Institute for the Wireless Internet of Things
at Northeastern University

Colosseum Evolution: NRDZs and AI

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Let's hear your thoughts

What capability do you think is missing from Colosseum?

What would you like to use for your research?

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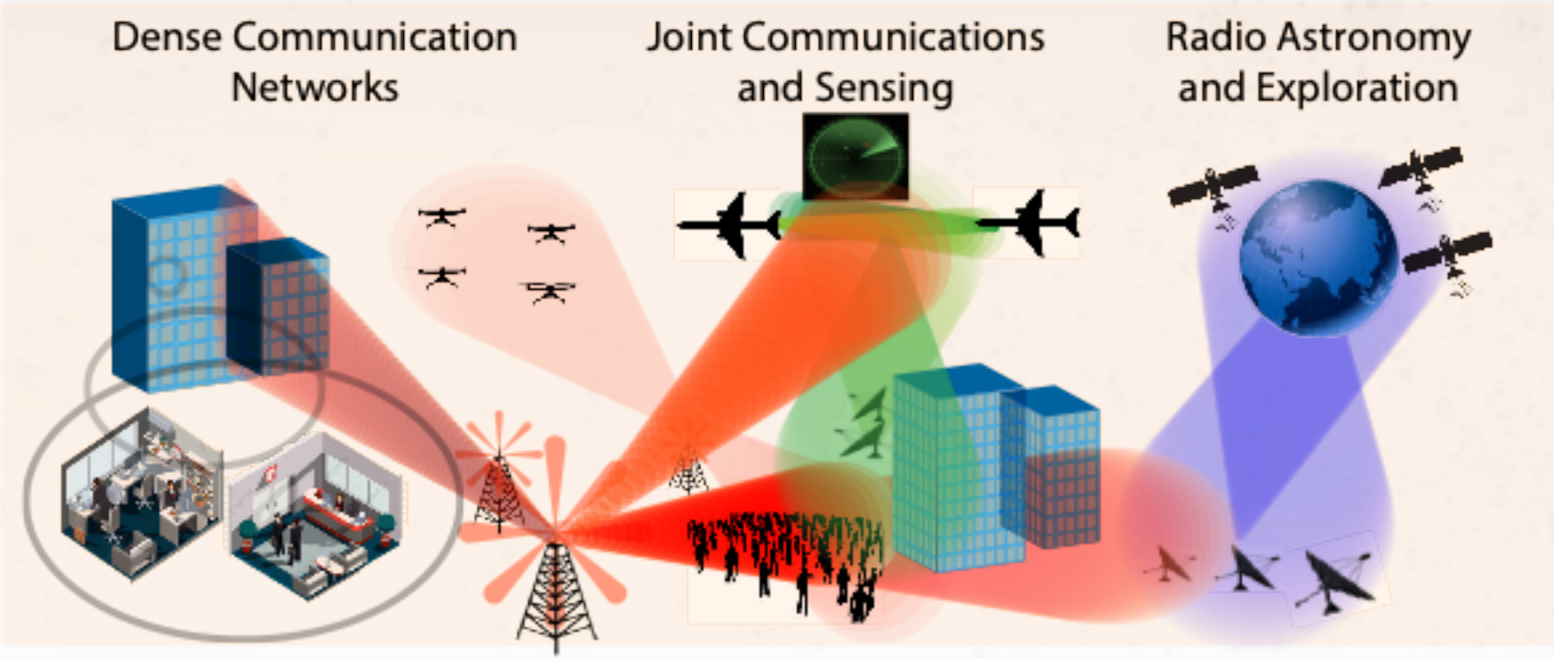
Outline

- ~~Discussion~~
- NRDZs
  - Idea
  - Colosseum for NRDZs
- AI JumpStart

National Radio Dynamic Zones



Spectrum is a

- **limited** resource with
- many **different** uses and stakeholders

How can we improve the coexistence of different services?

M. Polese et al., Coexistence and Spectrum Sharing Above 100 GHz, https://arxiv.org/abs/2110.15187

NRDZ Goal

NRDZ is an NSF program that wants to:

- Create safe playgrounds for spectrum experiments that are not allowed under current regulations

- Bring together passive and active users to explore new uses of spectrum and spectrum sharing

NRDZ and Colosseum

How can we enable controlled, repeatable experiments for NRDZs?

- Controlled environment
- No risk of harming actual active/passive users
- Multiple RF scenarios

- Hardware-in-the-loop
- Software-based protocol stacks

Emulate NRDZs in Colosseum

1. Open RF experimental environment available to the NSF community
2. Large scale
3. Integrated with other over-the-air testbeds (PAWR)

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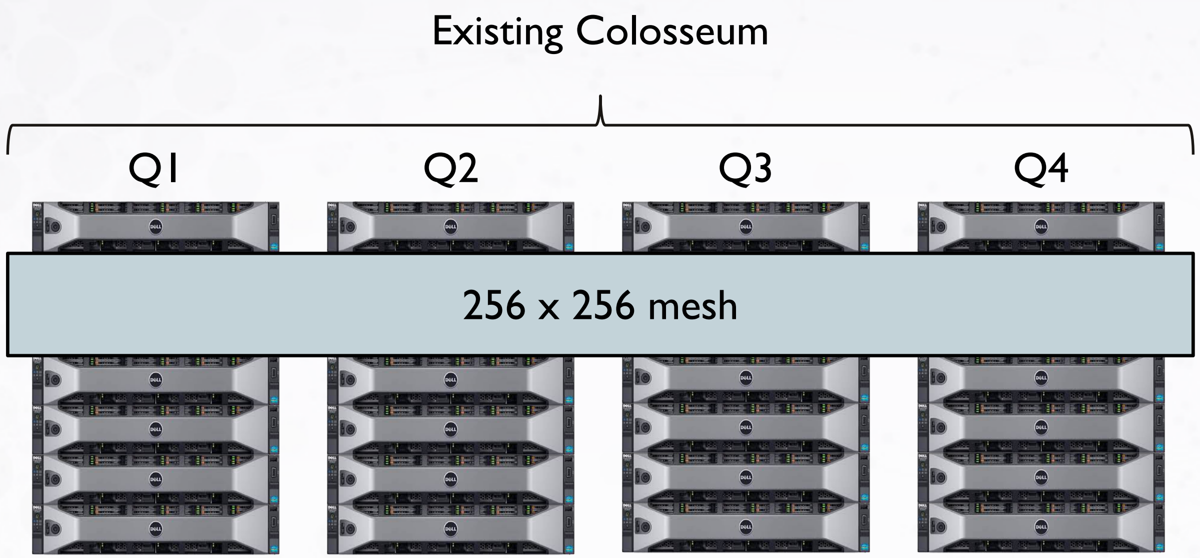
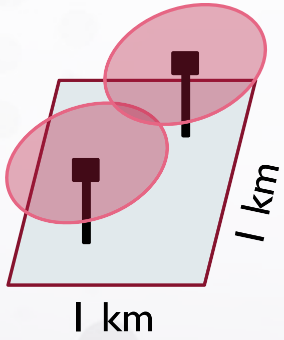
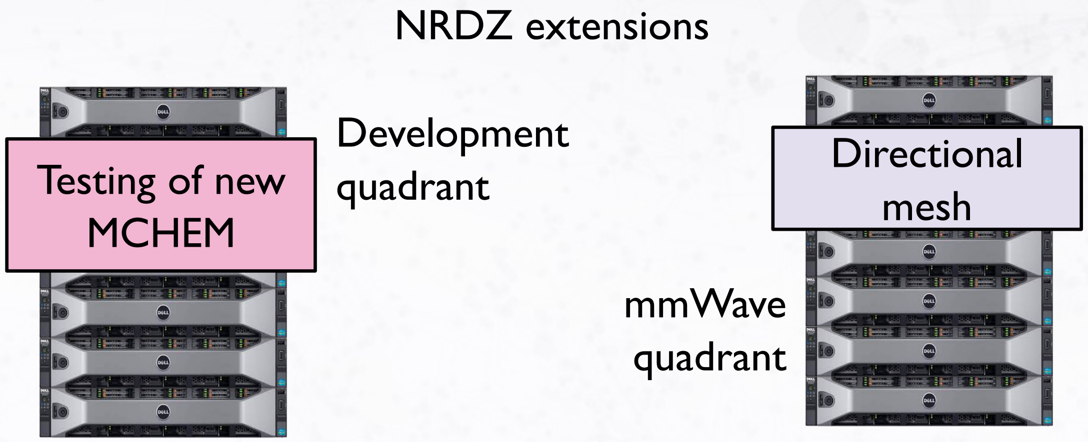
Current Colosseum and planned extensions

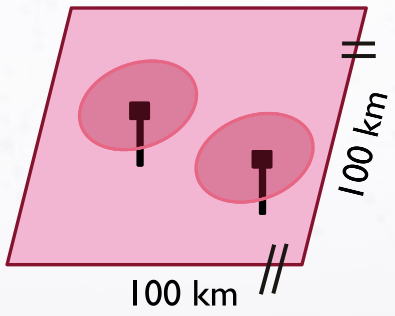




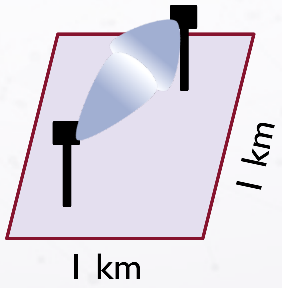
Sub-6 GHz – Omnidirectional



New Wireless Emulation Capabilities



mmWave Directional



mmWave quadrant – Colosseum limitations

Current channel modeling/emulation in Colosseum:

- focused on sub-6 GHz scenarios
- does not consider phased arrays / directional communications
- does not consider dynamic updates of the scenario
- 4 taps (may not be an issue)
- 80 MHz bandwidth (address by processing fewer channels per MCHEM rack)

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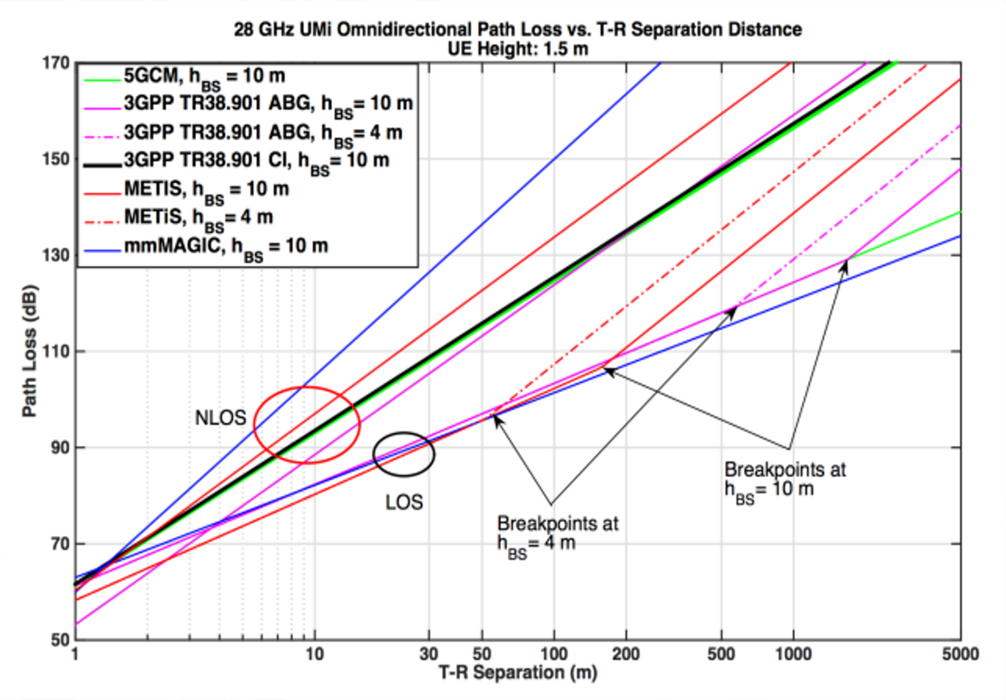
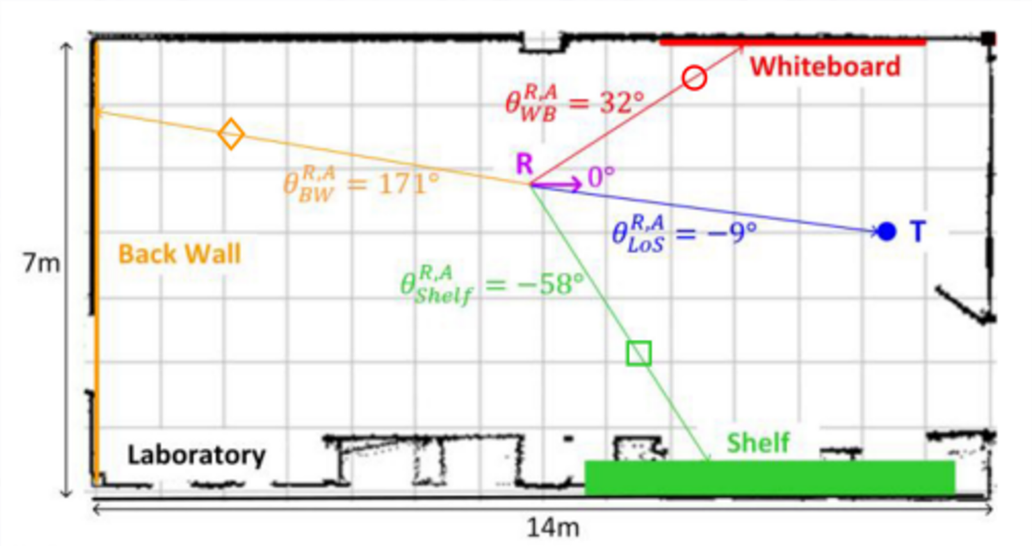
mmWave channel – characteristics

High free propagation loss (low range)



Spatially sparse (directional)



A. Hughes et al., "Measuring the Impact of Beamwidth on the Correlation Distance of 60 GHz Indoor and Outdoor Channels," in IEEE Open Journal of Vehicular Technology, vol. 2, pp. 180-193, 2021, doi: 10.1109/OJVT.2021.3067673.

Rappaport, T., Xing, Y., MacCartney, G.R., Molisch, A., Mellios, E., & Zhang, J. (2017). Overview of Millimeter Wave Communications for Fifth-Generation (5G) Wireless Networks—With a Focus on Propagation Models. IEEE Transactions on Antennas and Propagation, 65, 6213-6230.

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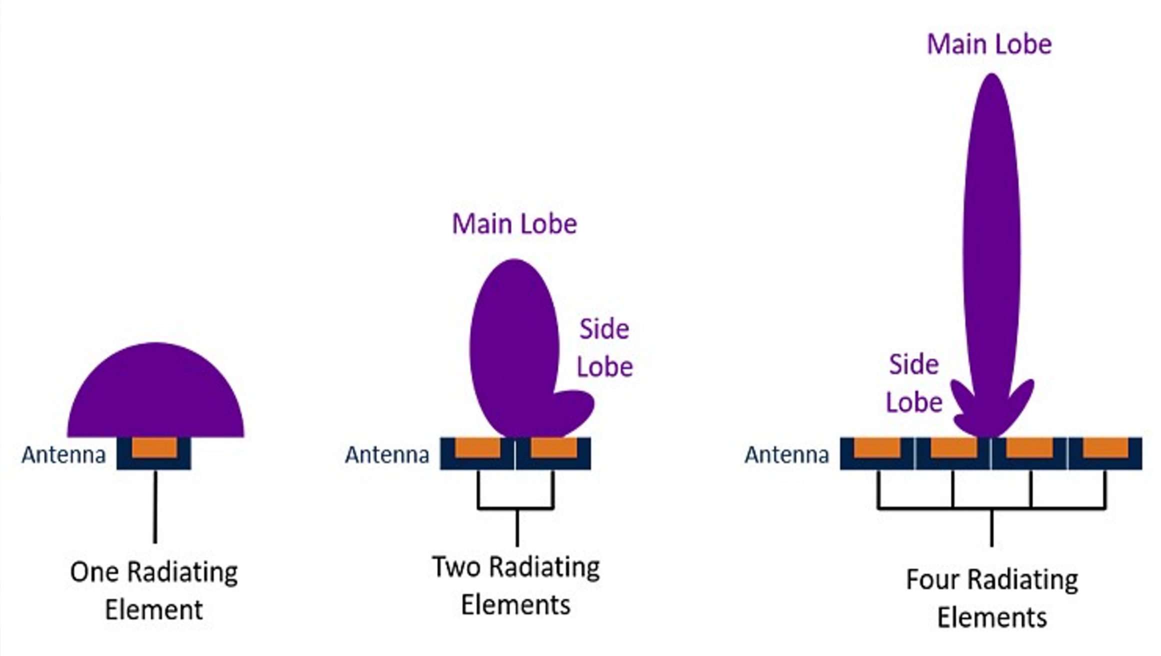
mmWave channel – characteristics

Usually exploiting large antenna arrays for beamforming…



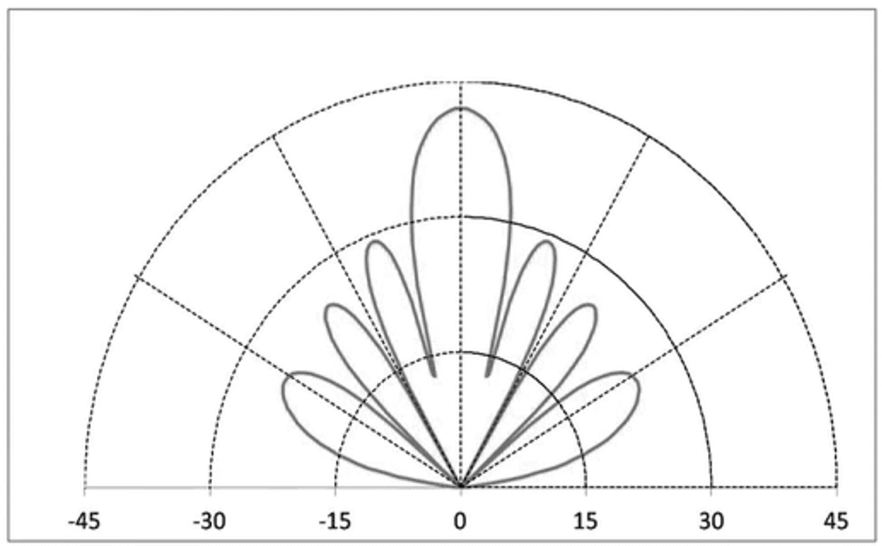


Figure from https://www.analogictips.com/mmwave-antennas-and-antenna-management-for-5g/

mmWaves and Phased Arrays

- Need to model antenna arrays
  - With some assumptions, the channel between antenna arrays takes the form of a matrix $H \in \mathbb{R}^U \times \mathbb{R}^S$, indicating the channel between pairs of antenna elements
  - Channel taps become complex matrices $H(t, \tau)$
  - Beamforming vectors combine the channel matrix into a scalar:

$$h(t, \tau) = b_{\mathrm{RX}}^T H(t, \tau) b_{\mathrm{TX}}$$

mmWave quadrant – channel modeling approaches

Current Colosseum and MCHEM modeling capabilities need to evolve and take these elements into account

mmWave quadrant – channel modeling approaches

Different trade offs

Computations required at runtime

New MCHEM design
High runtime computational cost
Higher flexibility

Limited modifications to MCHEM (almost plug-and-play)
Lower runtime computational cost
Limited flexibility

Flexibility and runtime configurability

We will keep you posted!

AI Jumpstart for Colosseum

Goal: *extend* ***AI*** *capabilities of* ***Colosseum*** *and provide researchers access to unique* ***AI+wireless*** *experimental facilities*

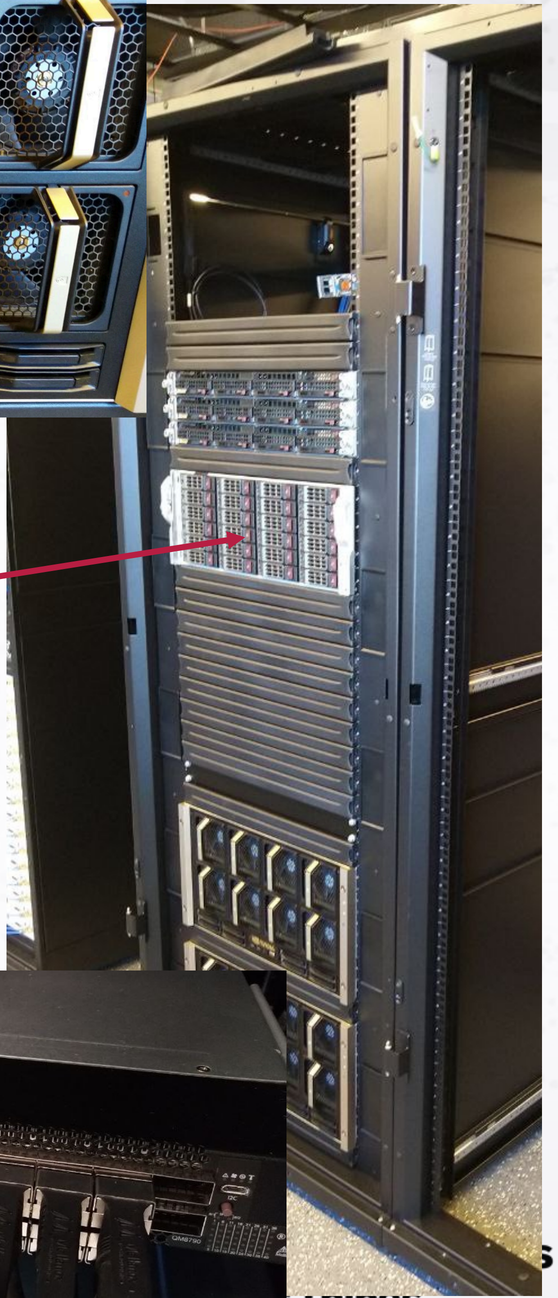
Possible use cases:

- Efficient training of large-scale wireless datasets collected on Colosseum
- Real-time, AI-driven 5G signal processing on for PHY layer & above
- Model-free adaptation to current network conditions and requirements

AI Jumpstart Rack

State-of-the-art ML hardware:

- 2x DGX A100 – 10 petaFLOPS of compute power
- 1 large memory node – 3 TB RAM
- 3x compute nodes
- 1x Mellanox Infiniband switch – Tbps dedicated switching fabric



AI Jumpstart Integration in Colosseum

The system will be fully integrated with Colosseum:

- Users can reserve SRNs and GPU resources
- Container orchestration based on Nomad
  - Test pilot on AI Jumpstart system to evaluate future applications to the whole Colosseum