Indoor/In-Building Testing

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PSCR Stakeholder's Meeting

June 4, 2014

Acknowledgements

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- My colleagues on the PSCR Test Team whose expertise and excellent support made this possible
- Dr. Ken Baker & students of the Interdisciplinary Telecommunications Program
- Steven Pizzi & Rocco Carbone of the University of Colorado

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Objectives

- Facilitate first-responder communications in indoor environments
- Focus on Band-14 LTE systems (763 & 793 MHz)
- Investigate different building types & system deployments
- Comprehensive series of measurements
- Share findings with the public safety community

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Methodology

- Select buildings within the coverage area of the PSCR Band 14 LTE network
- Measure PSCR network coverage within the selected structures
- Backpack with scanner/LTE modem to measure radio signal levels & quality, data throughput & quality
- Supplement in-building coverage using a COTS small cell & cell on wheels (COW)

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Discovery Learning Center

- Located on the campus of the University of Colorado (PSCR CRADA Partner)
- Working with Dr. Ken Baker & students of the Interdisciplinary Telecommunications Program
- Network connectivity to BRAN optical fiber network… excellent backhaul

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Discovery Learning Center cont'd

- Built in 2002… four floors & 45,000 sq feet
- Steel & Concrete… really absorbs radio signals!
- Lots of windows… Low-E glass reduces 763 MHz signal power levels by a factor of 100
- Challenging structure for any macro network to penetrate

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Case Study -Discovery Learning Center

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Discovery Learning Center

PSCR Green Mountain Station
Line of sight from the Royal
Terrace

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In-Building Coverage Options

- PSCR Macro network
- Cell on Wheels (COW)
- Small Cell with COTS Antennas (discrete)
- Small Cell with Distributed Antenna System (DAS)
- Combinations

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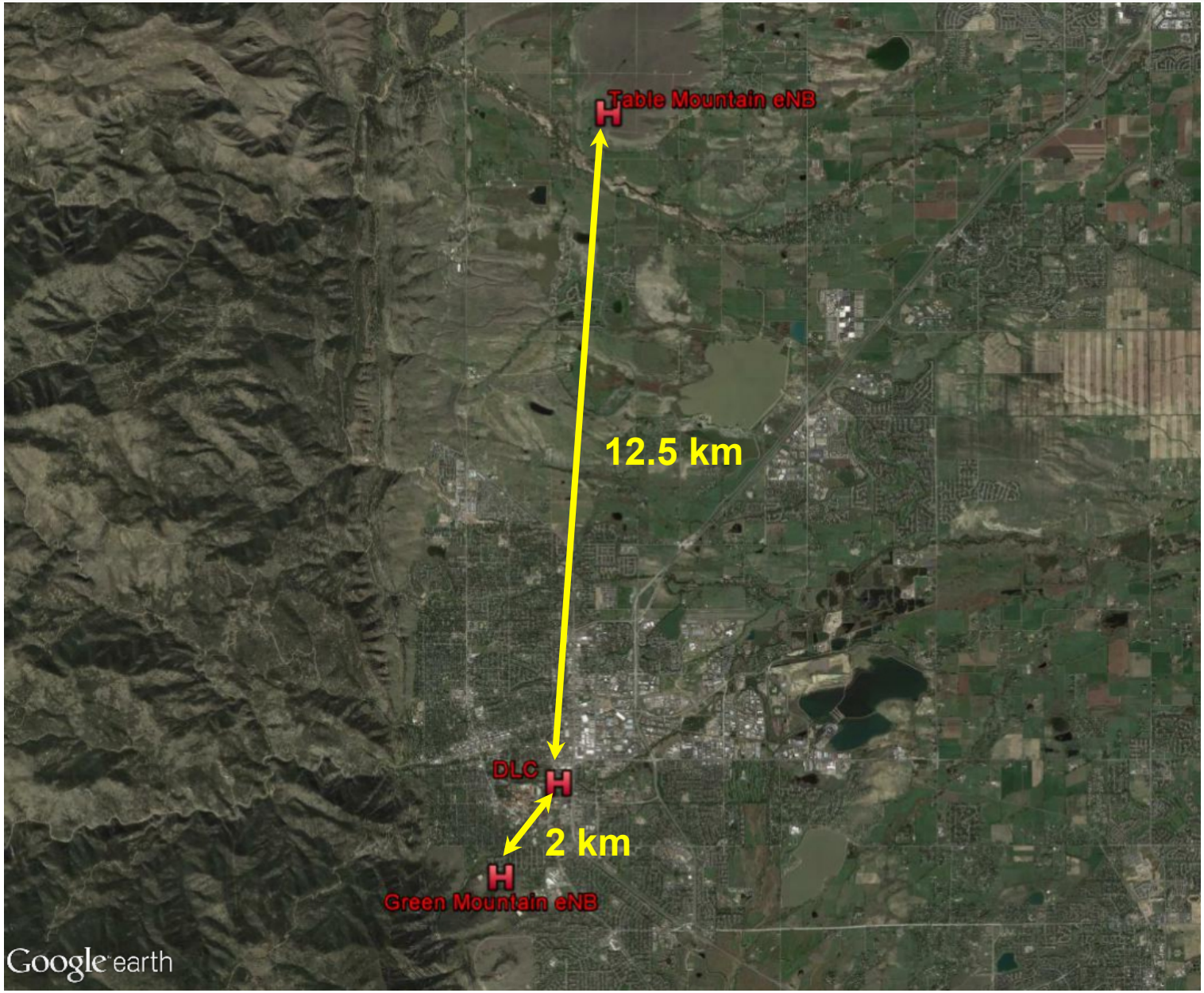
The PSCR Band 14 LTE Network



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Backpack Measurement System

- Tablet computer
- USB Hub
- Scanner
- LTE Modem (dongle)
- RF signal levels & Data quality & throughput
- Waypoint indoor navigation… no GPS

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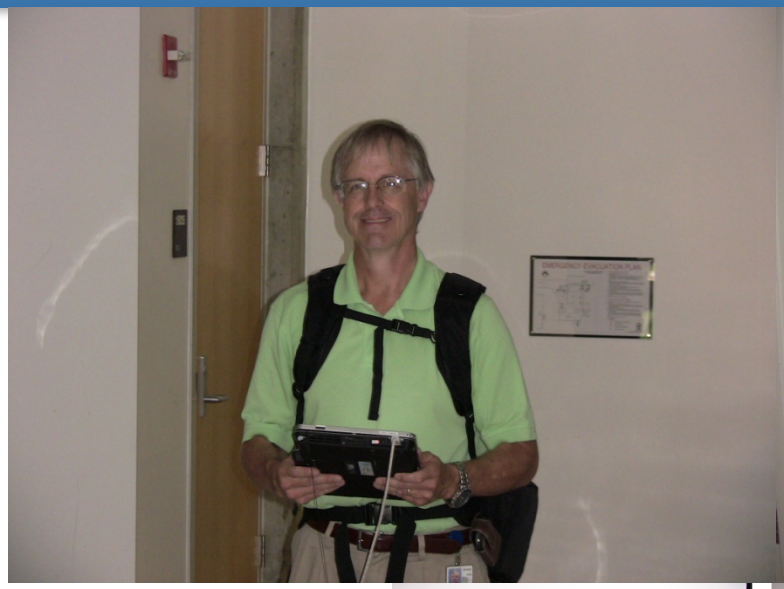
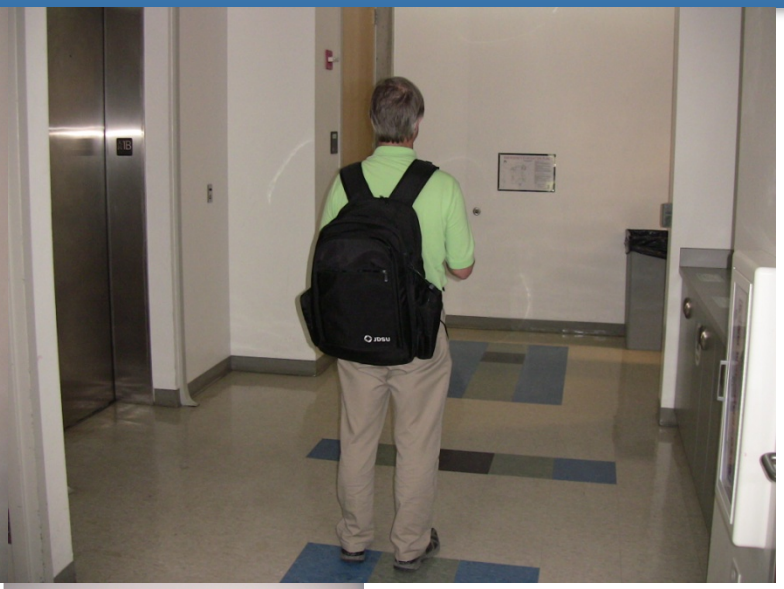
Backpack Measurement system





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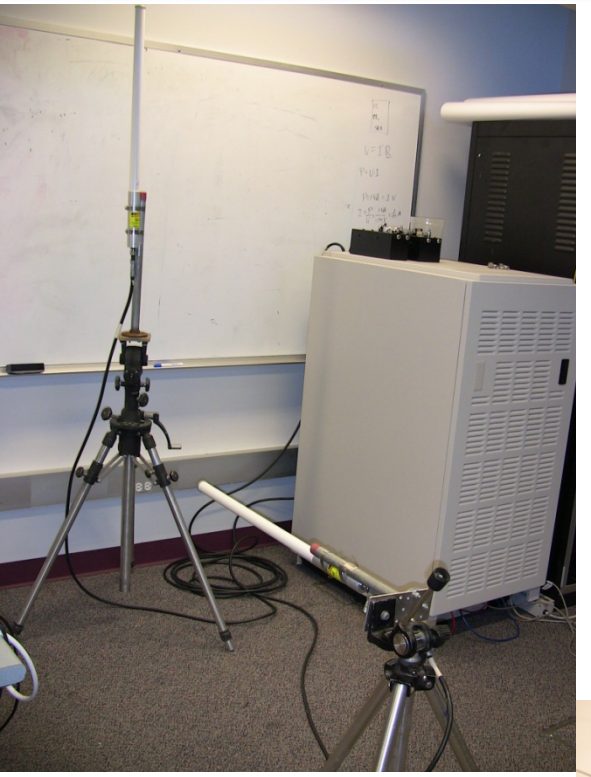
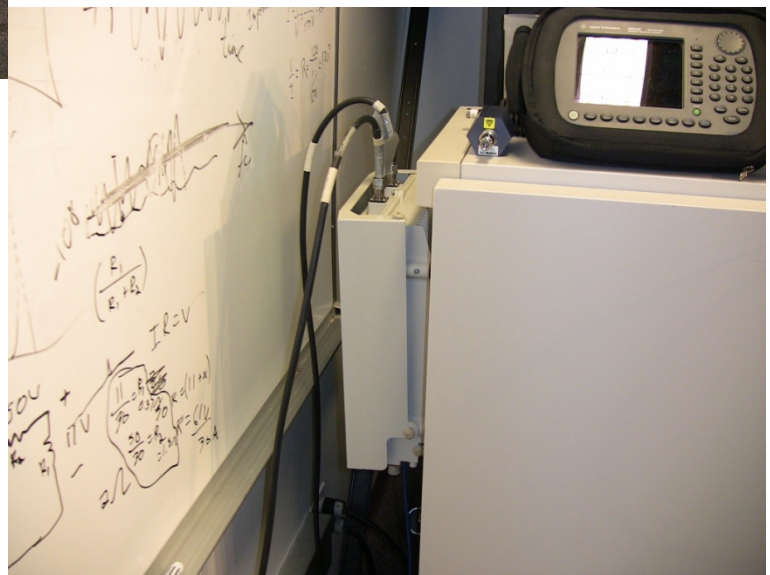
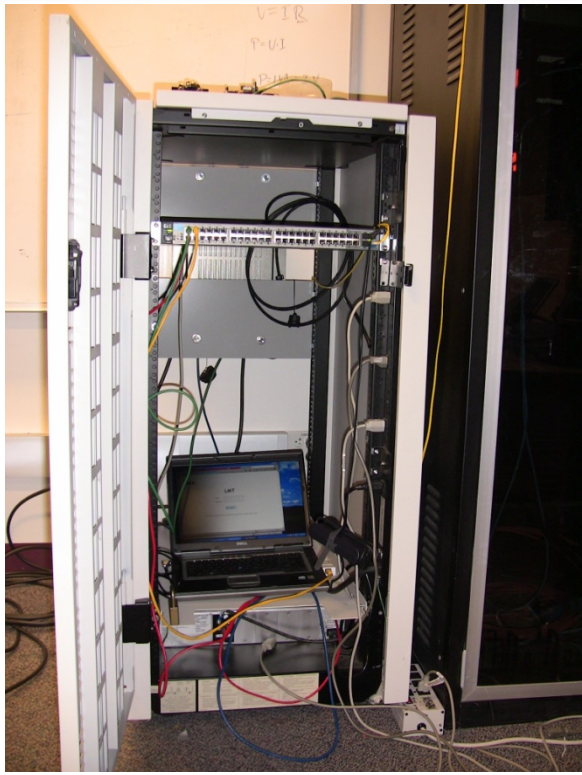
Small Cell Deployment with Discrete Antennas







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Cell on Wheels (COW)

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Placement of the COW

Discovery Learning Center

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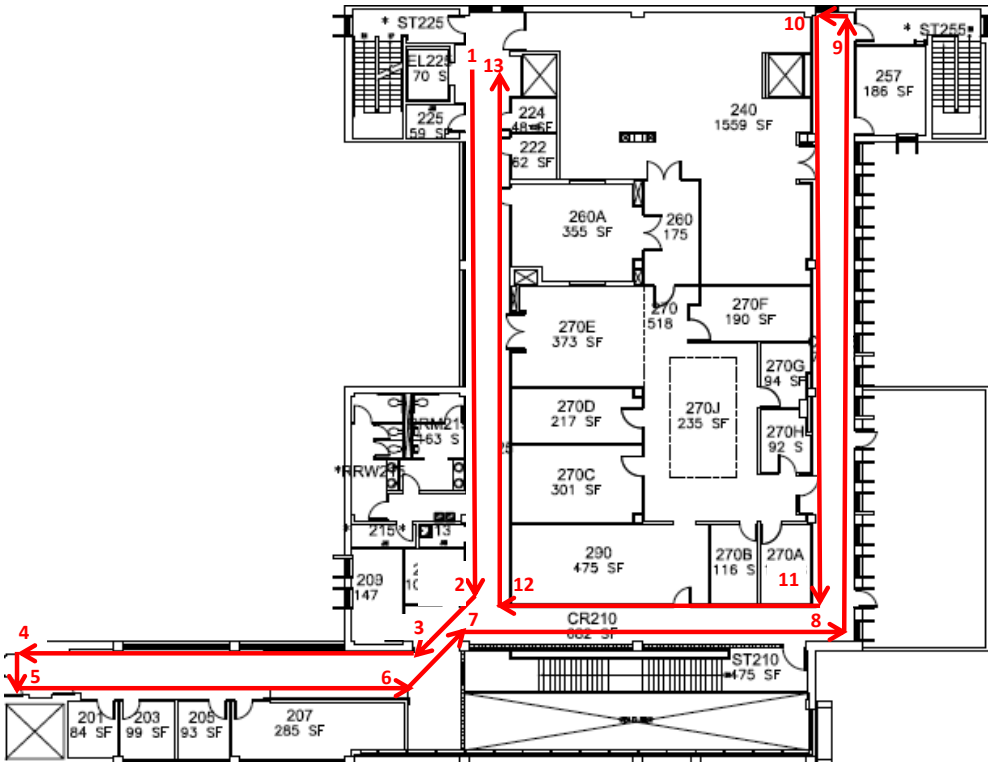
Selected Walk Routes

Second Floor



Outside

Measurements-Macro Network Only

- Walk tested the DLC with PSCR macro network only
- Achieved connectivity in roughly 50 % of the building
- No connectivity on ground floor & basement
- Signal not measureable in basement!
- Where we could connect, system performance was poor
- Battery drain high

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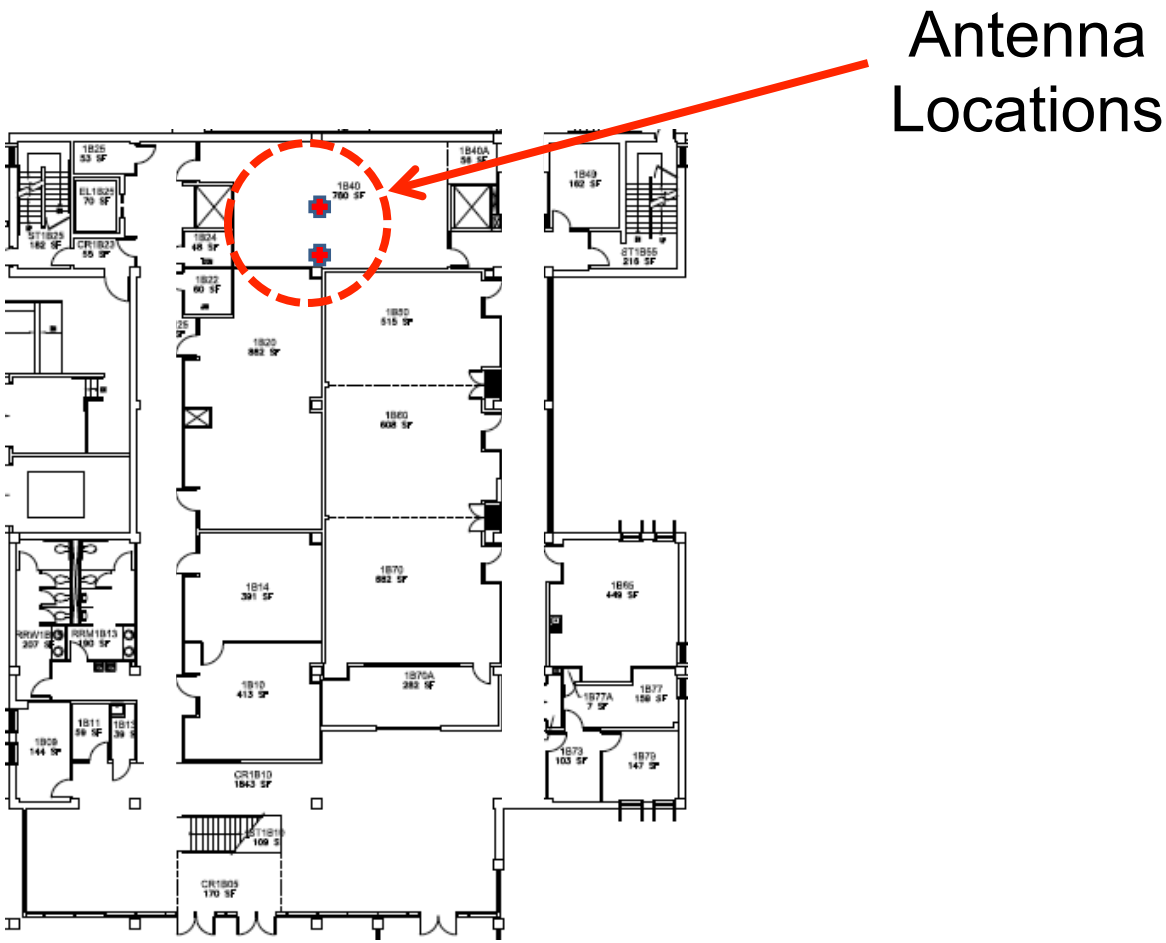
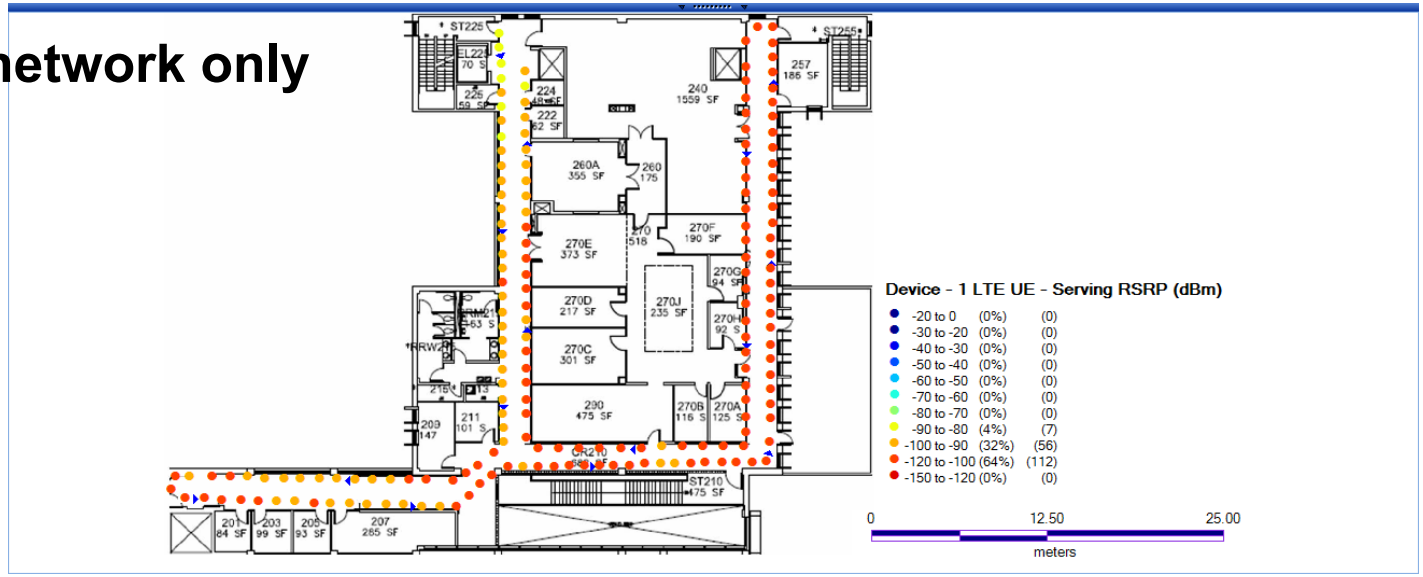
Small Cell Location for Tests

- Placed in Lab on Ground floor @5 W

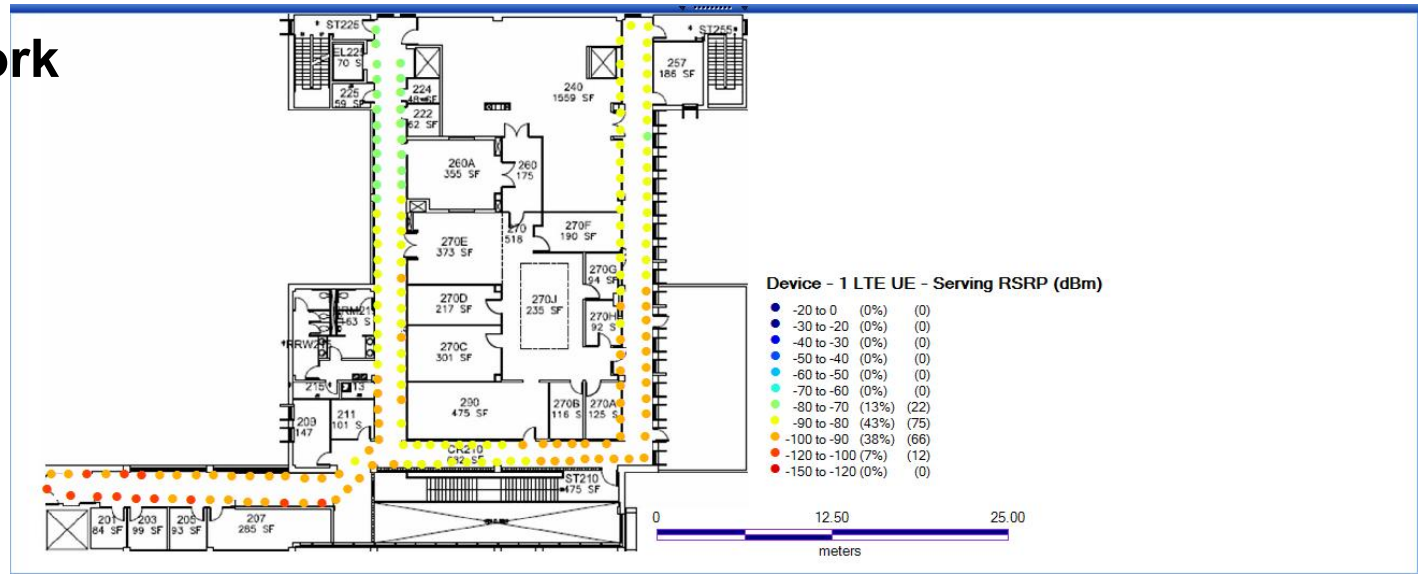


Second Floor Comparisons-RF Signal Levels

PSCR macro network only



PSCR macro network + small cell



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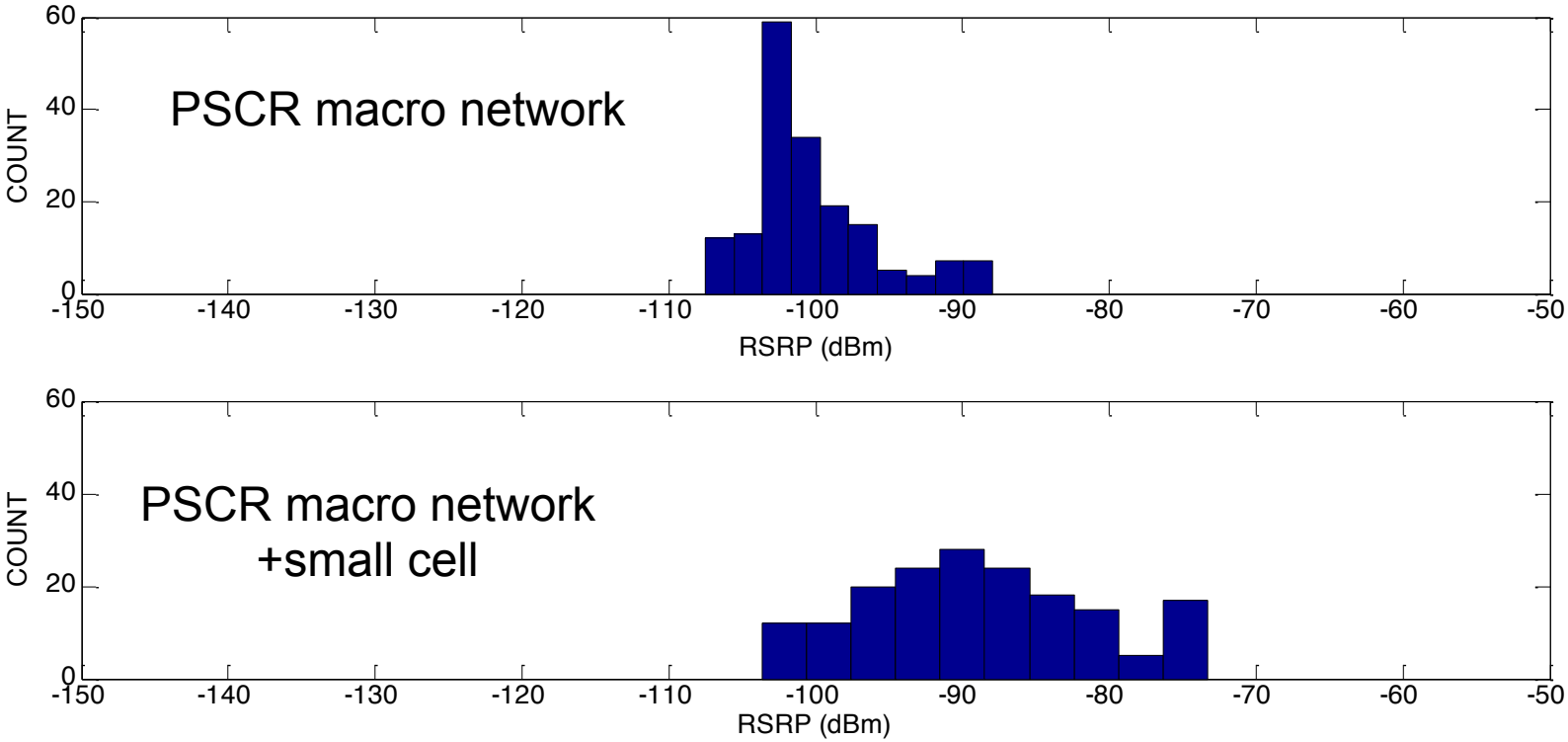
RF signal level comparisons



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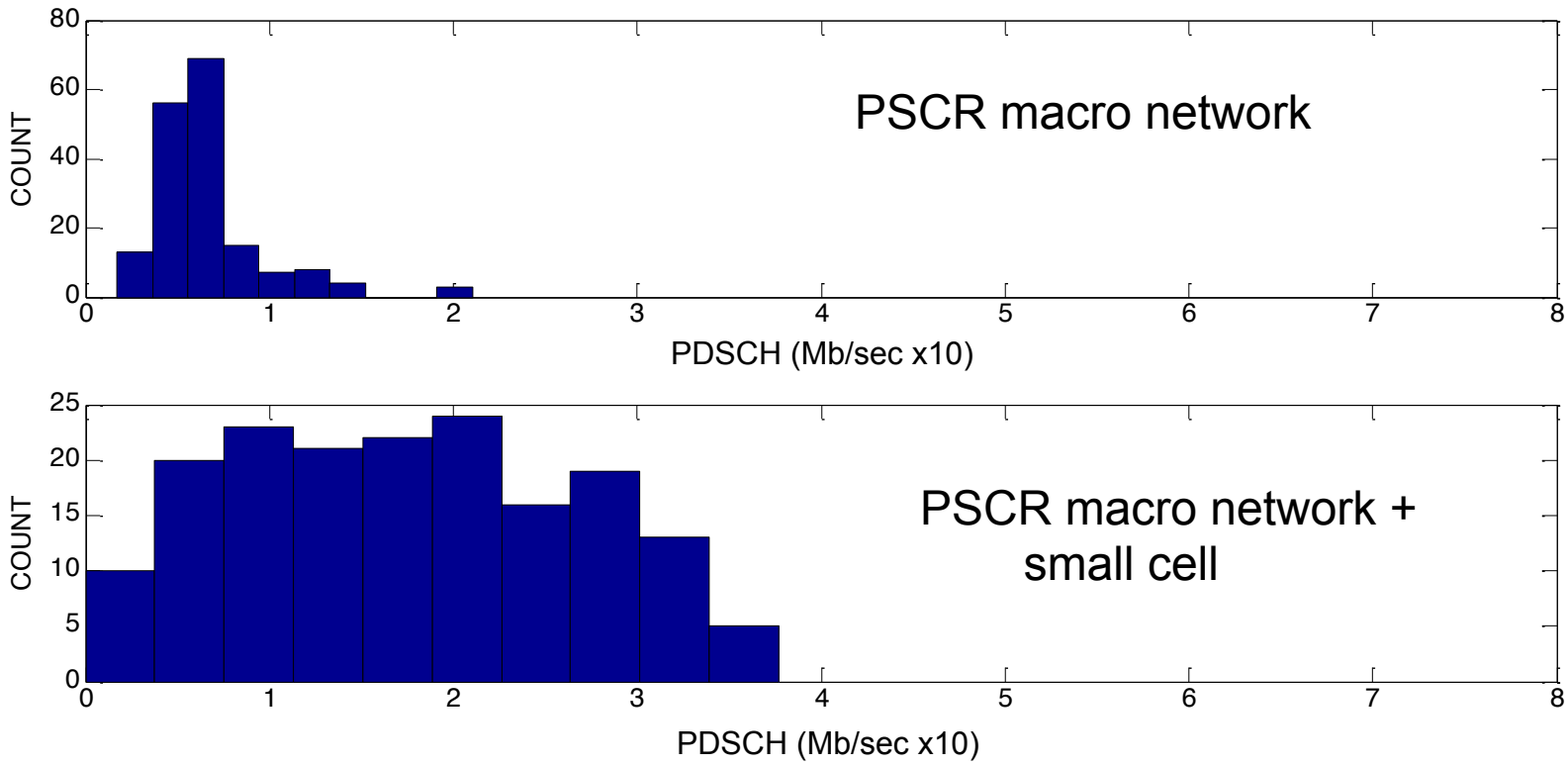
Second Floor DL Data Rates



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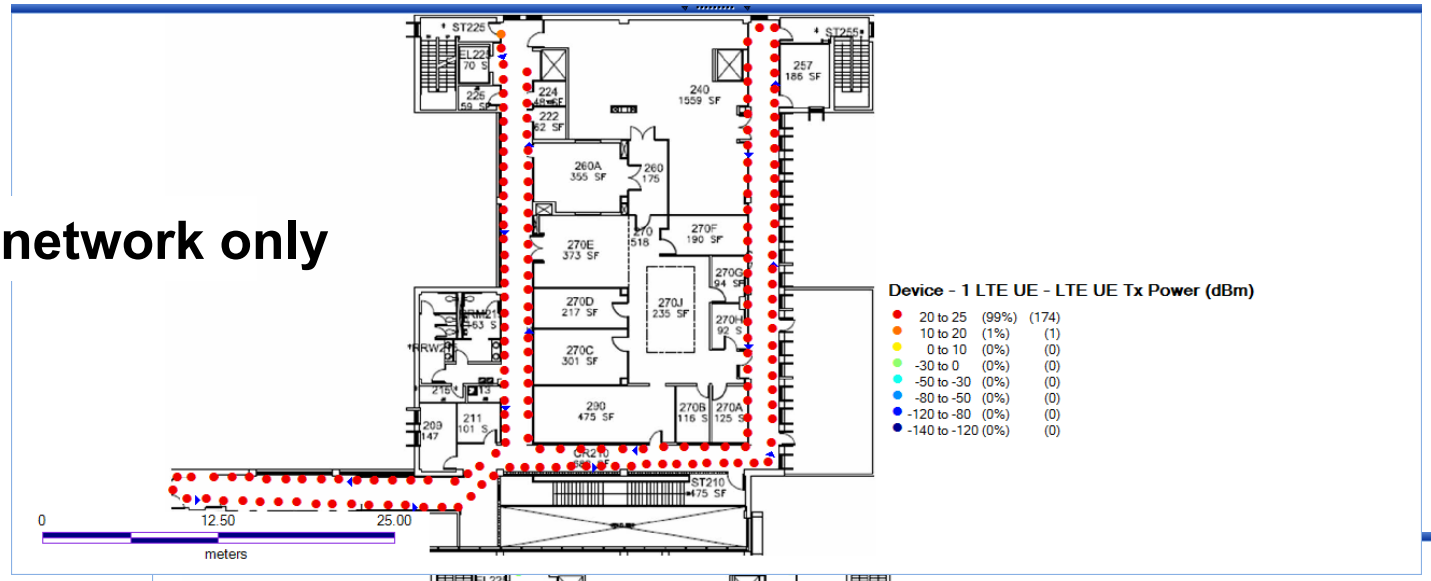
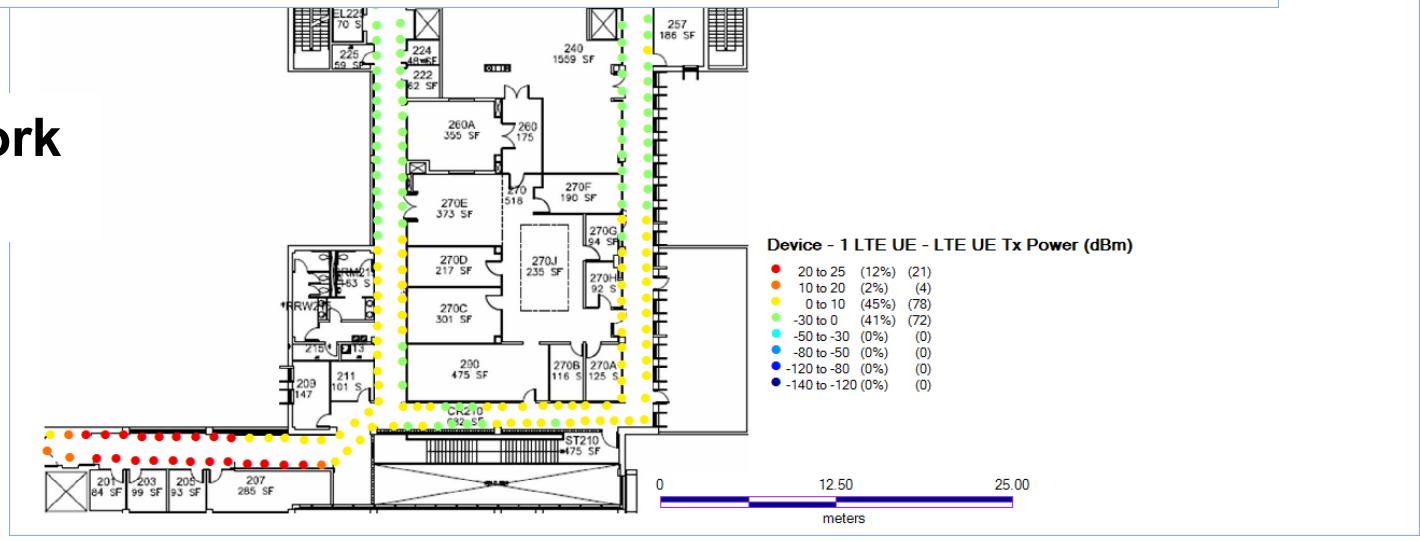
Second Floor Comparisons-transmit power

PSCR macro network only



PSCR macro network + small cell



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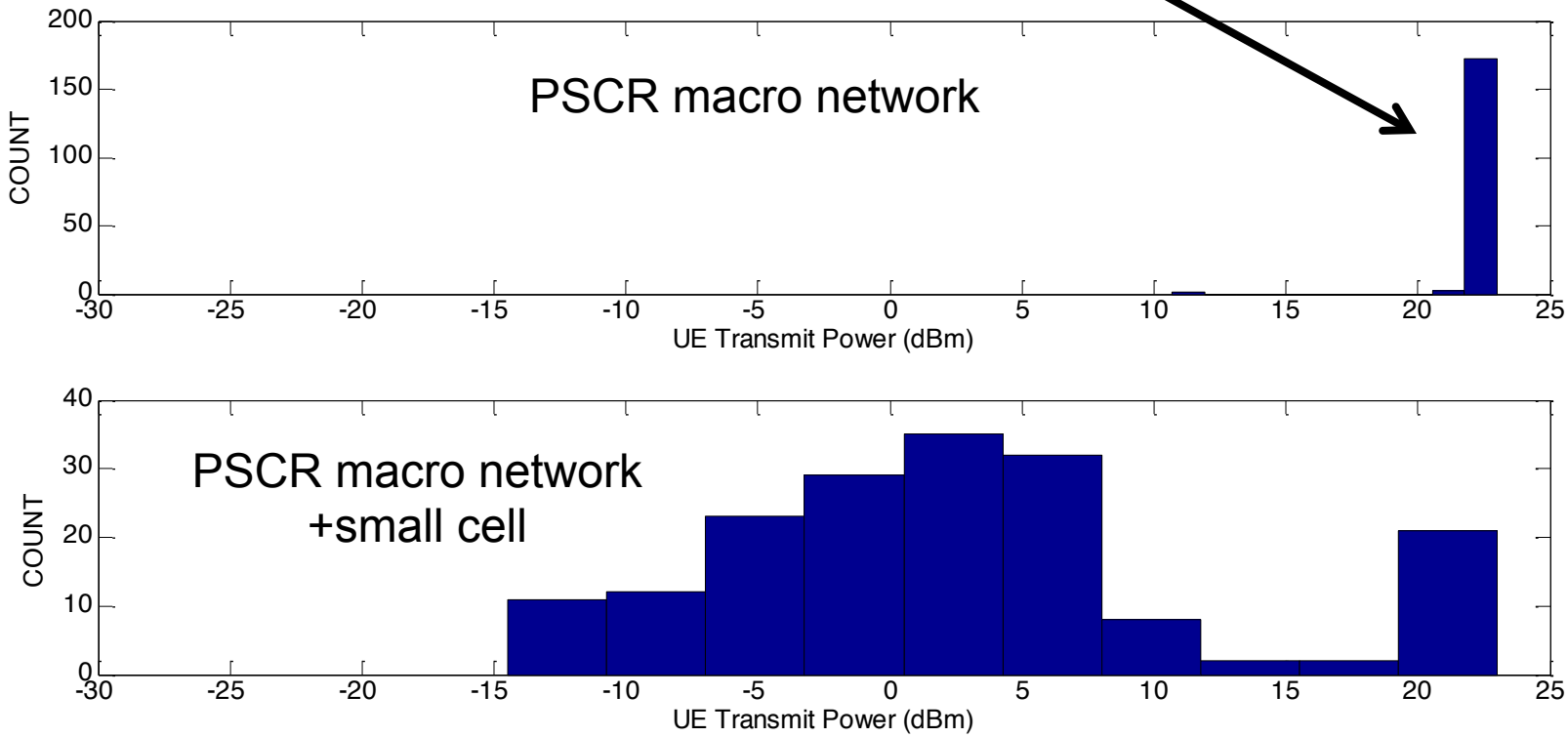
Second Floor Comparisons-transmit power

High Battery Drain!



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Taking it to the basement…

- COW located in adjacent parking lot 240' from east wall
- COW powered up at 8 W & later at 40W
- Panel antenna @ 25 feet beaming directly at the east wall of the building
- No macro network coverage
- Let's see what happens…

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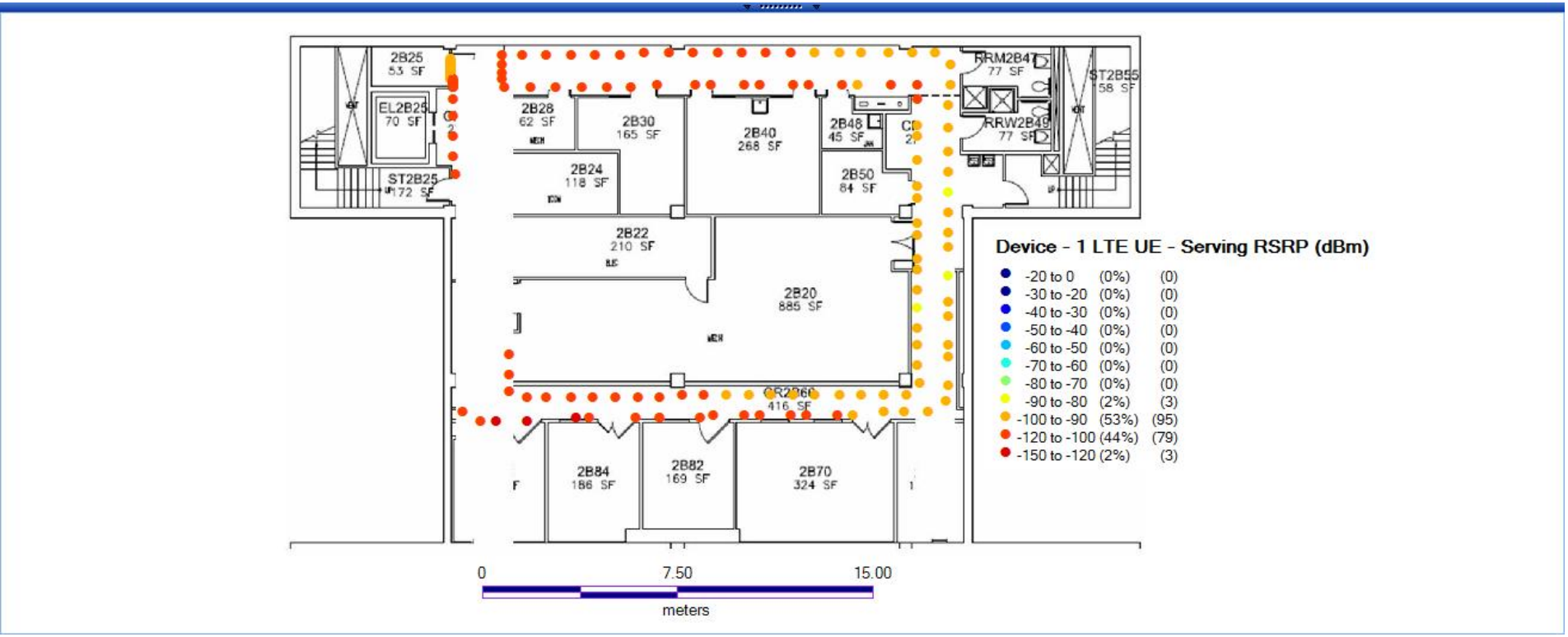
COW at 8 watts…

Received Signal RSRP



You don’t get full coverage!

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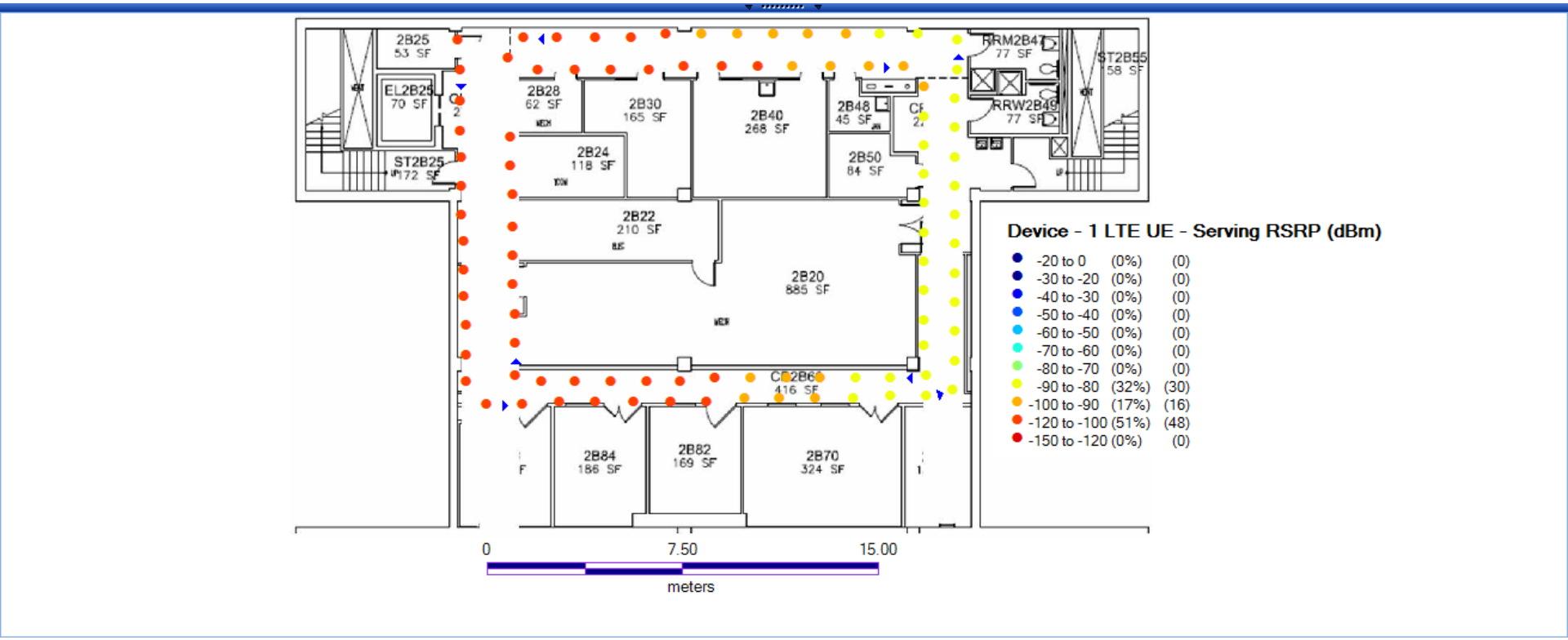
Turn COW up to 40 watts…

Signal Levels-RSRP



You are connected but we can do better…

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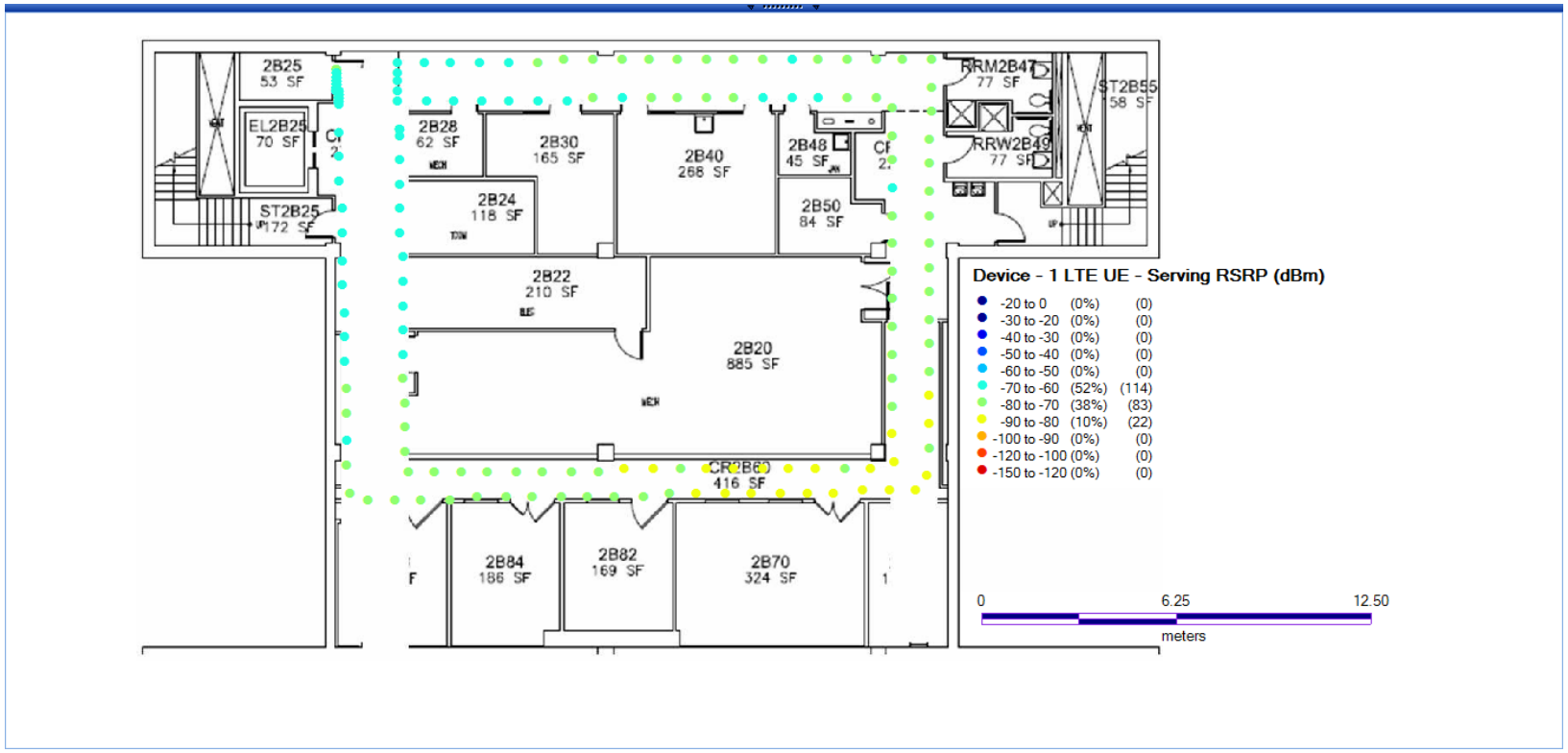
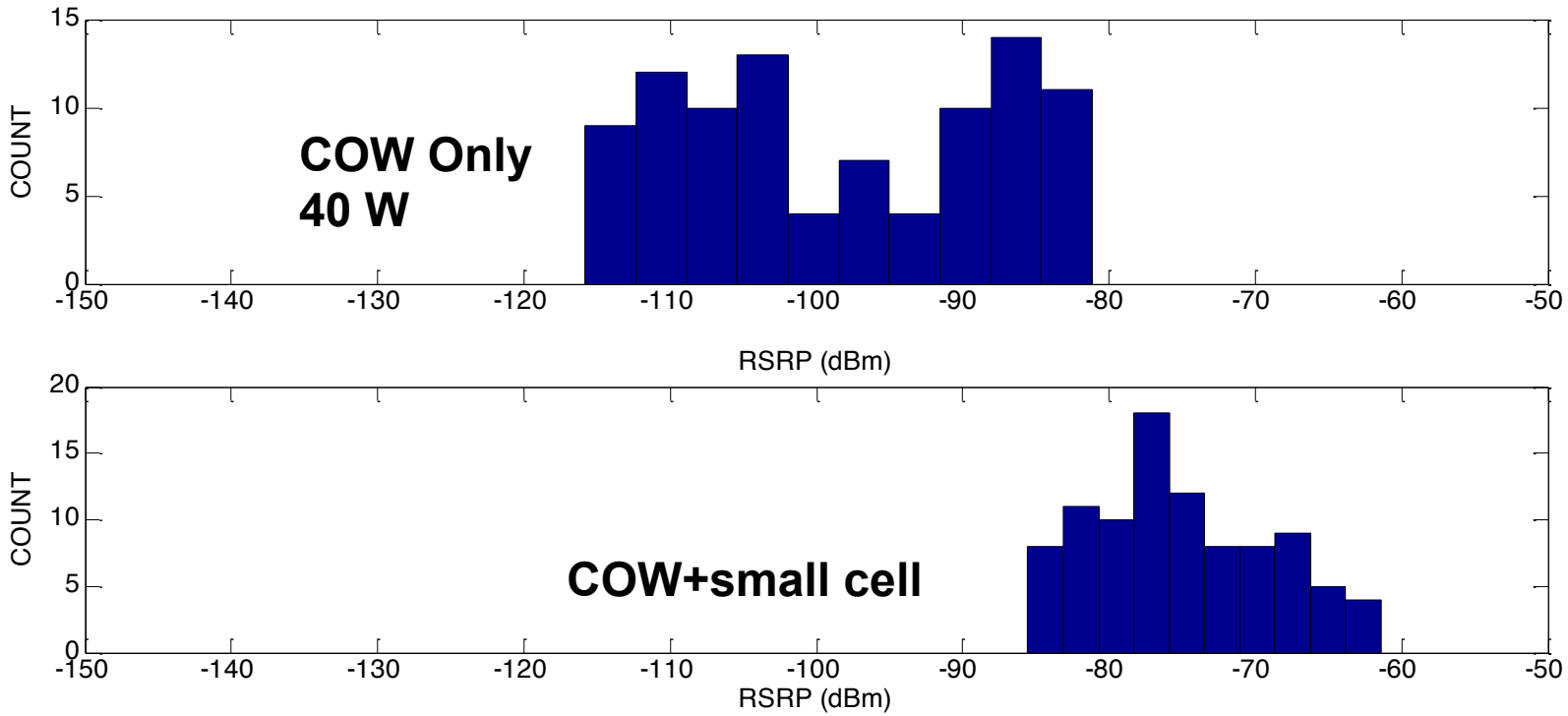
Add a small cell…

Things have really improved!



Let's take a closer look…

Basement -Signal Level Comparisons



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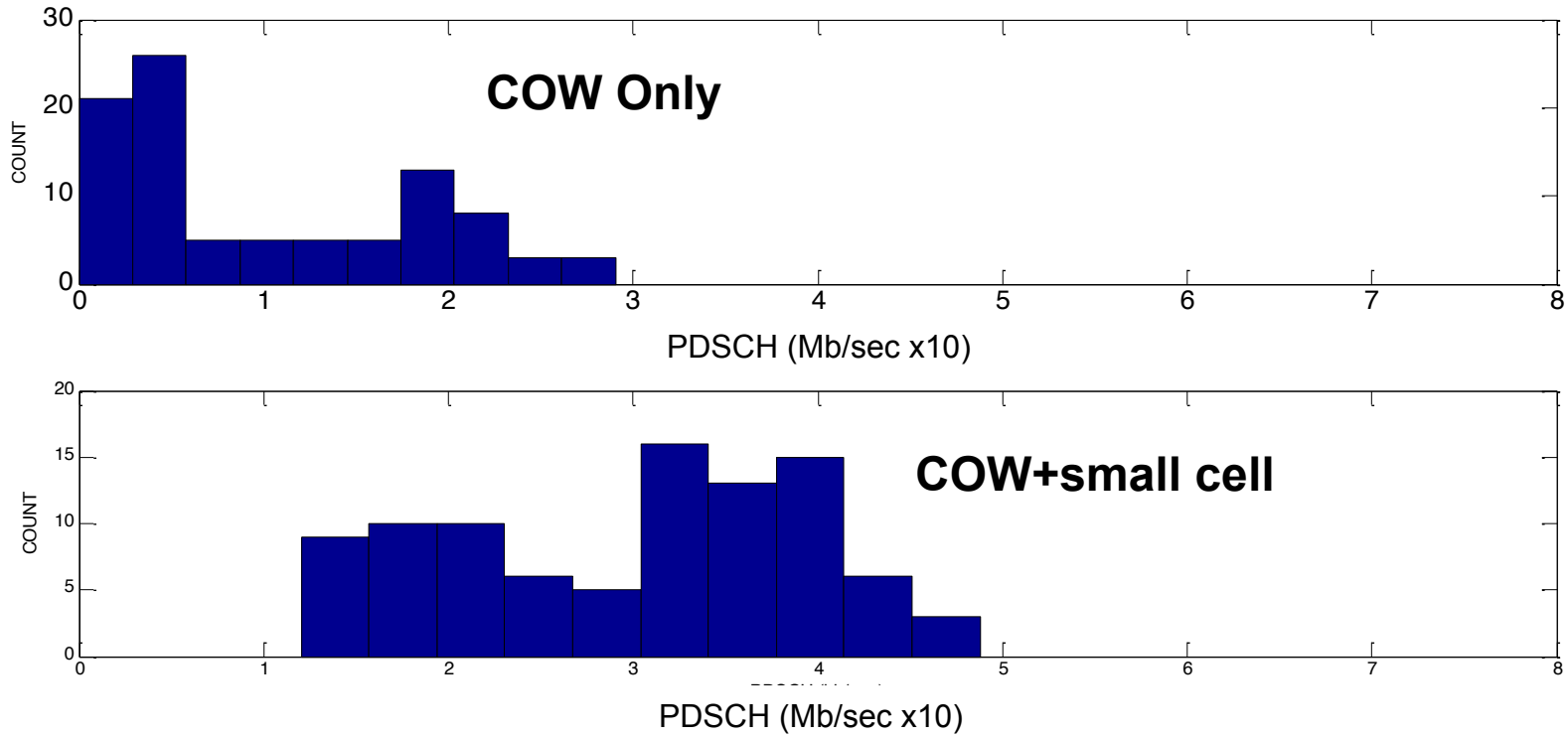
Basement- DL Data Rate Comparisons



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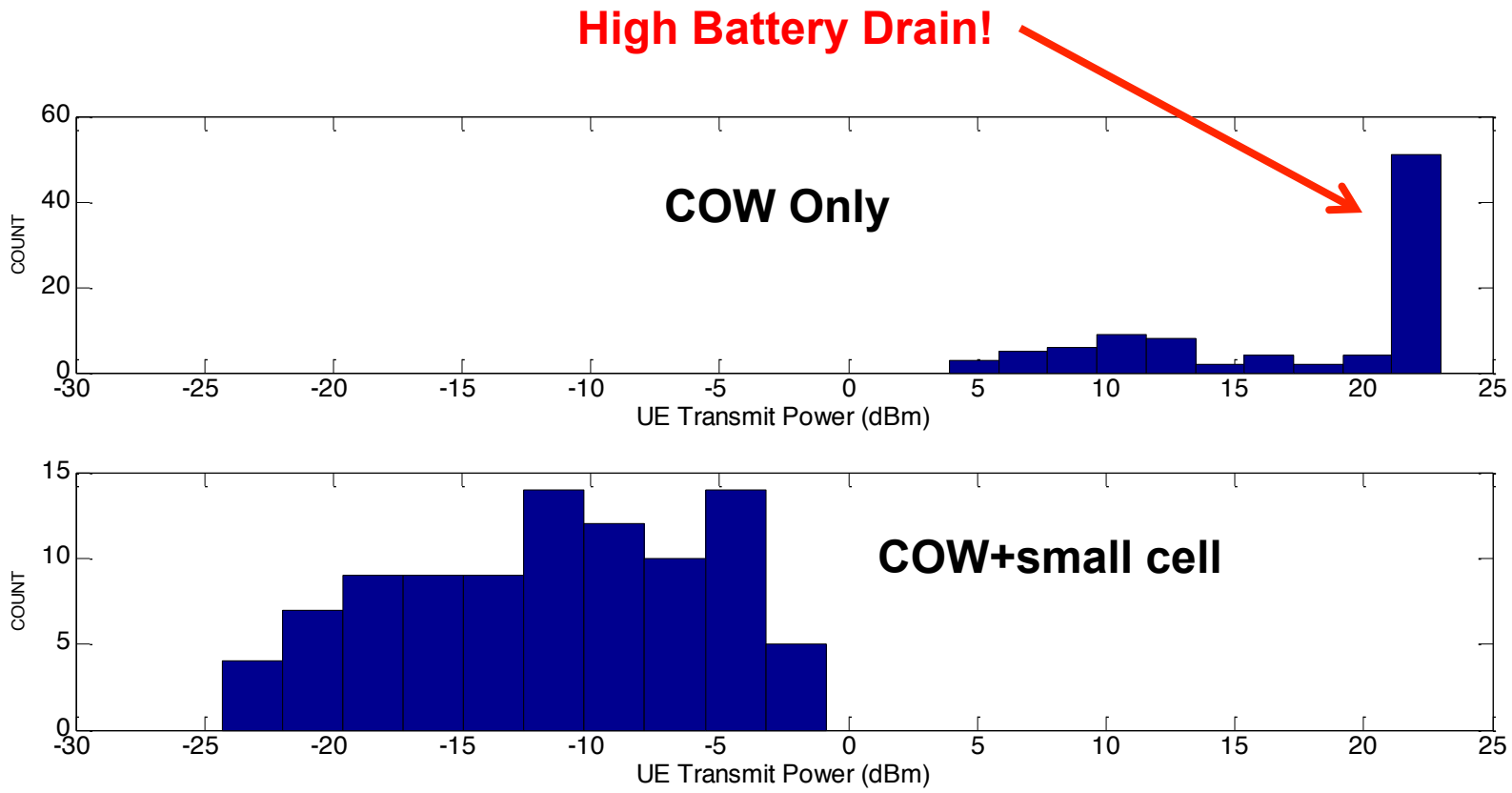
Basement-UE Transmit Power Levels



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Distributed Antenna System (DAS)

- Designed & Fabricated by Dr. Ken Baker & his students of the University of Colorado-capstone project
- Initial design developed by student team Dr. Baker's Maymester course on in-building DAS (May 2013)
- Passive design: Band 14 antennas, couplers, & low-loss 50 Ohm coax cables
- Further modified to accommodate full MIMO

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Distributed Antenna System (DAS) cont'd

- Deployed on level 1b (ground floor) of DLC
- 4-antenna design
- Symmetrically deployed in two hallways
- Fed by a small cell
- Transmit power set @ +23 dBm at each antenna port
- Let's take a look at the deployment…

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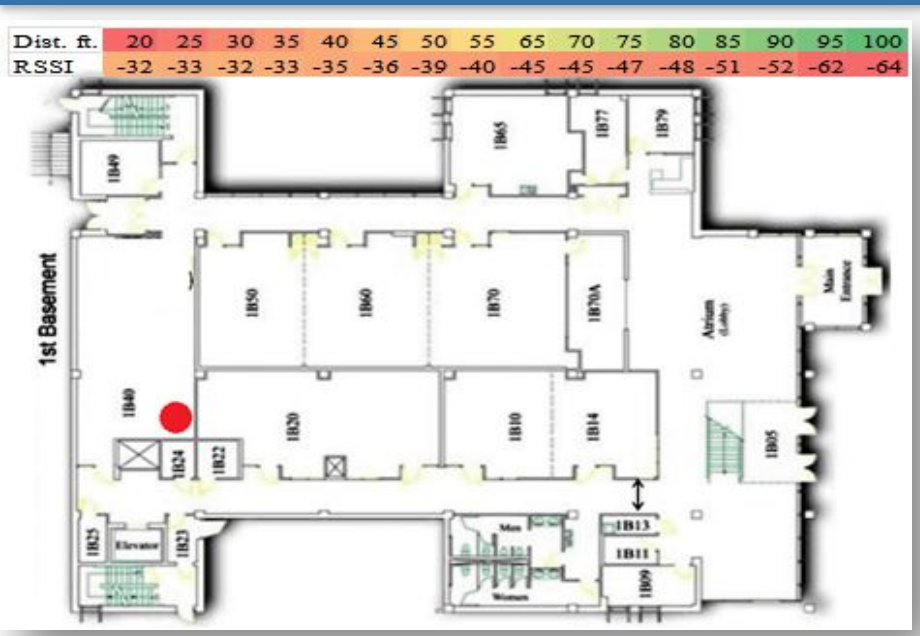
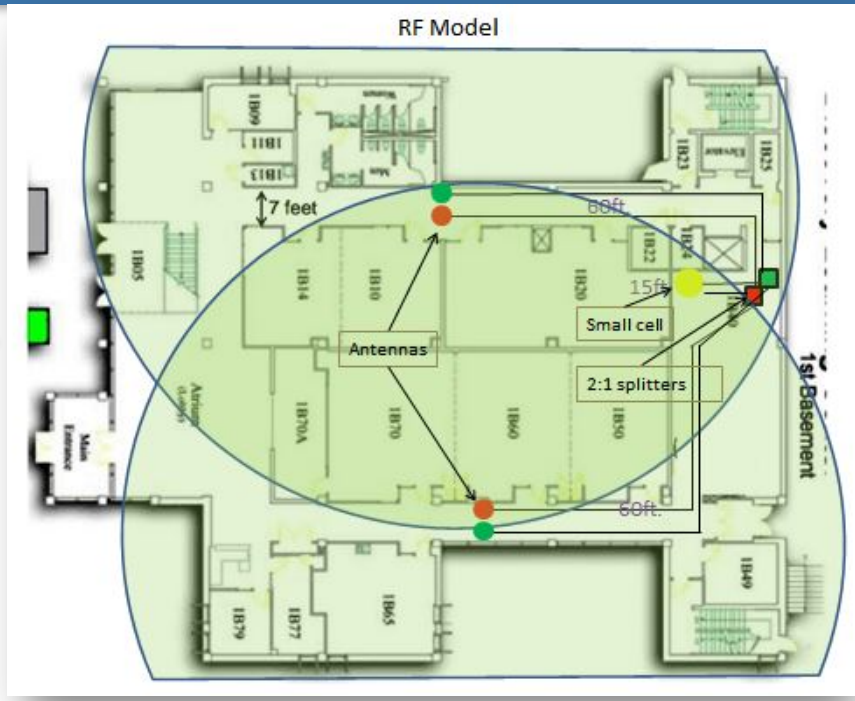
DAS Layout


Dist. ft. 20 25 30 35 40 45 50 55 65 70 75 80 85 90 95 100
RSSI -32 -33 -32 -33 -35 -36 -39 -40 -45 -45 -47 -48 -51 -52 -62 -64
1st Basement


RF Model
7 feet
60ft
15ft
Small cell
Antennas
2:1 splitters
60ft.
1st Basement

DAS Layout cont'd…

Installation

Testing

DAS Layout cont'd

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DAS Cont'd…

- Measurements carried out by ITP students…
- Downlink & uplink data flows
- DAS results compared with

  1) small cell+COTS antennas

  2) PSCR macro network

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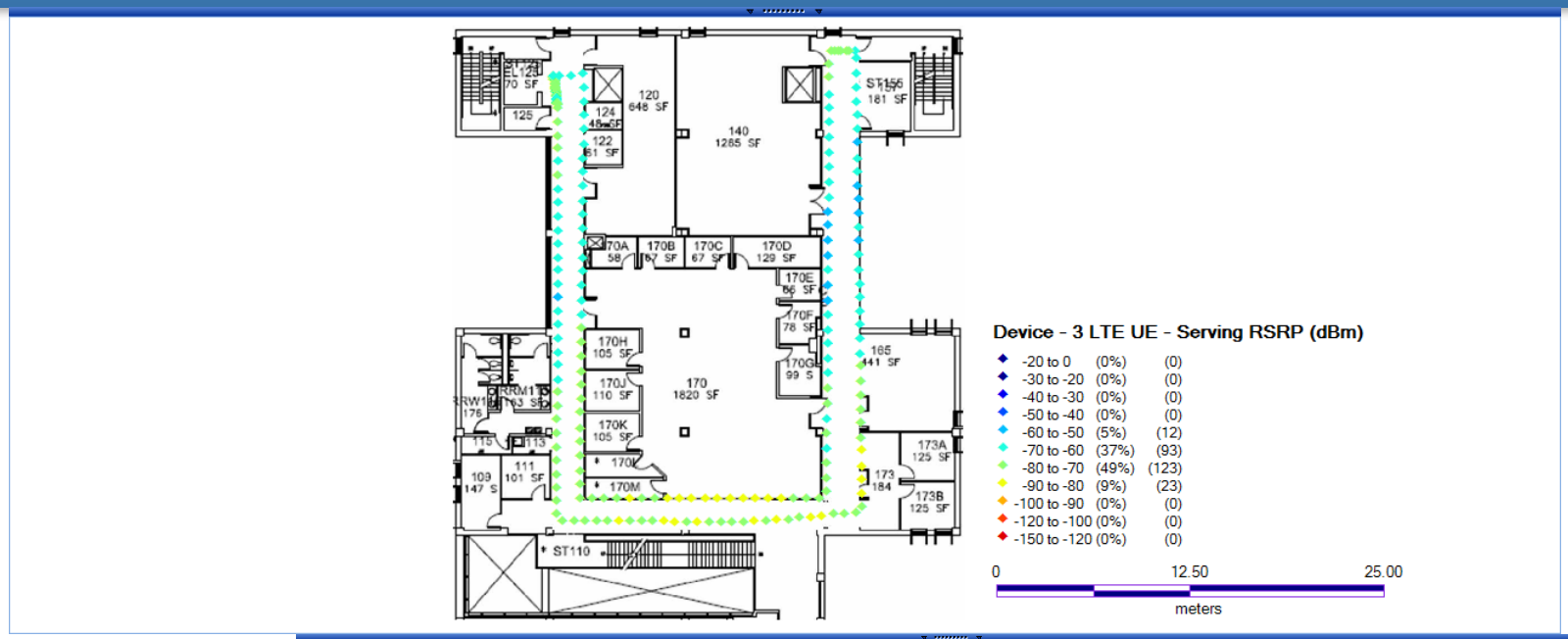
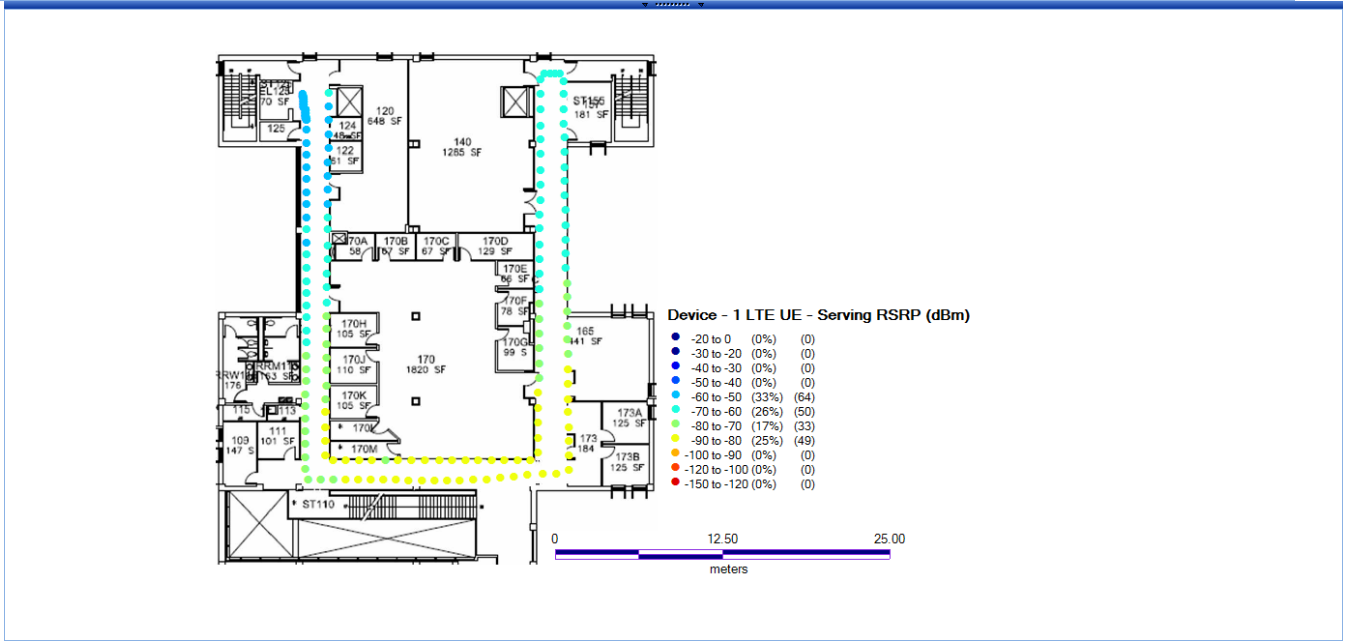
DAS vs small cell w discrete antenna





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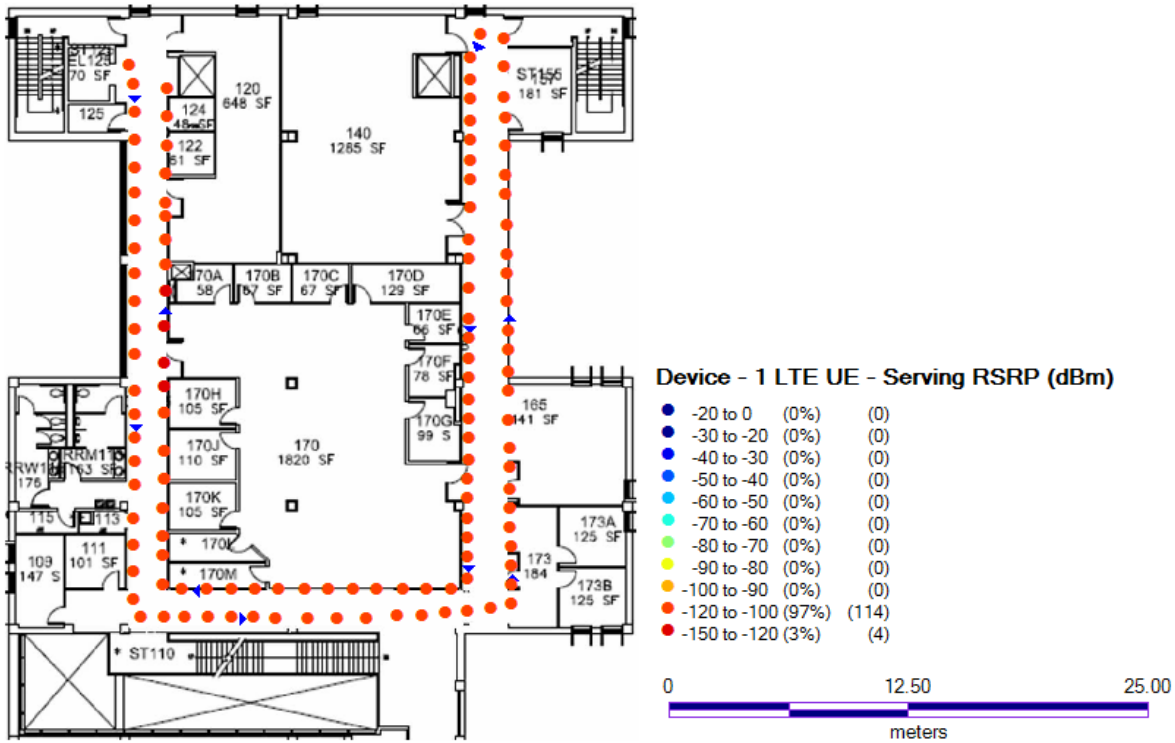
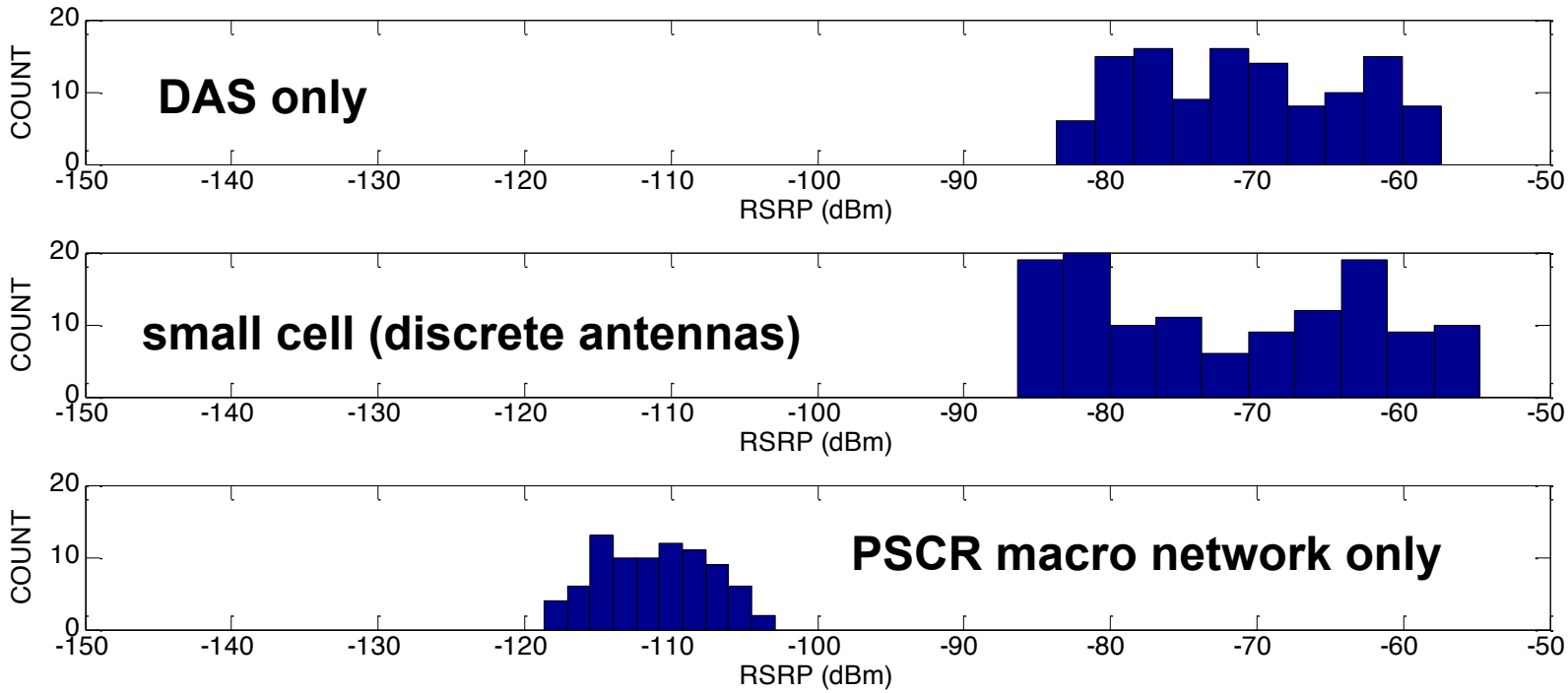
PSCR Macro Network Only



Let's look at some data…

Level 1 RF Signal Level Comparisons (RSRP)



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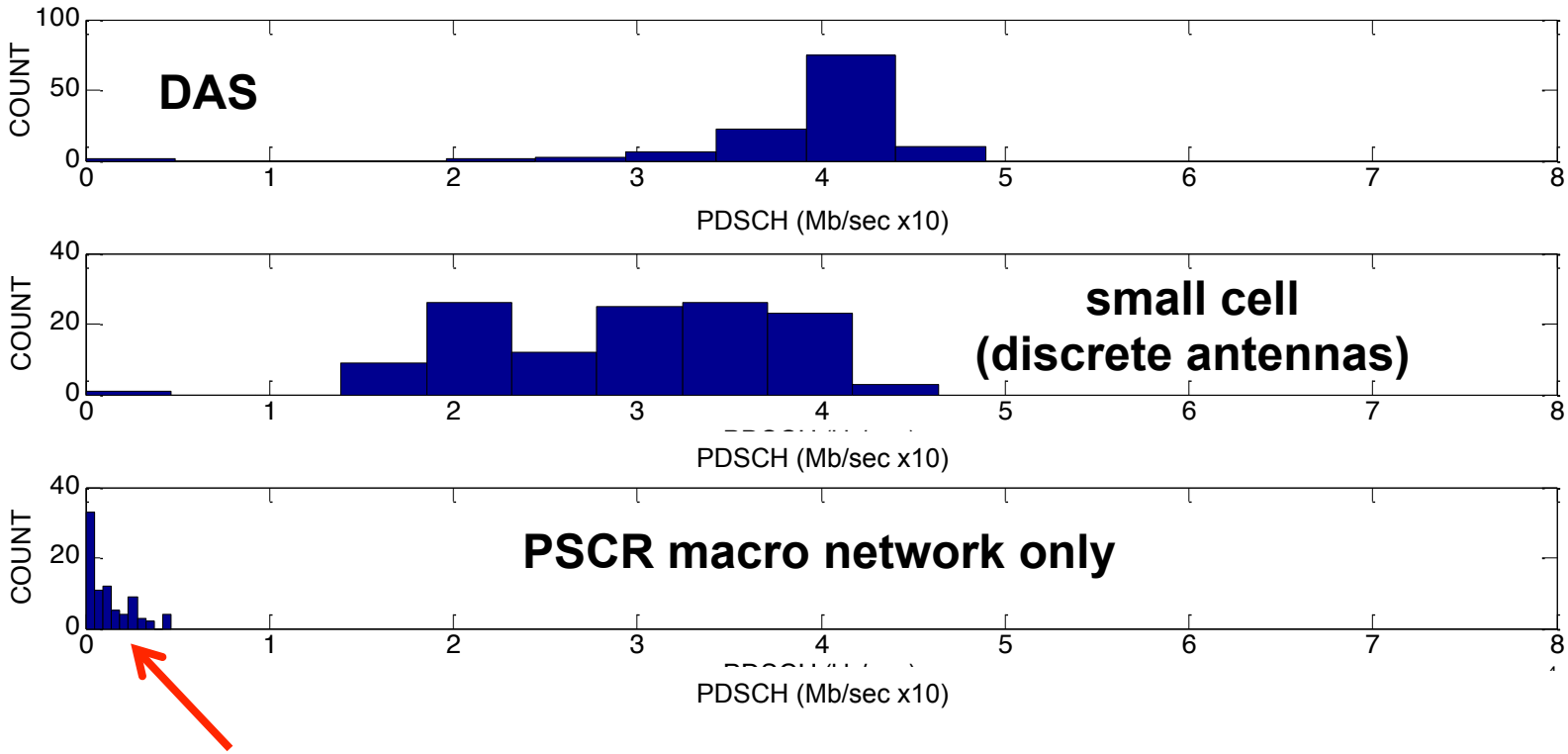
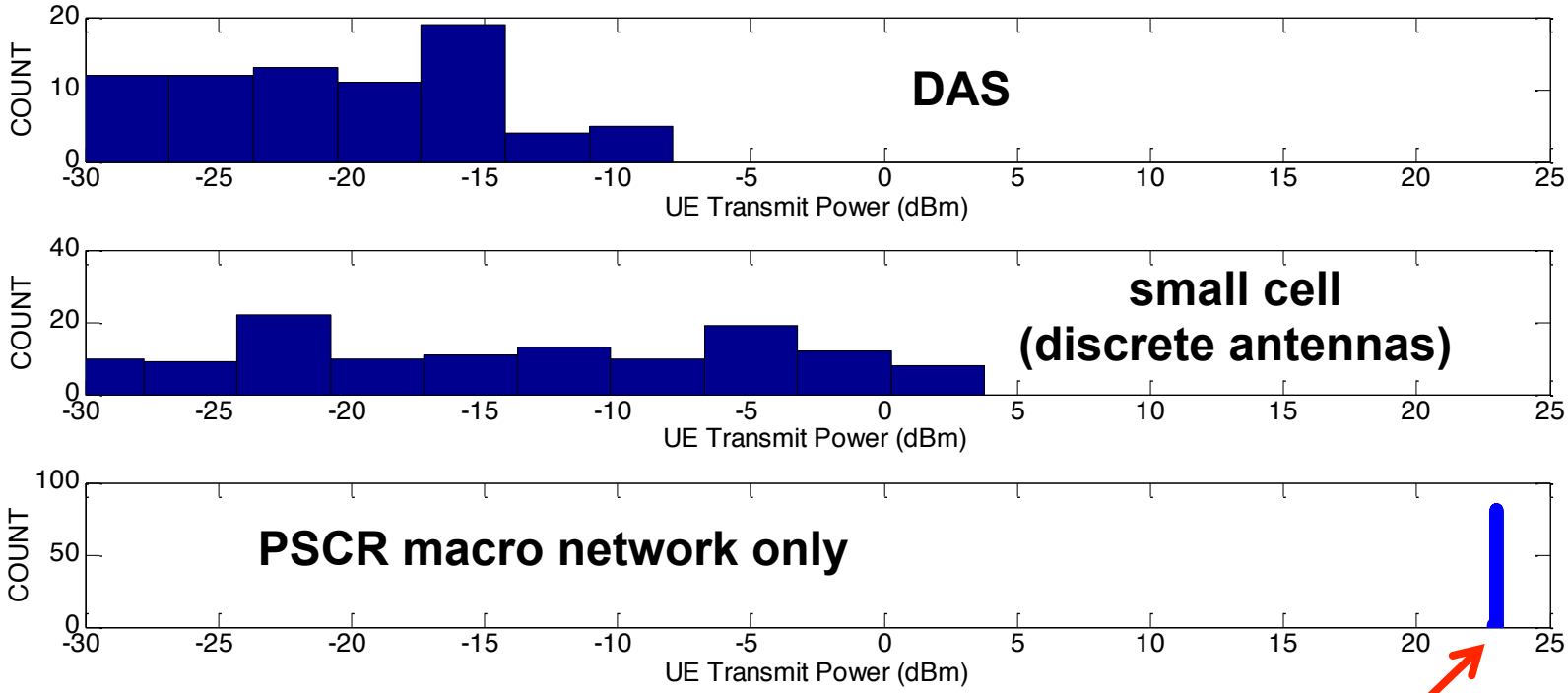
Level 1-DL Data Rate Comparisons



Poor Network Performance!

UE Transmit Power Levels



High Battery Drain!

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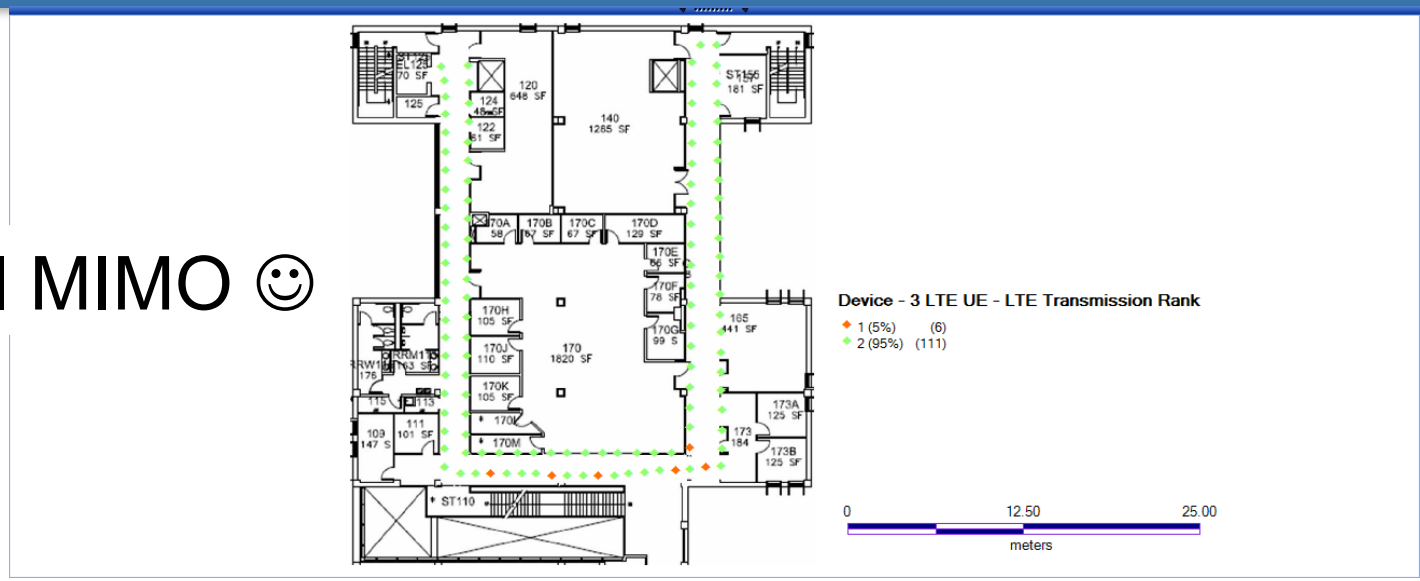
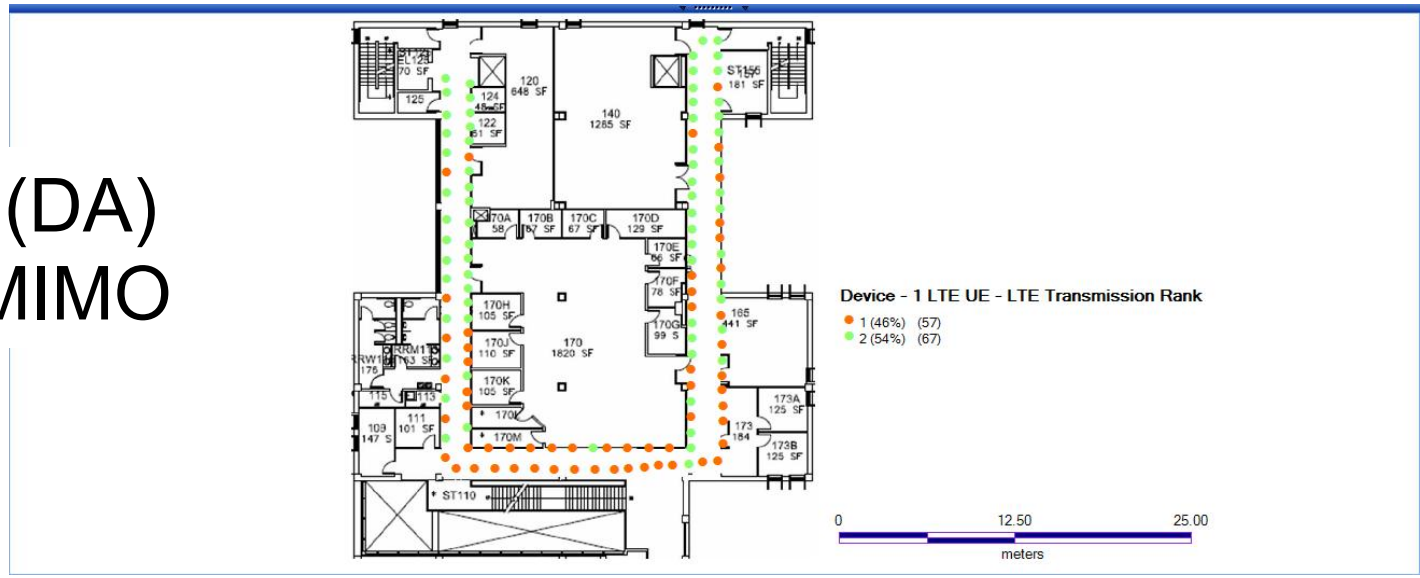
Another Comparison… MIMO Rank

DAS-95 % Full MIMO ☺



Small Cell (DA)
67 % Full MIMO



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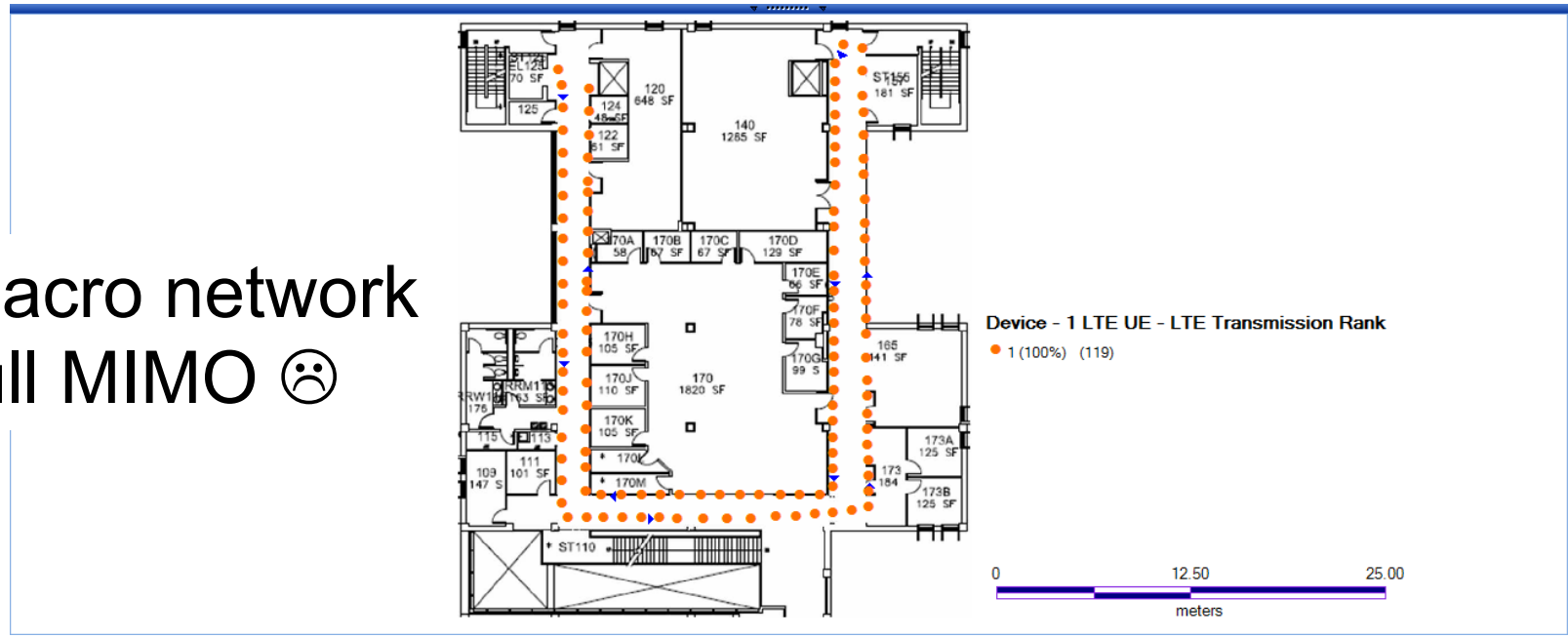
MIMO cont'd

PSCR macro network
0% Full MIMO ☹



Some Observations

- DAS performance best… a pleasant surprise
- Macro network performance degrades significantly inside the DLC
- Some form of in-building support needed to provide good network performance at the DLC

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Coors Events Center (CEC)

- Owned & Operated by the University of Colorado
- Sports & Academic functions
- Seats 11,000
- Built in 1979 & expanded in 2010
- Steel & Concrete with Low-E glass
- Electromagnetically "hard"… high shielding

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COORS Events Center (CEC)

Stadium

Training/Practice Facilities

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Coors Events Center Stadium

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Approach

- PSCR macro network active
- Supplement coverage in two ways:

  1) Small cell + COTS Band 14 antennas installed on catwalk above stadium

  2) COW placed in adjacent parking lot north of the CEC

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Coverage Goals

- Small cell to enhance coverage in stadium area
- COW to enhance coverage in the training/ practice facilities section on the north side of CEC
- Microwave backhaul to PSCR
- PSCR macro network used as the baseline

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Implementation

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Implementation cont'd…

PSCR

Implementation cont'd

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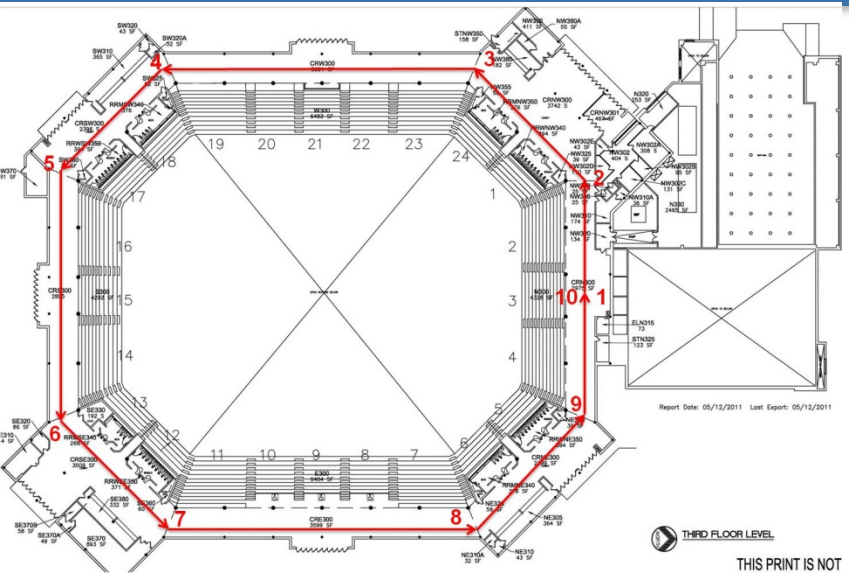
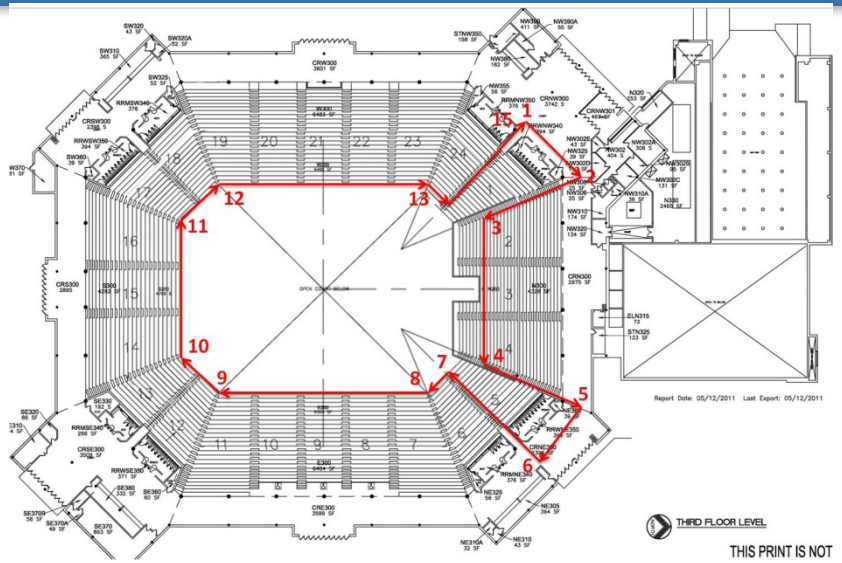
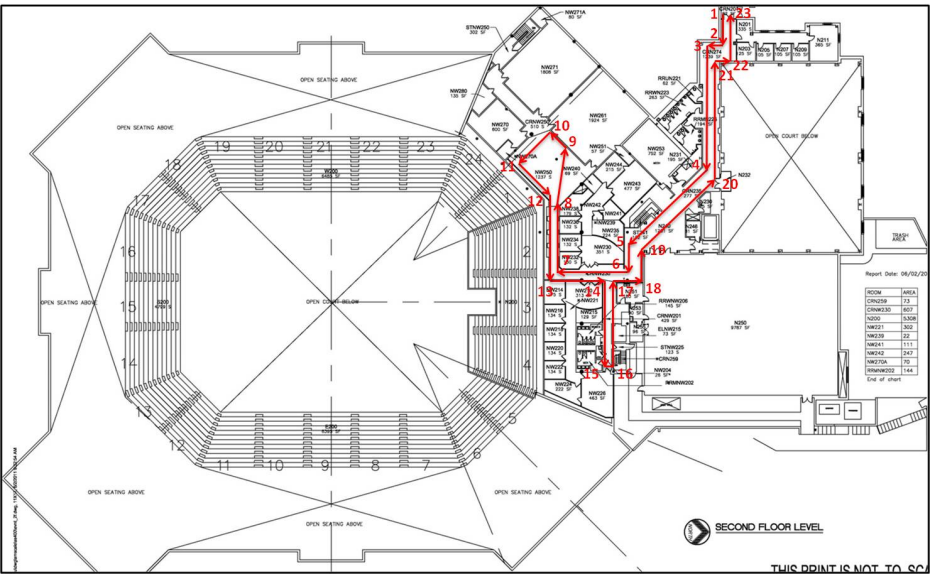
Sample Walk Routes

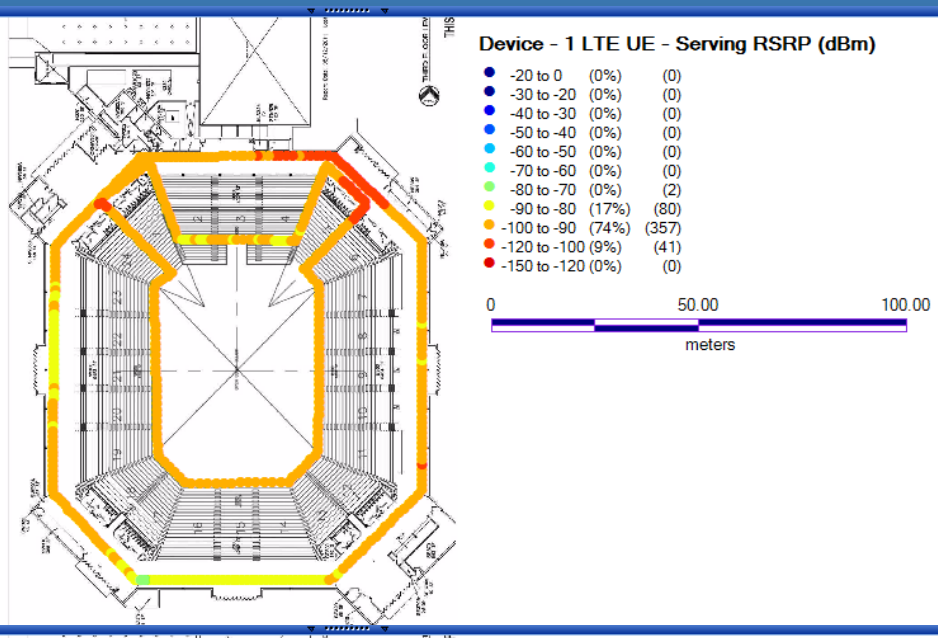




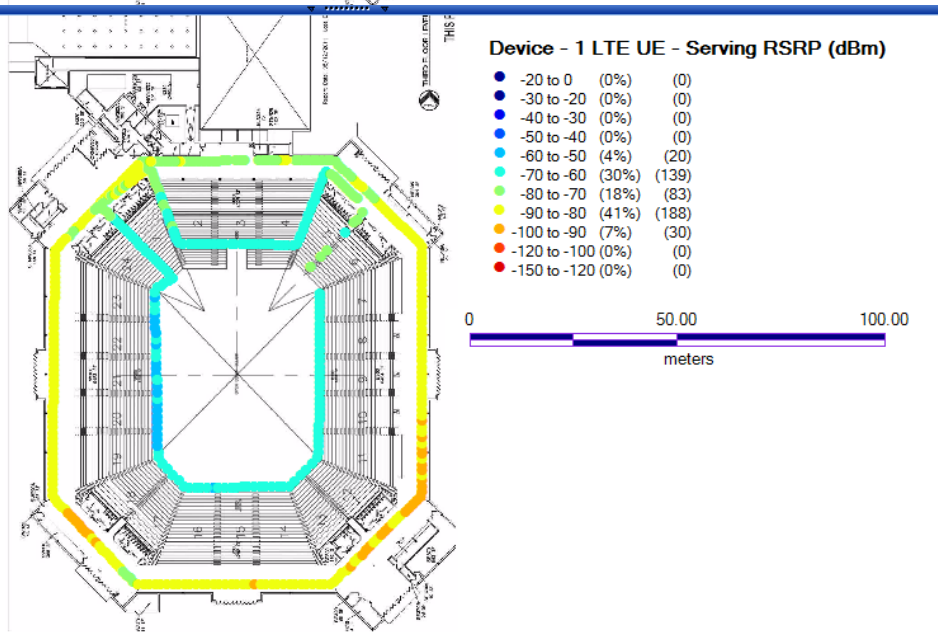


Stadium Results-RSRP

PSCR macro network



PSCR macro network
+
COW



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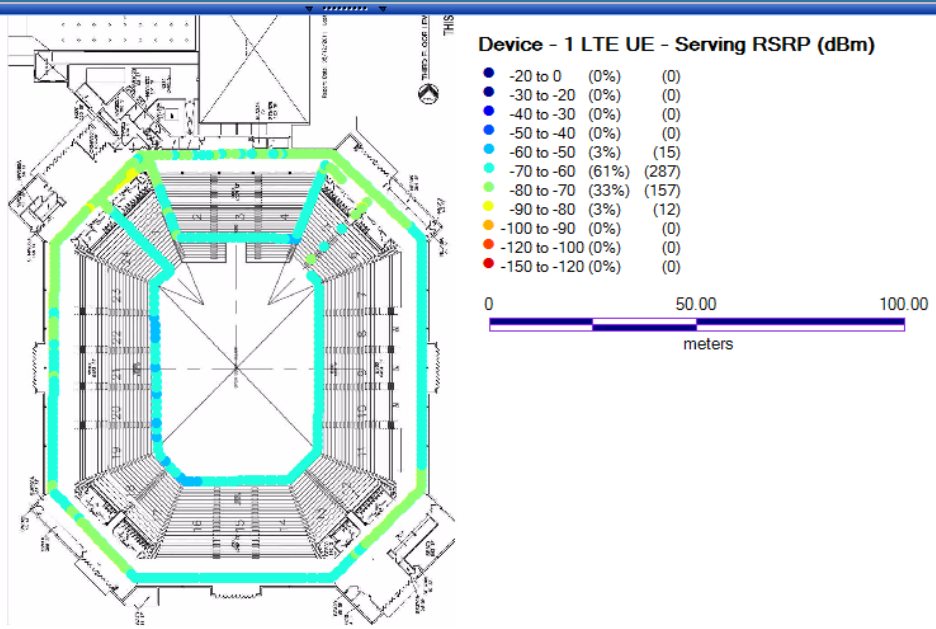
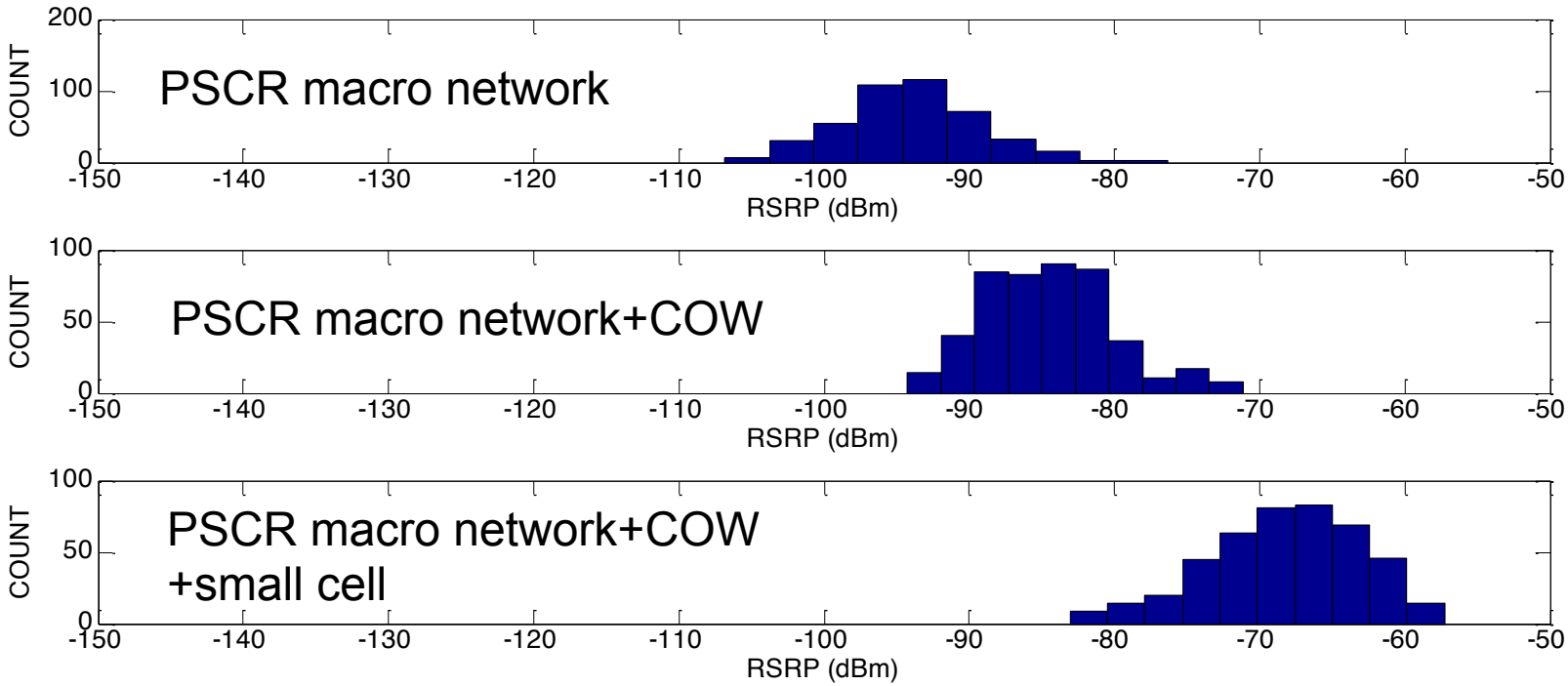
Stadium Results-RSRP

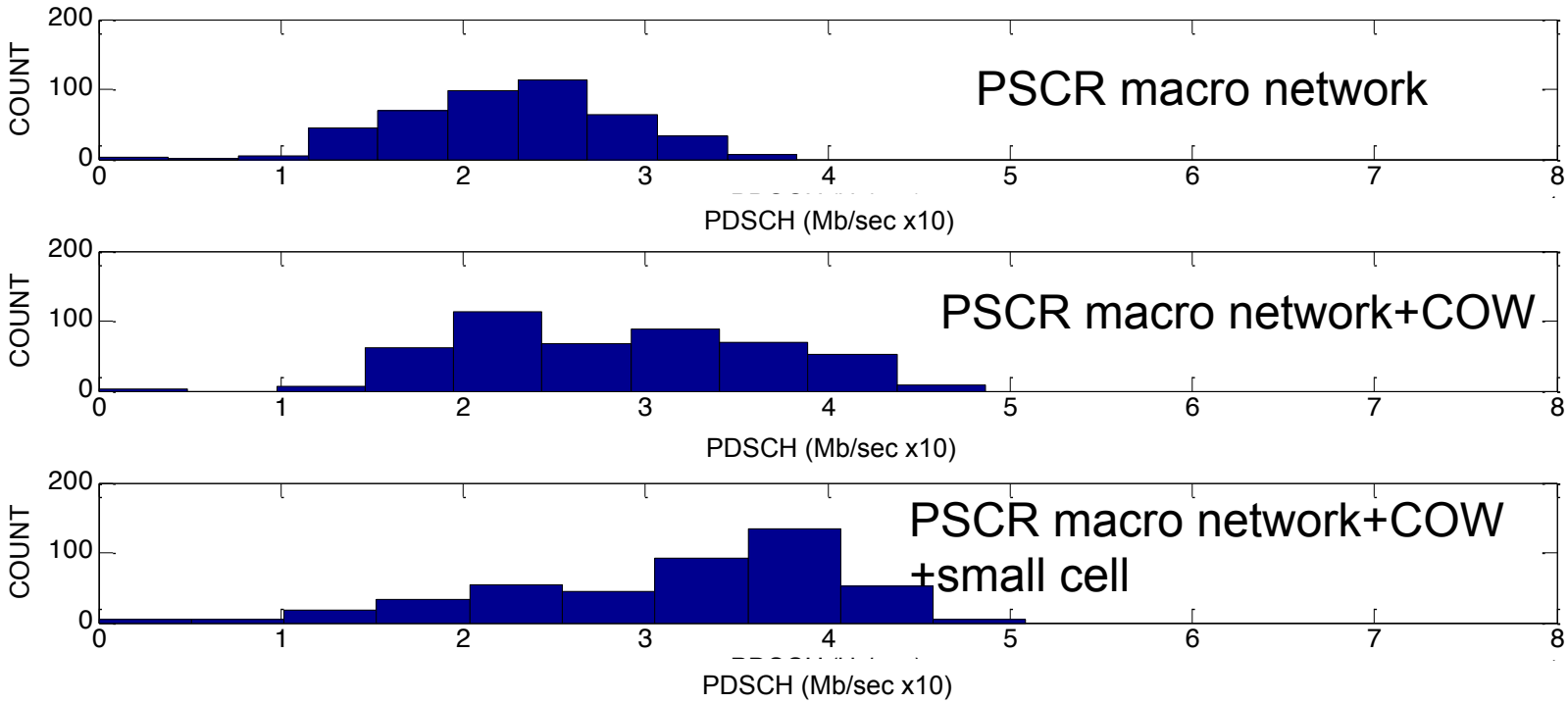
PSCR macro network
+
COW
+
small cell



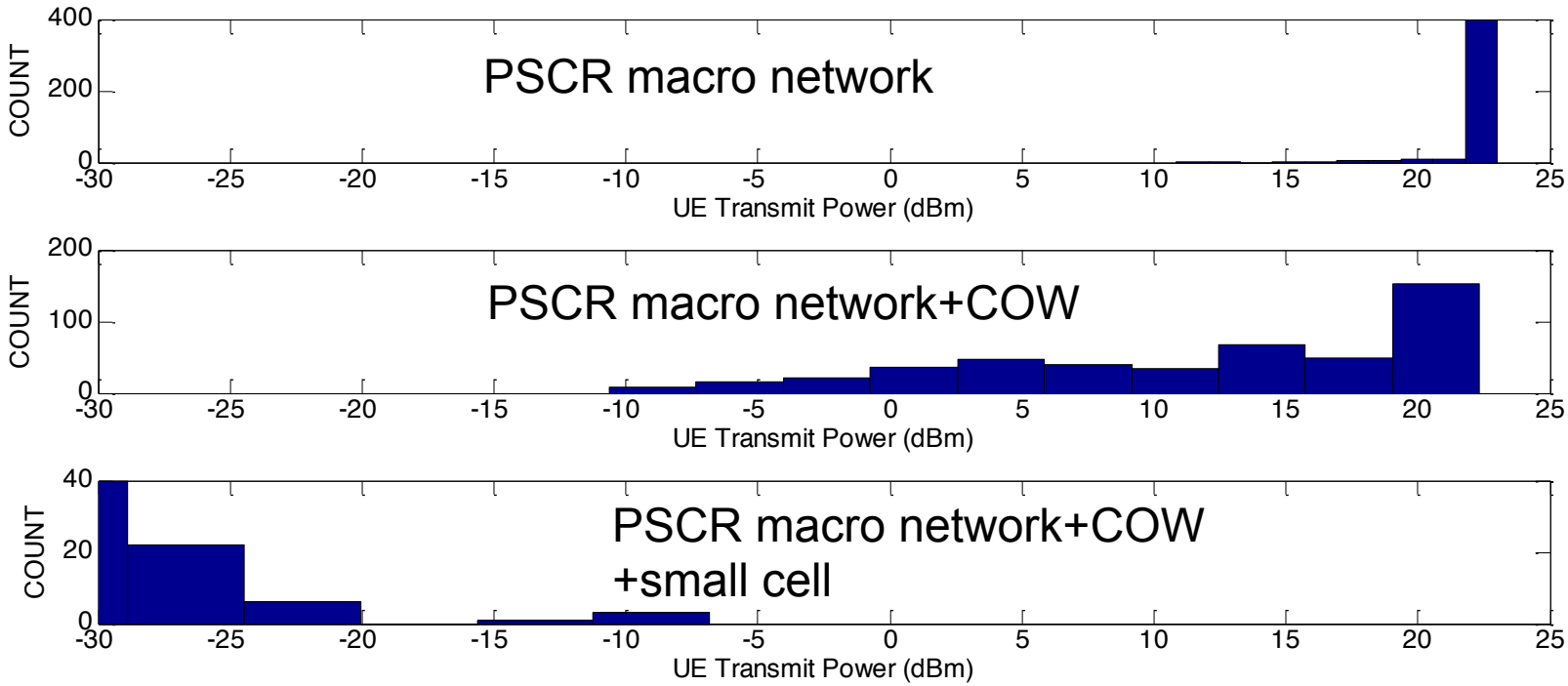
Stadium RSRP Comparisons



Stadium DL Data Rate Comparisons



Stadium UE Tx Power Comparisons



Some Observations

- The use of a small cell & COW greatly improves in-building network performance at CEC
- Small cell has greatest influence in the stadium area
- COW provides coverage in the training/office section
- PSCR Macro network cannot cover CEC in its current configuration

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In-building Measurement Uncertainties

- How repeatable are in building measurements?
- Measurement uncertainties?
- Discussions with
- Dereck Orr, Kent Rocheford, Jack Wang, and Brad Alpert
- We did a series of repeated measurements at the DLC over a 2-day period
- Weak and strong-signal conditions (macro network and small cell)

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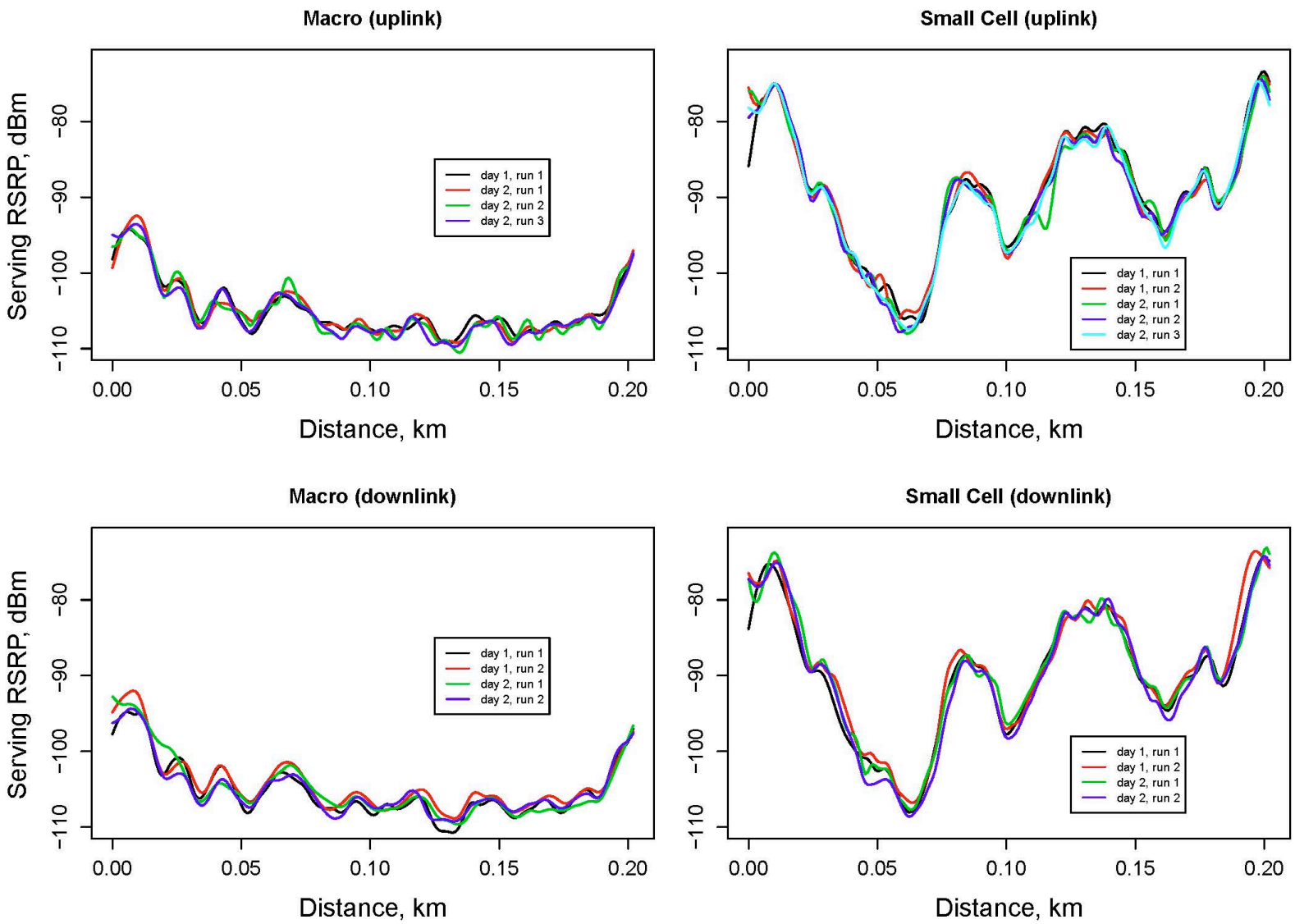
Early Results… more to come



Conclusions

- Two structures investigated: Discovery Learning Center & Coors Events Center
- Macro network coverage was not complete in the structures investigated
- In-building coverage & system performance improves significantly using small cell/ antenna & small cell DAS combinations
- Building effects need to be considered
- Thank you & questions

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