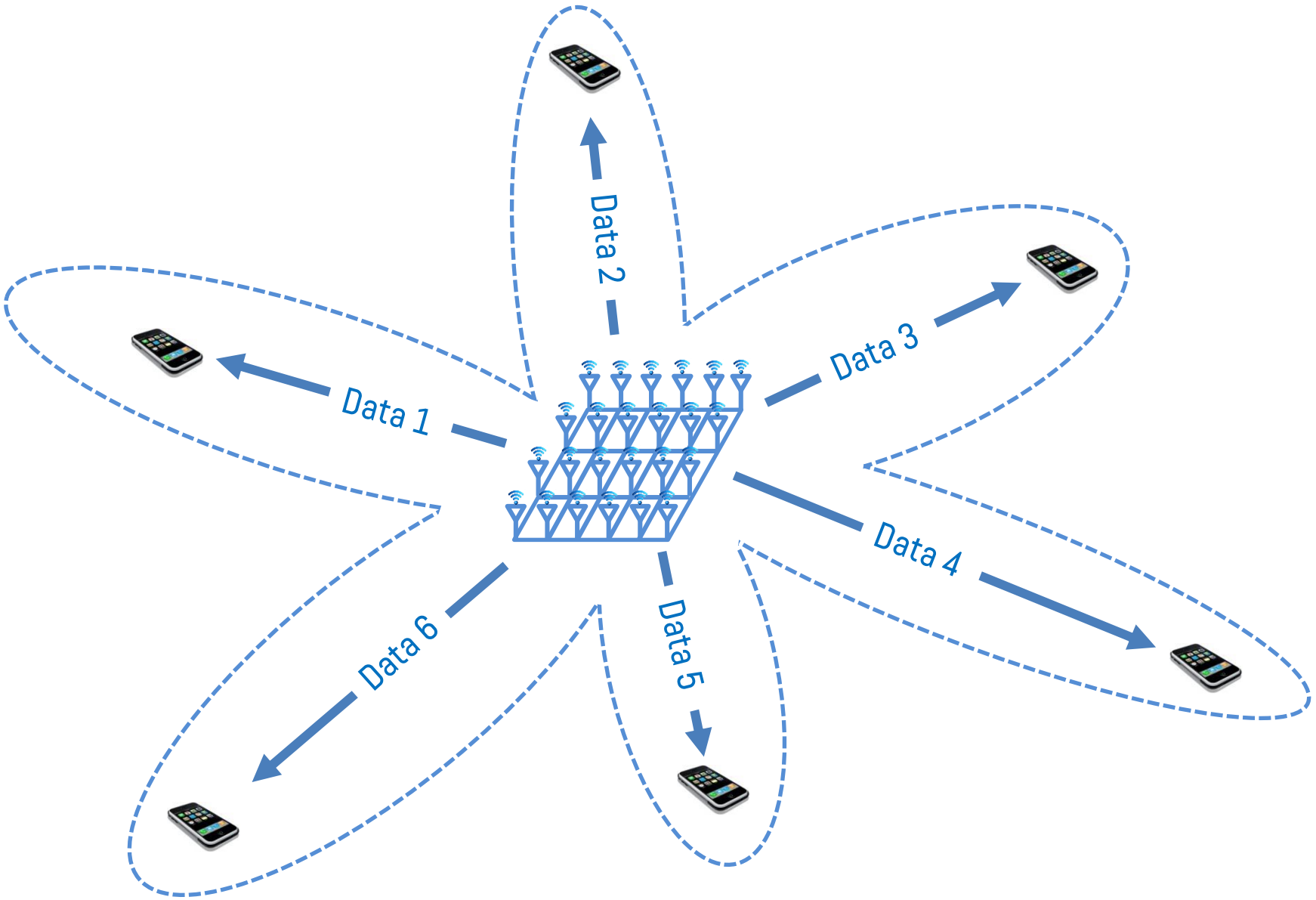
Argos | Practical Massive MIMO

Clayton Shepard

Noncooperative Cellular Wireless with Unlimited Numbers of Base Station Antennas

Thomas L. Marzetta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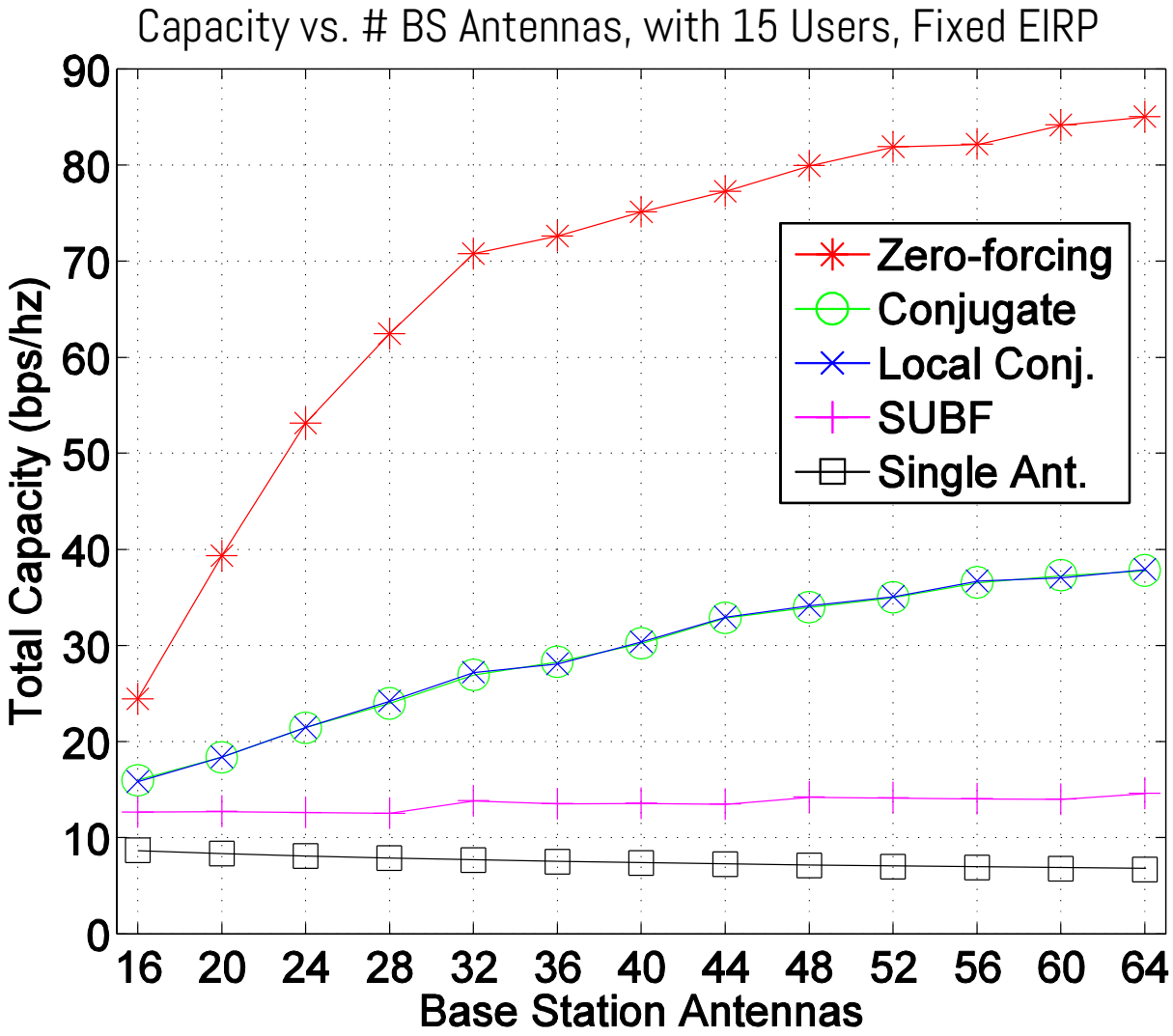
Does it work?

Linear Gains as # BS Ant. Increases

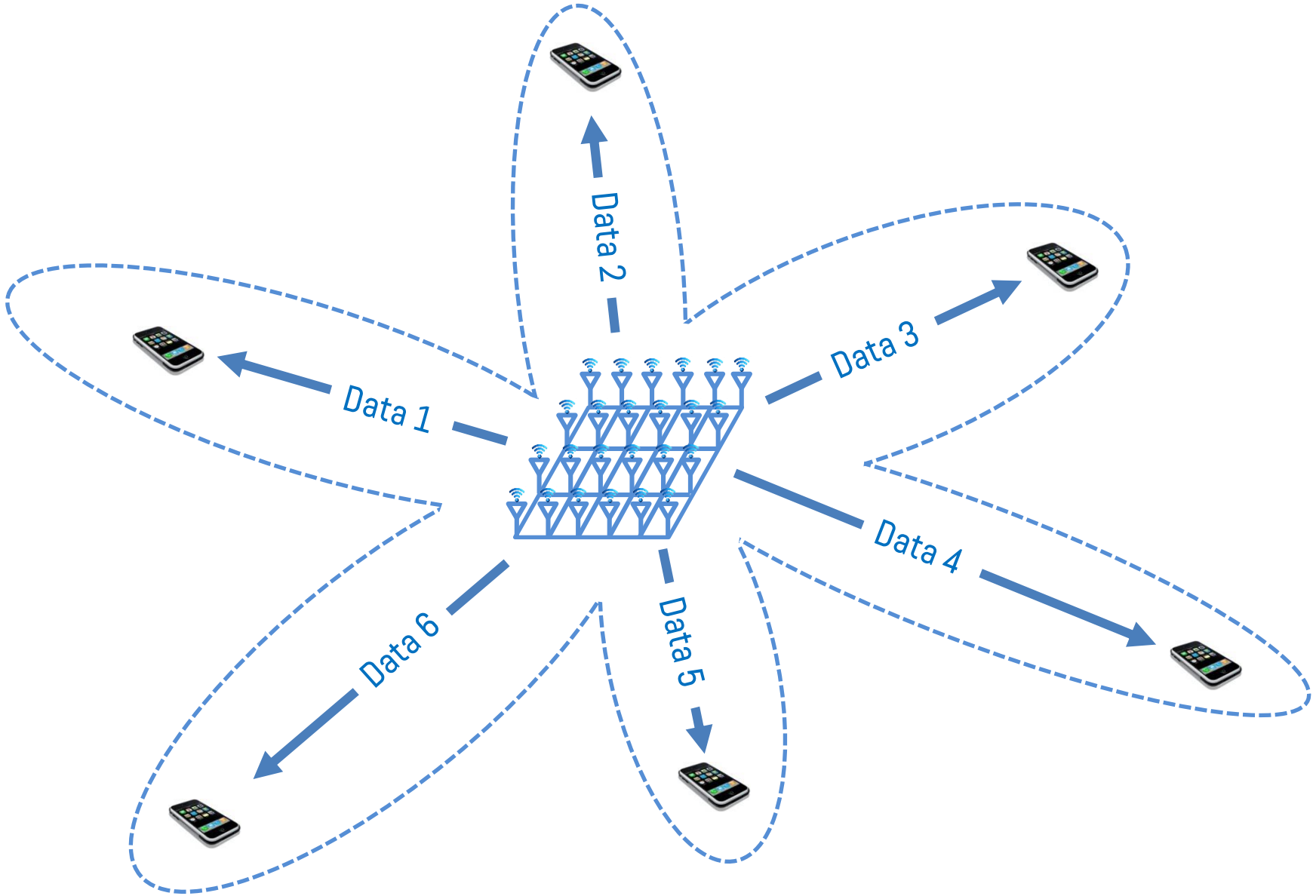


C. Shepard, et al., "Argos: Practical Many-Antenna Base Stations," *MobiCom*, 2012.

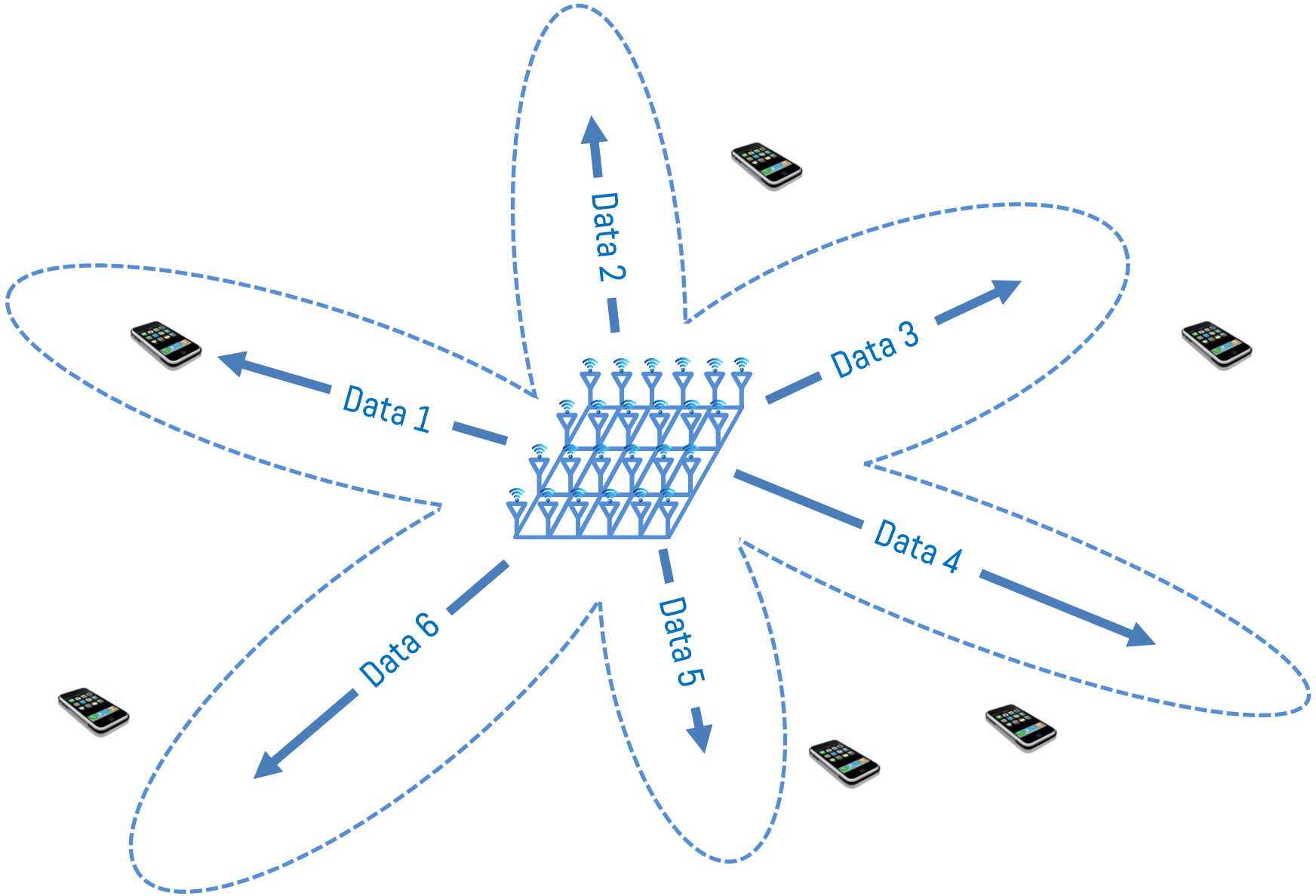
It works!

... in the lab.

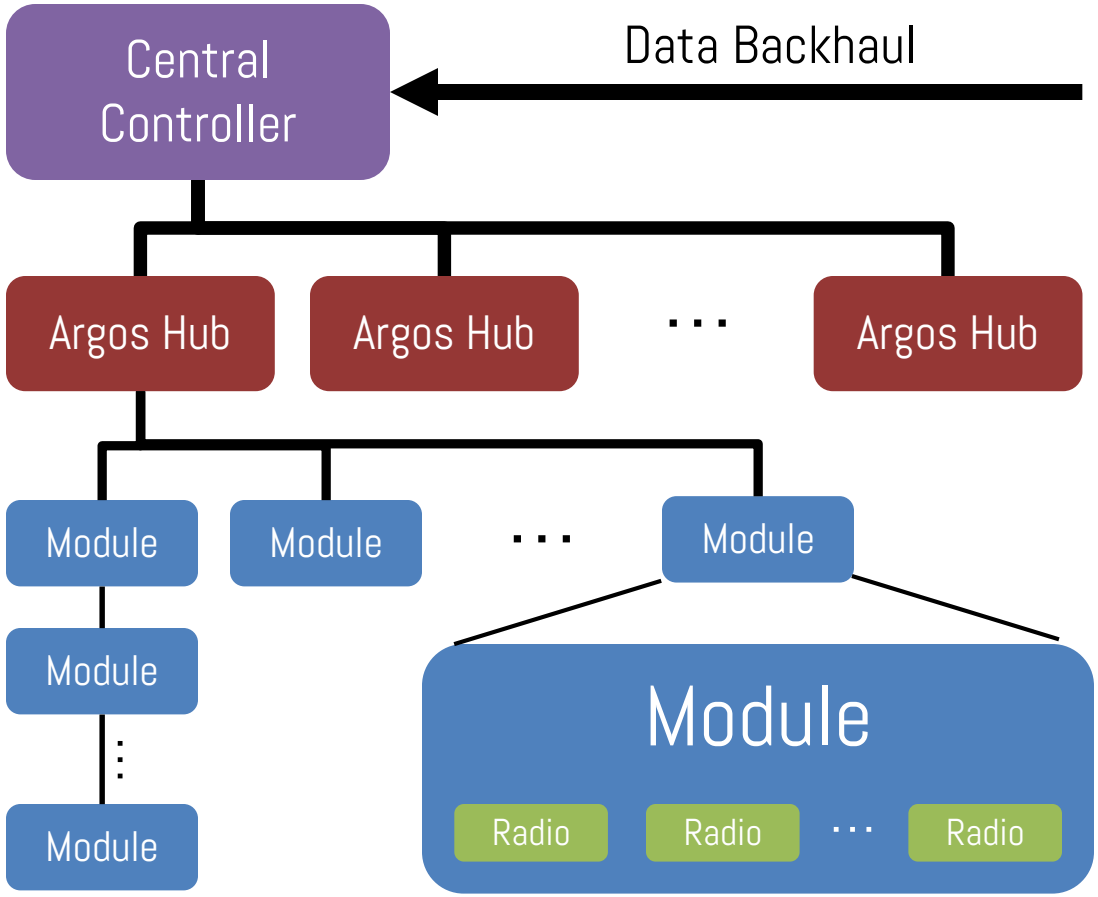
Mobility fundamentally limits capacity!



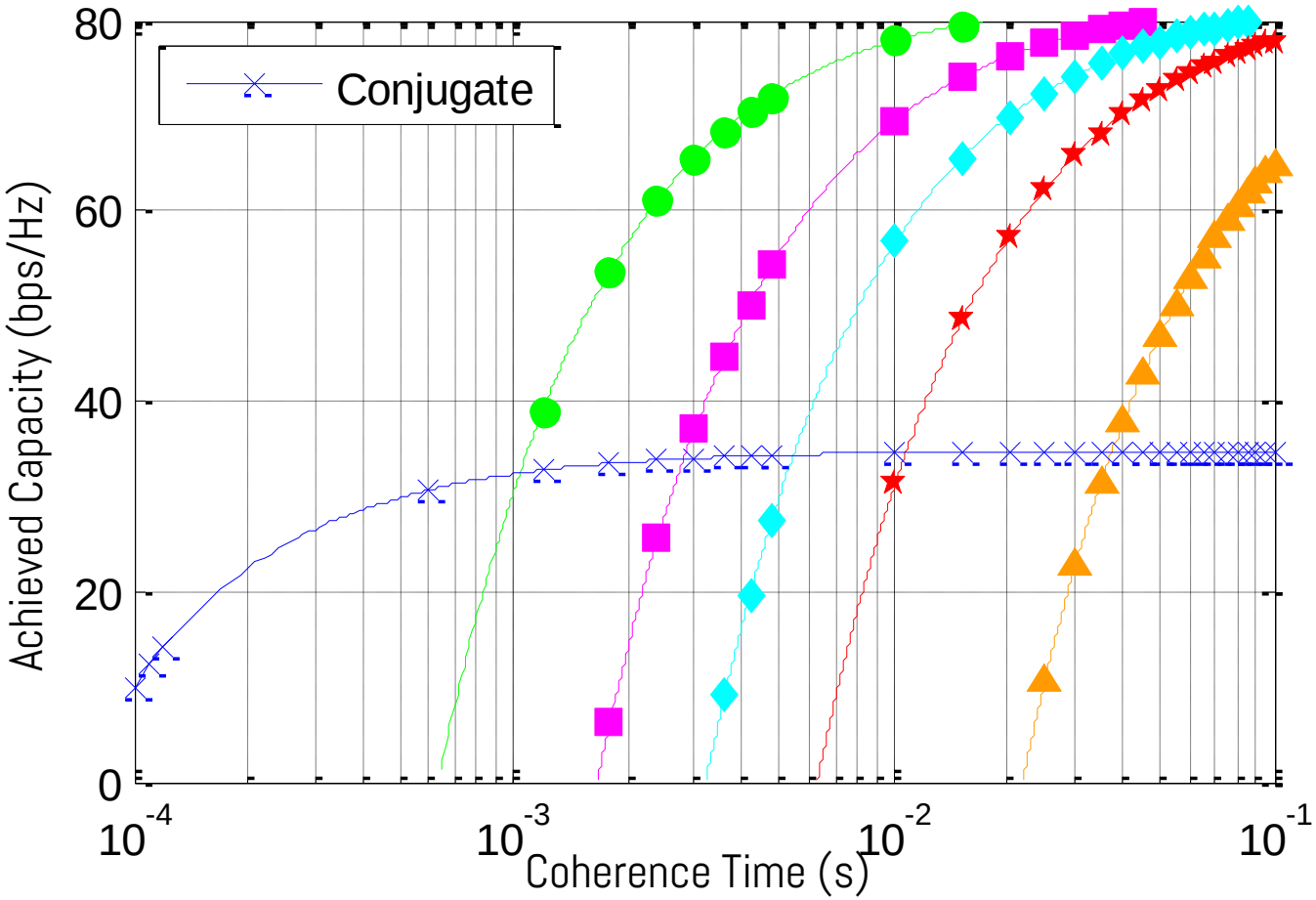
Mobility fundamentally limits capacity!



Argos Base Station Architecture



C. Shepard, et al., "Argos: Practical Many-Antenna Base Stations," *MobiCom*, 2012.



	Type	S	L	Inv. Type	Sym.
Super	Infiniband	40 Gbps	1 μs	FPGA	●
Cluster	4x10GbE	40 Gbps	20 μs	8xIntel i7	■
High	2x10GbE	20 Gbps	20 μs	4xIntel i7	♦
Mid	10GbE	10 Gbps	20 μs	2xIntel i7	★
Low	GbE	1 Gbps	20 μs	Intel i7	▲

Zeroforcing with various hardware configurations

C. Shepard, et al., " Practical Performance of MU-MIMO Precoding in Many-Antenna Base Stations," *CellNet, 2013*.

Ramifications

More Antennas Faster Processing Mobility

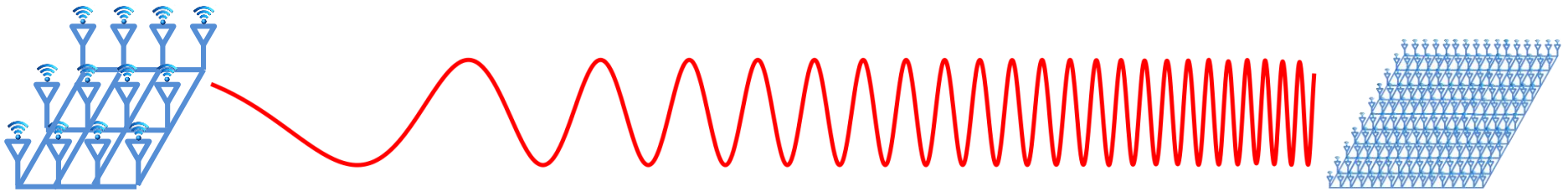
Zero-forcing

Adaptive Precoding

Conjugate

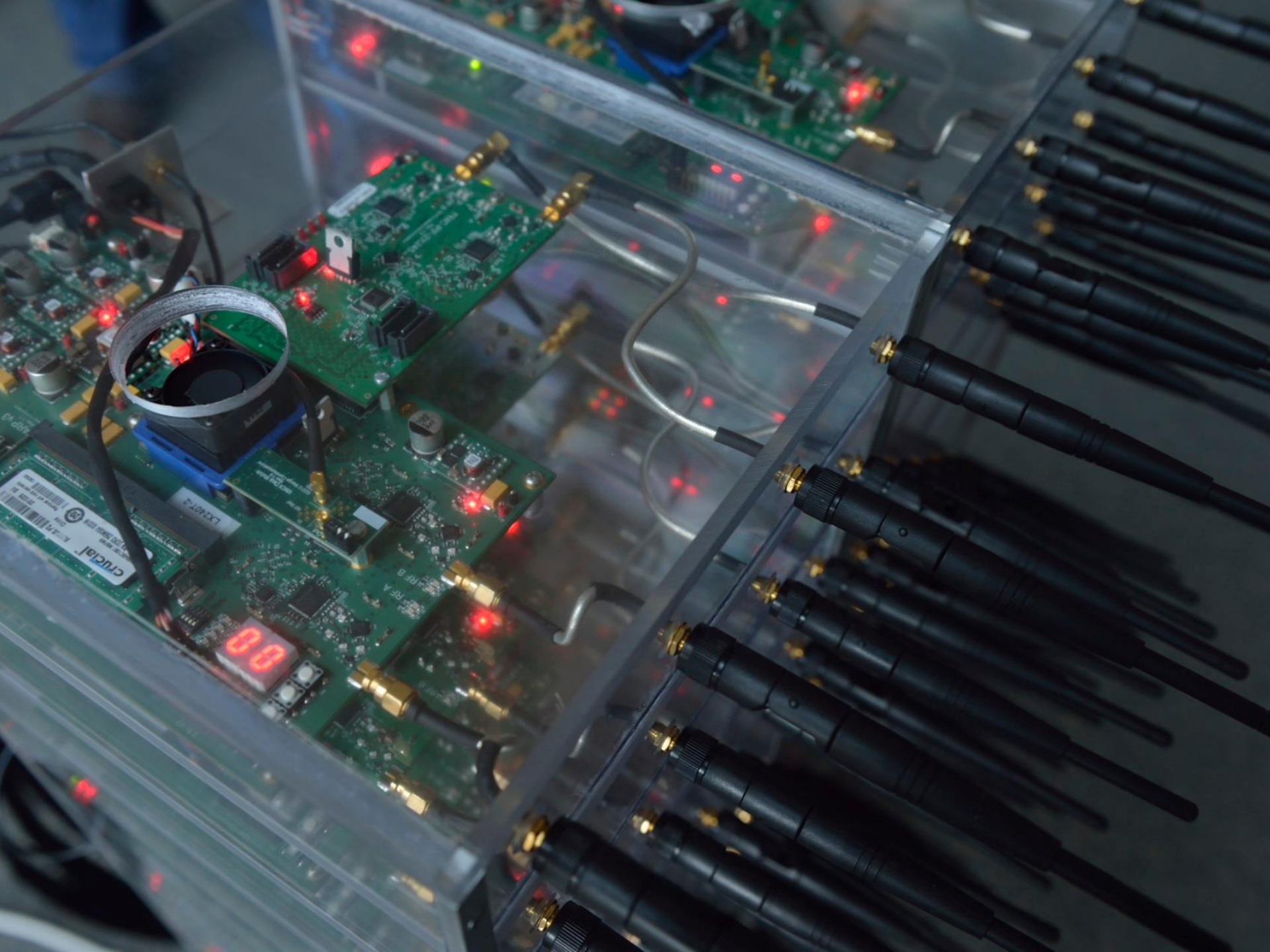
1 GHz

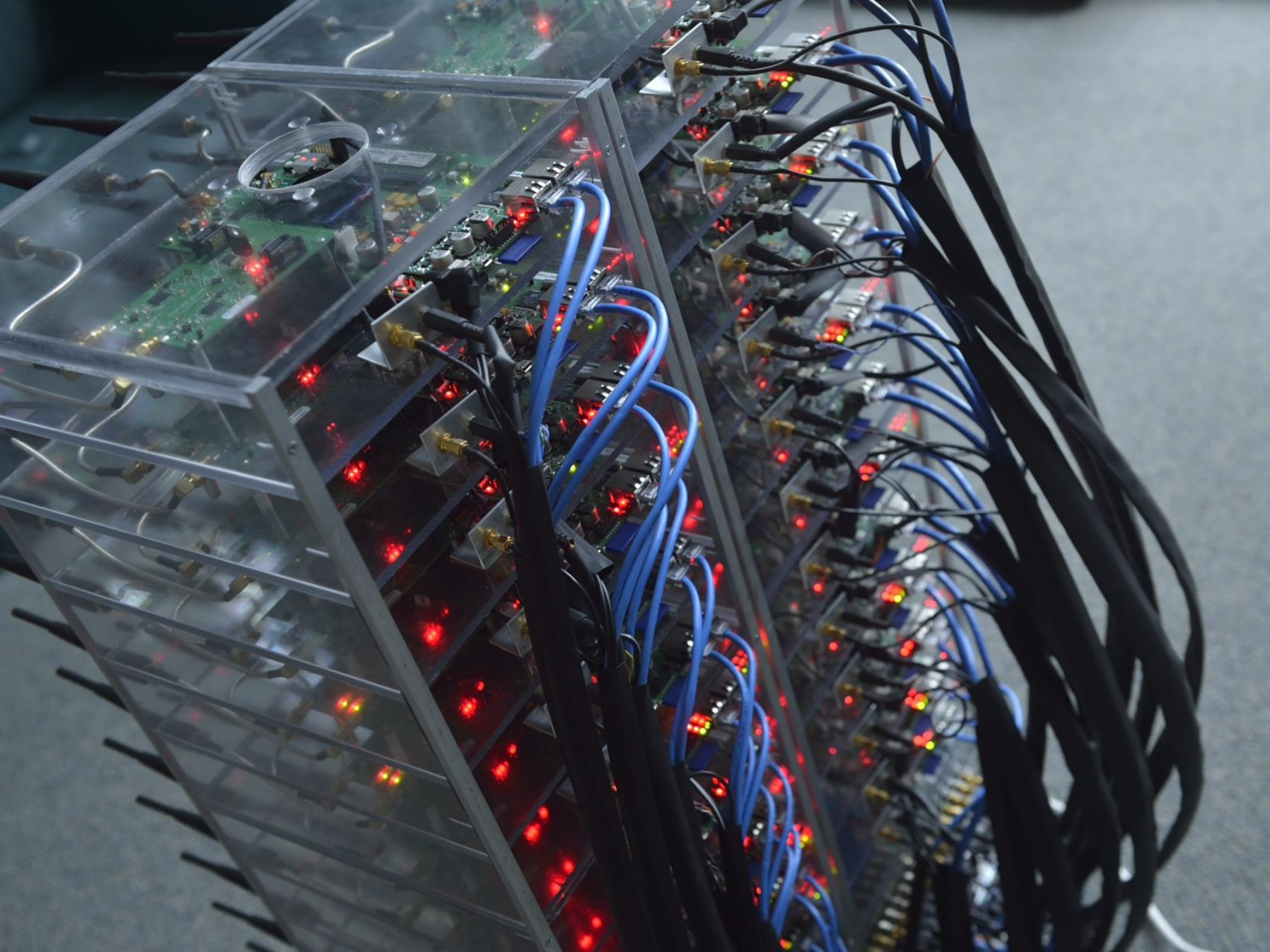
10 GHz

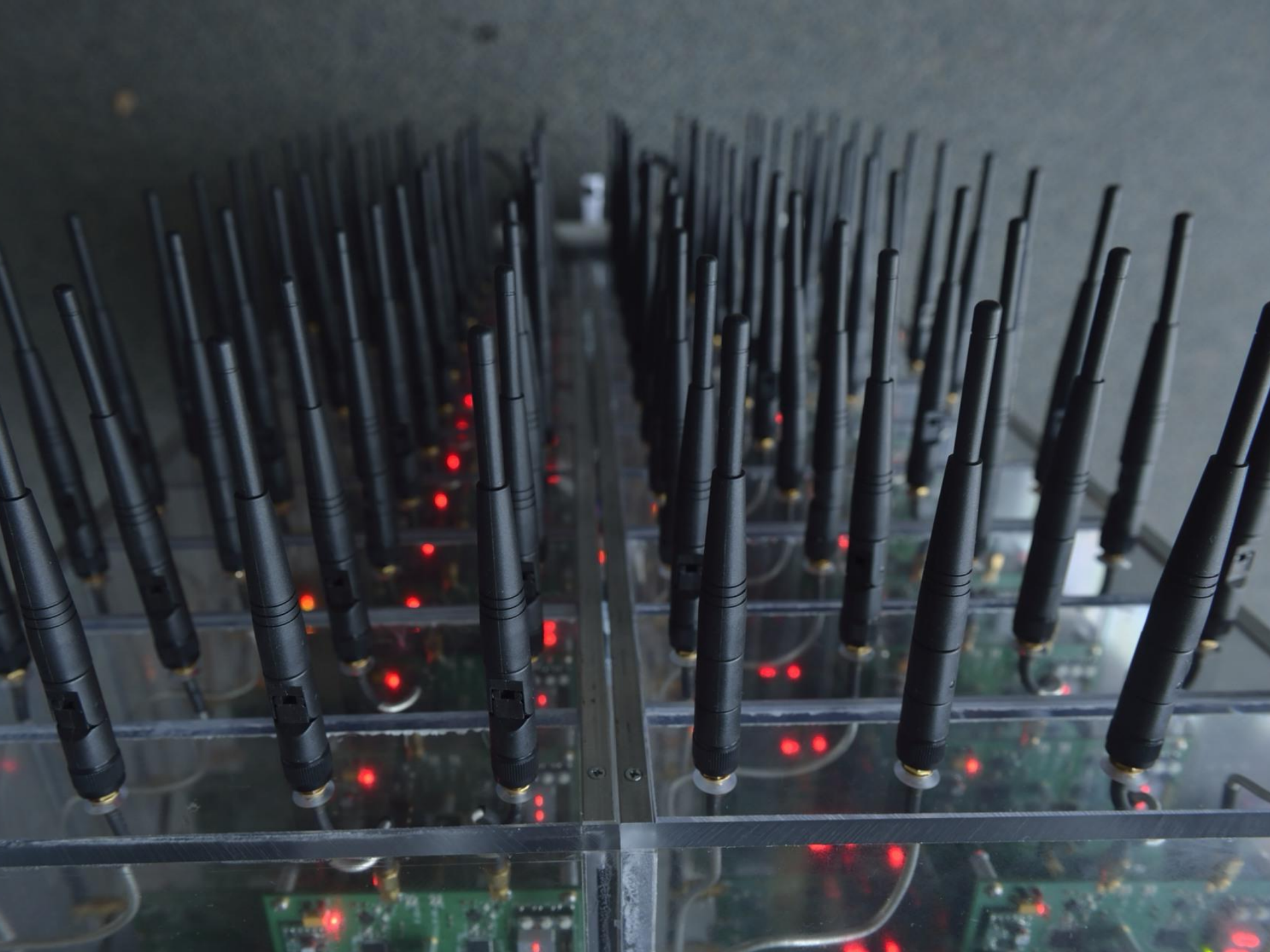


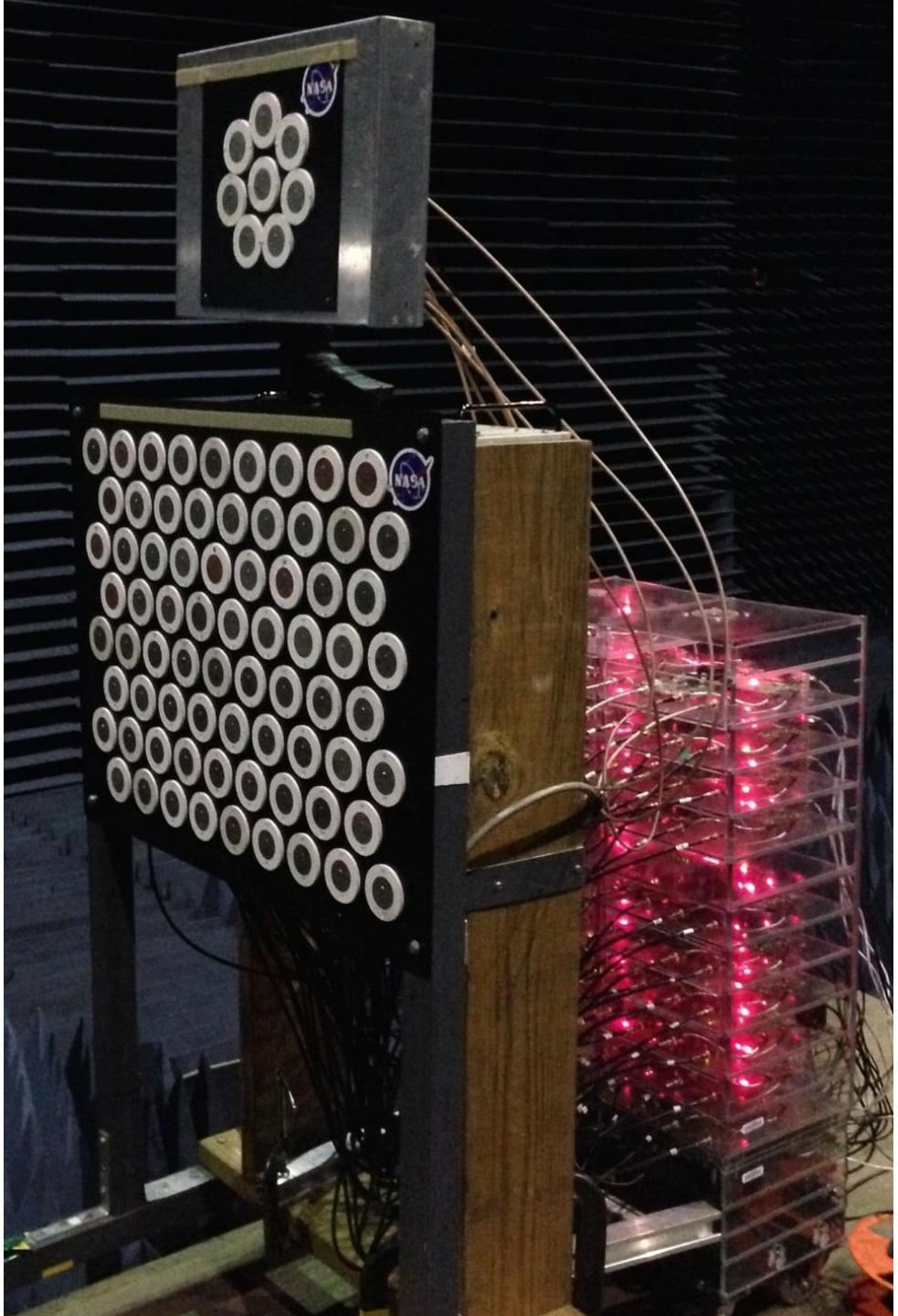
C. Shepard, et al., " Practical Performance of MU-MIMO Precoding in Many-Antenna Base Stations," *CellNet, 2013*.

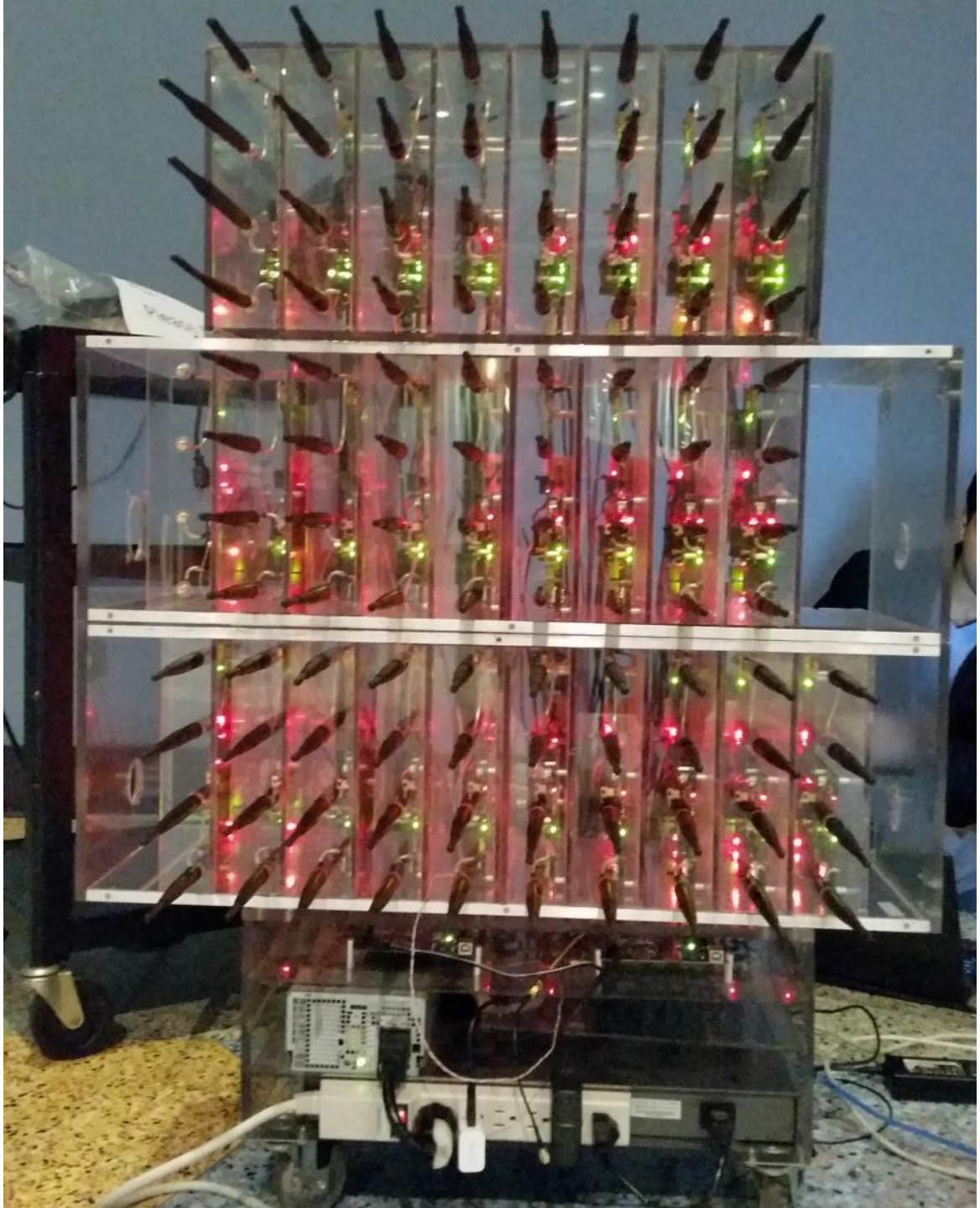
Back to the shop.

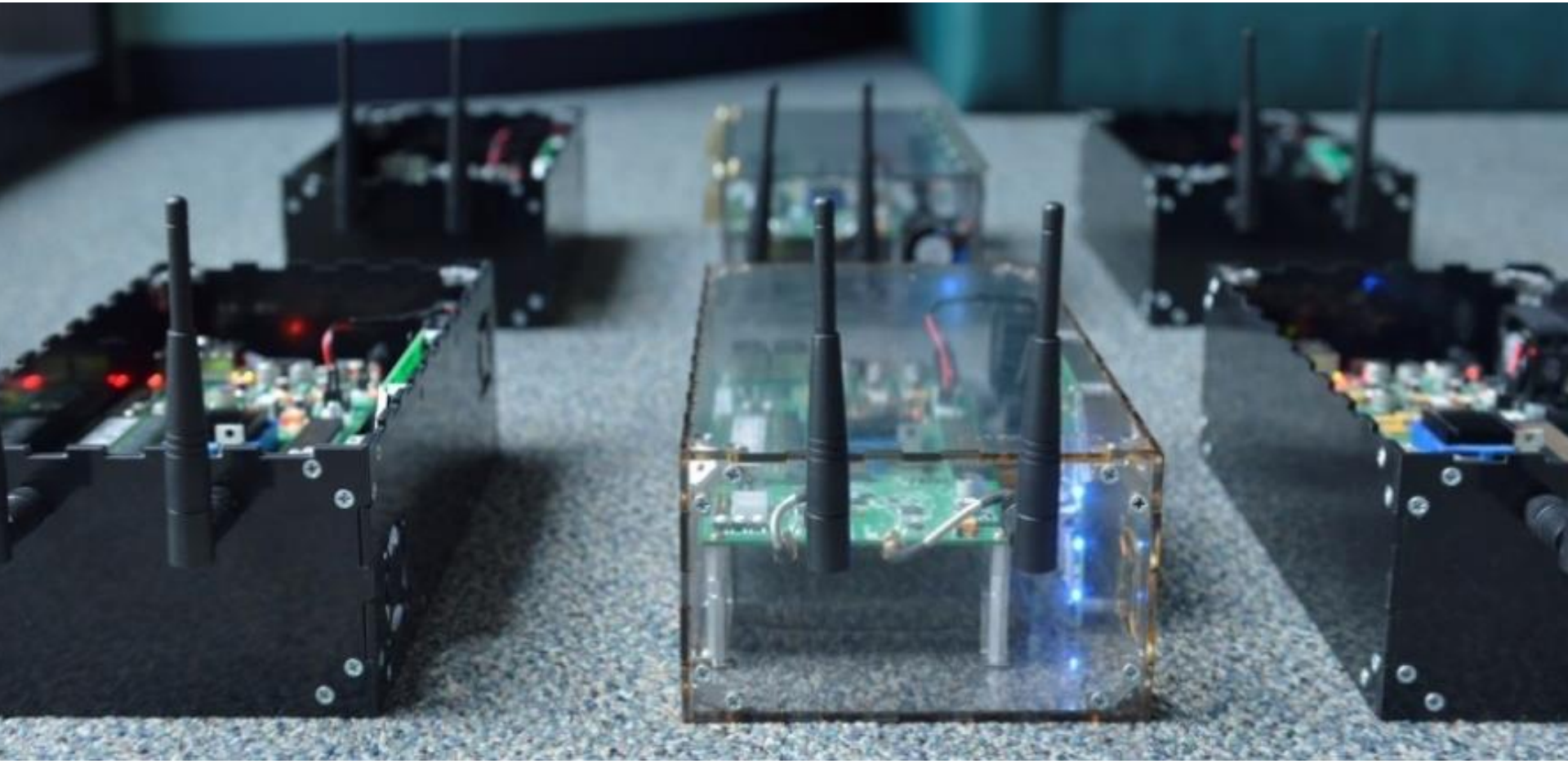

crucial









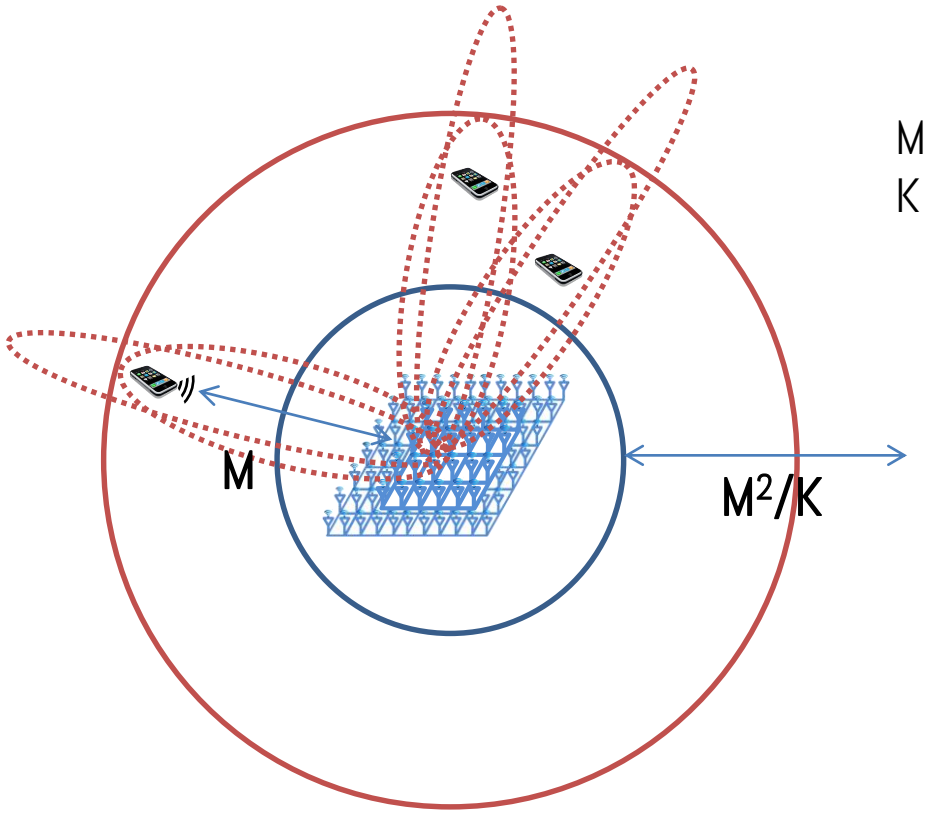


C. Shepard, et al., "ArgosV2: A Flexible Many-Antenna Research Platform," *MobiCom*, 2013.

On to realtime measurements!

Houston, we have a problem.

Gain Gap grows with M^2!

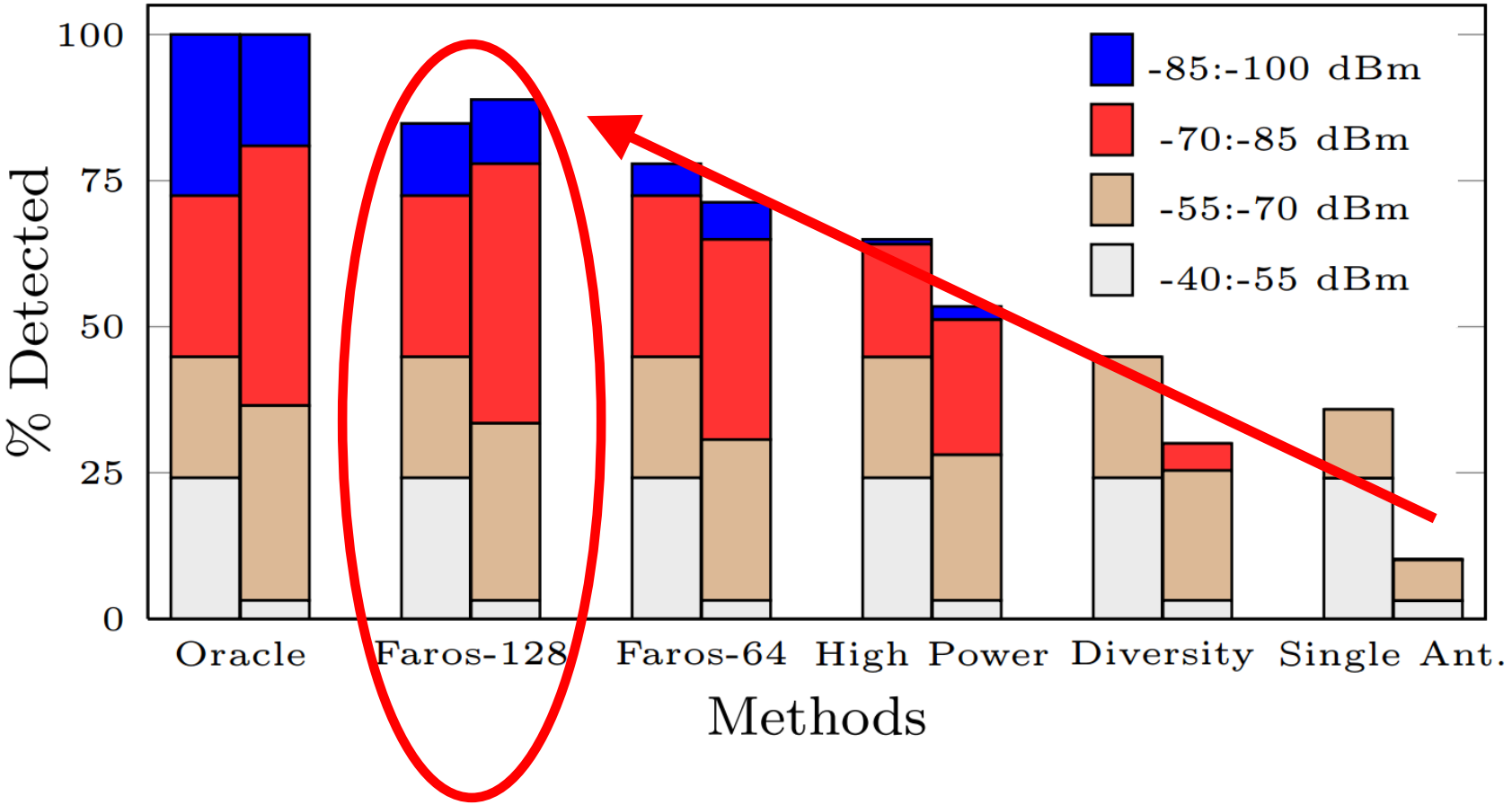


M Base Station Antennas
K Users

Traditional Sync MU-MIMO

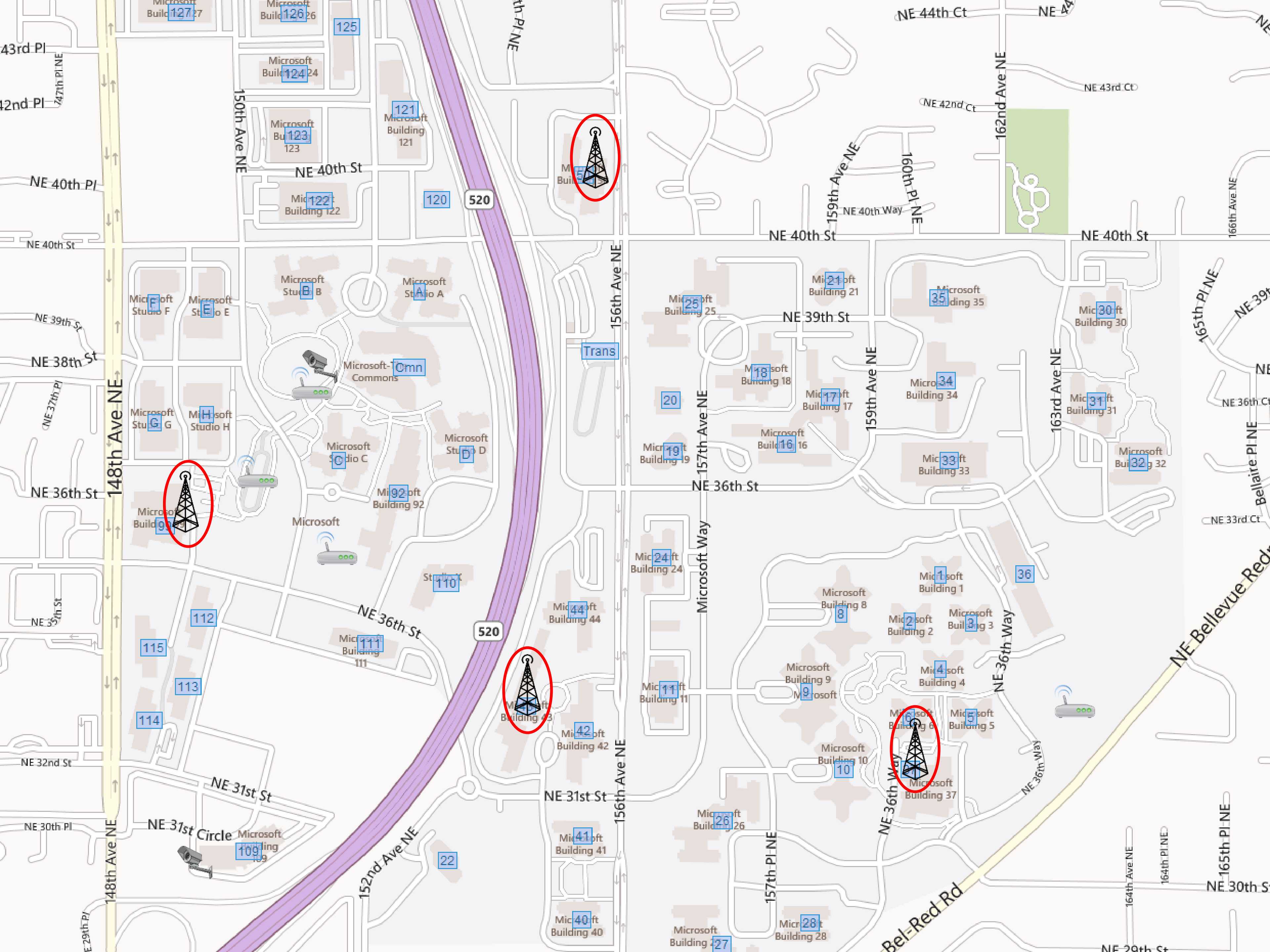
C. Shepard, et al., "Control Channel Design for Many-Antenna MU-MIMO," *MobiCom*, 2015.

Faros Many-Antenna Control Channel



C. Shepard, et al., "Control Channel Design for Many-Antenna MU-MIMO," *MobiCom*, 2015.

Now on to real measurements!



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Bel-Red Rd
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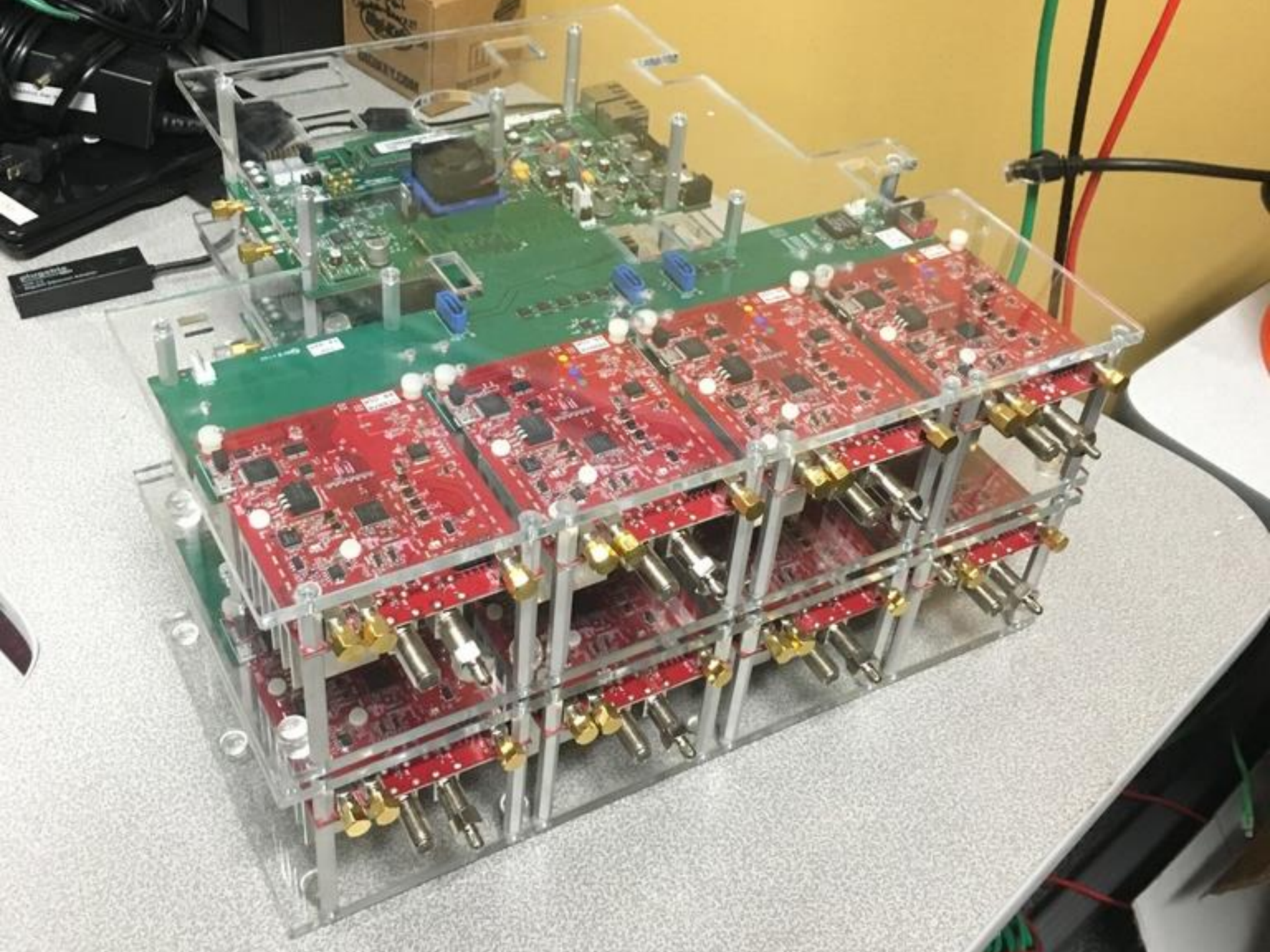

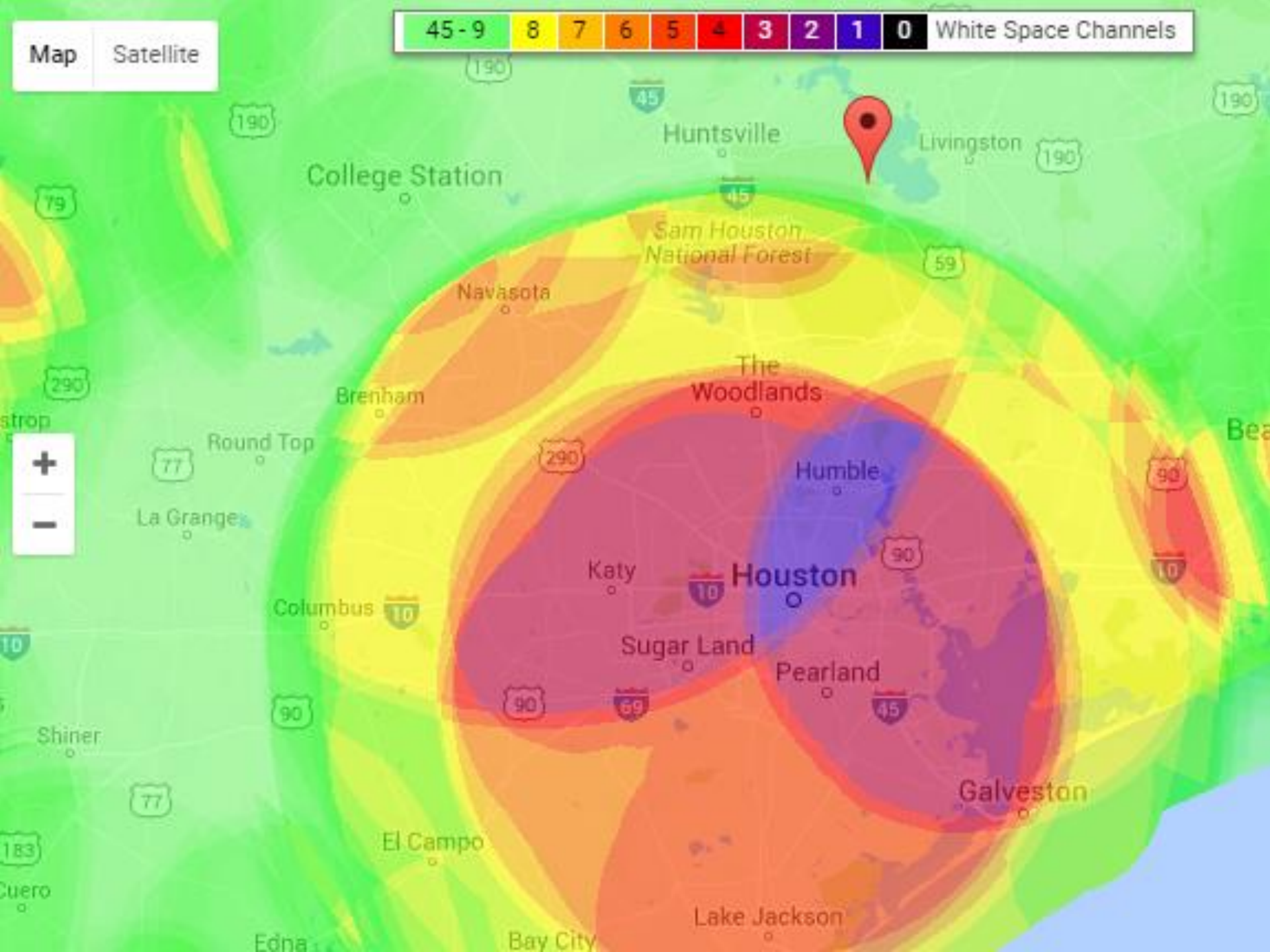
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White Space Channels
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Livingston
College Station
Sam Houston National Forest
Navasota
The Woodlands
Brenham
Round Top
La Grange
Humble
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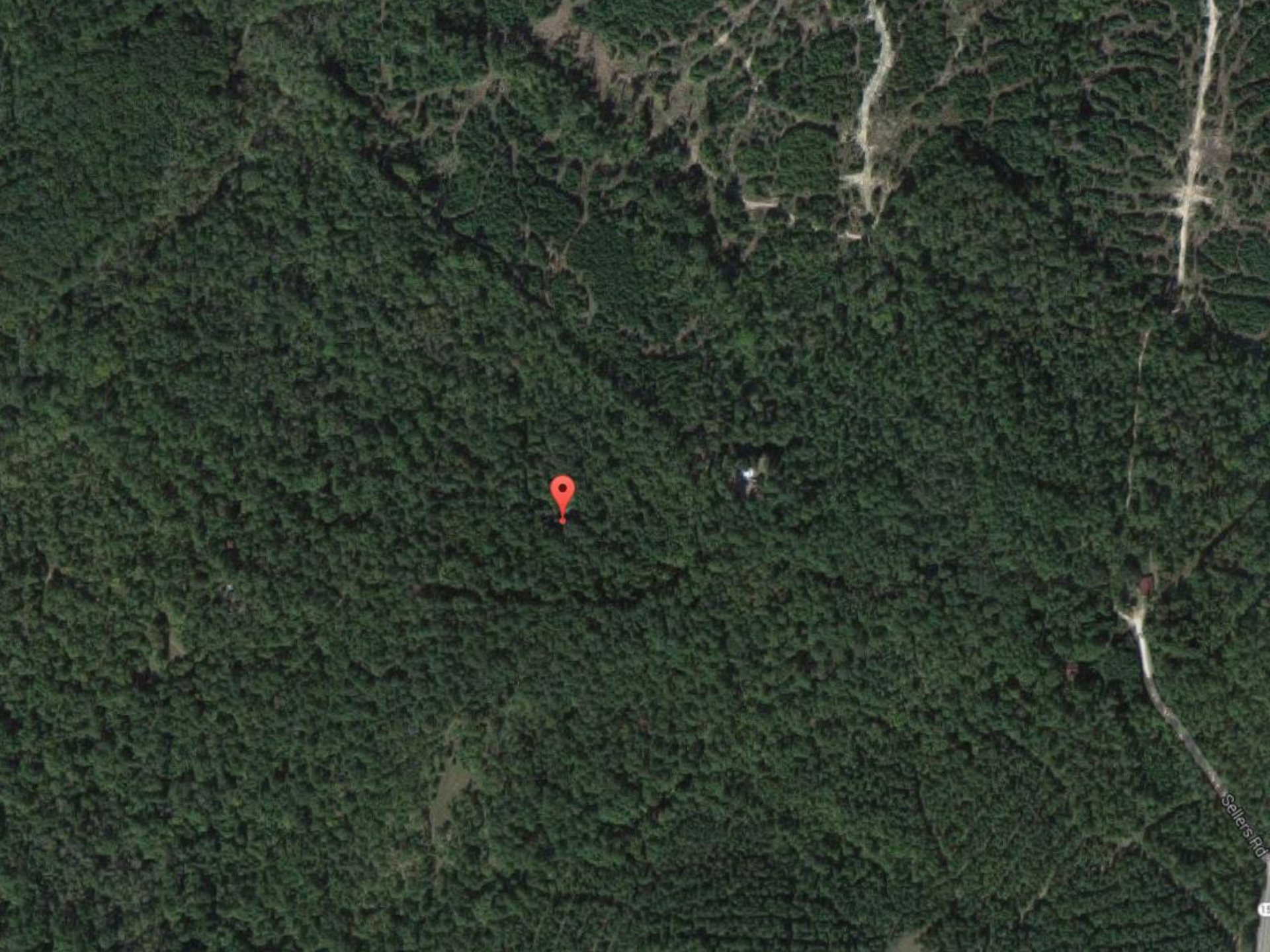
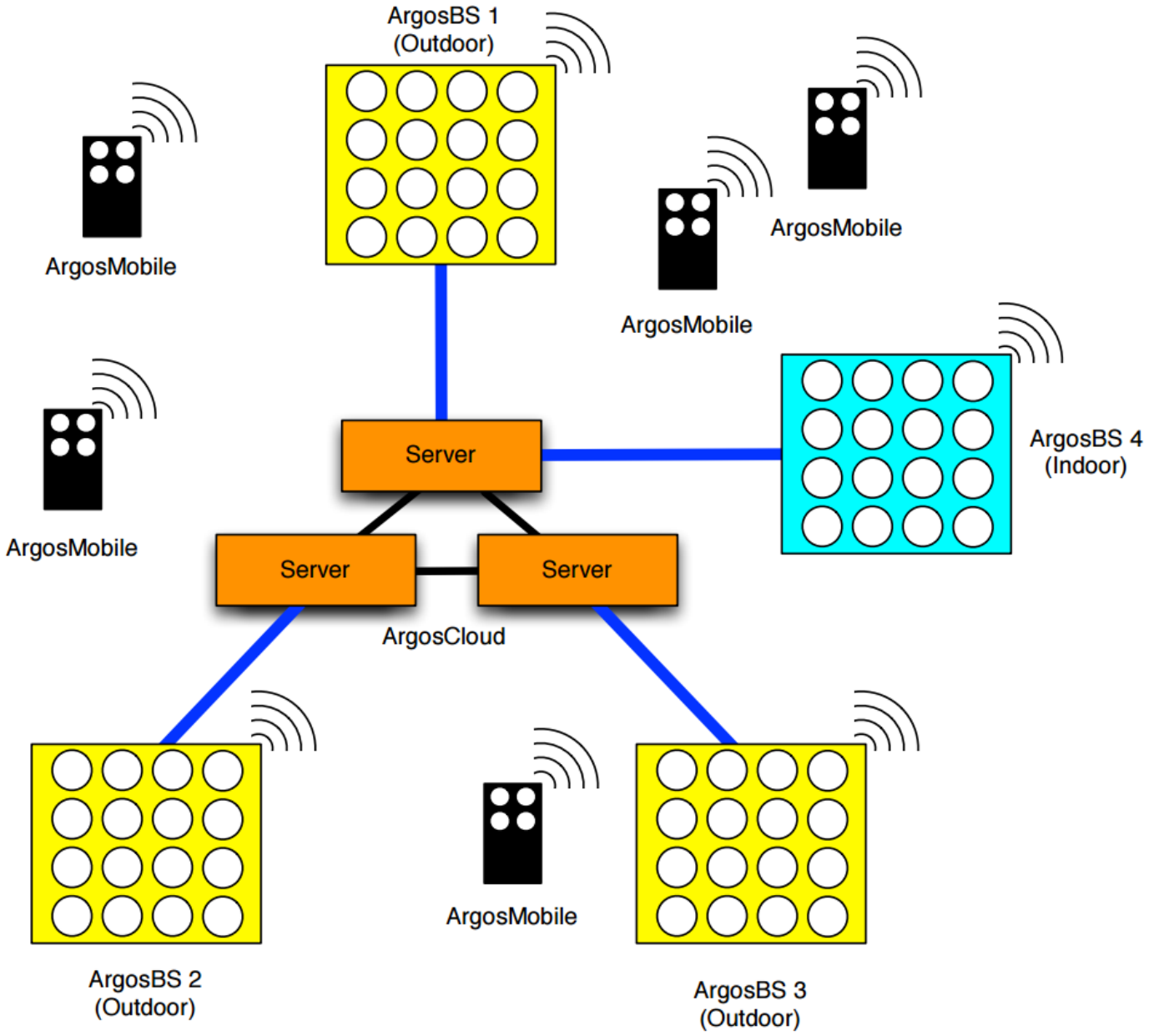
Pearland
Galveston
Shiner
El Campo
Lake Jackson
Bay City
Edna


Sellers Rd

ArgosNet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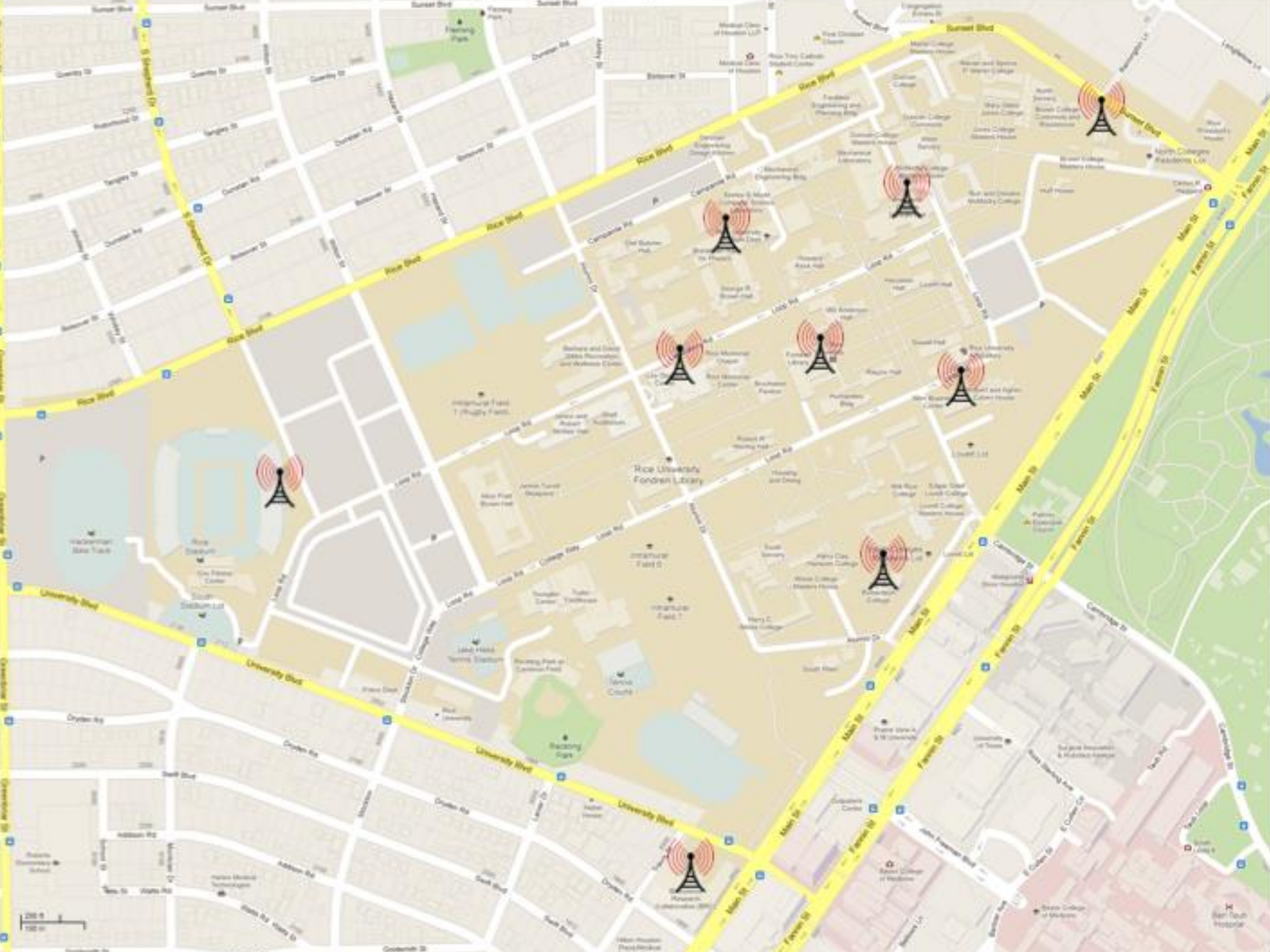
ArgosBS 2
(Outdoor)
ArgosBS 3
(Outdoor)


Sunset Blvd
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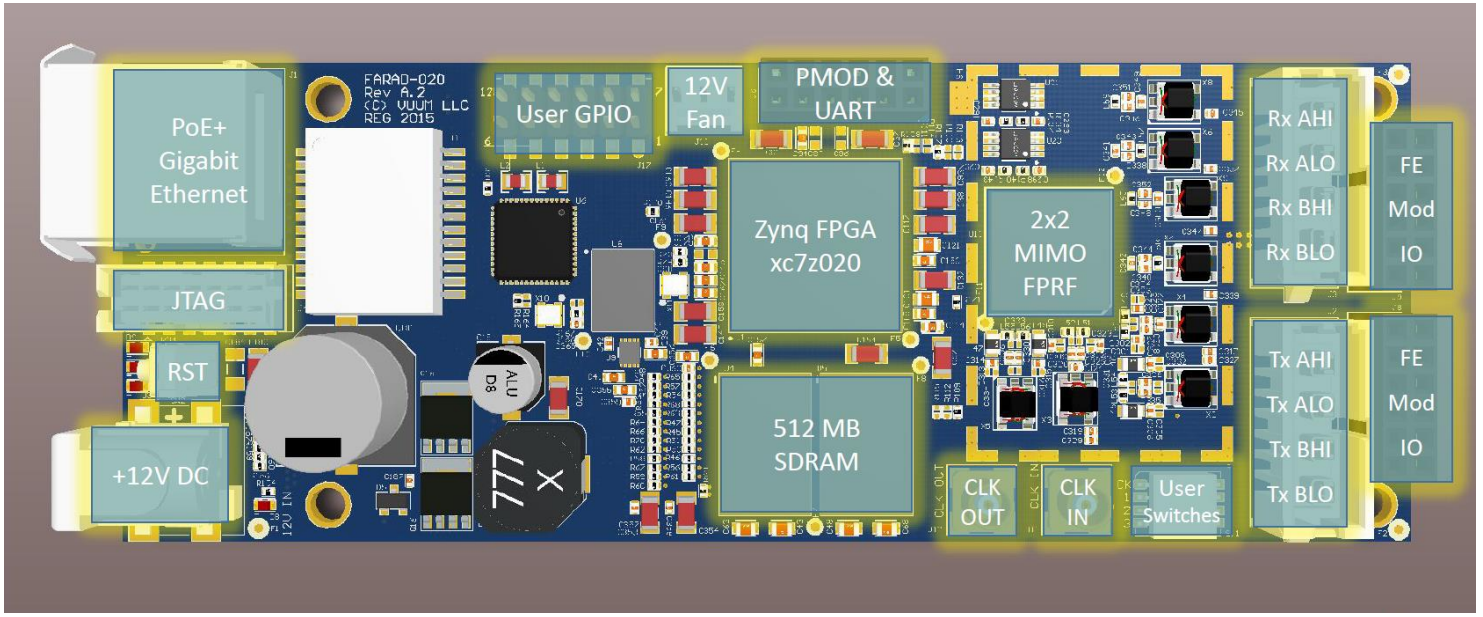
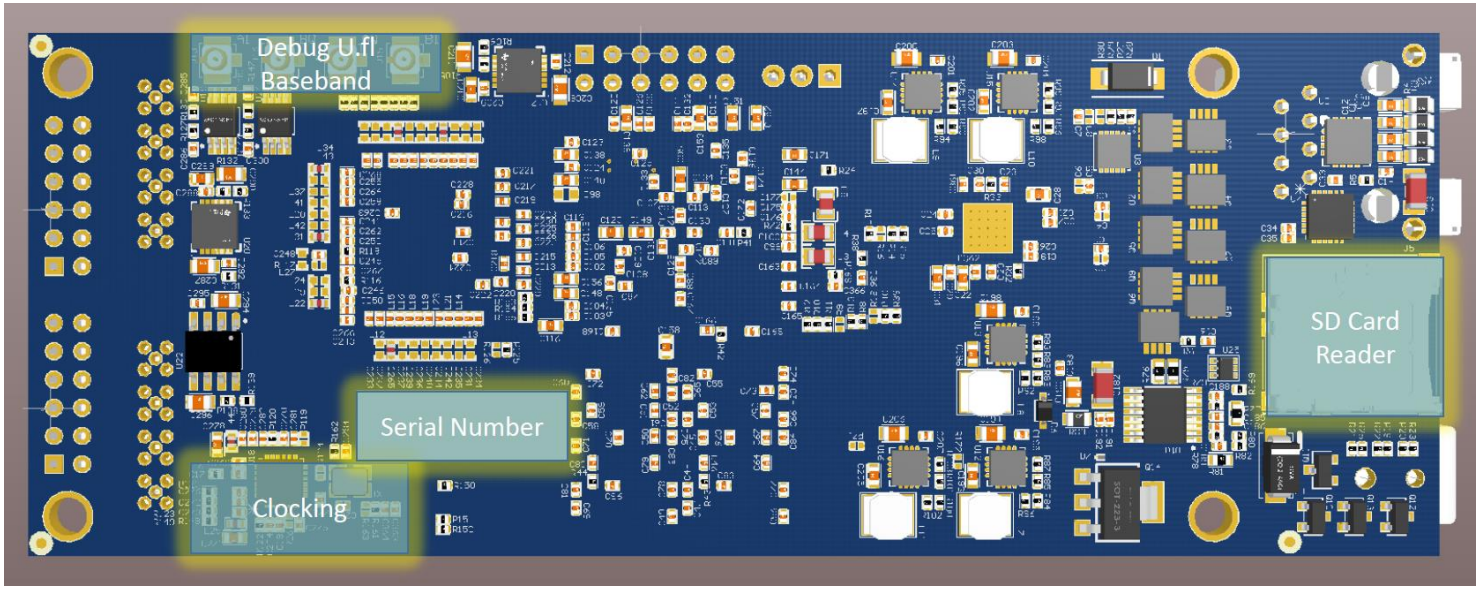
Rice Stadium

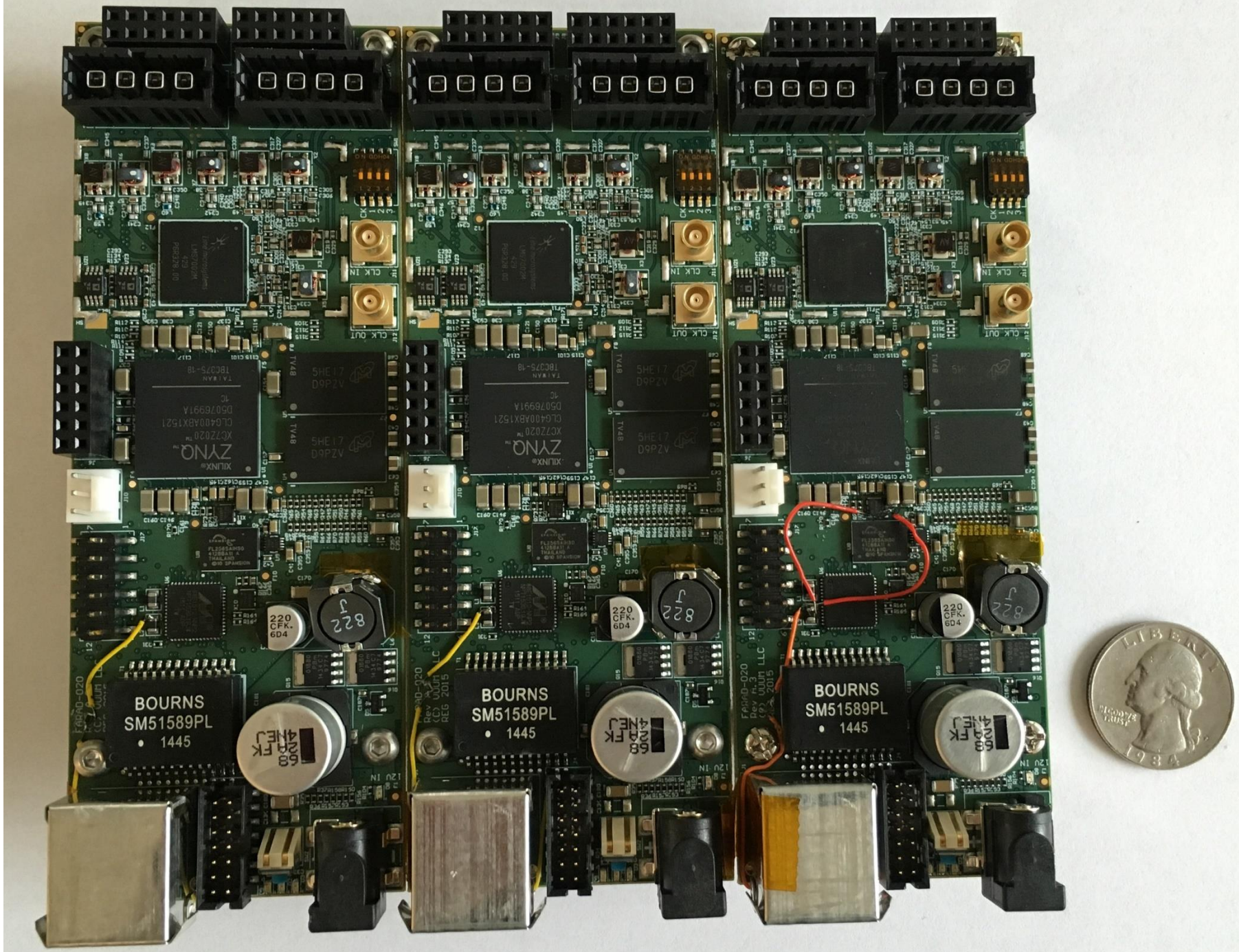
SKYLARK

WIRELESS

Skylark Iris



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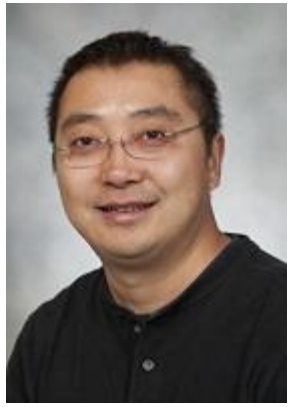
LIBERTY

Acknowledgements

Ryan Guerra

Abeer Javed

Victor Bahl



Lin Zhong

Edward Knightly

Evan Everett

Ashutosh Sabharwal

NSF

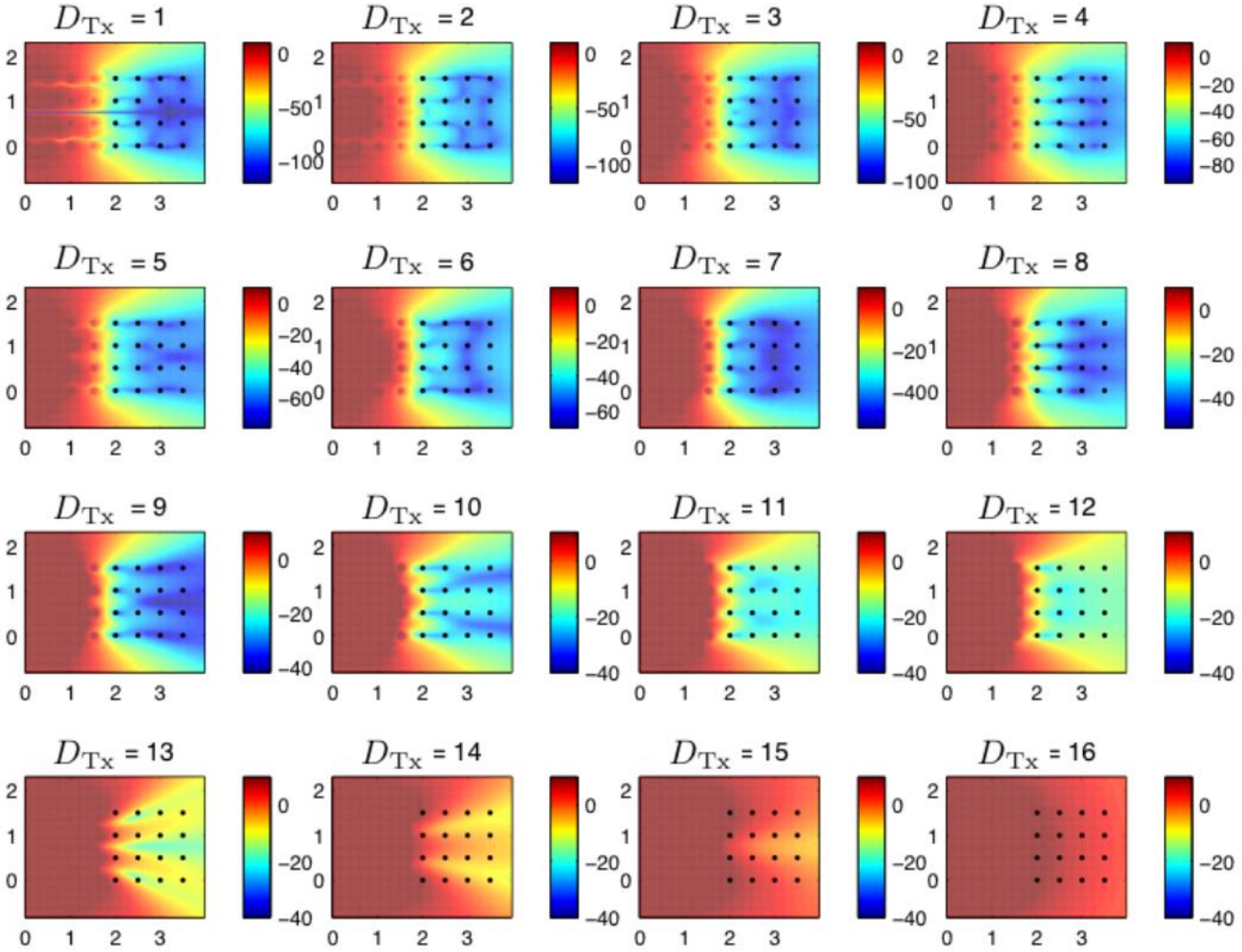
Bell Laboratories

NDSEG

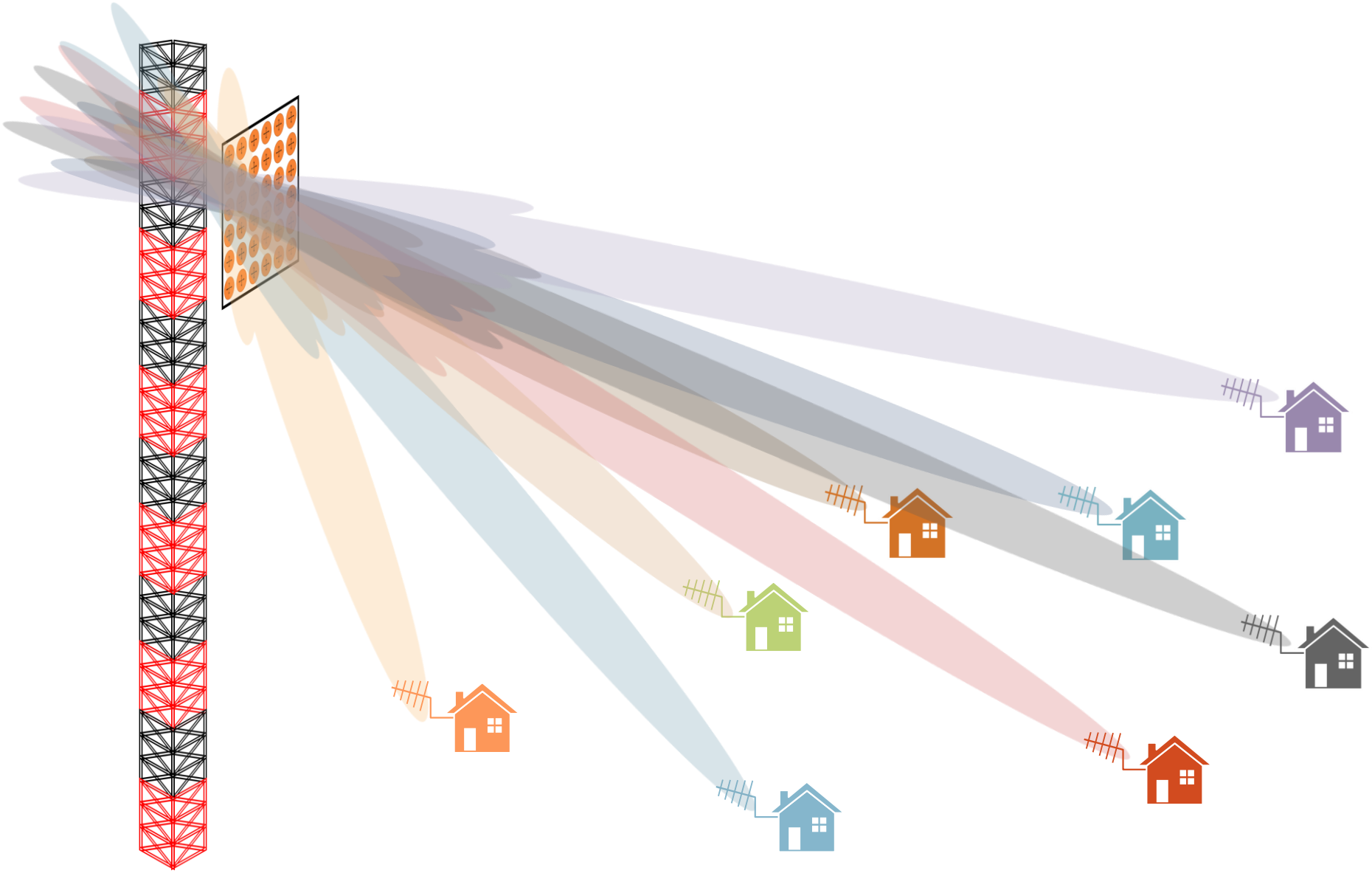
NATIONAL DEFENSE SCIENCE & ENGINEERING GRADUATE FELLOWSHIP

NASA

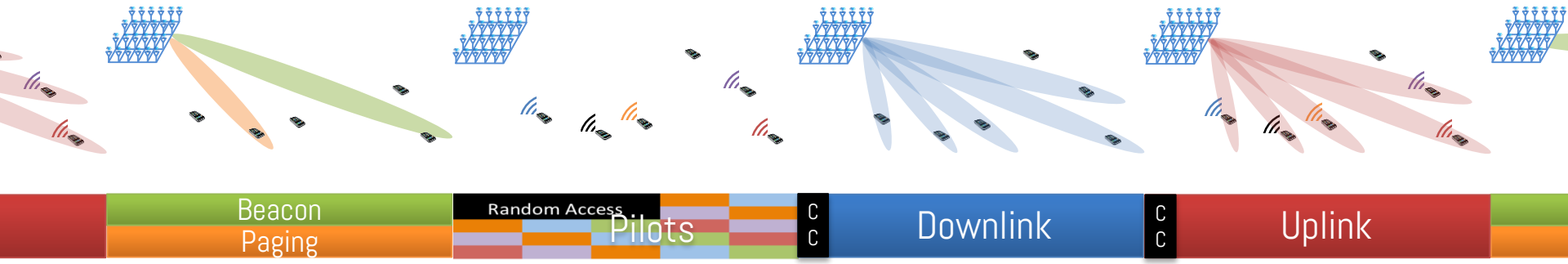
SoftNull: Many-Antenna Full-Duplex

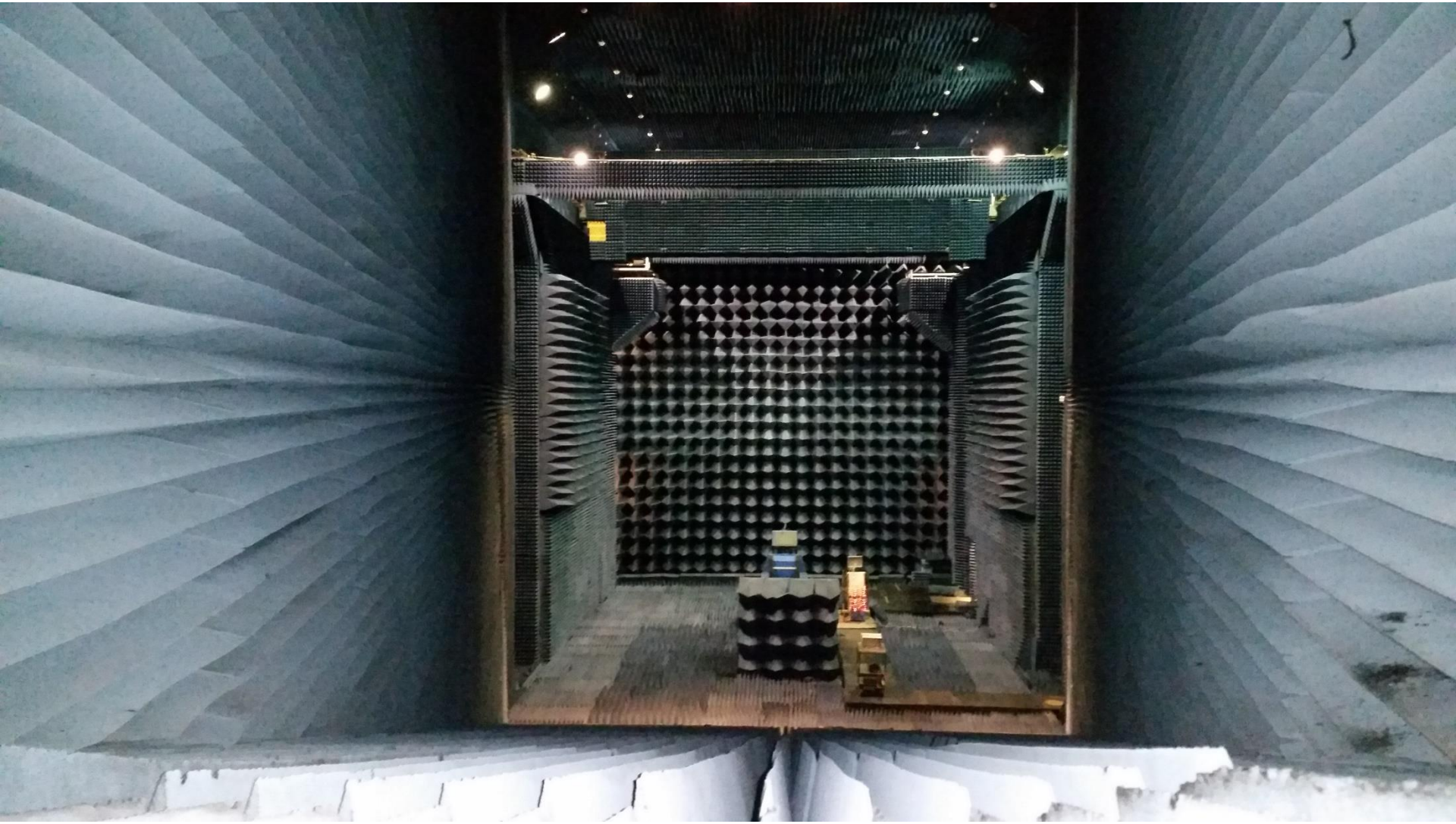


E. Everett, et al., "Measurement-driven Evaluation of All-digital Many-antenna Full-duplex Communication," *arXiv*, 2015.



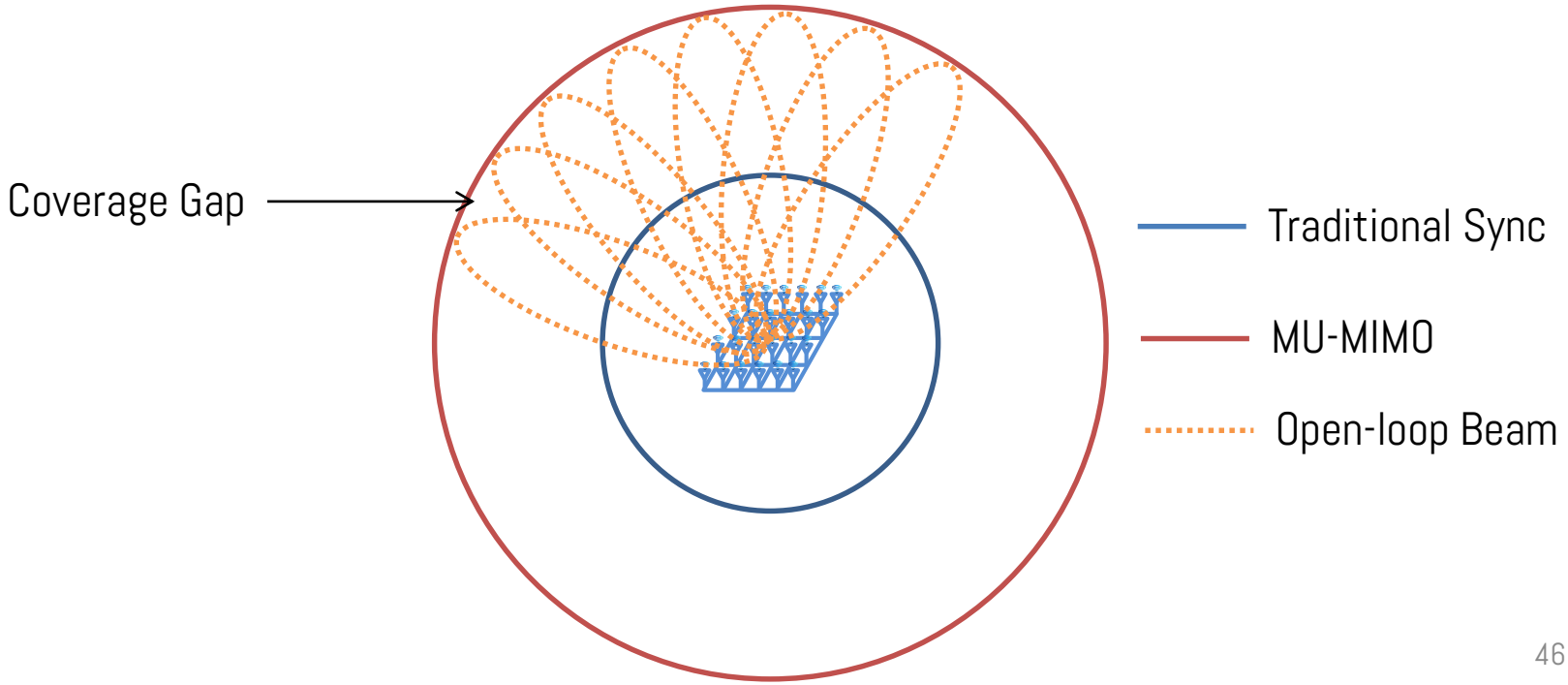
MU-MIMO Frame Structure





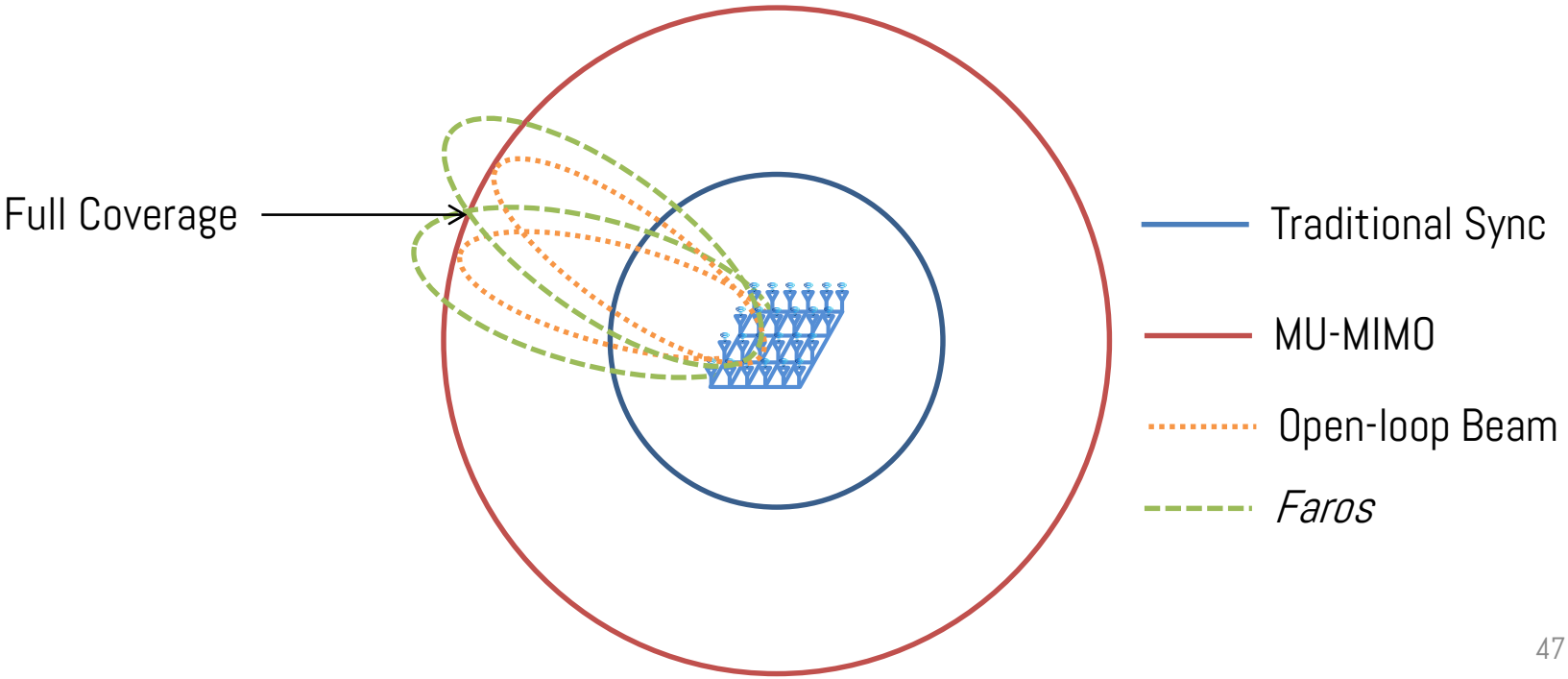
Faros Gain Matching: Beamforming

- Sweep open-loop beams!
  - No time-distortion
  - Power scales with M^2
  - Needs many beams (more time)
  - Still doesn't provide full range

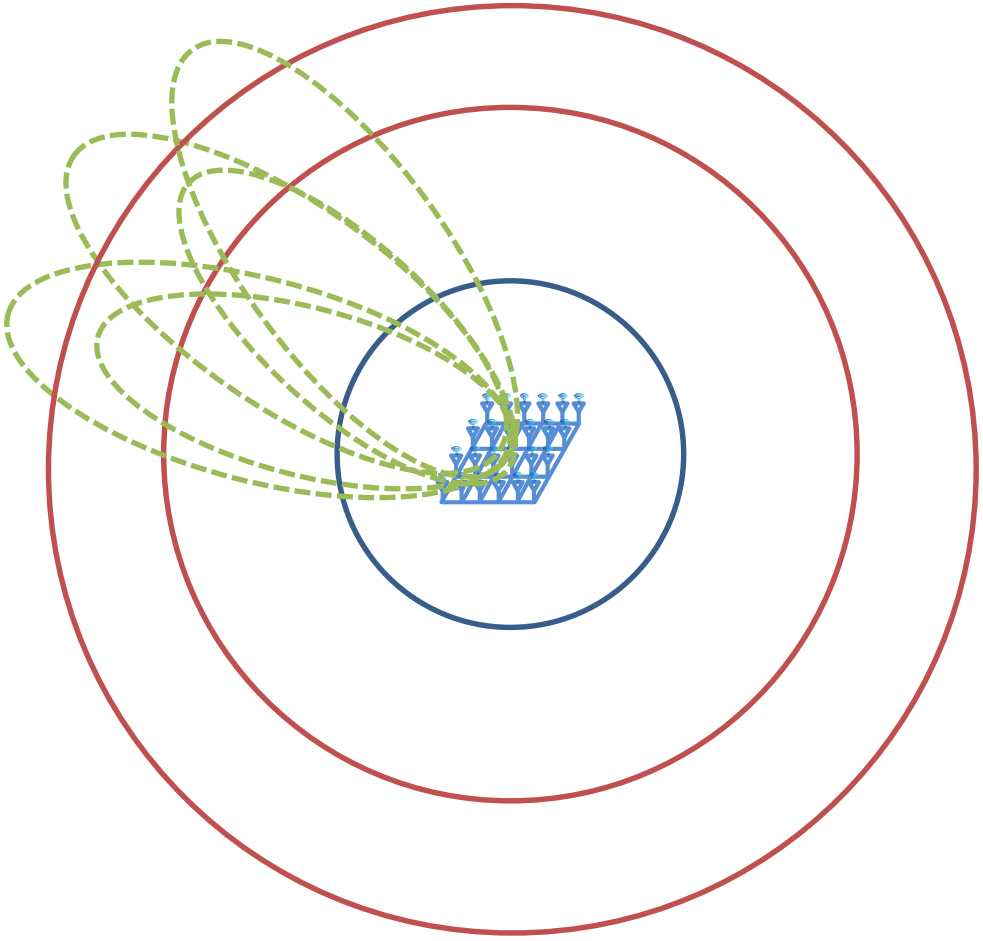


Gain Gap: Solution

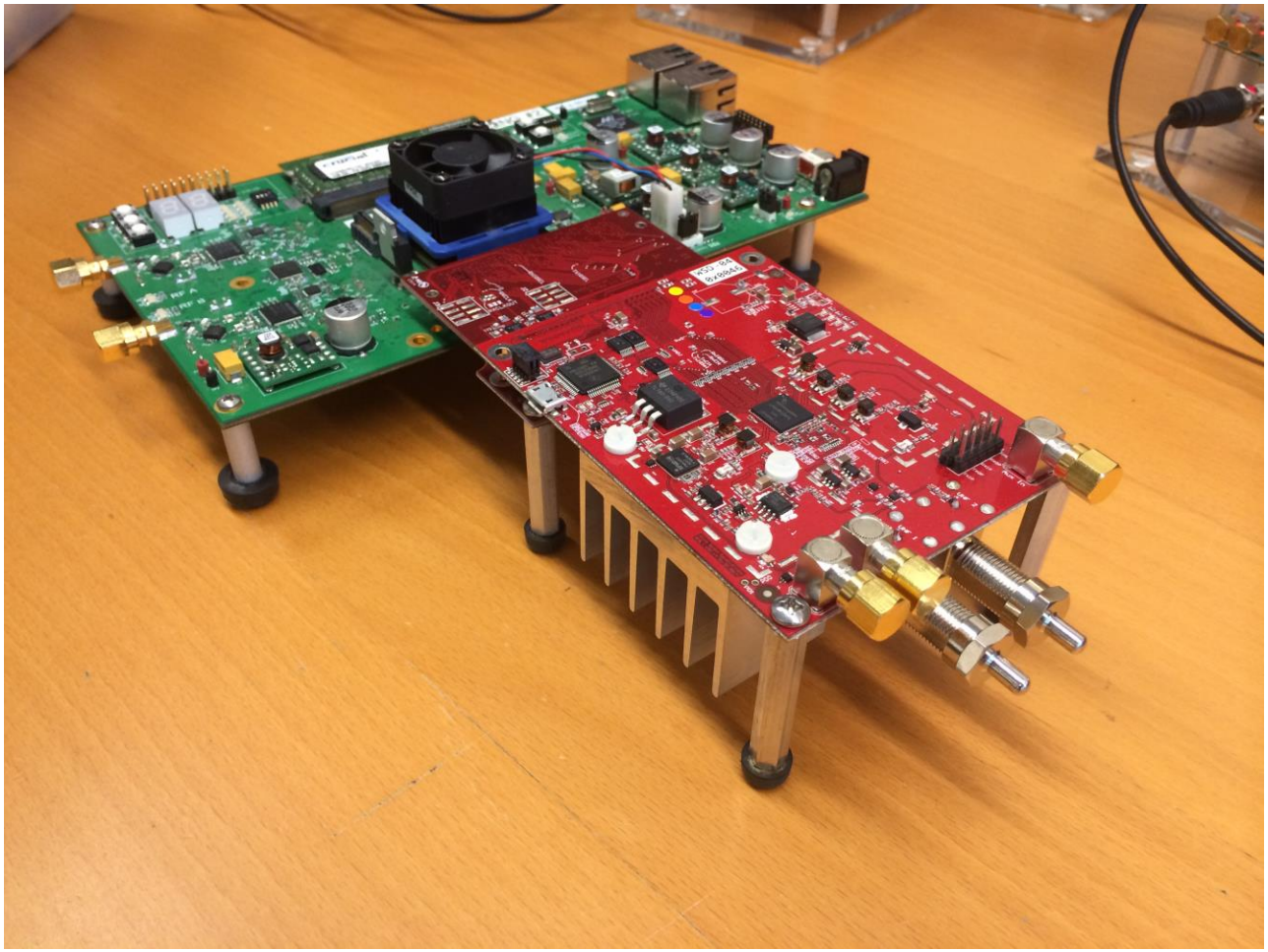
- Use coding gain!
  - Increase coverage area
  - Flexible range control
  - Takes more time



Faros Gain Matching Flexibility



Skylark WURC Platform



Contributions

- Scalable Base Station Architecture
- Distributed Beamforming Algorithm
- Internal Implicit Reciprocal Calibration
- Capacity Model for Realworld Beamforming
- Highly-Efficient Control Channel
- Many-Antenna Full-Duplex