4x4 MIMO – The Performance Boost for LTE

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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

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 considered:
  – 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"

**2x4**
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

**4x2**
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

**4x4**
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
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
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

<table>
<thead>
<tr>
<th>Configuration</th>
<th>eNB</th>
<th>UE</th>
<th>Average Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Cluster 1</td>
</tr>
<tr>
<td>2T2R</td>
<td>1T2R</td>
<td></td>
<td>1.53 (baseline)</td>
</tr>
<tr>
<td></td>
<td>1T4R</td>
<td></td>
<td>1.92</td>
</tr>
<tr>
<td>4T4R</td>
<td>1T2R</td>
<td></td>
<td>1.72</td>
</tr>
<tr>
<td></td>
<td>1T4R</td>
<td></td>
<td>2.48</td>
</tr>
</tbody>
</table>
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

![Graph](image_url)
4x4 MIMO Gains

**Stationary, Outdoor, Near Cell:**
Throughput 4x4 MIMO vs. 2x2 MIMO

<table>
<thead>
<tr>
<th>Throughput (Mbps)</th>
<th>Average</th>
<th>Normalized</th>
</tr>
</thead>
<tbody>
<tr>
<td>2x2MIMO [256QAM]</td>
<td>91</td>
<td>134.8</td>
</tr>
<tr>
<td>4x4MIMO [256QAM]</td>
<td>172.4</td>
<td>213.1</td>
</tr>
</tbody>
</table>

**Mobility, Outdoor, Near to Far Cell:**
Spectral Efficiency 4x4 MIMO vs. 2x2 MIMO

<table>
<thead>
<tr>
<th>eNodeB →</th>
<th>2T2R</th>
<th>4T4R</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLUSTER 1</td>
<td>CLUSTER 2</td>
<td>CLUSTER 1</td>
</tr>
<tr>
<td>1T2R</td>
<td>1.0 (baseline)</td>
<td>1.1</td>
</tr>
<tr>
<td>1T4R</td>
<td>1.4</td>
<td>1.5</td>
</tr>
</tbody>
</table>

- 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

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

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