Matthias Schulist, Akos Kezdy, Dusan Milenkovic
Qualcomm CDMA Technologies GmbH, Nuremberg, Germany
Nitin Agarwal, Long Duan - Qualcomm Technologies Inc., San Diego, USA

Qualcomm Technologies, Inc.

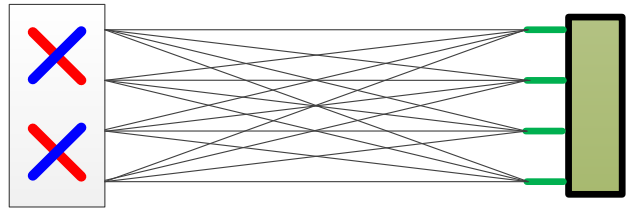
4x4 MIMO – The Performance Boost for LTE

80-xxxxx-x Rev. A

LTE Downlink 4x4 MIMO

3GPP and System Deployment

- DL 4x4 MIMO has been standardized in LTE Rel.8
  - **Devices**
    - In earlier 3GPP releases it required UE Cat. 5 – not seeded
    - Later 3GPP releases decoupled UE DL and UL requirements – newer devices support 4x4
  - **Networks**
    - Most LTE deployments today are still 2x2 MIMO based
    - Need for higher spectral efficiency and capacity in networks
    - Many 4x4 MIMO upgrades observed now
- Massive MIMO
  - 3GPP standardized FD-MIMO starting with Rel.13
  - Vendor proprietary solutions
  - Multi-user aspect



eNB with 4T4R
2 cross-polarized
antenna pairs

end user device
(UE)
4 receive antennas

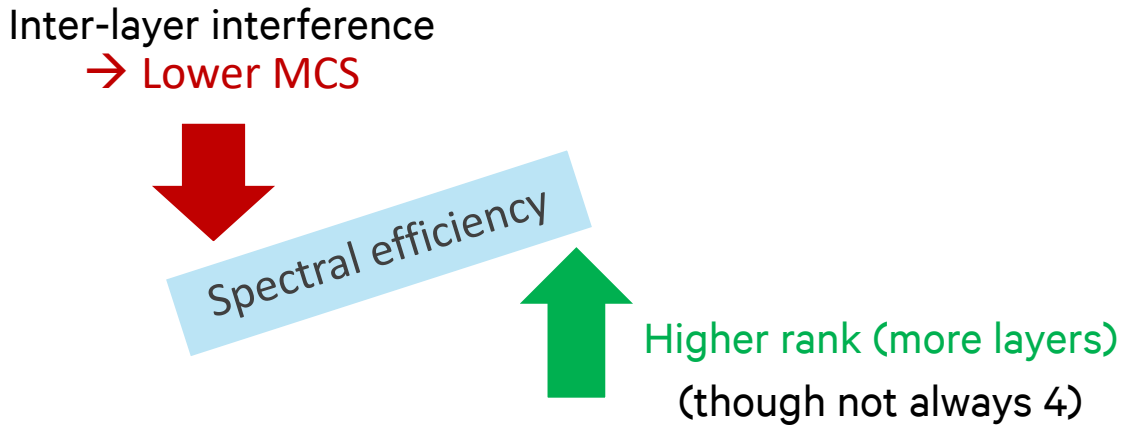
4x4 MIMO is the first step to increased device and network performance on the massive MIMO road

Performance Expectations: Theory and Practice

Setting Realistic Expectations

- Upgrading 2x2 MIMO to 4x4 MIMO potentially can double the DL throughput and system capacity

- In practice, it has to be consider:
  - Rank 4 is not achievable everywhere and anytime
    - Stationary vs. mobility conditions
    - eNB antenna system and channel characteristics
  - Spatial layers cause mutual interference to each other
    → SINR degradation, lower MCS and hence degraded capacity per layer compared to 2x2



Performance Expectations

Gains Compared to 2x2 MIMO Systems

↓ eNB Tx x UE Rx

2 x 4 **Enhanced devices in legacy network**	• UE Rx diversity gain • Better DL SINR in all RF conditions • Significant DL throughput gain on enhanced UE with 4 Rx antennas • No additional CAPEX from network side
4 x 2 **Legacy devices in enhanced network**	• eNB Tx diversity gain • Better DL SINR in all RF conditions • DL throughput gain on legacy UE • UL throughput and/or power saving gains due to eNB Rx diversity
4 x 4 **Enhanced devices and network**	• Highest gains • Increased spatial diversity and multiplexing gain • Better SINR from 4 Rx antennas • Significant DL throughput gain on new UE allowing up to 4 layer DL transmission • UL throughput and/or power saving gains

Performance Drivers

Factors Impacting 4x4 MIMO Performance

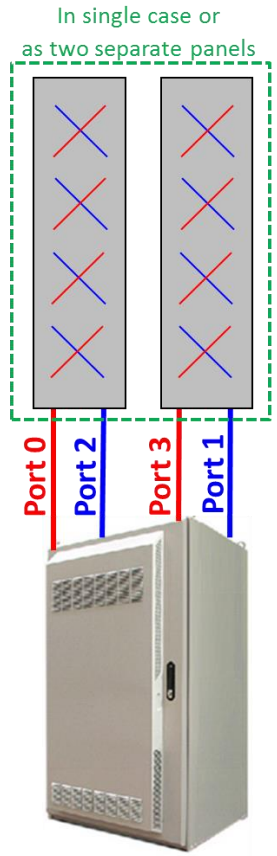
Antenna Placement on eNB
- Antenna spacing, front to back ratio
- Antenna port mapping
- Neighbor sector leakage
- Cross-polarization / omni directional antenna / lambda spacing

SINR
- 4 layer gains require high signal-to-noise ratio
- CRS cancellation algorithms / interference rejection improves SINR

Power & System Parameters
- Available eNB PA power (e.g. 4x10W / 4x20W / 4x25W)
- DL power allocation parameters (p-a / p-b / RS power)
- System bandwidth
- Transmission mode: tm3 / tm4

UE Receiver
- UE antenna placement & design
- SINR distribution on individual receiver chains

Antenna Port Mapping



Examples: Outdoor – Macro network, Mobility

Spatial Rank in Outdoor vs. Indoor Setup

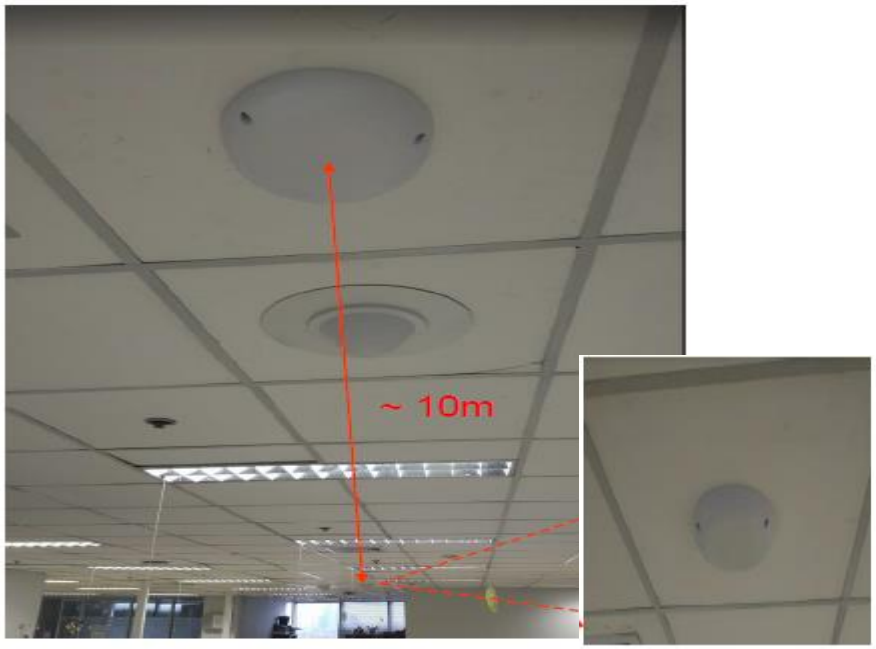
- Legacy 2x2 MIMO configuration with legacy UE provided average spatial rank of ~1.5 (baseline)
  - Using enhanced UE (with 4 antennas and 4 Rx chains) in legacy network improved rank to ~1.9 (i.e., close to theoretical maximum)
- Upgrading to 4x4 MIMO configuration increased average spatial rank to ~2.5
  - Legacy UE on 4x4 MIMO network also showed improved rank of up to ~1.7

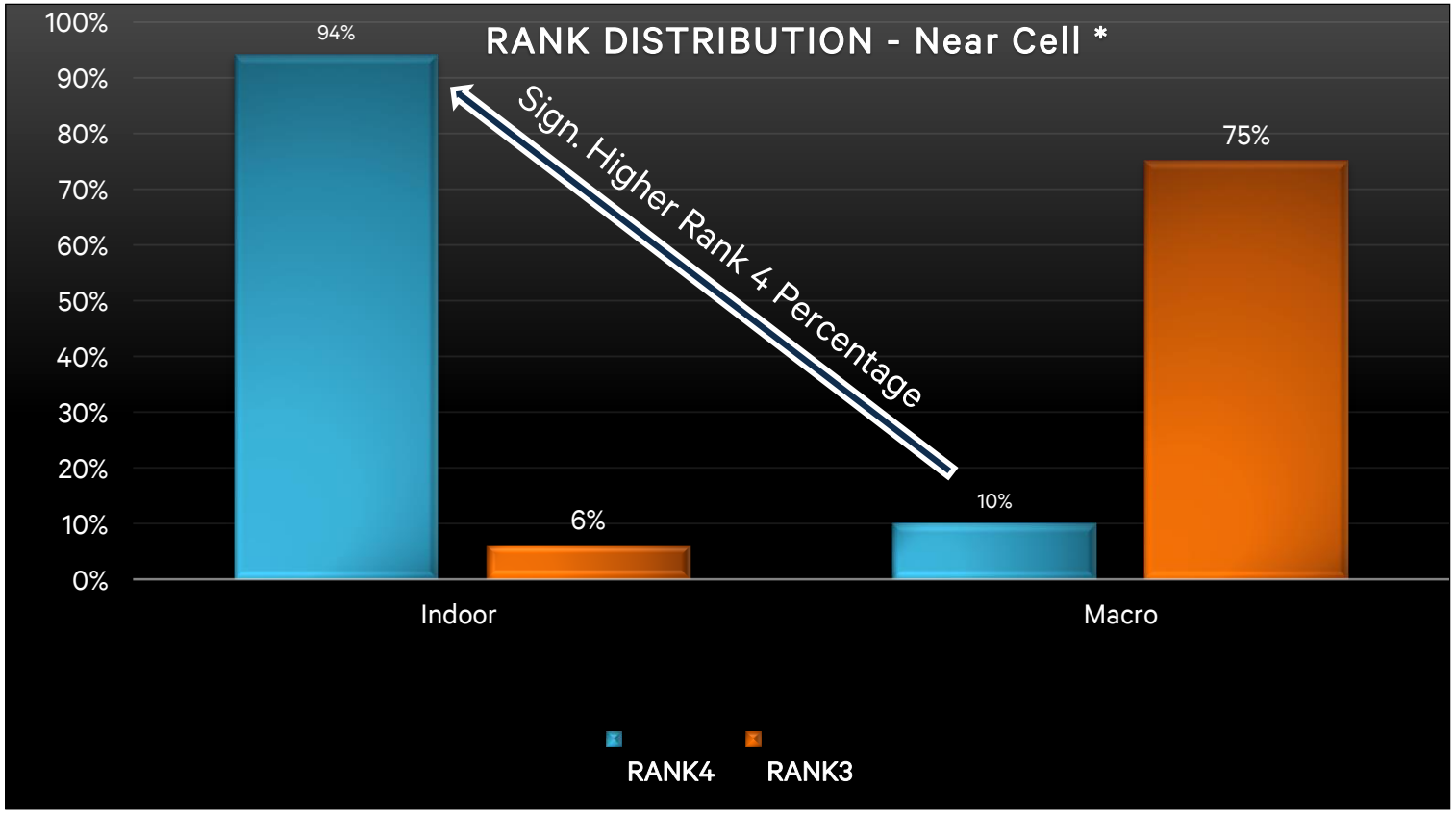
Configuration		Average Rank	
eNB	UE	Cluster 1	Cluster 2
2T2R	1T2R	1.53 (baseline)	1.45 (baseline)
	1T4R	1.92	1.88
4T4R	1T2R	1.72	-
	1T4R	2.48	2.62

Examples: Indoor - Picocell, Pedestrian

Spatial Rank in Outdoor vs. Indoor Setup

- In typical macro outdoor scenarios Rank 4 is rarely observed
- Spatial antenna separation is feasible in indoor setups leading to high percentage of Rank 4

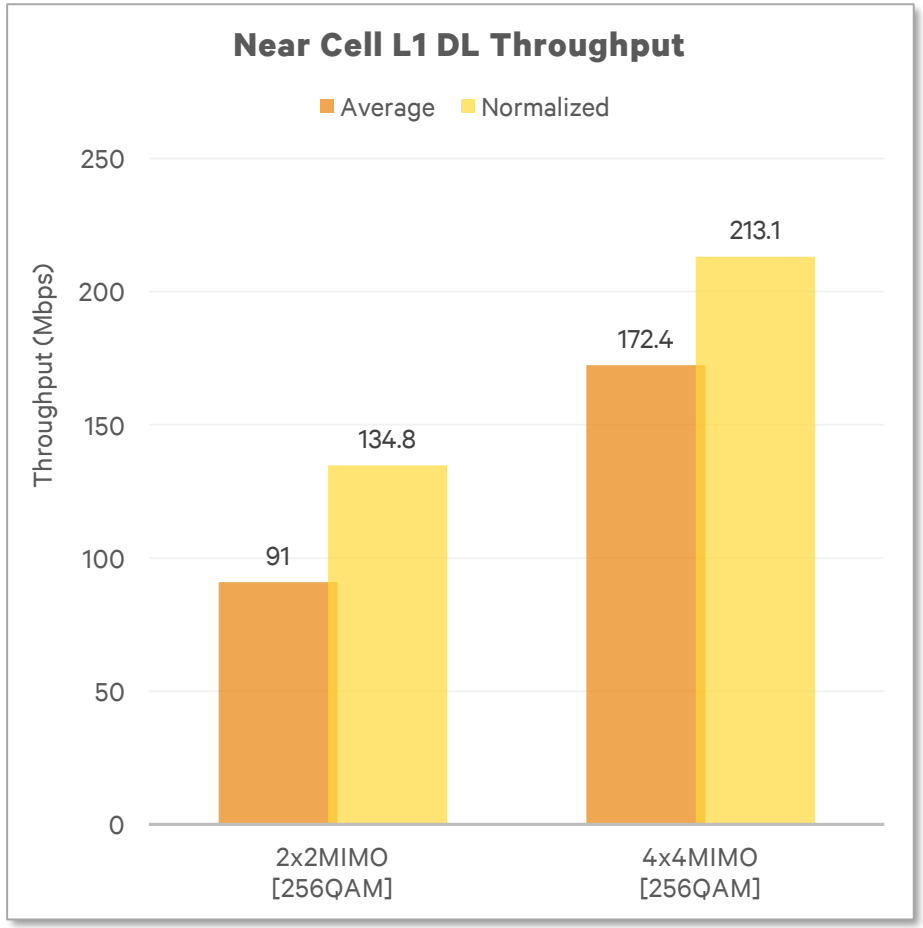




4x4 MIMO Gains

Stationary, Outdoor, Near Cell:

Throughput 4x4 MIMO vs. 2x2 MIMO



Mobility, Outdoor, Near to Far Cell:

Spectral Efficiency 4x4 MIMO vs. 2x2 MIMO

eNodeB → / UE ↓	2T2R		4T4R	
	Cluster 1	Cluster 2	Cluster 1	Cluster 2
1T2R	1.0 (baseline)		1.1	1.1
1T4R	1.4	1.5	1.5	1.8

- Measured spectral efficiency shows clear benefit of higher order MIMO
  - Improvement factor: 1.5 to 1.8 when both the eNodeB and the UE is upgraded (vs. theoretical maximum: 2.0)
  - Improvement factor: 1.4 to 1.5 when only the UE is upgraded

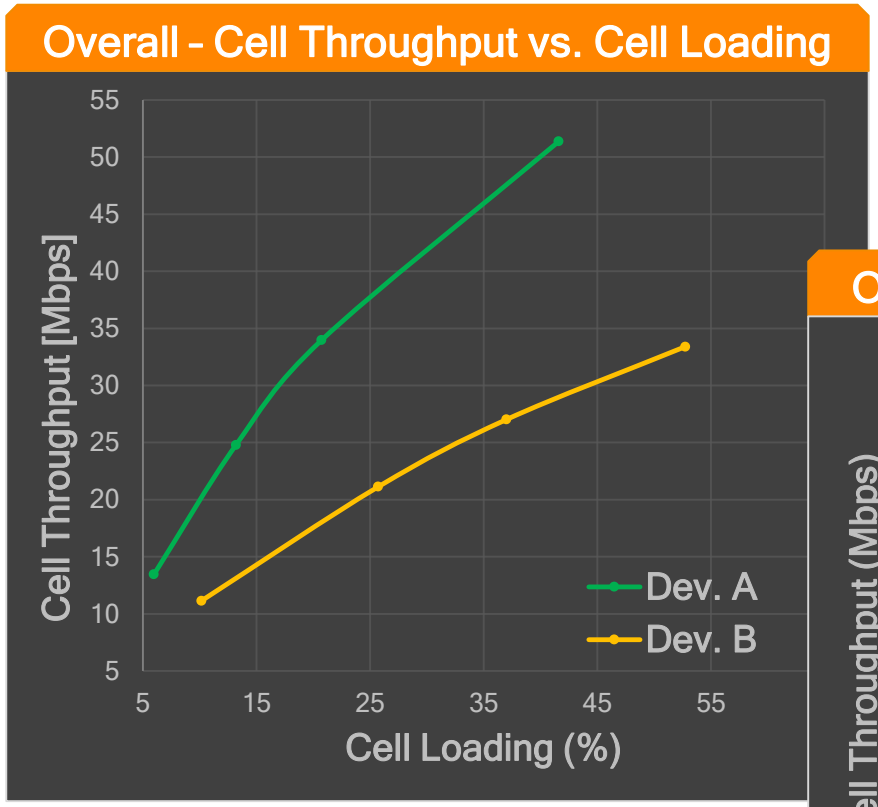
Commercial Device 4x4 MIMO Feature Impact on Network (simulations)

Capacity & Coverage Comparison

- Overall cell/network **capacity gains of 80%** at a typical 40% network load
- User experience speed improvement

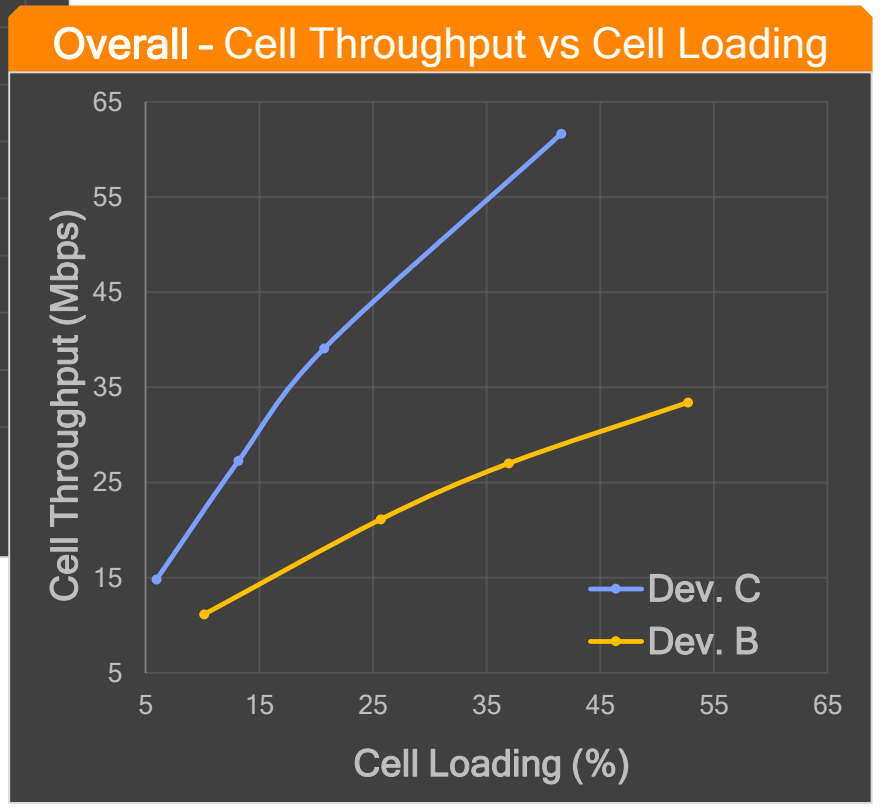
Differentiating features for **4x4 MIMO support** are 10/12 vs.. 6-layers

- Device A, 10L
- Device B, 6L
- Device C, 12L



Scenario 1

Scenario 2



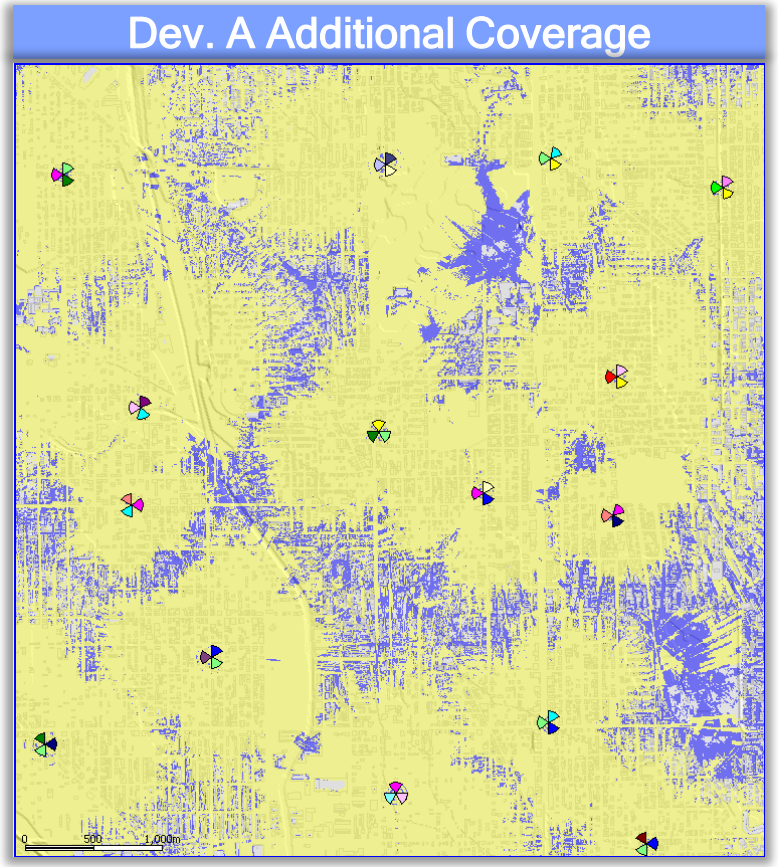
Device B de-featuring results in a significant loss of network efficiency and user data speeds

Commercial Device 4x4 MIMO Feature Impact on Network (simulations)

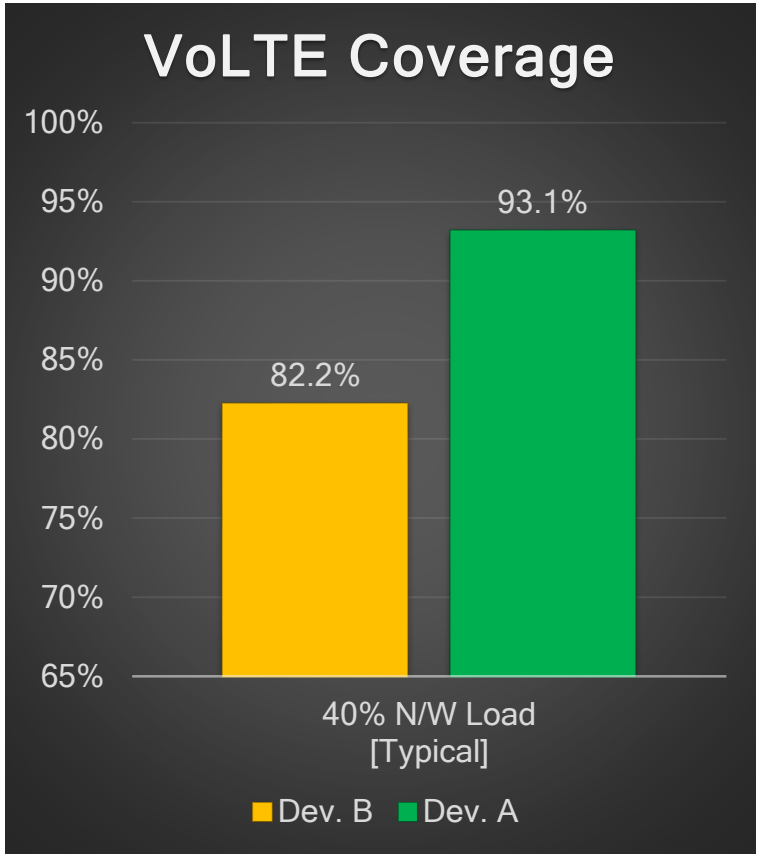
Capacity & Coverage Comparison

- Considerable coverage gains for Dev. A
- VoLTE coverage is 11%-points higher for Dev. A

Differentiating features are 4x4 MIMO (or 4Rx dependent on band), 10-layer vs. 6-layer and LAA



Indicates areas with additional Dev. A VoLTE coverage



Device B de-featuring results in a significant loss of network voice coverage

System Performance and Device Capability Impact

Network and User KPI Improvements

Capacity

- Maximize use of valuable spectrum
- Lower OpEx/CapEx
- Reduced Congestion
- Leverage to Unlimited Data

Coverage

- Fewer dropped calls
- Deeper indoor penetration
- Lower site counts OpEx/CapEx
- Lower handover signaling
- Battery savings

User Experience

- Improved video streaming experience
- Reduced buffering and latency
- Faster music and App downloads
- Battery savings

Thank You !