Multi-lobe Beam Searching for Initial Access in mmWave Systems

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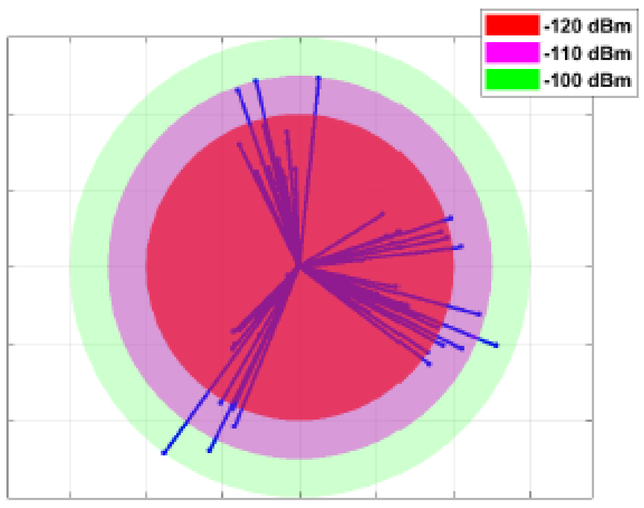
Millimeter-Wave RCN

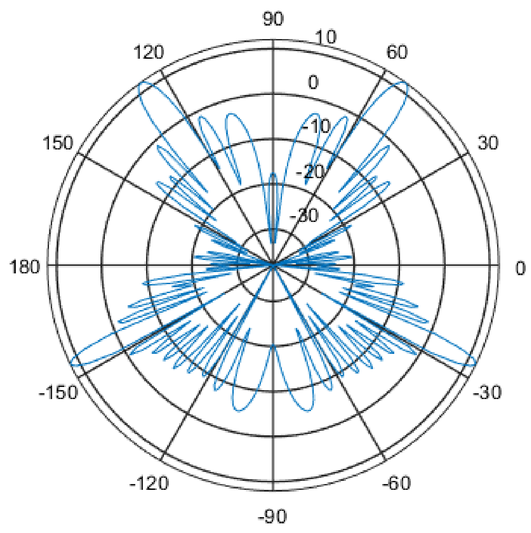
Introduction

Motivation:

- mmW communications are highly directional
  - Initial access & network discovery can be challenging, esp. under mobility
- Frequent significant beam misalignments (even under pedestrian speeds)
- Received energy is **clustered** into multiple distinct angular directions



2D AoA Profile of an Rx (28 GHz)



Example Multi-lobe Pattern (Azimuth)

Main Research Thrusts:

- Identify all dominant signal directions within one search cycle
  - High alignment accuracy, low discovery time & confidentiality
- Use inferred signal directions for uplink transmissions
  - Allocate different powers to different beam directions to enhance data rate

Overview

Existing Scanning Techniques:

Exhaustive search: Brute-force sequential beam scanning

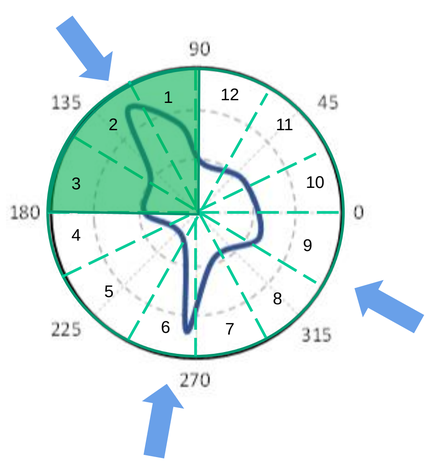
Iterative search: Two-stage (wide and narrow) scanning of angular space

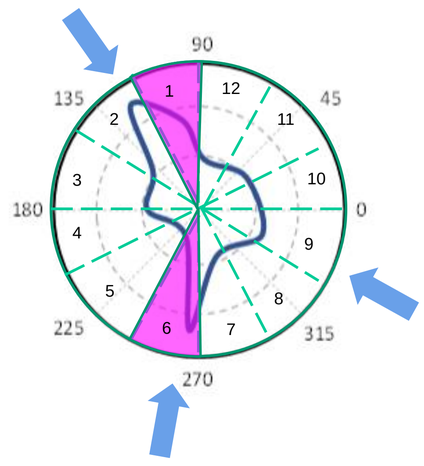
CI-based search: Relies on GPS to locate BS and MUs

Require long time or find only one cluster direction

Proposed Approach:

- Detect multiple clusters to improve Rx power and increase data rate
  - Determine the directions of the dominant signals



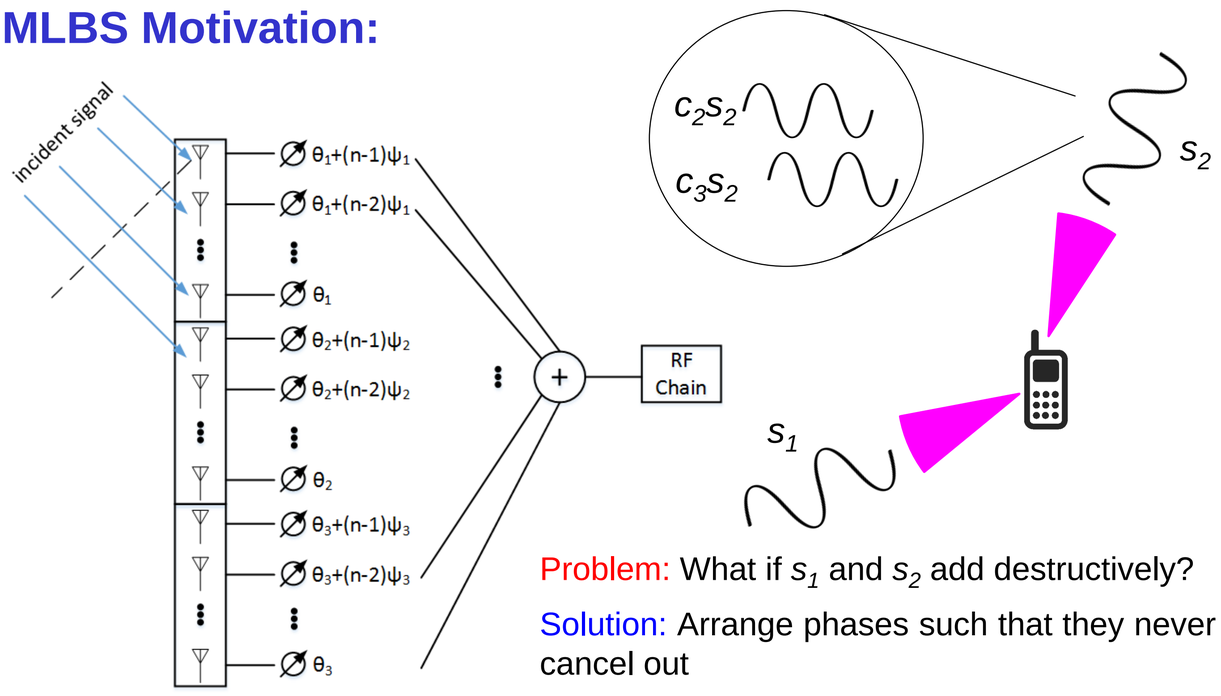


Iterative Scan Sequence	1,2,3	4,5,6	7,8,9	10,11,12	1	2	3	4	5	6	7	8	9
Scan Outcome	+	+	+	-	-	+	-	-	-	+	-	-	+

MLBS Scan Sequence	1,6	2,7	3,8	4,9	5,10	6,11	7,12	9,2
Scan Outcome	+	+	-	+	-	+	-	+

Preliminary Design

MLBS Motivation:



Problem: What if s_1 and s_2 add destructively?

Solution: Arrange phases such that they never cancel out

MLBS Algorithm:

Divide antennas into 3 → Design 3 beams s.t. $\psi_1 \neq \psi_2 = \psi_3$ → Arrange phases s.t. $\theta_2 \neq \theta_3$

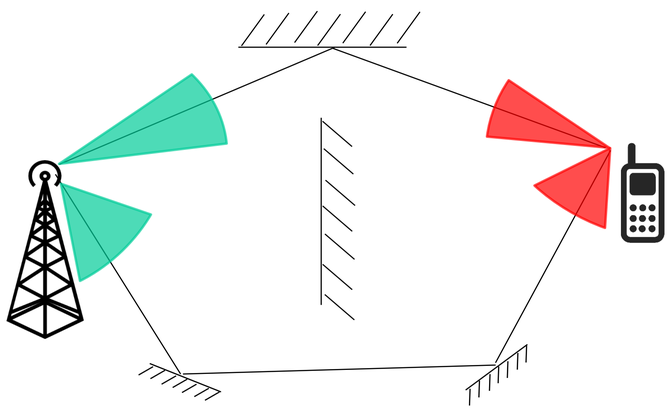
Received signal:

$$s = c_1 s_1 + c_2 s_2 + c_3 s_2$$

where

$$c_3 = c_2 e^{j(\theta_2 - \theta_3)}$$

The energy can be **certainly** detected if pattern captures at least one signal

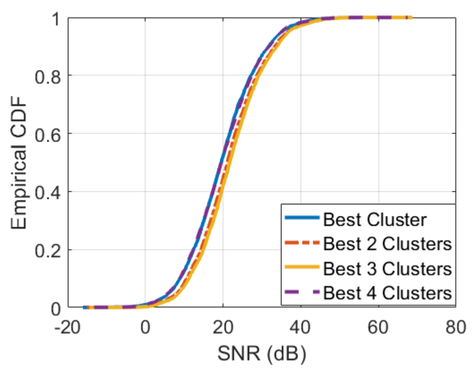


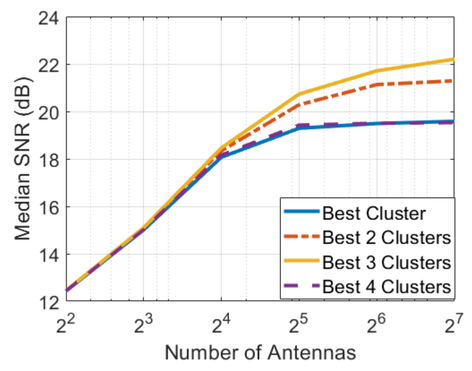
Key Design Issues:

- Lobes are not symmetric s.t. each direction is covered by more than one pattern
  - Find what the true signal direction is
- Number of lobes are chosen according to the statistical channel properties
- Tx power is allocated to lobes in a way to maximize the uplink data rate

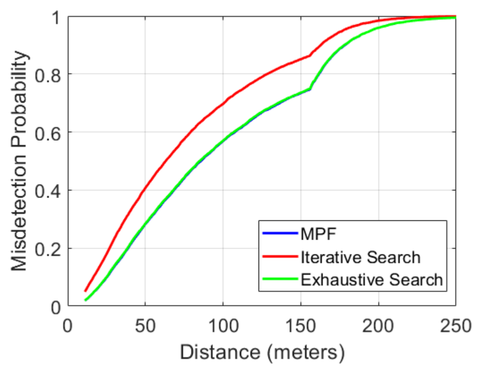
Evaluation

Effect on SINR

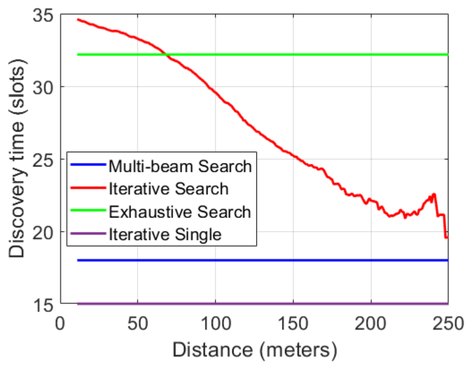




Misdetection Prob.

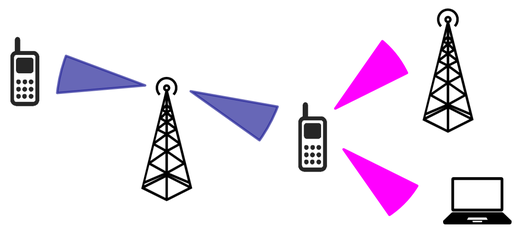


Discovery Time



Future Tasks

- Simultaneous multi-node device discovery



- Hardware experiments

- Beam tracking algorithm
  - Exploit machine learning to find optimum directions
  - Backup beam constantly searches for alternate directions
- Application to directional MANETs
  - High security (via directional communications)
  - Limited data interruptions (high reliability)