
# Beamspace MIMO Technology
# Gigabit mmWave Wireless for 5G and Beyond

5G Densification and Enabling Technologies
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Akbar M. Sayeed

Wireless Communications and Sensing Laboratory
Electrical and Computer Engineering
University of Wisconsin-Madison
http://dune.ece.wisc.edu

# mmWave Beamspace MIMO for 5G Gigabit Applications

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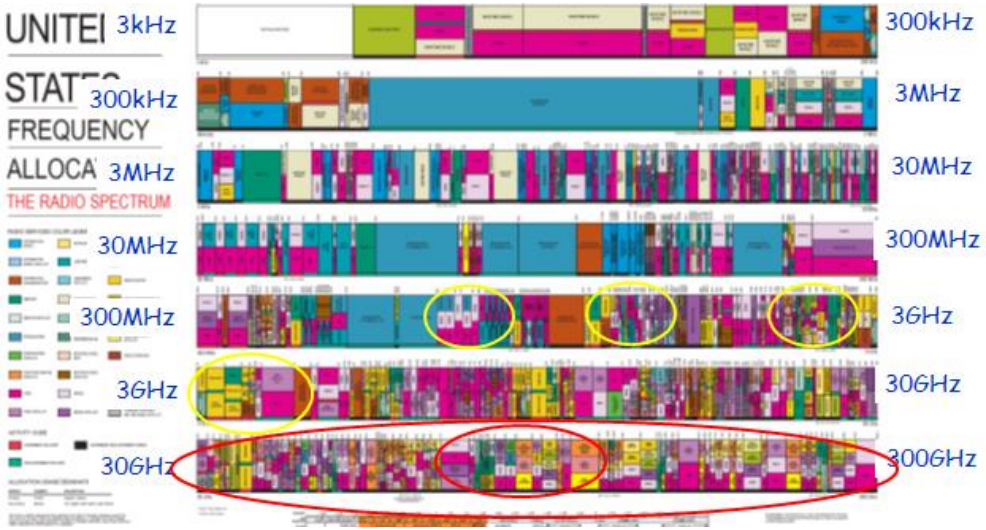
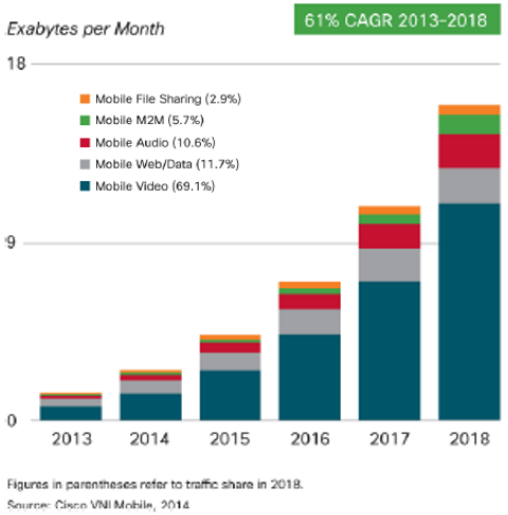



mmWave: 30-300GHz

Orders-of-magnitude larger bandwidth (GHz)

## Multi-Gbps speeds sub-millisecond latency

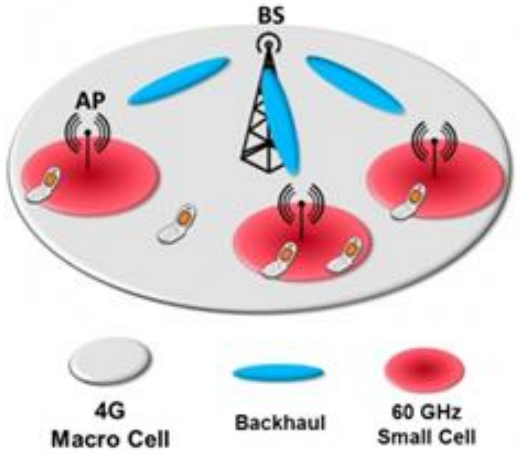



## Key 5G Use Cases:

Backhaul

Last Mile

Small-Cell Mobile Access

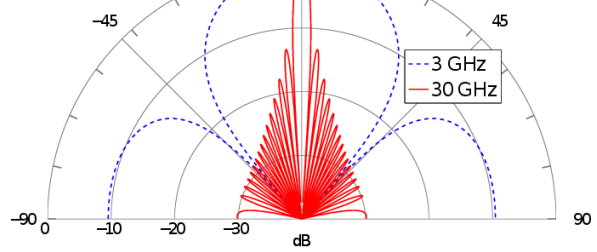



## Highly directive narrow beams

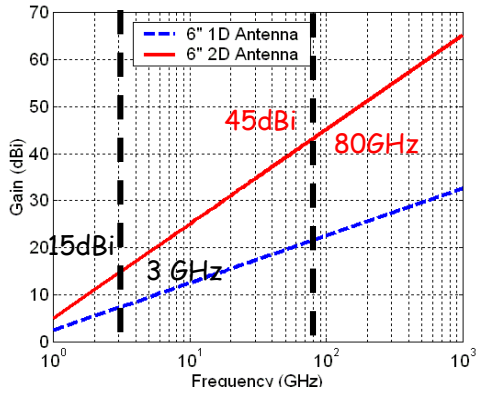
35 deg @ 3GHz (15dBi Gain)

6" antenna

4 deg @ 30GHz (45dBi Gain)




## Large antenna gain



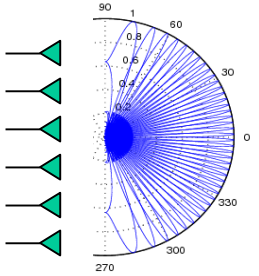

## Beamspace MIMO: Multiplexing Data into Beams

Antenna space multiplexing

Spatial Fourier Transform

Beamspace multiplexing

n-element array ( $\frac{\lambda}{2}$ spacing)

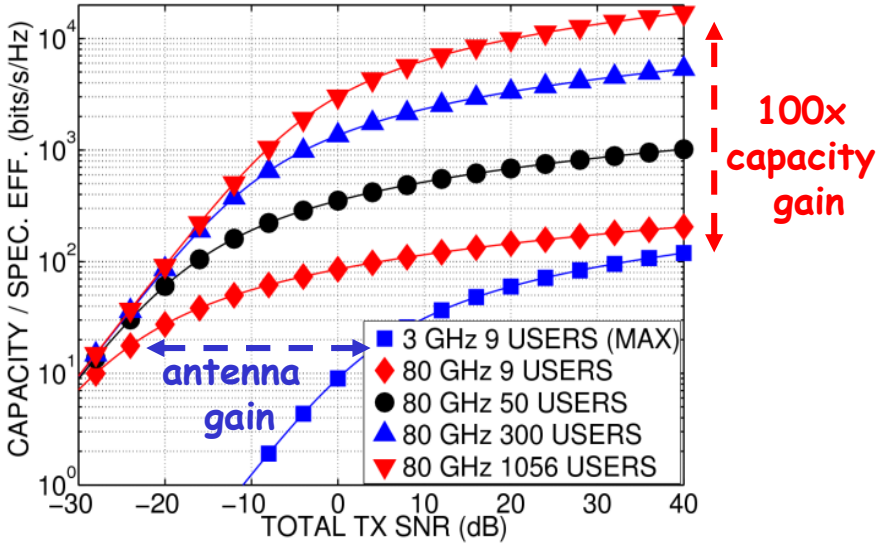


n orthogonal beams

# Dense Beamspace Multiplexing – Massive MIMO

6" x 6" antenna: 9 elements @3GHz vs. 6000 elements @80GHz

## Potential power & spectral efficiency gains



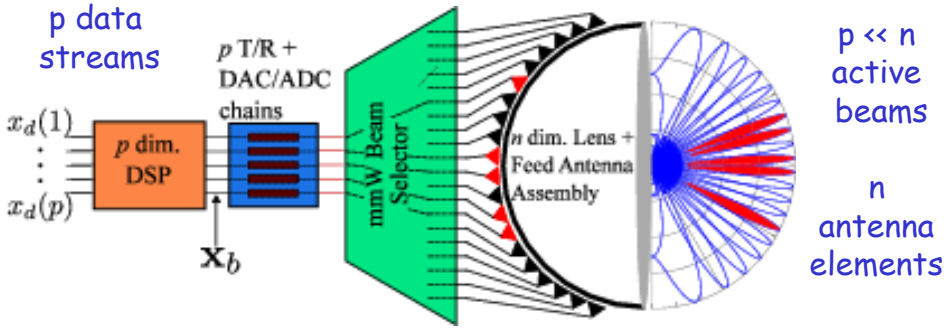

mmWave (80 GHz)
5 GHz BW
10 Tbps (100 users)
100 Gbps/user

LTE-A (3 GHz)
100 MHz BW
10 Gbps (9 users)
1 Gbps/user

## Key Functionality:
Multi-beam Steering & Data Multiplexing

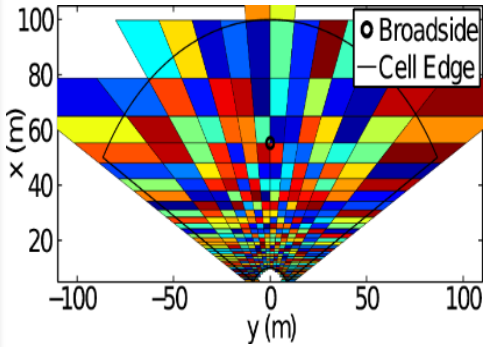
## Key Challenge:
Complexity (hardware & computational)

## CAP-MIMO Architecture:
Lens-Array for Analog Beamforming

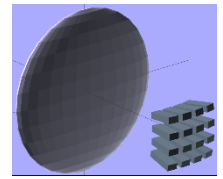


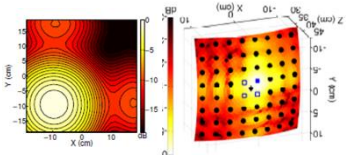

Scalable performance-complexity optimization

## Beam Footprints

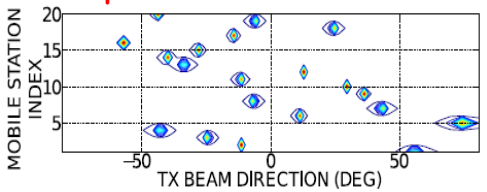



## 2D Lens Array





## Sparse active beams



# Competing mmW Beamforming MIMO Approaches

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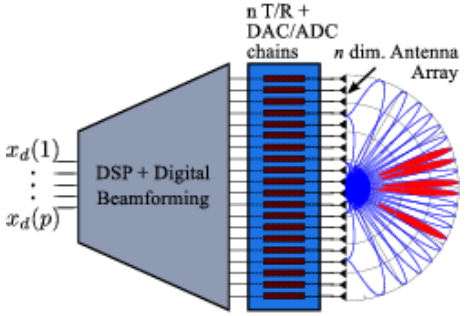
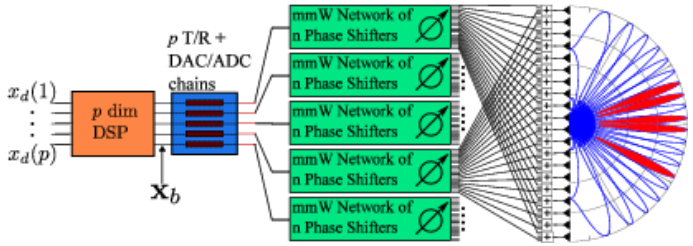
## Conventional MIMO: Digital Beamforming



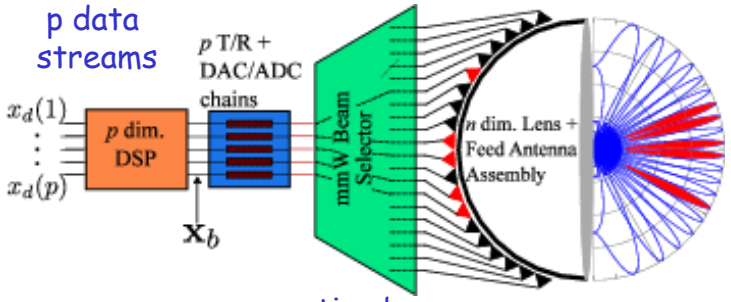

Prohibitive complexity

## Phased Array Architecture (All Competing Prototypes)




Limited to single-beam (no MIMO)

## CAP-MIMO Architecture

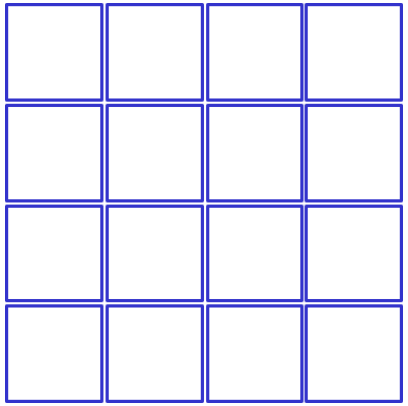


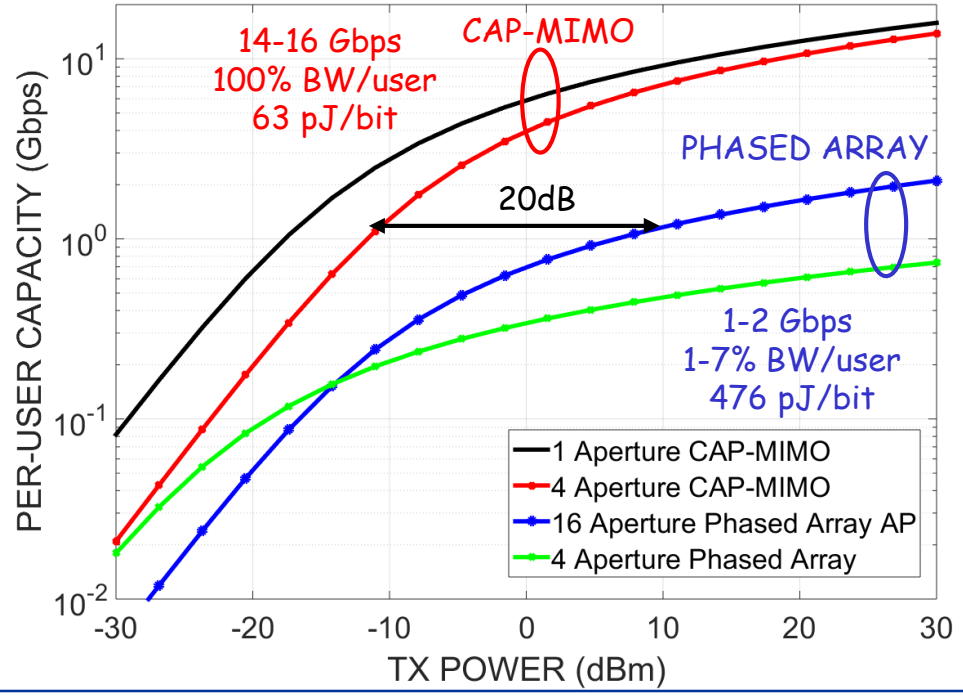

p << n active beams

performance-complexity optimization

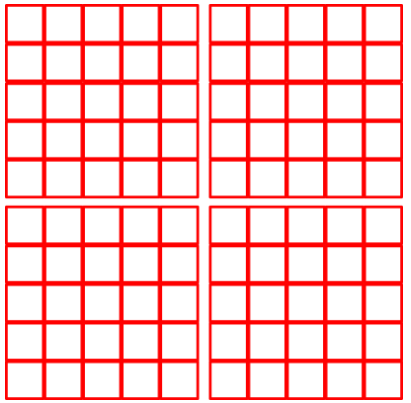
## 100 User Small Cell: 28 GHz, 1GHz BW, 6"x6" Ant.

16, single-beam Phased Arrays (16 total beams) (7 users/beam)






4, 25-beam CAP-MIMO Arrays (100 total beams) (1 user/beam)



28 GHz CAP-MIMO prototype