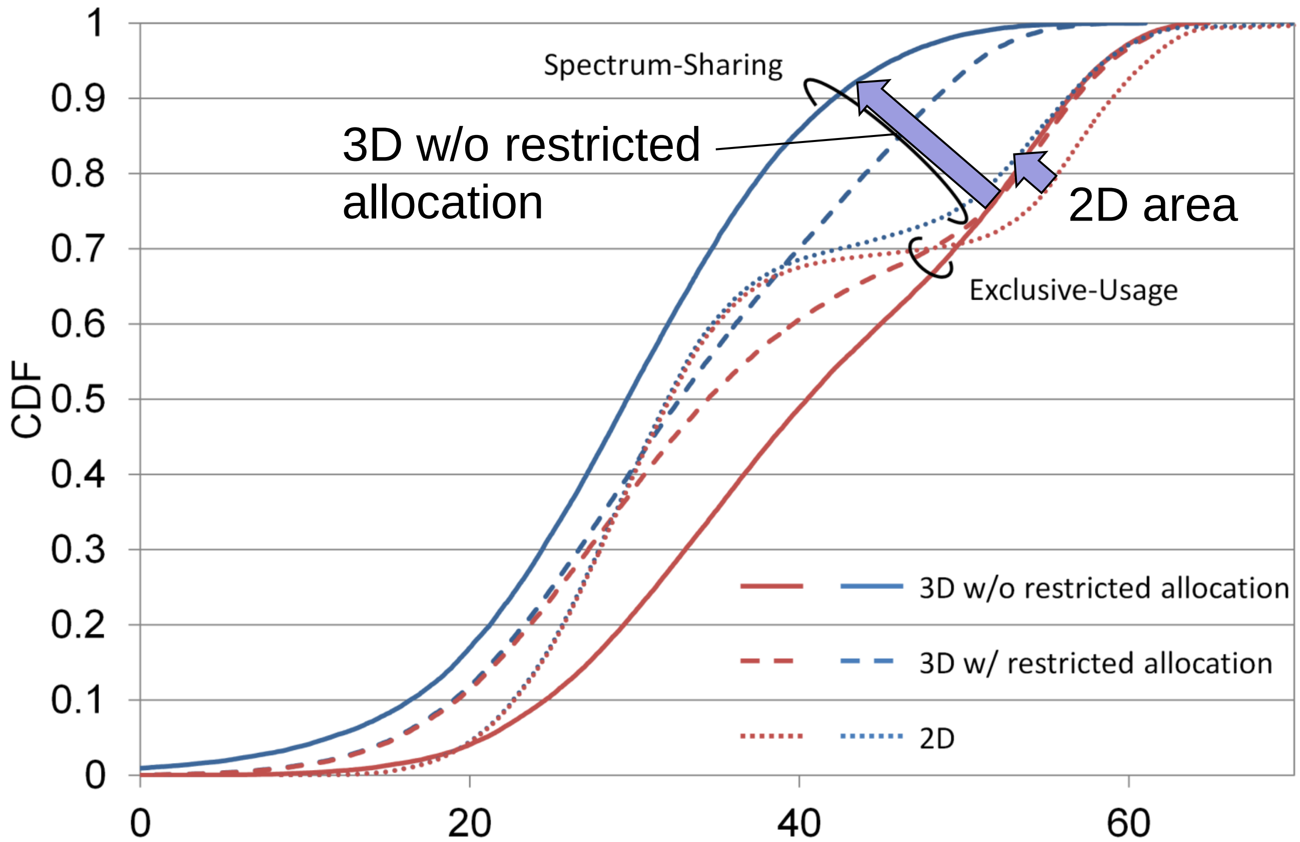


3D w/ restricted allocation: Only on the 1st floor or road



2D area based method overestimates **InH-to-UMa** interferences, mainly due to the lack of vertical dimension for InH BS allocation.

3.1 SINR distribution at InH MSs

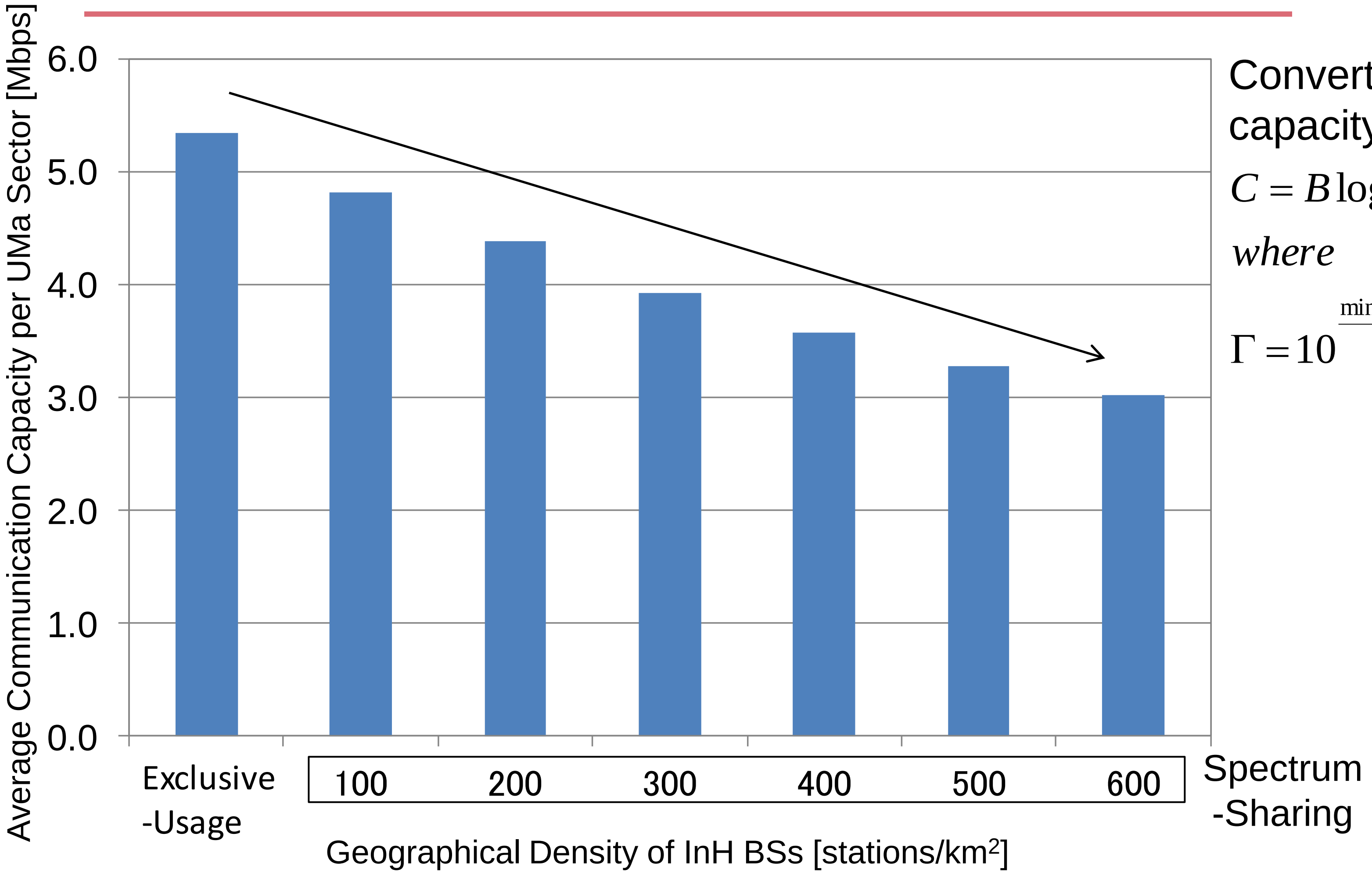


Geographical Density of InH BS: 400[stations/km²]

Better ->

2D area based method underestimates UMa-to-InH interferences.

3.2 Communication Capacity of UMa BS



Convert SINR to capacity

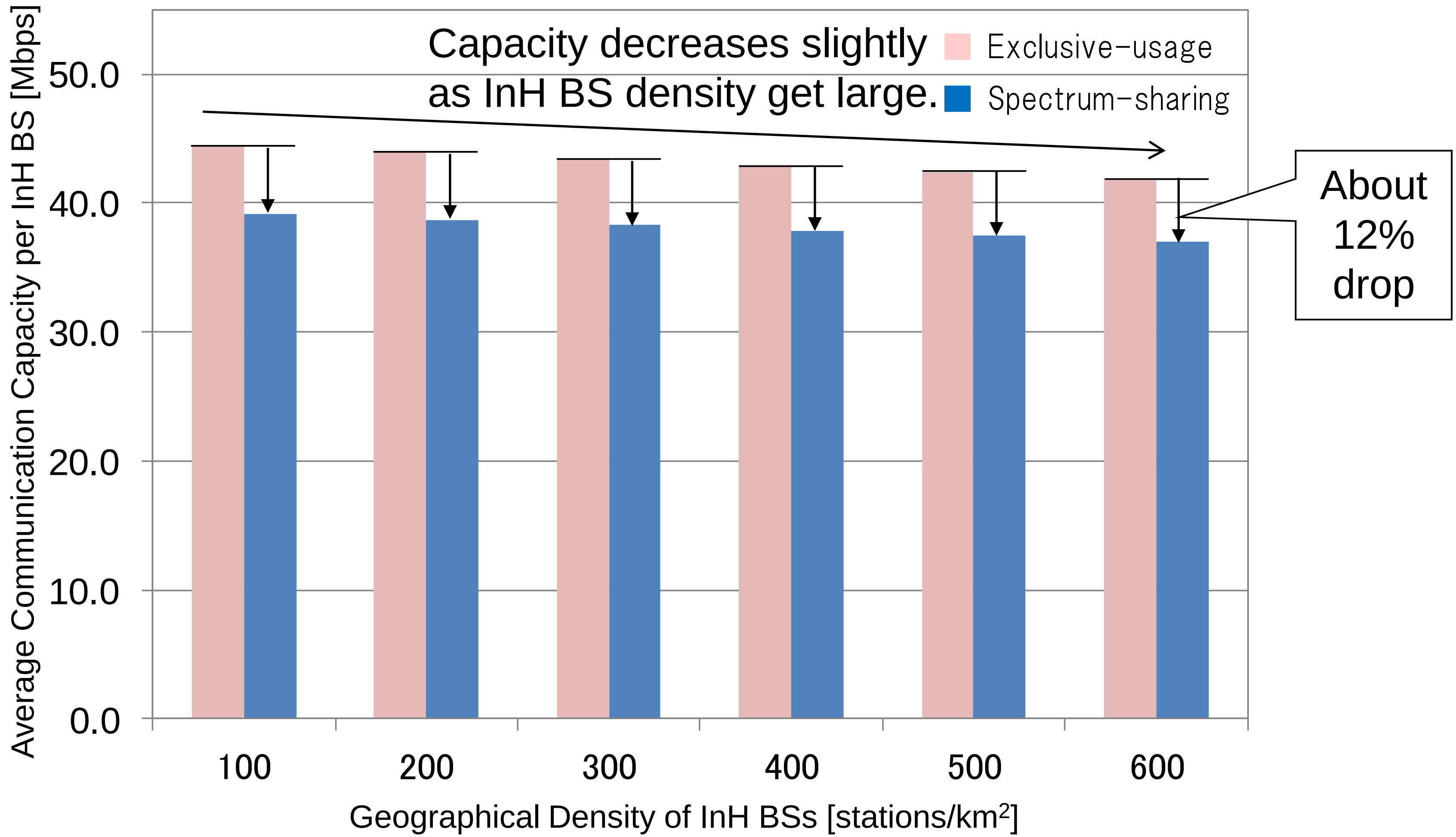
$$C = B\log_2\left(1+0.5\Gamma\right)$$

where

$$\Gamma = 10^{\frac{\min\left(SINR,30[dB]\right)}{10}}$$

UMa loses about 7% capacity per 100 InH BS increase.

3.2 Communication Capacity of InH BS



InH loses About 12% capacity regardless of the assumed InH BSs density, because the interference from UMa BSs is the dominant factor to limit the InH capacity.

4. Summary

- Proposed system-level simulation method for heterogeneous network
  - Full 3-Dimensional area with buildings
  - Perform tracing only direct path between Tx-Rx pairs
  - Select appropriate statistical model and additional loss
- Comparison between proposed method and conventional 2D model reveals that
  - 2D-based system level simulation **largely Overestimate** InH-to-UMa interference.
  - 2D-based system level simulation **Underestimate** UMa-to-InH interference

  ⇒ Full 3D-based system level simulation seems inevitable for the evaluation of heterogeneous network performances.
- Impacts of inter-system interferences on capacities achieved by UMa and InH under a heterogeneous network environment were also evaluated
  - UMa loses about 7% capacity per 100 InH BS increase.
  - InH loses About 12% capacity regardless of the assumed InH BSs density.

Acknowledgement

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