5G Small Cell Technology

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IoT value capture from 5G Evolution and Revolution towards 1 Tbs/km² …

Three-pronged requirements for 5G networks
Small Cell Deployment Context

- **LTE Macro**
  - High Capacity / EIRP

5G mmWave
- High Capacity / High Power to maximize coverage area

- **5G <6 GHz**
  - Macro

5G mmWave + LTE Indoor Small Cell
- Indoor and street level optimized designs to address capacity hot spots

- **5G <6 GHz**
  - High Capacity / High Power + LTE Small Cell
5G is to enable above 6 GHz access & optimize below 6 GHz access

Expanding the spectrum assets to deliver capacity and experience

Spectrum availability

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Cell Size</th>
<th>LOS/NLOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>90 GHz</td>
<td>10 cm</td>
<td>LOS</td>
</tr>
<tr>
<td>30 GHz</td>
<td>1m</td>
<td>NLOS</td>
</tr>
<tr>
<td>10 GHz</td>
<td>10 cm</td>
<td>LOS</td>
</tr>
<tr>
<td>3 GHz</td>
<td>1m</td>
<td>NLOS</td>
</tr>
<tr>
<td>300 MHz</td>
<td>1m</td>
<td>NLOS</td>
</tr>
</tbody>
</table>

Spectrum

- **mmWave**: Ultra broadband
- **cmWave**: Enhanced SC*
- **< 6GHz**: Wide area

Antenna technologies

- **Low Rank MIMO/BF**: ~1 GHz carrier bandwidth, efficient beam steering
- **Higher Rank MIMO & BF**: Several ~100 MHz carrier bandwidth, dynamic TDD
- **High Rank MIMO & beamforming**: Up to 100 MHz carrier bandwidth, diverse spectrum, FDD and TDD

Interference conditions

- **More noise limited (70-90GHz)**
- **Strong interference handling**
- **Full coverage is essential**

*) SC = Small Cells

Different spectrum licensing, sharing, and usage schemes.

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5G (New Radio) Schedule in 3GPP (Release 16/17 schedule TBC)

- 5G study items completed
- Standalone higher layers, new core
- Enhancements (Unlicensed, Non-orthogonal multiple access, …)
- 5G above 52.6GHz

Timeline:
- 2017
  - Release 15
  - 5G above 52.6GHz
- 2018
  - L1/L2 freeze
  - Release 16
- 2019
  - Release 17
- 2020
- 2021
  - Release 18

Release 15 contains intermediate ASN.1 freeze for Non-standalone in March 2017

Full ASN.1 freeze September 2018 for full 5G feature set
Summary of 5G RAN prioritization

Phase 1 WI (Rel-15)
- Main assumption: general support for stand-alone NR below 40GHz (option 2 scenario) including DC
- 4G-5G interworking
- MIMO/Beamforming (fundamental features)
- Mini-slot (note: enabler for URLLC and ensures forward compatibility)
- Public warning/emergency alert (for regulatory needs)
- SON functionality for Dual Connectivity
- RRC inactive data

Phase 2 WI (Rel-16)
- Potential enhancements for eMBB support below 40GHz
- URLLC (below 40GHz)
- 4G-5G interworking – remaining options
- Shared spectrum and 5GHz unlicensed spectrum
- Location/positioning functionality (for regulatory needs)
- MIMO enhancements

Note: some Phase 1 SIs might belong to Phase 2 WI as well (not shown here explicitly)

Phase 1 SI (Rel-15)
- Unlicensed spectrum
- URLLC (below 40GHz)
- Non-orthogonal multiple access
- Location/positioning functionality (for regulatory needs)
  - Indoor/Outdoor
- New SON functionality
- Sidelink (use cases out of reach of LTE evolution)
- NR-Wi-Fi interworking
- Integrated Access Backhaul
- Non-terrestrial networks
- eV2V evaluation methodology

Phase 2 SI (Rel-16)
- mMTC
- Waveforms for >40GHz
- URLLC for >40GHz
- MIMO for >40GHz
- Multi-connectivity (for >2 nodes)
- Uplink based mobility
- 2-step RACH
- TX interference coordination
- V2V and V2X (use cases out of reach of LTE evolution)
- NAICS

Note: Multimedia Broadcast/Multicast Service
- Air-to-ground and light air craft communications
- Extreme long distance coverage
- Satellite communication
- Other verticals
- 60GHz unlicensed spectrum
<table>
<thead>
<tr>
<th>Frequency range/LTE band</th>
<th>Operators whose request is included in the frequency range</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.3-4.2 GHz</td>
<td>DOCOMO, KDDI, SBM, CMCC, China Unicom, China Telecom, KT, SK Telecom, LG Uplus, Etisalat, Orange, Telecom Italia, British Telecom, Deutsche Telekom</td>
</tr>
<tr>
<td>4.4-4.99 GHz</td>
<td>DOCOMO, KDDI, SBM, CMCC, China Unicom, China Telecom,</td>
</tr>
<tr>
<td>24.25-29.5 GHz</td>
<td>DOCOMO, KDDI, SBM, CMCC, KT, SK Telecom, LG Uplus, Etisalat, Orange, Verizon, T-mobile, Telecom Italia, British Telecom, Deutsche Telekom</td>
</tr>
<tr>
<td>31.8-33.4 GHz</td>
<td>Orange, Telecom Italia, British Telecom</td>
</tr>
<tr>
<td>37-40 GHz</td>
<td>AT&amp;T, Verizon, T-mobile</td>
</tr>
<tr>
<td>1.427-1.518G</td>
<td>Etisalat</td>
</tr>
<tr>
<td>1710-1785MHz/1805-1880MHz (Band 3)</td>
<td>CMCC, China Telecom</td>
</tr>
<tr>
<td>2500-2570MHz/2620-2690MHz (Band 7)</td>
<td>CHTTL, British Telecom</td>
</tr>
<tr>
<td>880-915MHz/925-960MHz (Band 8)</td>
<td>CMCC</td>
</tr>
<tr>
<td>832–862MHz/791–821MHz (Band 20)</td>
<td>Orange</td>
</tr>
<tr>
<td>703-748MHz/758–803MHz (Band 28)</td>
<td>Orange, Swisscom, Telecom Italia, Telefonica, Vodafone</td>
</tr>
<tr>
<td>2496-2690MHz (Band 41)</td>
<td>Sprint, China Telecom, C-Spire, China Unicom</td>
</tr>
<tr>
<td>1710-1780MHz/2110-2200MHz (band 66)</td>
<td>T-mobile, Dish</td>
</tr>
<tr>
<td>1920-1980MHz/2110-2170MHz (Band 1)</td>
<td>China Unicom, China Telecom</td>
</tr>
</tbody>
</table>
FCC mmWave Spectrum Allocation
5G Peak Rates

• 4G achieved 10-15% of the target bit rate in the first deployment and the full target four years later.
• Extrapolating to 5G would give 5 Gbps by 2020 and 50 Gbps by 2024

<table>
<thead>
<tr>
<th>Target bit rate</th>
<th>3GPP specs</th>
<th>1st deployment</th>
<th>Full blown deployment</th>
</tr>
</thead>
<tbody>
<tr>
<td>4G = LTE-Advanced</td>
<td>1 Gbps</td>
<td>3GPP Release 10</td>
<td>2013</td>
</tr>
<tr>
<td>5G</td>
<td>50 Gbps</td>
<td>3GPP Release 14</td>
<td>2020</td>
</tr>
</tbody>
</table>
## 5G Technology Components for Enhancing S.E. Compared to LTE (sub 6Ghz)

<table>
<thead>
<tr>
<th>Technology component</th>
<th>Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enhanced beamforming</td>
<td>+0.60%</td>
</tr>
<tr>
<td>Lean carrier</td>
<td>+20%</td>
</tr>
<tr>
<td>Enhanced inter-cell cancellation</td>
<td>+20%</td>
</tr>
<tr>
<td>Improved spectral usage</td>
<td>+10%</td>
</tr>
<tr>
<td>Non-orthogonal transmission</td>
<td>?</td>
</tr>
<tr>
<td>Dynamic TDD in small cells</td>
<td>+30%</td>
</tr>
</tbody>
</table>

**Total gain**

Gain values preliminary

+50..150%
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
## 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>
</tr>
<tr>
<td>• Uplink CRAN</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<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>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
5G vs. 4G Capacity per Cell (sub 6 GHz)

5x More Spectrum with 2 – 4x More Efficiency

LTE2600 with 2x2 MIMO

- 2.6 GHz
- 20 MHz
- 2 bps / Hz
- 40 Mbps cell throughput

5G 3500 with massive MIMO beamforming

- 3.5 GHz
- 100 MHz
- 4-8 bps / Hz
- 400-800 Mbps cell throughput

10-20 x

10-20 x

10-20 x
NR frame/subframe structure

- **DL only subframe**
- **UL only subframe**
- **Self-contained subframe**

**0.125ms frame with cascaded UL/DL control signals**

**0.5 ms user plane latency**

**0.1 ms**

**Control channel just before data**

**Flexible UL/DL**

**Same physical layer in UL and DL**

**Energy-effective processing**
Massive MIMO in 3GPP New Radio – Beam Based Air Interface

**Beamformed Control Channels**
- Lower carrier frequencies (digital arch) - Single-beam
- Higher carrier frequencies (hybrid/analog beamforming architecture) - Multi-beam

**Beam Scanning**

**Beam Management**

- Acquisition and maintenance of a set of beams for TX and RX at base and UE
- CoMP is built in
Early 5G use case: Extreme broadband to the home (mmWave)

28 GHz, 512 elements (16,16,2)

- No Foliage
- Heavy Foliage

vRAN & EPC
Antenna Array Comparisons - AP Antenna Aperture Constant vs. Frequency

5dBi ant element gain, 7dBm AP Pout per element, 1dBm UE Pout per element, shown to scale

28 GHz, 256 elements (8x16x2)
Max EIRP ≈ 60.2 dBm
103% area relative to 28GHz
Room to grow…normalized array size is ~4.5dBm more than above

39 GHz, 512 elements (16x16x2)
Max EIRP ≈ 66.2 dBm
52% area relative to 28GHz

73 GHz, 1024 elements (16x32x2)
Max EIRP ≈ 72.2 dBm
59% area relative to 28GHz

28 GHz, 32 elements, (4x4x2)
Max EIRP ≈ 36.1 dBm

39 GHz, 32 elements, (4x4x2)
Max EIRP ≈ 36.1 dBm

73 GHz, 32 elements, (4x4x2)
Max EIRP ≈ 36.1 dBm

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System Simulation Results for the Suburban Micro Environment
Constant Antenna Aperture for 28 GHz, 39 GHz and 73 GHz

Mean UE Throughput

Cell Edge Throughput

Downlink

Uplink

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Basic Network Building blocks

• 5G mmW basestation and integrated wireless backhaul will be a small box which is easy to install to lamp posts, walls or small masts.
• The cost of the box is mainly in RF, antennas and BB-SoC, of course some cost goes for cover mechanics and power supply.
• Investigating how to arrange the creation and manufacturing of the RF and antenna components.
• Multi-sector sBH is the assumption