5G Study
Simulation Results with different TX Powers & Bandwidths

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Physical Layer Simulation Study

Overview

- Evaluated System Level performance of a suburban neighborhood with residential UEs
  - 39GHz band with 200, 400, 800 MHz bandwidth
  - Various transmit powers at the AP and UE
    - AP EIRP: 62dBm per 100MHz or 85dBm
    - UE EIRP: 43dBm or 53dBm
  - Indoor UEs vs. Outdoor UEs, Downlink and Uplink
  - AP Antenna Array: 2D XP: 8 Rows, 4 Columns, 2 Polarizations: 64 total elements
  - UE Antenna Array: 2-antenna omni XP array
  - Static TDD system with 50-50 UL/DL split
- Purpose:
  - Continue the study of system level performance of outdoor mmWave systems started in [4] for urban street canyons based on the METIS scenarios.
  - Explore system level behavior with different system bandwidth and transmit powers

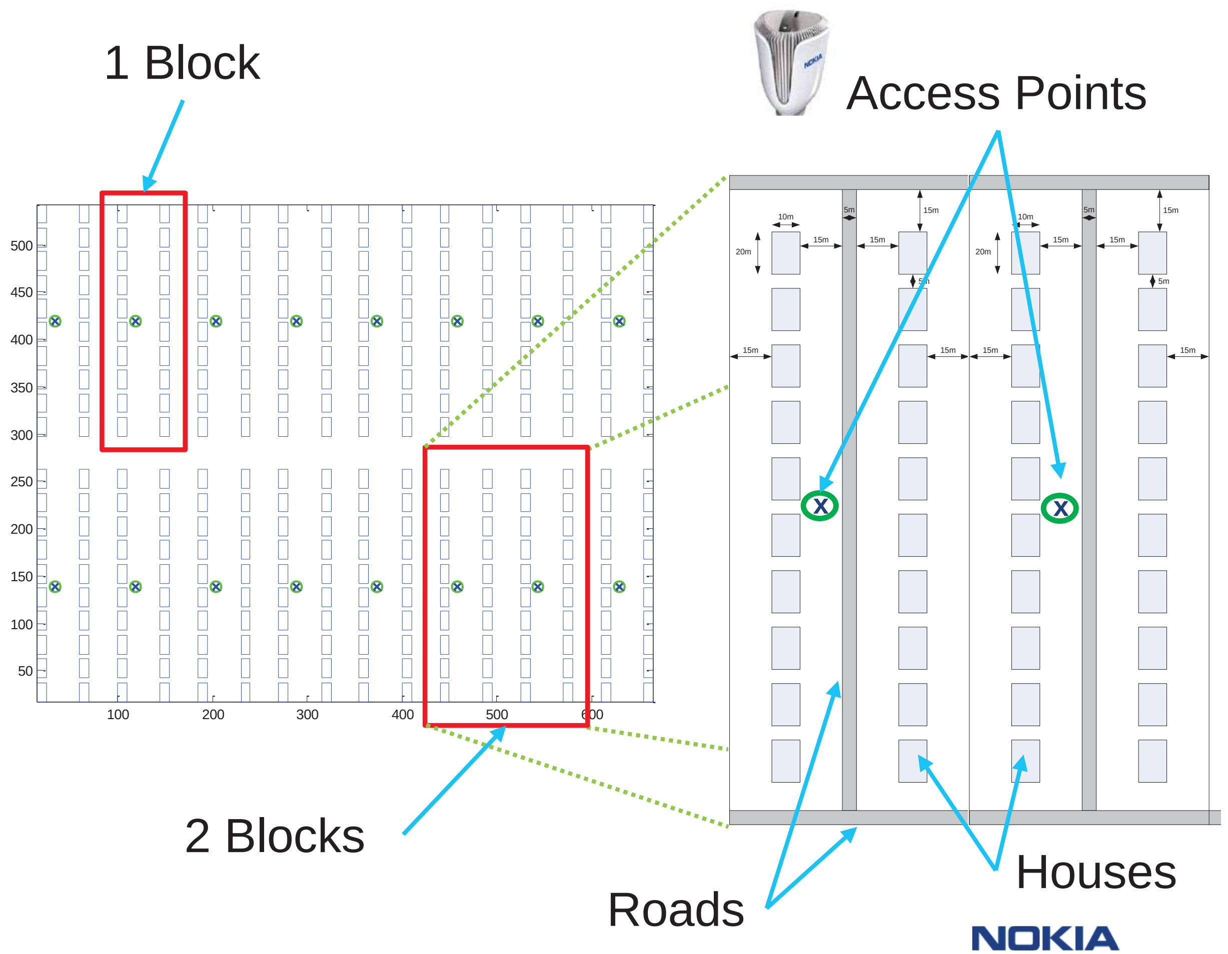
Physical Layer Simulation Study - Methodology

- Leverage 3GPP-RAN1-compliant system level simulator with appropriate modifications
  - Access Point and UE locations – leverage methodology in [4]
  - Path loss model with penetration loss – leverage parameters from [5]
  - Blocking model for objects in environment – random blockage similar to [4]
  - Multipath Channel Model for 39 GHz – leverage [3]
  - System numerology modified as appropriate for OFDM with the nominal bandwidth
  - Detailed PHY layer modeling:
    - Traffic scheduler
    - Link adaptation: CQI, RI, SRS/PMI as appropriate
    - Full antenna array & multipath channel modeling
    - MIMO and Beamforming transmission and reception
    - HARQ, retransmissions, etc.

Neighborhood Layout

Grid Arrangement

- 2x8=16 blocks
- 20 houses per block
- 320 Houses total
- 1 AP per block
- Patterned after a Schaumburg IL Neighborhood
- 10 UEs served per AP site
- AP is a 3-sector site at 6m height
- 39GHz Carrier
- Static TDD with 50-50 split

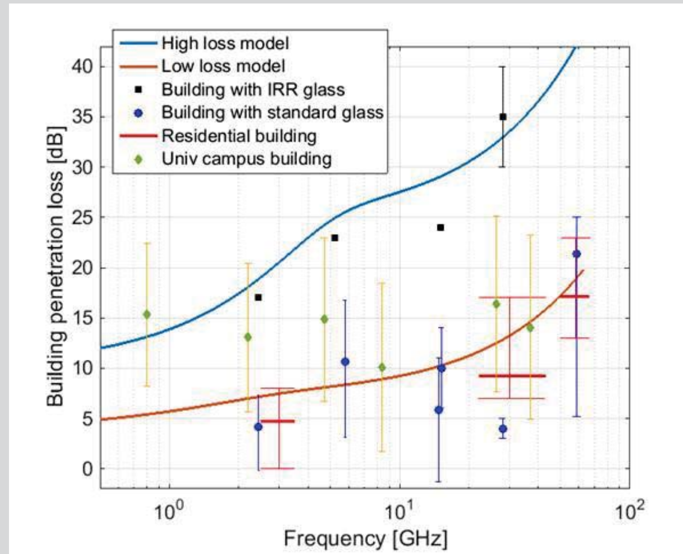


Propagation Modeling

Path loss, random blockage, multipath fading

Propagation Modeling Parameters	Value (39 GHz)
Reference Distance	1m
Path Loss Exponent (LOS)	1.98
Path Loss Exponent (NLOS)	3.13
Shadow Fading (LOS)	3.1
Shadow Fading (NLOS)	8.93
Penetration Loss (Low-Loss) (dB)	15 dB
Penetration Loss (high-Loss) (dB)	36 dB
Blocking Model	Statistical [4]
Multipath Fading Model	mmWave-UMi [3]

Frequency-Dependent Penetration Loss



- Assume some percentage of indoor UEs follow the high loss model and the remaining indoor UEs follow the low loss model
- Concerns:
  - Lack of sufficient data at high frequencies?
  - Potential for extrapolation error?
  - What is the typical US residence?

Null-Cyclic-Prefix Single Carrier System Parameters

NCP-SC Parameter	Value (200 MHz)	Value (400 MHz)	Value (800 MHz)
Operating Band	39 GHz	39 GHz	39 GHz
Nominal Bandwidth	200 MHz	400 MHz	800 MHz
Roll-off Factor	0.25	0.25	0.25
FFT Size	256	512	1024
Subcarrier Spacing (kHz)	600	600	600
Null-to-Null Bandwidth (MHz)	192	384	768
Tsample (nsec)	6.5	3.3	1.6
NCP Duration (nsec)	46	48	50.5
NCP Overhead	2.7%	2.9%	3.0%
TTI duration (sec)	0.0001	0.0001	0.0001
Duplexing	TDD	TDD	TDD
TDD Split	50-50	50-50	50-50
Link Adaptation Table	LTE	LTE	LTE
Resource overhead from control/pilots, (not including NCP overhead)	20%	20%	20%
Peak per-UE theoretical throughput (max rank=2)	0.661 Gbps	1.322 Gbps	2.645 Gbps

Access Point Parameters

Access Point Parameters	Value
Number of Sectors per Site	3
AP TX EIRP (dBm)	62dBm per 100MHz 85dBm
AP Noise Figure (dB)	5
AP Antenna Array Options (3-Sector AP) per sector	XP2D: 8 rows by 4 columns by 2 pol (64 antennas)
AP Antenna Element Beamwidth (3-Sector) (degrees)	60, azimuth and elevation
AP Array downtilt (degrees)	3
AP Height (m)	6
Traffic Model, etc.	Full Buffer with HARQ
DL TX method	Wideband Eigenbeamforming based on ideal sounding reference signals (SRS)
SU-MIMO: Max Rank per UE	2
Channel Estimation Error Model	Ideal

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UE Parameters

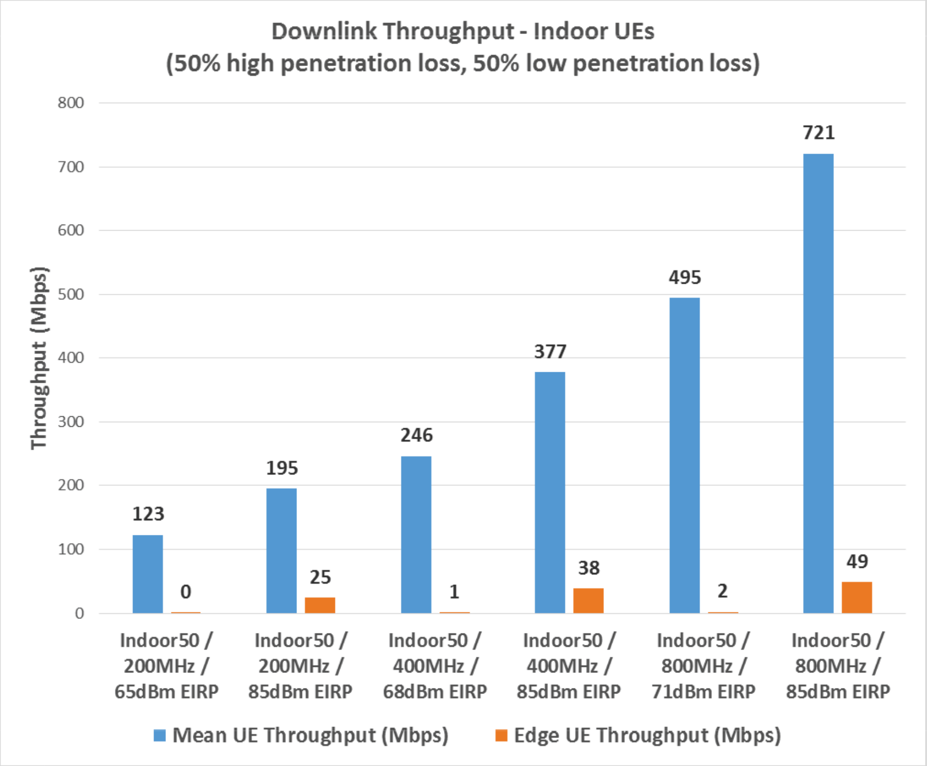
UE Parameters	Value
UE Antenna Array options	XP-ULA (omni), 2 antennas
UE Transmit EIRP (dBm)	43dBm or 53dBm
UE Noise Figure (dB)	9
Percent of UEs that are indoors	100% or 0%
Percent of Indoor UEs that have high penetration loss rather than low penetration loss	50% or 0%
UE Height (m)	1.5

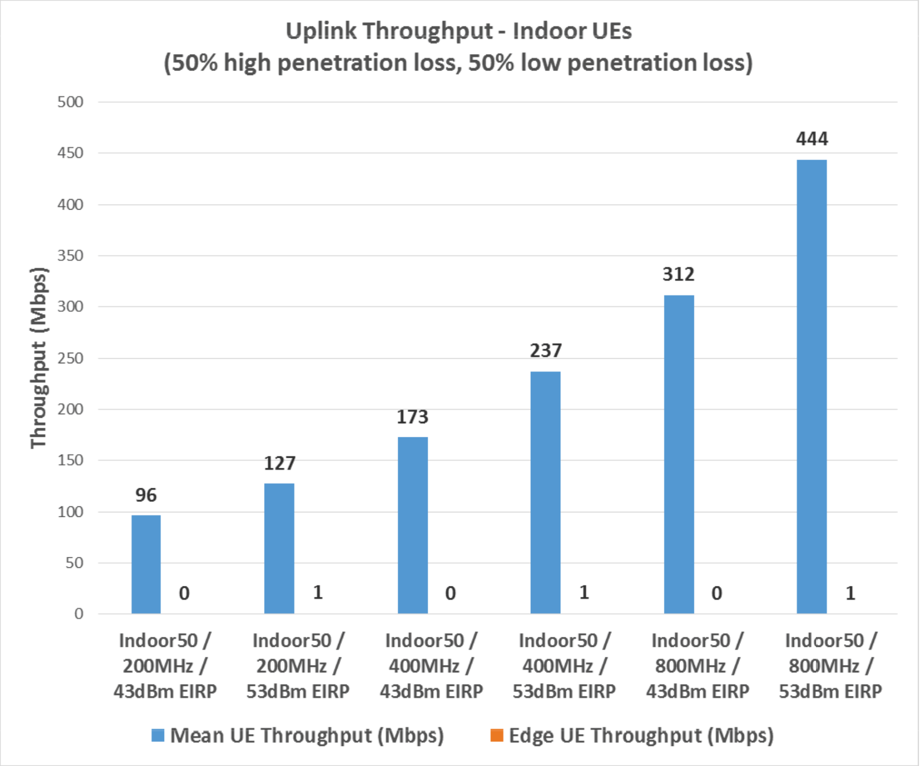
Simulation Cases
Major points of comparison

- 39GHz
- Bandwidth
  - 200MHz, 400MHz, 800MHz
- Scenarios:
  - [indoor50] All UEs are indoors, where 50% of the UEs have the high penetration loss value, and 50% of the UEs have the low penetration loss value
  - [indoor00] All UEs are indoors, and all UEs have the low penetration loss value.
  - [Outdoor] All UEs are outdoors (all UEs have zero penetration loss)
- AP EIRP:
  - 62dBm per 100MHz
  - 85dBm
- UE EIRP:
  - 43dBm
  - 53dBm

UE Throughput Results

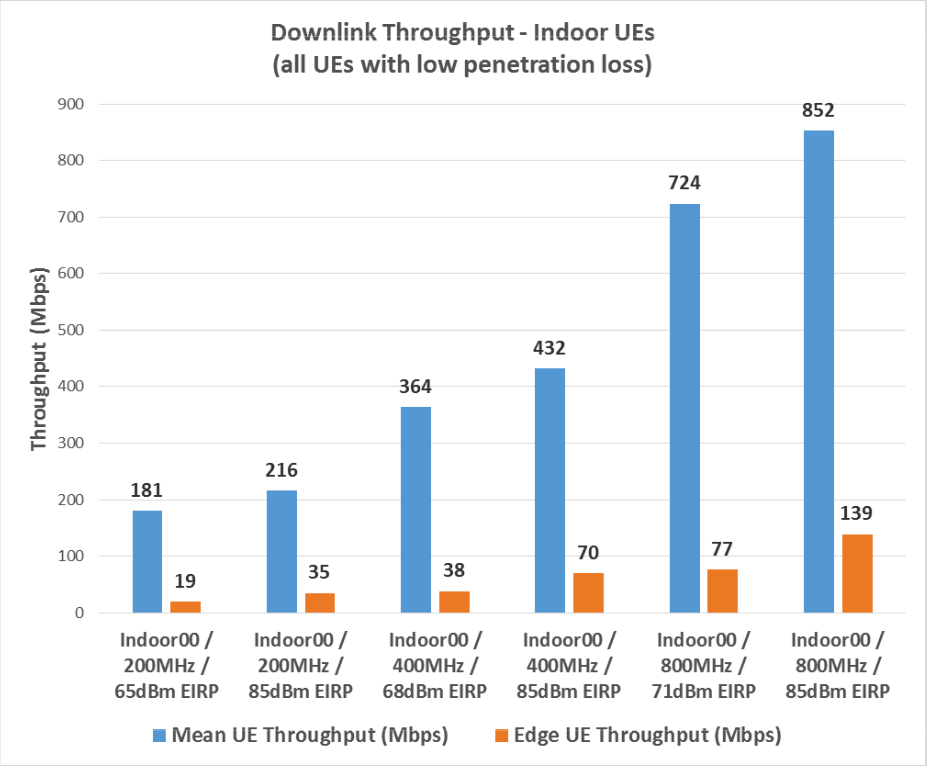
Indoor UEs: 50% high penetration loss, 50% low penetration loss

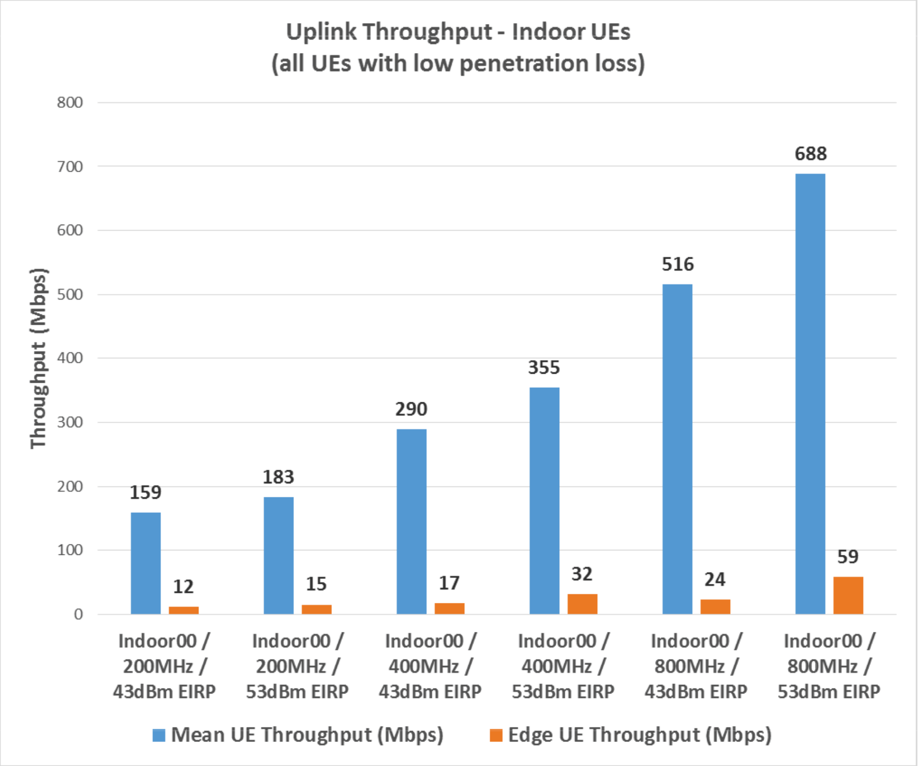




UE Throughput Results

Indoor UEs: 0% high penetration loss, 100% low penetration loss





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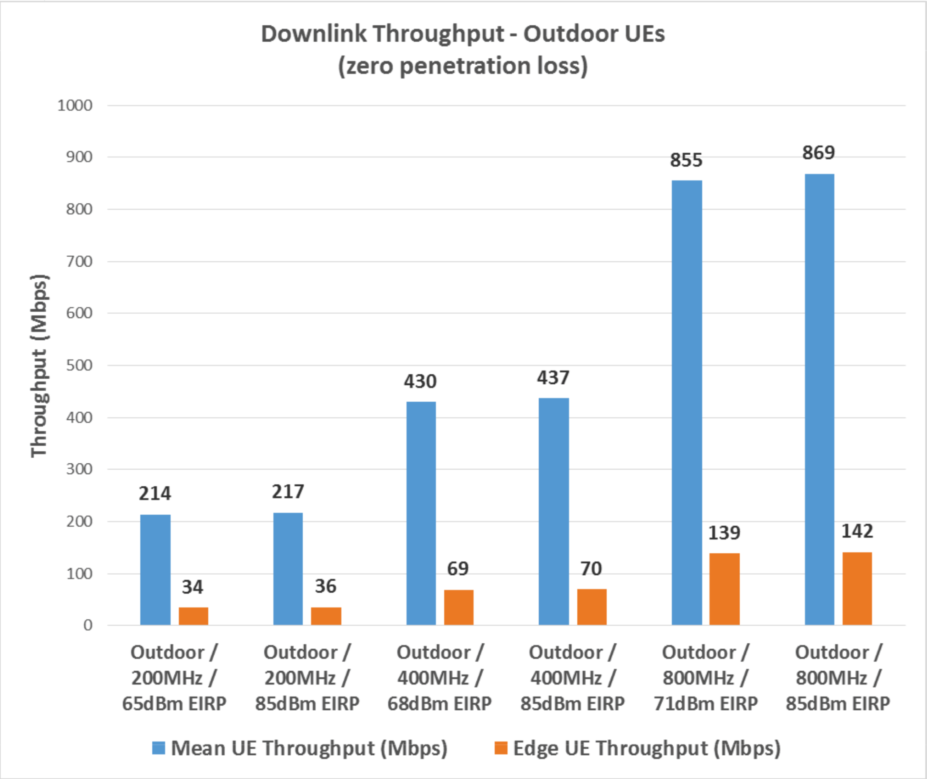
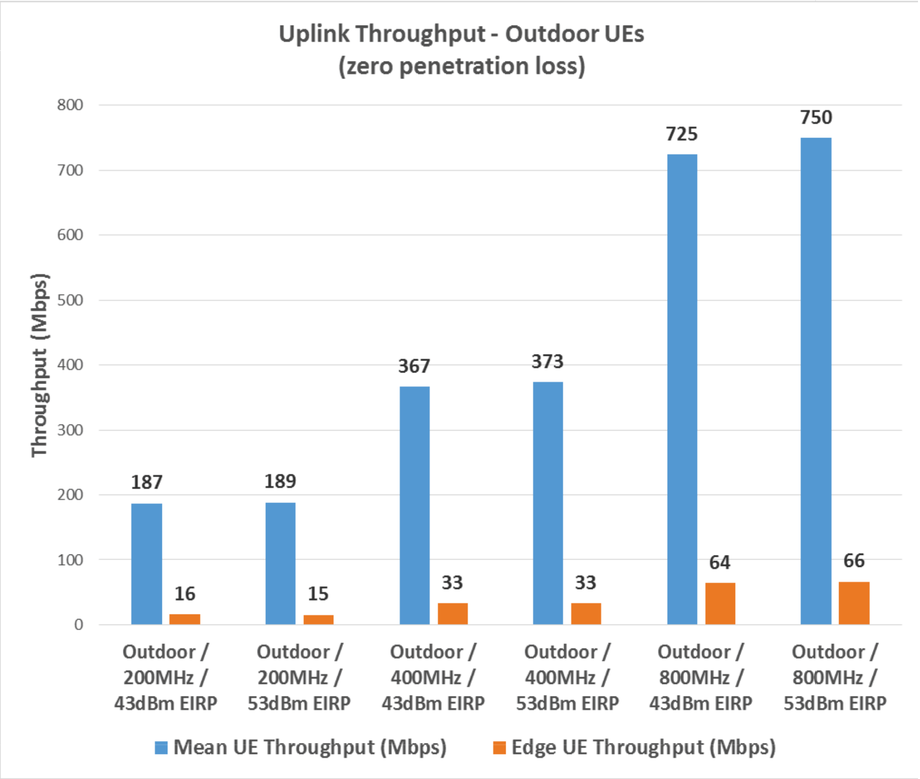
UE Throughput Results
Outdoor UEs: 0dB penetration loss



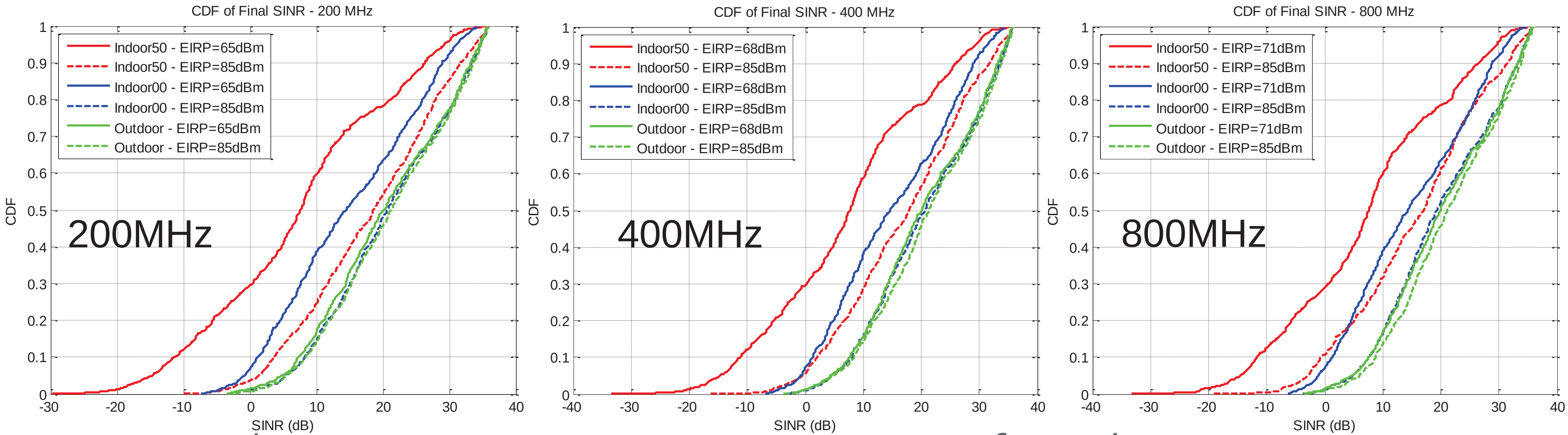


Observations (1)

- Increasing the bandwidth can significantly improve the throughput performance in all cases
  - As expected!
- With UEs deployed indoors at 39GHz with a 50-50 mix of high-low penetration loss, the low EIRP choice resulted in a system with cell edge (5th percentile) rates at or near zero.
  - Given the fixed nature of the deployment, such a system is clearly unusable as a stand-alone system.
- For indoor UEs, increasing the transmit power can significantly improve the throughput performance.
  - The system is clearly path loss limited
- For outdoor UEs, but there is virtually no performance difference between the two transmit power levels.
  - The system is clearly interference limited
- All observations are limited to the system and scenarios under study

CDF of Final SINR at UE Receiver

Effect of increasing TX power



- For Indoor UEs, increasing TX power significantly increases UE SINR statistics [Path Loss Limited]
- For Outdoor UEs, increasing TX power does not significantly increase SINR statistics [Interference Limited]

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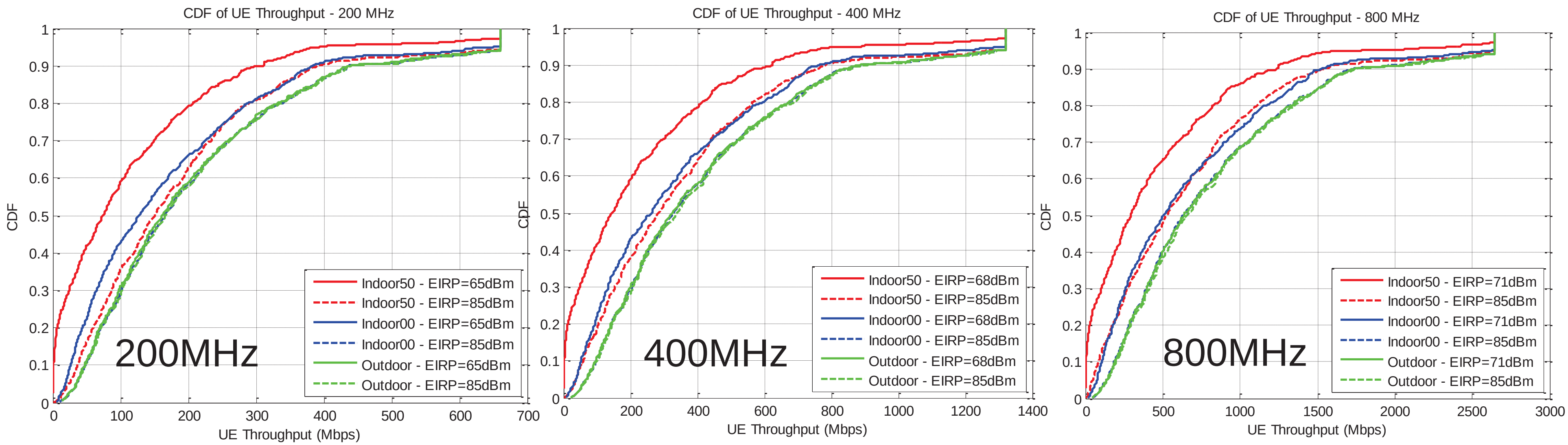
CDF of UE Throughput on Downlink

Effect of increasing TX power



- For Indoor UEs, increasing TX power significantly increases UE throughput statistics [Path Loss Limited]
- For Outdoor UEs, increasing TX power does not significantly increase throughput statistics [Interference Limited]

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Observations (2)

- Increasing the transmit power can provide significant improvements in the SINR and throughput statistics for the indoor UE scenarios.
  - Confirms the path-loss limited nature of the deployment under consideration when the UEs are indoors.
- For the outdoor UE scenario, the two downlink EIRP levels provided virtually identical SINR and throughput statistics.
  - Confirms the interference-limited nature of the deployment under consideration when the UEs are outdoors.

References

- [1] A. Ghosh, et al., “Millimeter wave enhanced local area systems: A high data rate approach for future wireless networks,” IEEE JSAC Special Issue on 5G Cellular, June 2014.
- [2] G. R. MacCartney and T. S. Rappaport, “73 GHz millimeter wave propagation measurements for outdoor urban mobile and backhaul communications in New York City,” ICC-2014.
- [3] T. A. Thomas, et al., “3D mmWave channel model proposal,” IEEE VTC-2014/Fall
- [4] T. A. Thomas, F. W. Vook, “System Level Modeling and Performance of an Outdoor mmWave Local Area Access System,” IEEE PIMRC-2014
- [5] 5G white paper, “5G Channel Model for Bands up to 100 GHz,” Available at: http://www.5gworkshops.com/5GCM.html

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