Massive MIMO for the New Radio – Overview and Performance

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IEEE 5G Summit
June 5th, 2017
What is “Massive MIMO”

ANTENNA ARRAYS
large number (>>8) of controllable antennas

ANTENNA SIGNALS
adaptable by the physical layer

Not limited to a particular implementation

Enhance Coverage
High gain adaptive beamforming

Enhance Capacity
High order spatial multiplexing
## Massive MIMO: Why now?

<table>
<thead>
<tr>
<th>Capacity requirements</th>
<th>Coverage requirements</th>
<th>Technology capability</th>
<th>3GPP spec support</th>
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<tbody>
<tr>
<td>Most macro networks will become congested</td>
<td>Below 6GHz: Deploy LTE/NR on site grids sized for lower carrier frequencies</td>
<td>Active Antennas are becoming technically and commercially feasible</td>
<td>3GPP: LTE: Rel-13/14 NR: Rel-15</td>
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<tr>
<td>Spectrum &lt; 3GHz and base sites will run out of capacity by 2020</td>
<td>Above 6GHz: Large bandwidths but poor path loss conditions</td>
<td>Massive MIMO requires Active Antenna technology</td>
<td>3GPP-New-Radio will be a “beam-based” air interface</td>
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Evolution to Active Antenna Systems

Conventional base station
- Passive antennas
- 2D-MIMO
- RET
- COAX jumpers
- Tower mounted amplifier
- COAX cable
- BBU
  - Radios/ TXRUS/ PA, filters

Remote Radio Head (RRH)
- Passive antennas
- 2D-MIMO
- RET
- COAX jumpers
- RRH (Radios/ TXRU/PA)
- CPRI
- BBU

Active Antenna System (AAS)
- Active antennas
- 3D-MIMO
- CPRI
- BBU

Reduced footprint and more efficient delivery of power
### MIMO in 3GPP

<table>
<thead>
<tr>
<th>Release 8</th>
<th>Release 9</th>
<th>Release 10</th>
<th>Release 11</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 4x4MIMO</td>
<td>• 8TX TM8</td>
<td>• 8TX TM9</td>
<td>• Downlink CoMP (TM10)</td>
</tr>
<tr>
<td>• 4x2MIMO</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• 8RX uplink</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>• Uplink CRAN</td>
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<table>
<thead>
<tr>
<th>Release 12</th>
<th>Release 13</th>
<th>Release 14</th>
<th>Release 15+</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Downlink eCoMP</td>
<td>• Massive MIMO 16TX</td>
<td>• Massive MIMO 32TX</td>
<td>• 5G massive MIMO 64TX+</td>
</tr>
<tr>
<td>• New 4TX codebook</td>
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</tbody>
</table>
Higher efficiency with Massive MIMO (full dimension MIMO / 3D MIMO)

- 16x2 → 2.5x gain over 2x2
- 64x2 → 3.0x gain over 2x2
- 64x2 → +50% gain over 8x2

4 columns of XPOL antennas for 8TX - 64TX
Massive MIMO field performance: TD-LTE 2600

High-order multi-user spatial multiplexing
## Massive MIMO at Higher Carrier Frequencies (>>6 GHz)

<table>
<thead>
<tr>
<th>Poor path loss conditions</th>
<th>Cost &amp; power consumption</th>
<th>Antenna array implementation</th>
<th>Beam based air interface</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large number of antennas needed to overcome poor path loss</td>
<td>Full digital solutions require transceiver units behind all elements</td>
<td>Smaller form factors</td>
<td>Single sector-wide beam may not provide adequate coverage</td>
</tr>
<tr>
<td>Obtaining channel knowledge per element is difficult</td>
<td>Wide bandwidths: A/D and D/A converters are very power hungry</td>
<td>Distributed PA solutions</td>
<td>→ Beamform all channels!</td>
</tr>
<tr>
<td></td>
<td>→ Hybrid arrays Beamforming at RF with baseband digital Precoding</td>
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</tbody>
</table>
Beamformed control channels

Lower carrier frequencies (digital arch)
- Single-beam

Higher carrier frequencies (hybrid/analog beamforming architecture)
- Multi-beam

Beam scanning

Massive MIMO in 3GPP New Radio – beam based air interface

Beam management

Acquisition and maintenance of a set of beams for TX and RX at base and UE
CoMP is built in
Control Channel Coverage – LTE vs NR

Coverage performance when deploying a 3.5GHz system on a site grid sized for 800MHz:

**LTE**
- Grid-of-Beams
- 10° downtilt
- 2-port SFBC

**NR**
- Grid-of-Beams
- 2-port SFBC

CDF of downlink control channel SINR

**LTE (800MHz & 3.5GHz)**

**NR (3.5GHz)**
Massive MIMO in 3GPP New Radio - advanced CSI

Type II Linear Combination Codebooks in NR promise to provide significant gains over the Rel-14 LTE codebooks for the same array size.

<table>
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<tr>
<th>Performance of NR CB over LTE Rel-14 CB *</th>
<th>Gain in mean UE throughput</th>
<th>Gain in cell edge throughput</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full buffer traffic</td>
<td>18%</td>
<td>15%</td>
</tr>
<tr>
<td>Bursty traffic</td>
<td>33%</td>
<td>65%</td>
</tr>
</tbody>
</table>

* LTE: Rel-14, 16-port CB with 2 beams per polarization
* NR: Candidate Type II 16-port CB with 4 beams per polarization and sub-band scaling
3GPP New Radio at mmWave
Large spatial multiplexing gains at 30GHz with multi-panel hybrid arrays

Four-panel TRP: 256 elements

Four-panel UE: 128 elements

SU-MIMO

\[ \Rightarrow \text{~60\% from leveraging high-rank single-user MIMO transmission} \]

MU-MIMO

\[ \Rightarrow \text{~20\%-50\% from multi-user MIMO transmission} \]
Early 5G use case: Extreme broadband to the home

The last 200m

28 GHz, 512 elements (16,16,2)
Massive MIMO for the new radio

Summary

Massive MIMO is being deployed today.

Massive MIMO will improve coverage and capacity in current LTE bands and also in newly-allocated sub-6GHz, cmWave, and mmWave bands.

Massive MIMO in 3GPP New Radio promises large gains over massive MIMO in LTE.