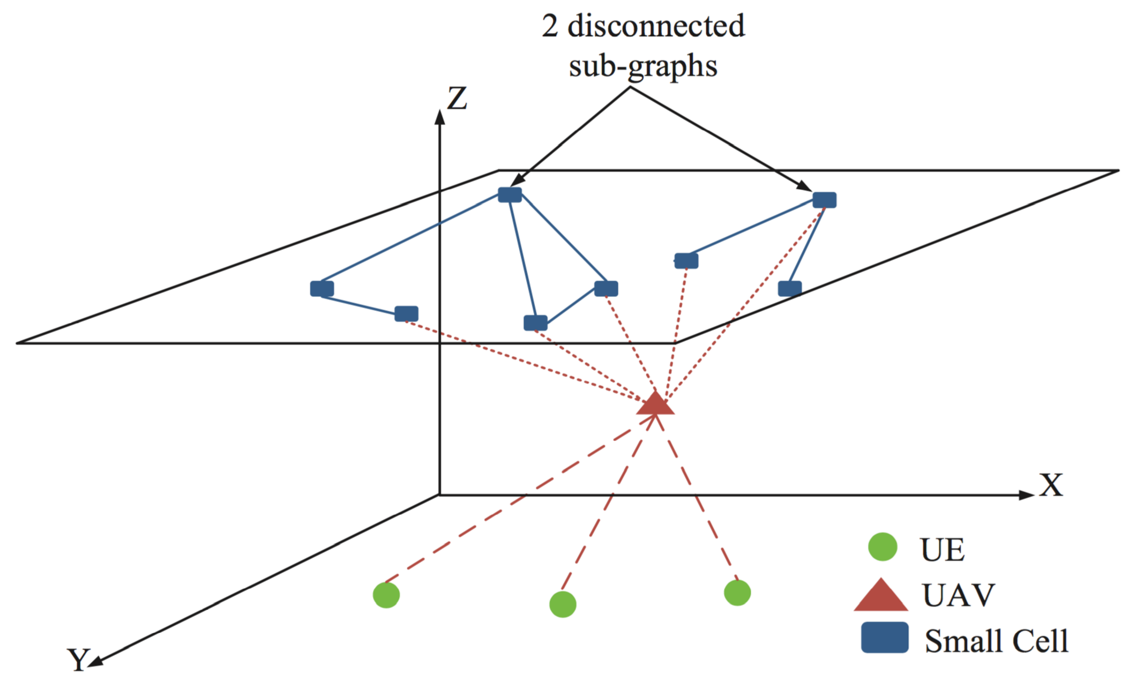
UAV Positioning for Improving Coverage-Connectivity Tradeoff in Millimeter-Wave Wireless Channels

Mai A. Abdel-Malek, Ahmed S. Ibrahim and Mohamed Mokhtar

Electrical and computer Engineering department, email: aibrahim@fiu.edu

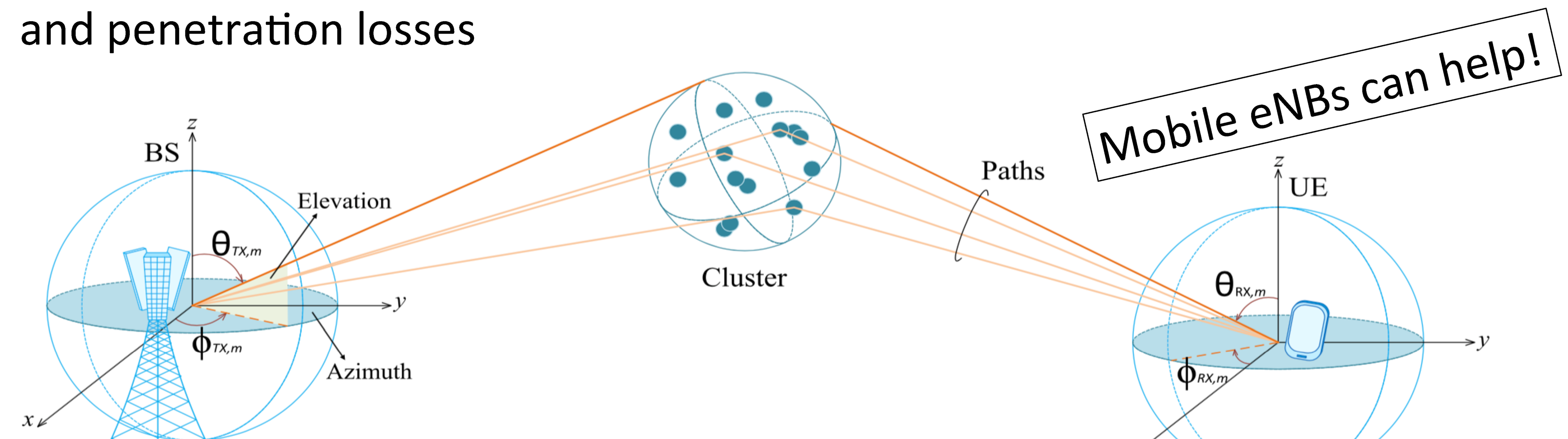
Motivation



- UAV mobility ➔ Additional degree of freedom
- How to enhance backhaul connectivity and coverage simultaneously?

Objectives and Challenges

- Provide a new framework for UAV positioning
- Present a low complexity optimization problem for UAV positioning
- Exploiting UAV's mobility to tackle the main mm-wave challenges: high path and penetration losses



From F. Ademaj, M. Taranetz, and M. Rupp. "3GPP 3D MIMO Channel Model: A Holistic Implementation Guideline for Open Source Simulation Tools." *EURASIP Journal on Wireless Communications and Networking* 2016, no. 1 (2016): 55.

System Model

- Communication links among the small cells is modeled as a graph *G(V,E)*
- The graph connectivity is characterized Fiedler value of its Laplacian matrix

$0 \leq \lambda_2(\mathbf{L}) \leq \infty$

Less connected ⟵ ⟶ More connected

- UEs are connected to UAV through mm-wave links quantified by its SNR
- NYUSIM channel simulator by Rappaport et al. is adopted

Performance metrics

SCs: Algebraic connectivity appropriate for multi-hop	UEs: SNR appropriate for point-to-point

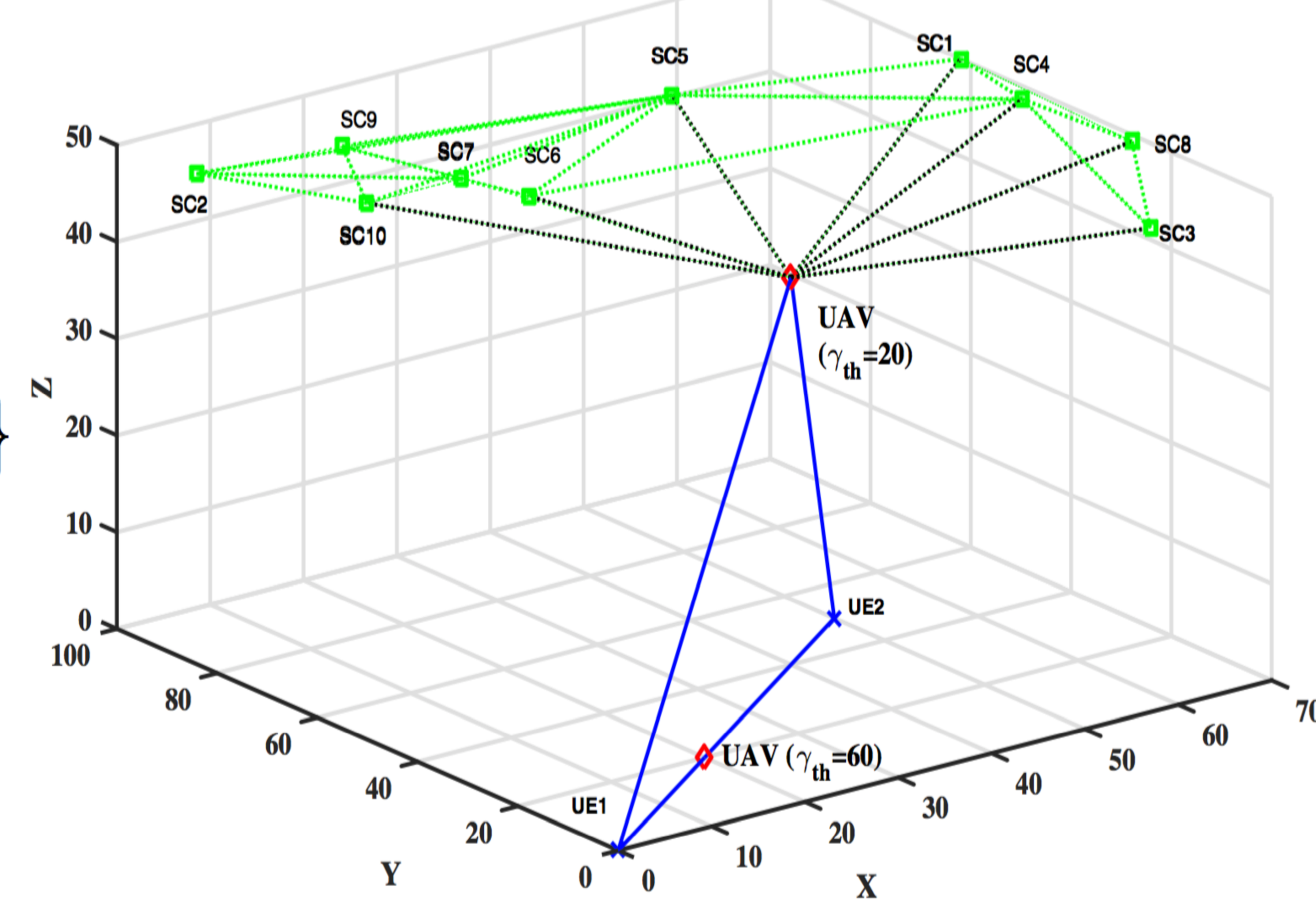
Problem Formulation and Solution Approach

$$\max_{\mathbf{u}} \quad \lambda_2(\mathbf{L}'(\mathbf{u}))$$
$$\text{s.t.} \quad \mathrm{SNR}_i \geq \gamma_{\text{th}}, \ \forall i \in \{1, \cdots, N\}$$

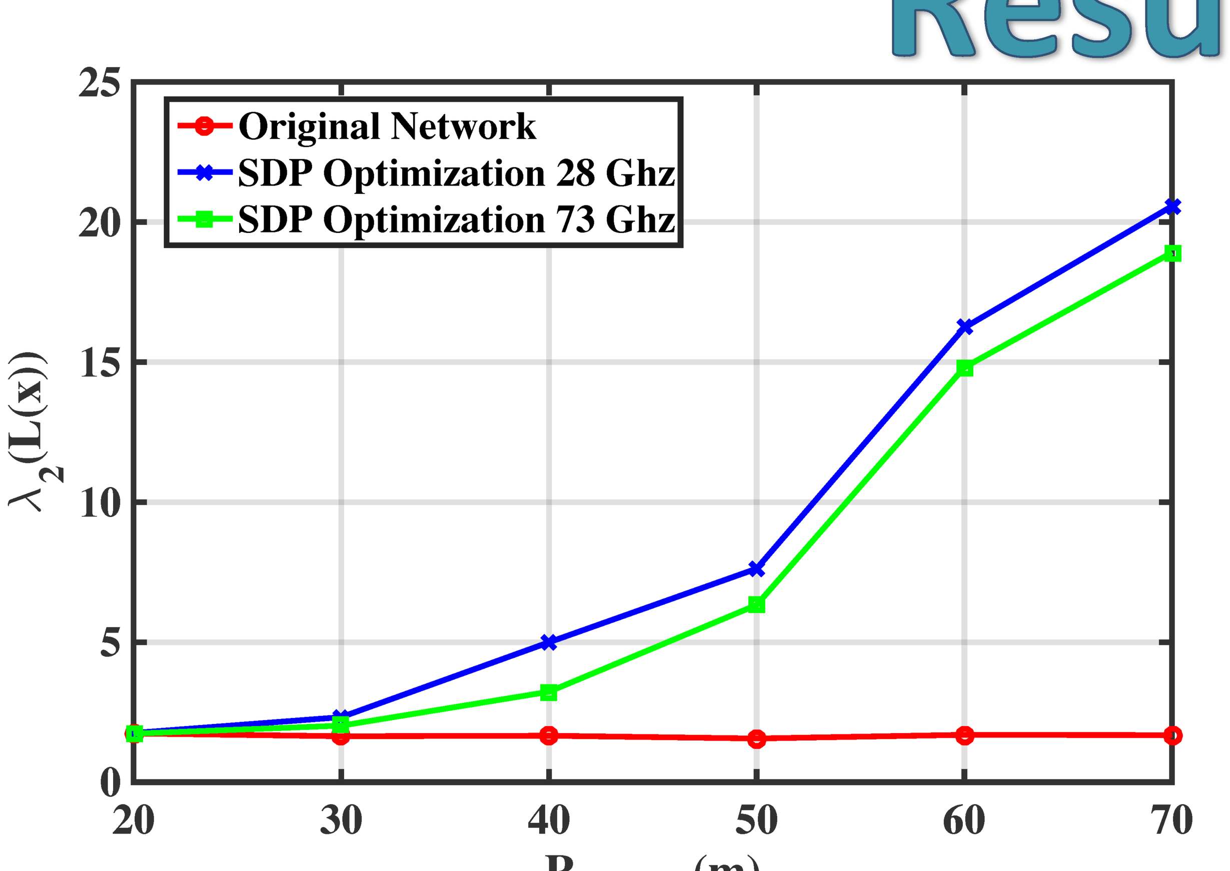
- A non-convex optimization problem
- To overcome non-convexity, we uniformly quantize the 3-D space occupied by SCs and UEs into β candidate positions
- Introduce the β x 1 optimization vector **x** whose all entries are zeros except single entry = 1 corresponding to the grid point occupied by the UAV
- To avoid combinatorial optimization, we relax this constraint to get

$$\max_{\mathbf{x},s} \quad s$$
$$\text{s.t.} \quad s\left(\mathbf{I} - \frac{1}{\beta}\mathbf{1}\mathbf{1}^T\right) \preceq \mathbf{L}'(\mathbf{x})$$
$$\mathbf{x}^T \mathbf{v}_i \geq \gamma_{\text{th}}, \ \forall i \in \{1, \cdots, N\}$$
$$0 \leq \mathbf{x} \leq 1$$

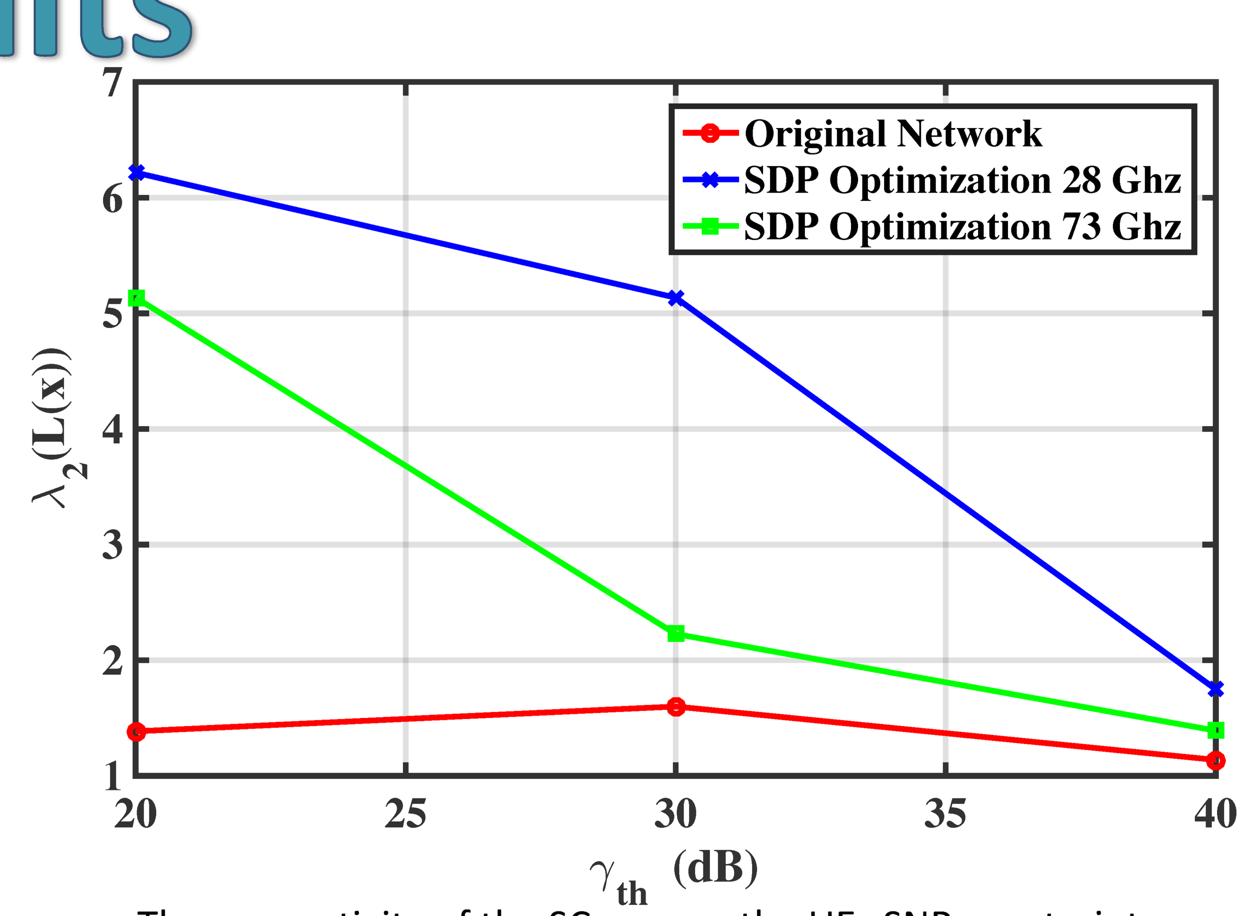
- It is standard convex SDP problem with efficient solvers such as CVX and SDPT3



Results



The connectivity of the SCs versus the UAV transmission range



The connectivity of the SCs versus the UEs SNR constraint

- As UAV transmission range increases, more SCs can be connected with UAV ➔ Increases the overall connectivity
- As UEs SNR constraint increases, the UAV gets closer UEs ➔ Only few SCs can be connected to UAV and connectivity is decreased
- The higher the mm-wave carrier frequency is, the more it suffers from path loss, the closer the UAV to the UEs is required to satisfy their SNR constraint, and the lower SCs connectivity is realized

Conclusions

- Proposed utilizing UAV to enhance the SCs backhaul network connectivity and achieve better UEs coverage
- Developed low complexity algorithm to solve for optimum UAV position
- Showed the effects of mm-wave carrier frequency on network connectivity and UAV position

Acknowledgment

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