3GPP LTE / LTE-A Standardization: Status and Overview of Technologies

Workshop session on “Technologies for LTE-Advanced: from Theory to Practice”

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Outline

• ITU- 4G introduction
• IMT-Advanced (4G) high-level requirements
• IMT-Advanced, LTE-Advanced and wireless standard evolution/timeline
• IMT-Advanced system performance requirements
• LTE-Advanced requirements
• Key LTE-Advanced documents
• LTE/LTE-Advanced bands of operation
• Rel-10 and beyond proposals
  – New UE categories
  – CA
  – Enhanced uplink multiple access
  – Enhanced MIMO
  – CoMP
  – Relay
  – HeNB
  – ......
ITU – 4G Introduction

• The International Telecommunications Union‘s (ITU) “4G” program is officially called IMT-Advanced

• The term 3.9G was widely used to describe LTE since it was developed prior to the ITU defining IMT-Advanced (aka 4G)

• LTE-Advanced is intended to be 3GPP’s “official” 4G technology

• The “3G” program was officially called IMT-2000

In October 2010 the ITU-Radio Working Party decided that the following IMT-Advanced submissions meet the ITU requirements:

• 3GPP LTE-Advanced

• IEEE WirelessMAN-Advanced (802.16m)
IMT-Advanced 4G High-Level Requirements*

• A high degree of commonality of functionality worldwide
• Compatibility of services within IMT and with fixed networks
• High quality mobile services
• User-friendly and cost efficient applications, services and equipment
• Worldwide roaming capability
• Enhanced peak data rates to support advanced services and applications (100 Mbps for high mobility and 1 Gbps for low mobility were established as targets for research).

## IMT-Advanced Timeline

<table>
<thead>
<tr>
<th>Year</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
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</thead>
<tbody>
<tr>
<td><strong>ITU-R</strong></td>
<td>WP5D meetings</td>
<td>#1</td>
<td>#2</td>
<td>#3</td>
<td>#4</td>
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<tr>
<td><strong>WRC-07</strong></td>
<td>Circular letter to invite proposals</td>
<td>Proposals</td>
<td>Evaluation</td>
<td>Consensus</td>
<td>Specification</td>
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<td>#5</td>
<td>#6</td>
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<td><strong>WP5D meetings</strong></td>
<td>#10</td>
<td>#11</td>
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</tbody>
</table>

### Key Events:
- **2007**: WP5D meetings, Circular letter to invite proposals
- **2008**: Proposals, Submissions of candidate RIT
- **2009**: Evaluation, Consensus, Specification
- **2010**: IMT-Advanced Spec in Feb. 2011
- **2011**: 802.16m Approval in H2'10

### Technical Specifications:
- 3GPP RAN
- LTE-Advanced

### Work Items:
- 3GPP RAN CR phase
- LTE CR phase
- 802.16m Approval in H2'10
- Technical specifications
- Release 10 Spec Approval

### Key Dates:
- **2009**: IMT-Advanced Spec in Feb. 2011
- **2010**: 802.16m Approval in H2'10
- **2011**: Technical specifications, Release 10 Spec Approval
LTE-Advanced timeline

2008

2009

2010

2011

2012

2013

ITU-R

Proposals

Evaluation

Consensus

Specification

3GPP

Rel-9 study item

Rel-10 work item

ITU-R Submission Sept 2009

TR36.912 v 2.2.0
R1-093731, Characteristic template
R1-093682, Compliance template
R1-093741, Link Budget template

Early deployment?
Wireless evolution 1990 - 2011

- **2G**
  - PDC (Japan)
  - GSM (Europe)
  - IS-136 (US TDMA)
  - IS-95A (US CDMA)

- **2.5G**
  - iMODE
  - HSCSD
  - IS-136 (US TDMA)
  - IS-95A (US CDMA)

- **3G**
  - W-CDMA (FDD & TDD)
  - TD-SCDMA (China)
  - E-GPRS (EDGE)
  - cdma2000 (1x RTT)

- **3.5G**
  - HSDPA
  - HSUPA
  - 1x EV-DO
  - 1x EV-DO A
  - 1x EV-DO B

- **3.9G/4G**
  - HSPA+
  - E-HSPA
  - LTE (R8/9 FDD & TDD)
  - LTE-Advanced (R10 & beyond)

- **4G / IMT-Advanced**
  - LTE (R8/9 FDD & TDD)
  - LTE-Advanced (R10 & beyond)
  - 802.16m / WiMAX2
  - 802.16e (Mobile WiMAX)
  - 802.16d (Fixed WiMAX)
  - WiBRO (Korea)

- **W-LAN**
  - 802.11b
  - 802.11a/g
  - 802.11h
  - 802.11n

- **W-LAN**
  - 802.11ac
  - 802.11ad

Increasing efficiency, bandwidth and data rates

Market evolution

Technology evolution

Increasing efficiency, bandwidth and data rates

2011-06-17
IMT-A System Performance Requirements

• Peak data rate goals
  – Key feature stated in Circular Letter is 100 Mbps for high mobility and 1 Gbps for low mobility (downlink)
  – For LTE-Advanced the 1 Gbps data rate is achieved by 4x4 MIMO with transmission bandwidth wider than approximately 70 MHz (carrier aggregation)

• Peak spectrum efficiency
  – DL: Rel. 8 LTE satisfies IMT-Advanced requirement
  – UL: Need to double from Release 8 to satisfy IMT-Advanced requirement

<table>
<thead>
<tr>
<th></th>
<th>Rel. 8 LTE</th>
<th>LTE-Advanced¹</th>
<th>802.16m² (TDD)</th>
<th>IMT-Advanced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak data rate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DL</td>
<td>300 Mbps</td>
<td>1 Gbps</td>
<td>1 Gbps</td>
<td>1 Gbps</td>
</tr>
<tr>
<td>UL</td>
<td>75 Mbps</td>
<td>500 Mbps</td>
<td>~452 Mbps</td>
<td>1 Gbps</td>
</tr>
<tr>
<td>Peak spectrum efficiency [bps/Hz]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DL</td>
<td>15</td>
<td>30</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>UL</td>
<td>3.75</td>
<td>15</td>
<td>6.75</td>
<td>6.75</td>
</tr>
</tbody>
</table>

¹ From 3GPP TR 26.913 V8.0.0 (2008-6) Requirements for Further Advancements of E-UTRA (LTE-Advanced)
² From IEEE 802.16m-07/002r9, 802.16m System Requirements
LTE-Advanced Requirements & proposals

- 3GPP stated intention is to meet or exceed IMT-Advanced requirements
- LTE-A must support IMT-A requirements with same or better performance than LTE.
- An LTE terminal should be able to work in an LTE-Advanced network and vice versa. Any exceptions will be considered by 3GPP.
- Requirements must recognize those parts of the world in which wideband channels are not available.
- Specific targets exist for average and cell-edge spectral efficiency (see next slide). LTE-Advanced should be focused on the very real challenges of raising average and cell-edge performance.
- Similar requirements as LTE for synchronization, latency, coverage, mobility…
# LTE-Advanced spectral efficiency requirements

<table>
<thead>
<tr>
<th>Item</th>
<th>Sub-category</th>
<th>LTE (3.9G) target</th>
<th>LTE-Advanced (4G) target</th>
<th>IMT-Advanced (4G) target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Spectral Efficiency (b/s/Hz)</td>
<td>Downlink</td>
<td>16.3 (4x4 MIMO)</td>
<td>30 (up to 8x8 MIMO)</td>
<td>15 (4x4 MIMO)</td>
</tr>
<tr>
<td></td>
<td>Uplink</td>
<td>4.32 (64QAM SISO)</td>
<td>15 (up to 4x4 MIMO)</td>
<td>6.75 (2x4 MIMO)</td>
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<tr>
<td>Downlink cell spectral efficiency b/s/Hz 3km/h 500m ISD</td>
<td>2x2 MIMO</td>
<td>1.69</td>
<td>2.4</td>
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<td>4x2 MIMO</td>
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<td>2.6</td>
<td>2.6</td>
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<td></td>
<td>4x4 MIMO</td>
<td>2.67</td>
<td>3.7</td>
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<tr>
<td>Downlink cell-edge user spectral efficiency b/s/Hz 5 percentile 10 users 500m ISD</td>
<td>2x2 MIMO</td>
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<td>0.07</td>
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<td>4x2 MIMO</td>
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<td>0.09</td>
<td>0.075</td>
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<tr>
<td></td>
<td>4x4 MIMO</td>
<td>0.08</td>
<td>0.12</td>
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</tr>
</tbody>
</table>

ISD is Inter Site Distance

LTE provides 2x to 4x efficiency of Rel-6 HSPA
Key LTE-Advanced Documents - and where to find them

**Study Item** RP-080599

**Requirements** TR 36.913 v9.0.0 (2009-12)

**Study Phase Technical Report** TR 36.912 v9.3.0 (2010-06)

**Latest study item status report** RP-100080

**Physical Layer Aspects** TR 36.814 v9.0.0 (2010-03)

A comprehensive summary of the entire LTE-Advanced proposals including radio, network and system can be found in the 3GPP submissions to the first IMT-Advanced evaluation workshop.

### LTE Frequency bands

**FDD bands based on 36.101 va.2.0 Table 5.5-1**

<table>
<thead>
<tr>
<th>Band</th>
<th>Uplink MHz</th>
<th>Downlink MHz</th>
<th>Width</th>
<th>Duplex</th>
<th>Gap</th>
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<td>1</td>
<td>1920</td>
<td>1980</td>
<td>60</td>
<td>190</td>
<td>130</td>
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<td>1850</td>
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<td>80</td>
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<tr>
<td>3</td>
<td>1710</td>
<td>1785</td>
<td>75</td>
<td>95</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>1710</td>
<td>1755</td>
<td>45</td>
<td>400</td>
<td>355</td>
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<td>5</td>
<td>824</td>
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<tr>
<td>6</td>
<td>830</td>
<td>840</td>
<td>10</td>
<td>35</td>
<td>25</td>
</tr>
<tr>
<td>7</td>
<td>2500</td>
<td>2570</td>
<td>70</td>
<td>120</td>
<td>50</td>
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<tr>
<td>8</td>
<td>880</td>
<td>915</td>
<td>35</td>
<td>45</td>
<td>10</td>
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<tr>
<td>9</td>
<td>1749.9</td>
<td>1784.9</td>
<td>35</td>
<td>95</td>
<td>60</td>
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<td>1710</td>
<td>1770</td>
<td>60</td>
<td>400</td>
<td>340</td>
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<td>11</td>
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<td>20</td>
<td>48</td>
<td>28</td>
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<td>698</td>
<td>716</td>
<td>18</td>
<td>30</td>
<td>12</td>
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<td>13</td>
<td>777</td>
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<td>14</td>
<td>788</td>
<td>798</td>
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<td>-30</td>
<td>40</td>
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<td>15*</td>
<td>1900</td>
<td>1920</td>
<td>20</td>
<td>700</td>
<td>680</td>
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<td>16*</td>
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<td>2025</td>
<td>15</td>
<td>575</td>
<td>560</td>
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<tr>
<td>20</td>
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<td>862</td>
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<td>-41</td>
<td>71</td>
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<td>21</td>
<td>1447.9</td>
<td>1462.9</td>
<td>15</td>
<td>48</td>
<td>33</td>
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<tr>
<td>24</td>
<td>1626.5</td>
<td>1660.5</td>
<td>34</td>
<td>-101.5</td>
<td>135.5</td>
</tr>
</tbody>
</table>

**Points of note**
- Frequency bands are release independent
- There is a lot of overlap between band definitions for regional reasons
- The Duplex spacing varies from 30 MHz to 799 MHz
- The gap between downlink and uplink varies from 10 MHz to 680 MHz
- Narrow duplex spacing and gaps make it hard to design filters to prevent the transmitter spectral regrowth leaking into the receiver (self-blocking)
- Bands 13, 14, 20 and 24 are reversed from normal by having the uplink higher in frequency than the downlink
- Bands 15 and 16 are defined by ETSI (not 3GPP) for Europe only – these bands combine two nominally TDD bands to create one FDD band
Points of note

- For TDD there is no concept of duplex spacing or gap since the downlink and uplink frequencies are the same.
- As such, the challenge of separating transmit from receive does not require a duplex filter for the frequency domain but a switch for the time domain.

<table>
<thead>
<tr>
<th>Band</th>
<th>Uplink MHz</th>
<th>Downlink MHz</th>
<th>Width</th>
</tr>
</thead>
<tbody>
<tr>
<td>33</td>
<td>1900 1920</td>
<td>1900 1920</td>
<td>20</td>
</tr>
<tr>
<td>34</td>
<td>2010 2025</td>
<td>2010 2025</td>
<td>15</td>
</tr>
<tr>
<td>35</td>
<td>1850 1910</td>
<td>1850 1910</td>
<td>60</td>
</tr>
<tr>
<td>36</td>
<td>1930 1990</td>
<td>1930 1990</td>
<td>60</td>
</tr>
<tr>
<td>37</td>
<td>1910 1930</td>
<td>1910 1930</td>
<td>20</td>
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<td>38</td>
<td>2570 2620</td>
<td>2570 2620</td>
<td>50</td>
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<td>39</td>
<td>1880 1920</td>
<td>1880 1920</td>
<td>40</td>
</tr>
<tr>
<td>40</td>
<td>2300 2400</td>
<td>2300 2400</td>
<td>100</td>
</tr>
<tr>
<td>41</td>
<td>2496 2690</td>
<td>2496 2690</td>
<td>194</td>
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<tr>
<td>42</td>
<td>3400 3600</td>
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<tr>
<td>43</td>
<td>3600 3800</td>
<td>3600 3800</td>
<td>200</td>
</tr>
</tbody>
</table>
The work on defining new frequency bands shows no sign of slowing up. These are the bands currently being considered by 3GPP:

- **Band 22** 3410/3490 + 3510/3590 – UMTS/LTE 3500 MHz
- **Band 23** 2000/2020 + 2180/2200 - S band additional terrestrial component (ATC) of the mobile satellite systems (MSS)
- **Band 25** 1850/1915 + 1930/1995 - Extended 1900 band – has issues with GPS co-existence
- **Band 26** 814/849 MHz + 859/894 – Extended 850 upper band
- **Band 27** 806/824 + 851/869 – Extended 850 lower band

Other possibilities identified by the ITU:

- 3.6-4.2 GHz
- 450–470 MHz
- 698–862 MHz
- 790–862 MHz band (European digital dividend)
- 4.4-4.99 GHz band
Release 10 and beyond proposals
Radio aspects

1. New UE categories
2. Carrier aggregation
3. Enhanced uplink multiple access
   a) Clustered SC-FDMA
   b) Simultaneous Control and Data
4. Enhanced multiple antenna transmission
   a) Downlink 8 antennas, 8 streams
   b) Uplink 4 antennas, 4 streams
5. Coordinated Multipoint (CoMP)
6. Relaying
7. Home eNB mobility enhancements
8. Customer Premises Equipment
9. Heterogeneous network support
10. Self Optimizing networks (SON)

Rel 10 LTE-A proposed to ITU

Other Release 10 and beyond –
- Not essential to meet IMT-A requirements.
- Technologies under consideration
1. New LTE-A UE Categories

To accommodate the higher data rates of LTE-A, three new UE categories have been defined.

<table>
<thead>
<tr>
<th>UE category</th>
<th>Max. Data rate (DL / UL) (Mbps)</th>
<th>Downlink</th>
<th>Downlink</th>
<th>Uplink</th>
<th>Uplink</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Support for 64QAM</td>
<td>Max. #. spatial layers</td>
<td>Support for 64QAM</td>
<td>Max. #. spatial layers</td>
</tr>
<tr>
<td>Category 1</td>
<td>10 / 5</td>
<td>Yes</td>
<td>1</td>
<td>No</td>
<td>1</td>
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<tr>
<td>Category 2</td>
<td>50 / 25</td>
<td>Yes</td>
<td>2</td>
<td>No</td>
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<td>Category 3</td>
<td>100 / 50</td>
<td>Yes</td>
<td>2</td>
<td>No</td>
<td>1</td>
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<tr>
<td>Category 4</td>
<td>150 / 50</td>
<td>Yes</td>
<td>2</td>
<td>No</td>
<td>1</td>
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<tr>
<td>Category 5</td>
<td>300 / 75</td>
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<td>4</td>
<td>Yes</td>
<td>1</td>
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<td>Category 6</td>
<td>300 / 50</td>
<td>Yes</td>
<td>2/4</td>
<td>No</td>
<td>1/2</td>
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<tr>
<td>Category 7</td>
<td>300 / 150</td>
<td>Yes</td>
<td>2/4</td>
<td>Yes/No (Up-to RAN4)</td>
<td>1/2</td>
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<tr>
<td>Category 8</td>
<td>1200 / 600</td>
<td>Yes</td>
<td>8</td>
<td>Yes</td>
<td>4</td>
</tr>
</tbody>
</table>
2. Carrier Aggregation

- Support for 5 aggregated CCs upto 100 MHz
- CCs must be backward compatibility with legacy system (LTE Release 8 and 9)
- May be able to mix different CC types – bandwidths
- Contiguous and non-contiguous (with gaps) CC is allowed
- No. of CCs in downlink $\geq$ uplink - FDD
- No. of CCs in downlink $\geq$ uplink - TDD

Contiguous aggregation of two uplink component carriers
2. Carrier Aggregation

- IMT-Advanced requires at least 40 MHz, 100 MHz is a want
- Initially 12 scenarios were being studied, many more were proposed
- Due to complexity and limited time, Rel-10 has just three scenarios:
  - CA_40: Intra-band contiguous TDD
  - CA_1-5: Inter-band non-contiguous FDD
  - CA_3-7 Inter-band non-contiguous FDD

<table>
<thead>
<tr>
<th>Band</th>
<th>E-UTRA operating Band</th>
<th>Uplink (UL) band</th>
<th>Downlink (DL) band</th>
<th>Duple x mode</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>UE transmit / BS receive</td>
<td>Channel BW MHz</td>
<td>UE receive / BS transmit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$F_{UL_low}$ (MHz) – $F_{UL_high}$ (MHz)</td>
<td></td>
<td>$F_{DL_low}$ (MHz) – $F_{DL_high}$ (MHz)</td>
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<tr>
<td></td>
<td>5</td>
<td>824 – 849</td>
<td>[TBD]</td>
<td>869 – 894</td>
</tr>
<tr>
<td>CA_3-7</td>
<td>3</td>
<td>1710 – 1788</td>
<td>20</td>
<td>1805 – 1880</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>2500 – 2570</td>
<td>20</td>
<td>2620 – 2690</td>
</tr>
</tbody>
</table>

- In March 2011, 10 more combinations were agreed for Rel-11 reqs.
3. Enhanced Uplink Multiple Access
Clustered SC-FDMA and PUCCH with PUSCH

**Release 8:** SC-FDMA with alternating PUSCH/PUCCH (Inherently single carrier)

- Partially allocated PUSCH
- Partially allocated PUSCH
- Lower PUCCH
- Upper PUCCH
- Fully allocated PUSCH

**Release 10:** Clustered SC-FDMA with simultaneous PUSCH/PUCCH (Potentially in-channel multi-carrier)

- Partially allocated PUSCH + PUCCH
- Partially allocated PUSCH + PUCCH
- Partially allocated PUSCH + 2 PUCCH
- Partially allocated PUSCH only
- Fully allocated PUSCH + PUCCH
The use of clustered SC-FDMA increases the PAPR above non-clustered SC-FDMA, but not as much as full OFDM which can exceed the PAPR of Gaussian noise.

Clustered SC-FDMA enables up-link frequency selective transmission.
3. Enhanced Uplink Multiple Access
Design and test challenges

- Clustered SC-FDMA increases PAR by a few dB adding to
transmitter linearity challenges
- Simultaneous PUCCH and PUSCH also increases PAR
- Both feature create multi-carrier signals within the channel bandwidth
- High power narrow PUCCH plus single or clustered SC-FDMA
  creates large opportunity for in-channel and adjacent channel spur
generation
  - May require 3 to 4 dB power amp backoff for Rel-8 PA
  - Some scenarios may require 10 dB backoff.
- Due to the spur issues the status of the enhanced uplink is still to be
decided for Release 10
4. Enhanced multiple antenna transmission

From 4 antennas to 8 antennas (downlink)
- Baseline being 4x4 with 4 UE Receive Antennas
- Peak data rate reached with 8x8 SU-MIMO

From 1 antenna to 4 antennas (uplink)
- Baseline being 2x2 with 2 UE Transmit Antennae
- Peak data rate reached with 4x4 SU-MIMO

Focus is initially on downlink beam steering up to 4x2 antennas

Challenges of higher order antenna transmission
- Creates need for tower-mounted remote radio heads
- Increased power consumption
- Increased product costs
- Physical space for the antennae at both eNB and UE
Combinations of carrier aggregation and layers

There are multiple combinations of CA and layers that can meet the data rates defined for the new and existing UE categories.

The following tables define the most probable cases for which performance requirements will be developed.

<table>
<thead>
<tr>
<th>Downlink</th>
<th>Uplink</th>
</tr>
</thead>
<tbody>
<tr>
<td>UE category</td>
<td>capability [#CCs/BW(MHz)]</td>
</tr>
<tr>
<td>Category 6</td>
<td>1 / 20MHz</td>
</tr>
<tr>
<td></td>
<td>2 / 10+10MHz</td>
</tr>
<tr>
<td></td>
<td>2 / 20+20MHz</td>
</tr>
<tr>
<td></td>
<td>2 / 10+20MHz</td>
</tr>
<tr>
<td></td>
<td>2 / 20+20MHz</td>
</tr>
<tr>
<td>Category 7</td>
<td>1 / 20MHz</td>
</tr>
<tr>
<td></td>
<td>2 / 10+20MHz</td>
</tr>
<tr>
<td></td>
<td>2 / 10+20MHz</td>
</tr>
<tr>
<td>Category 8</td>
<td>2 / 20+20MHz</td>
</tr>
</tbody>
</table>
4. Enhanced multiple antenna transmission
Design and test challenges

- Higher order MIMO has a similar impact on the need for simultaneous transceivers as does carrier aggregation
- However, there is an additional challenge in that the antennas also have to multiply in number
- MIMO antennas also require to be de-correlated
- It is very hard to design a multi-band, MIMO antenna in a small space with good de-correlation
- This makes conducted testing of higher order MIMO terminals largely irrelevant in predicting the actual radiated performance in an operational network
- There is a study item in Rel-10 looking at MIMO Over the Air (OTA) testing which will address antenna performance
5. Coordinated Multi-Point – (CoMP)

**Downlink**
- Coordinated scheduling / beamforming
  - Payload Data is required only at the serving cell
- Coherent combining (also known as cooperative MIMO) / fast switching
  - Payload data is required at all transmitting eNB
  - Requires high speed symbol-level backhaul between eNB

**Uplink**
- Simultaneous reception requires coordinated scheduling
5. CoMP status

• Recent simulation by RAN WG1 has shown initial CoMP performance improvement to be in the 5% to 15% range.
• This is not considered sufficient to progress this aspect of the proposals within the Rel-10 timeframe
• Recent results from the EASY-C testbed also show limited performance gains in lightly loaded networks with minimal or no interference
• CoMP will be studied further for Release 11
• It remains unclear what eNB testing of CoMP might entail since it is very much a system level performance gain and very difficult to emulate
6. In-channel relay and backhaul

- Basic in-channel relaying uses a relay node (RN) that receives, amplifies and then retransmits DL and UL signals to improve coverage.

- Main use cases:
  - Urban or indoor throughput
  - Add dead zone coverage
  - Extend coverage in rural areas

- Advanced relays at layer 2 can decode transmissions before retransmitting them.
- The protocol stack of the RN can be extended up to Layer 3 to create a wireless router that operates in the same way that a normal eNB operates – its own resource allocation and scheduling.
6. In-channel relay and backhaul
Design and test challenges

- From the UE perspective, Relaying is completely transparent
- The challenge is all on the network side
- For the system to work, the link budget from the relay node to the macro eNB must be good
  - This implies line of sight positioning
- The main operational challenge with getting relaying to work will be in the management of the UE
  - The UE has to hand over to the relay node when in range
  - It must release the relay node when out of range
- If this process is not well-managed, the performance of the cell could go down not up
- Multi-hop relaying for coverage should be easier
  - e.g. a valley with no cabled backhaul
7. Home eNB mobility enhancements

- The HeNB (Femtocell) radio channel could be a channel shared with a larger cell (known as co-channel deployment) or it could be a dedicated channel.
- The femtocell connection back into the core network is provided locally by an existing DSL or cable internet connection.
- The concept of Home eNB (femtocells) is not new to LTE-A.
- In Release 8 femtocells were introduced for UMTS.
- In Release 9 they were introduced for LTE (HeNB).
- In Release 9 only inbound mobility (macro to HeNB) was fully specified.
- In Release 10 there will be further enhancements to enable HeNB to HeNB mobility.
- This is very important for enterprise deployments.
8. Customer Premises Equipment (CPE)

- The CPE is a “mobile” intended for fixed (indoor) operation
- The antenna may be internal (omni) or external (directional)
- The max output power is increased to 27 dBm
- Lack of concern for power consumption and a better radio link budget mean the CPE can deliver much higher performance e.g. For rural broadband applications
9. Heterogeneous Network Support

• LTE-Advanced intends to address the support needs of heterogeneous networks that combine low power nodes (such as picocells, femtocells, repeaters, and relay nodes) within a macrocell.

• Deployment scenarios under evaluation are detailed in TR 36.814 Annex A.
10. Self Optimizing networks (SON)

- Today’s cellular systems are very much centrally planned, and the addition of new nodes to the network involves expensive and time-consuming work, site visits for optimization, and other deployment challenges.
- One of the enhancements being considered for LTE-Advanced is the self-optimizing network (SON).
- The intent is to substantially reduce the effort required to introduce new nodes to the network. There are implications for radio planning as well as for the operations and maintenance (O&M) interface to the base station.
- Some limited SON capability was introduced in Release 8 and is being further elaborated in Release 9 and Release 10.
LTE-Advanced summary

• LTE-A is 3GPP’s submission to ITU-R IMT-Advanced “4G” program
• LTE-A is an evolution of LTE and is about two years behind LTE in standards
• Rel-8 LTE almost meets the IMT-Advanced requirements except for UL spectral efficiency and peak rates requiring wider bandwidths.
• Bandwidth up to 100MHz through aggregation of 20 MHz carriers
• Up to 1 Gbps (low mobility) with 8x8 MIMO
• Key new technologies include: carrier aggregation, enhanced uplink and advanced MIMO
• Spectral efficiency performance targets are a step up from the already very challenging Rel-8 LTE targets
• LTE-A Deployment timing is hard to predict and will depend heavily on the rollout of LTE