3GPP Radio Access Networks
LTE-Advanced Status

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3GPP TSG-RAN Chairman
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- LTE Release 8&9 overviews
- LTE Release 10 (LTE-Advanced)
  - Motivation
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3GPP TSG-RAN
Standardisation Activities
Releases of 3GPP Specifications

1999 - W-CDMA
2000 - 1.28Mcps TDD
2001 - HSDPA
2002 - HSUPA, MBMS
2005 - Release 8 LTE
2006 - Release 7 HSPA+ (MIMO, HOM etc.)
2007 - Release 6 HSDPA
2008 - Release 5
2009 - Release 4
2011 - ITU-R WP5D meeting in Oct. 2010 as a IMT-Advanced technology
2012 - Release 10 LTE-Advanced
2013 - Release 9 Minor LTE enhancements

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# Technology Evolution path in 3GPP Standards

<table>
<thead>
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<tbody>
<tr>
<td><strong>25 series</strong></td>
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</tr>
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<tr>
<td>HSDPA</td>
<td>HSUPA</td>
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<td><strong>HSPA+</strong></td>
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<tr>
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<td><strong>LTE-A</strong></td>
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LTE Asia, 6th September 2011
LTE and HSPA Evolutions

Peak Throughput (bps)

10 M 100 M 1 G 10 G

HSPA evolution

14 Mbps

64QAM or 2x2 MIMO

Dual cell (10 MHz BW)

LTE evolution

14 Mbps

21-28 Mbps

64QAM or 2x2 MIMO

Dual cell (10 MHz BW)

21 Mbps

64QAM, 4x4 MIMO, 20MHz BW

84 Mbps

2x2 MIMO, 4 carrier (20 MHz BW)

168 Mbps

64QAM, 8x8 MIMO, 100MHz BW

3 Gbps

336 Mbps?

2x2 MIMO, 8 carrier (40 MHz BW)

300 Mbps

64QAM, 8x8 MIMO, 100MHz BW

2x2 MIMO, 4 carrier (20 MHz BW)

3 Gbps

64QAM, 8x8 MIMO, 100MHz BW

2x2 MIMO, 8 carrier (40 MHz BW)

336 Mbps?
LTE Release 8 & 9
LTE Release 8 Key Features

High spectral efficiency
- OFDM in Downlink
  - Robust against multipath interference
  - High affinity to advanced techniques
    - Frequency domain channel-dependent scheduling
    - MIMO
- DFTS-OFDM ("Single-Carrier FDMA") in Uplink
  - Low PAPR
  - User orthogonality in frequency domain
- Multi-antenna application

Very low latency
- Short setup time & Short transfer delay
- Short HO latency and interruption time
  - Short TTI
  - RRC procedure
  - Simple RRC states

Support of variable bandwidth
- 1.4, 3, 5, 10, 15 and 20 MHz
Rel-9 LTE features

Small enhancements from LTE Release 8 mainly for higher layer

- HeNB (Home eNode B)
  - HeNB Access Mode
    - Rel-8: Closed Access Mode
    - Rel-9: Open and Hybrid Mode
  - HeNB Mobility between HeNB and macro
    - Rel-8: Out-bound HO
    - Rel-9: in-bound and inter-CSG HO
- SON (self-organizing networks)
  - Rel-8: Self configuration, Basic self-optimization
  - Rel-9: RACH optimization, etc
- MBMS
  - Rel-8: Radio physical layer specs
  - Rel-9: Radio higher layer and NW interface specs
- LCS (Location Services)
  - Rel-8: U-Plane solutions
  - Rel-9: C-Plane solutions, e.g. OTDOA
LTE Release 10 (LTE-Advanced)
Motivation of LTE-Advanced

- IMT-Advanced standardisation process in ITU-R
- Additional IMT spectrum band identified in WRC07
- Further evolution of LTE Release 8 and 9 to meet:
  - Requirements for IMT-Advanced of ITU-R
  - Future operator and end-user requirements
Key Requirements for LTE-Advanced

- LTE-Advanced shall be deployed as an evolution of LTE Release 8 and on new bands.
- LTE-Advanced shall be backwards compatible with LTE Release 8

Smooth and flexible system migration from Rel-8 LTE to LTE-Advanced

LTE-Advanced (LTE Release 10)

LTE-Advanced evolved from LTE Rel-8

LTE-Advanced contains all features of LTE Rel-8,9 and additional features for further evolution

LTE-Advanced backward compatibility with LTE Rel-8

An LTE-Advanced terminal can work in an LTE Rel-8 cell

An LTE Rel-8 terminal can work in an LTE-Advanced cell
## Target performance of LTE-Advanced

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

### Average spectrum efficiency [bps/Hz/cell]

<table>
<thead>
<tr>
<th>Antenna configuration</th>
<th>Rel. 8 LTE*¹</th>
<th>LTE-Advanced*²</th>
<th>IMT-Advanced*³</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DL</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-by-2</td>
<td>1.69</td>
<td>2.4</td>
<td>–</td>
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<tr>
<td>4-by-2</td>
<td>1.87</td>
<td>2.6</td>
<td>2.2</td>
</tr>
<tr>
<td>4-by-4</td>
<td>2.67</td>
<td>3.7</td>
<td>–</td>
</tr>
<tr>
<td><strong>UL</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-by-2</td>
<td>0.74</td>
<td>1.2</td>
<td>–</td>
</tr>
<tr>
<td>2-by-4</td>
<td>–</td>
<td>2.0</td>
<td>1.4</td>
</tr>
</tbody>
</table>

### Cell edge user throughput [bps/Hz/cell/user]

<table>
<thead>
<tr>
<th>Antenna configuration</th>
<th>Rel. 8 LTE*¹</th>
<th>LTE-Advanced*²</th>
<th>IMT-Advanced*³</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DL</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-by-2</td>
<td>0.05</td>
<td>0.07</td>
<td>–</td>
</tr>
<tr>
<td>4-by-2</td>
<td>0.06</td>
<td>0.09</td>
<td>0.06</td>
</tr>
<tr>
<td>4-by-4</td>
<td>0.08</td>
<td>0.12</td>
<td>–</td>
</tr>
<tr>
<td><strong>UL</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-by-2</td>
<td>0.024</td>
<td>0.04</td>
<td>–</td>
</tr>
<tr>
<td>2-by-4</td>
<td>–</td>
<td>0.07</td>
<td>0.03</td>
</tr>
</tbody>
</table>

*¹ See TR25.912(Case 1 scenario)  *² See TR36.913(Case 1 scenario)  *³ See ITU-R M.2135(Base Coverage Urban scenario)
Key Features in LTE Release 10

- **Support of Wider Bandwidth (Carrier Aggregation)**
  - Use of multiple component carriers (CC) to extend bandwidth up to 100 MHz
  - Common physical layer parameters between component carrier and LTE Rel-8 carrier
    - Improvement of peak data rate, backward compatibility with LTE Rel-8

- **Advanced MIMO techniques**
  - Extension to up to 8-layer transmission in downlink
  - Introduction of single-user MIMO up to 4-layer transmission in uplink
  - Enhancements of multi-user MIMO
    - Improvement of peak data rate and capacity

- **Heterogeneous network and eICIC (enhanced Inter-Cell Interference Coordination)**
  - Interference coordination for overlaid deployment of cells with different Tx power
    - Improvement of cell-edge throughput and coverage

- **Relay**
  - Type 1 relay supports radio backhaul and creates a separate cell and appear as Rel. 8 LTE eNB to Rel. 8 LTE UEs
    - Improvement of coverage and flexibility of service area extension

- **Coordinated Multi-Point transmission and reception (CoMP)**
  - Support of multi-cell transmission and reception
    - Improvement of cell-edge throughput and coverage
The self-evaluation results show:

- For LTE Release 10, FDD RIT and TDD RIT Component meets the minimum requirements of all 4 required test environments, individually.
- Baseline configuration exceeding ITU-R requirements with minimum extension
  - LTE release 8 fulfills the requirements in most cases (no extensions needed)
  - Extensions to Multi-user MIMO from Release 8 fulfills the requirements in some scenarios (Urban Macro/Micro DL)

Spectrum Efficiency: FDD DL, Indoor (MHz)
DOCOMO developed LTE-Advanced experimental system aligned with 3GPP LTE Release 10 specifications

- **Laboratory experiments**
  - **Total throughput of 1 Gbps** for 2 Mobile stations in downlink was achieved by applying 4x2 multi-user MIMO technique

- **Field experiments**
  - **Throughput of 600 Mbps** in downlink and **200 Mbps** in uplink was achieved by applying 2x2 single-user MIMO technique

**Laboratory**

- **Mobile station**
  - Tx Power: 1 W/ant.
  - Antenna: 2 Tx/Rx
  - UL Bandwidth: 40 MHz

- **Base station**
  - Tx power: 10 W/ant.
  - Antenna: 4 Tx/Rx
  - DL Bandwidth: 100 MHz

**Field @ Yokosuka, Japan**

- **Mobile station**
  - Tx Power: 1 W/ant.
  - Antenna: 2 Tx/Rx
  - UL Bandwidth: 40 MHz

LTE-Advanced key technologies, e.g., carrier aggregation and enhanced MIMO
NTT DOCOMO Field Trial

Downlink
- 600 Mbps
- 5 CCs 2x2 SU-MIMO

Uplink
- 200 Mbps
- 2 CCs 2x2 SU-MIMO

Panorama View
- 10 km/h
LTE Release 11
(LTE-Advanced)
Release 11 works for further enhancements of LTE-Advanced and HSPA have been started to complete by Sep. 2012.

So many Work Items and Study Items are proposed based on various requirements for further enhancements.

<table>
<thead>
<tr>
<th>WI/SI for LTE or LTE&amp;HSPA</th>
<th>WI/SI for HSPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Further Enhanced Non CA-based ICIC for LTE</td>
<td>1 Eight carrier HSDPA</td>
</tr>
<tr>
<td>2 LTE Carrier Aggregation Enhancements</td>
<td>2 Uplink Transmit Diversity for HSPA – Closed Loop</td>
</tr>
<tr>
<td>3 Study on Coordinated Multi-Point Operation for LTE</td>
<td>3 Study on Uplink MIMO</td>
</tr>
<tr>
<td>4 Study on Enhanced Uplink Transmission for LTE</td>
<td>4 Study on HSDPA multipoint transmission</td>
</tr>
<tr>
<td>5 Study on further Downlink MIMO enhancements for LTE-Advanced</td>
<td>5 Study item on HSPA enhancement for LCR TDD</td>
</tr>
<tr>
<td>6 Study on Further Enhancements to LTE TDD for DL-UL Interference Management and Traffic Adaptation</td>
<td>6 Four Branch MIMO transmission for HSDPA</td>
</tr>
<tr>
<td>7 Coordinated Multi-Point Operation for LTE</td>
<td>7 Uplink MIMO with 64QAM for HSUPA</td>
</tr>
<tr>
<td>8 Provision of low-cost MTC UEs based on LTE</td>
<td>8 Further Enhancements to CELL_FACH</td>
</tr>
<tr>
<td>9 Proposed SI on LTE Coverage Enhancements</td>
<td>9 HSDPA Multiflow Data Transmission</td>
</tr>
<tr>
<td>10 Improvements to LTE Relay Backhaul</td>
<td>10 Single Radio Voice Call Continuity from UTRAN/GERAN to E-UTRAN/HSPA</td>
</tr>
<tr>
<td>11 Study on LTE Device to Device Discovery and Communication - Radio Aspects</td>
<td>11 SID: Introduction of Hand phantoms for UE OTA antenna testing</td>
</tr>
<tr>
<td>12 Network-Based Positioning Support for LTE</td>
<td></td>
</tr>
</tbody>
</table>
The page contains information about the UMTS/LTE 3500MHz and LTE Advanced Carrier Aggregation of Band 4 and Band 12. It also includes studies on UMTS/LTE in the 900 MHz band and interference analysis between 800~900 MHz bands. The page features a spectrum table and discusses various bands and configurations.

### Spectrum Explosion in 3GPP

#### E-UTRA operating bands in the latest 3GPP spec

<table>
<thead>
<tr>
<th>E-UTRA Operating Band</th>
<th>Uplink (UL) operating band</th>
<th>Downlink (DL) operating band</th>
<th>Duplex Mode</th>
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<tbody>
<tr>
<td>BS receive</td>
<td>BS transmit</td>
<td>UE transmit</td>
<td></td>
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<tr>
<td>f_UL_low - f_UL_upp</td>
<td>f_DL_low - f_DL_upp</td>
<td>f_UL_low - f_UL_upp</td>
<td>FDD</td>
</tr>
<tr>
<td>1</td>
<td>1920 MHz – 1980 MHz</td>
<td>2110 MHz – 2170 MHz</td>
<td>FDD</td>
</tr>
<tr>
<td>2</td>
<td>1850 MHz – 1910 MHz</td>
<td>1930 MHz – 1990 MHz</td>
<td>FDD</td>
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<td>3</td>
<td>1710 MHz – 1785 MHz</td>
<td>1805 MHz – 1880 MHz</td>
<td>FDD</td>
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<tr>
<td>4</td>
<td>1710 MHz – 1755 MHz</td>
<td>2110 MHz – 2155 MHz</td>
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</tr>
<tr>
<td>5</td>
<td>824 MHz – 849 MHz</td>
<td>869 MHz – 894 MHz</td>
<td>FDD</td>
</tr>
<tr>
<td>6</td>
<td>830 MHz – 840 MHz</td>
<td>875 MHz – 885 MHz</td>
<td>FDD</td>
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<td>7</td>
<td>2500 MHz – 2570 MHz</td>
<td>2620 MHz – 2690 MHz</td>
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<tr>
<td>8</td>
<td>880 MHz – 915 MHz</td>
<td>925 MHz – 960 MHz</td>
<td>FDD</td>
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<tr>
<td>9</td>
<td>1749.9 MHz – 1784.9 MHz</td>
<td>1844.9 MHz – 1873.9 MHz</td>
<td>FDD</td>
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<td>10</td>
<td>1710 MHz – 1770 MHz</td>
<td>2110 MHz – 2170 MHz</td>
<td>FDD</td>
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<tr>
<td>11</td>
<td>1427.9 MHz – 1447.9 MHz</td>
<td>1475.9 MHz – 1495.9 MHz</td>
<td>FDD</td>
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<tr>
<td>12</td>
<td>699 MHz – 716 MHz</td>
<td>729 MHz – 746 MHz</td>
<td>FDD</td>
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<td>13</td>
<td>777 MHz – 787 MHz</td>
<td>746 MHz – 756 MHz</td>
<td>FDD</td>
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<td>14</td>
<td>788 MHz – 798 MHz</td>
<td>758 MHz – 768 MHz</td>
<td>FDD</td>
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<td>15</td>
<td>Reserved</td>
<td>Reserved</td>
<td>FDD</td>
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<tr>
<td>16</td>
<td>Reserved</td>
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<td>704 MHz – 716 MHz</td>
<td>734 MHz – 746 MHz</td>
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<td>18</td>
<td>815 MHz – 830 MHz</td>
<td>860 MHz – 875 MHz</td>
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<td>19</td>
<td>830 MHz – 845 MHz</td>
<td>875 MHz – 890 MHz</td>
<td>FDD</td>
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<tr>
<td>20</td>
<td>832 MHz – 862 MHz</td>
<td>791 MHz – 821 MHz</td>
<td>FDD</td>
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<tr>
<td>21</td>
<td>1447.9 MHz – 1462.9 MHz</td>
<td>1495.9 MHz – 1510.9 MHz</td>
<td>FDD</td>
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<td>22</td>
<td>2000 MHz – 2020 MHz</td>
<td>2180 MHz – 2200 MHz</td>
<td>FDD</td>
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<tr>
<td>23</td>
<td>1626.5 MHz – 1660.5 MHz</td>
<td>1525 MHz – 1559 MHz</td>
<td>FDD</td>
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<td>24</td>
<td>1800 MHz – 1915 MHz</td>
<td>1930 MHz – 1955 MHz</td>
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<td>26</td>
<td>2010 MHz – 2025 MHz</td>
<td>2010 MHz – 2025 MHz</td>
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<td>27</td>
<td>1850 MHz – 1910 MHz</td>
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<td>28</td>
<td>1930 MHz – 1950 MHz</td>
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<td>29</td>
<td>1910 MHz – 1930 MHz</td>
<td>1910 MHz – 1930 MHz</td>
<td>TDD</td>
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<tr>
<td>30</td>
<td>2570 MHz – 2620 MHz</td>
<td>2570 MHz – 2620 MHz</td>
<td>TDD</td>
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<tr>
<td>31</td>
<td>1880 MHz – 1920 MHz</td>
<td>1880 MHz – 1920 MHz</td>
<td>TDD</td>
</tr>
<tr>
<td>32</td>
<td>2300 MHz – 2400 MHz</td>
<td>2300 MHz – 2400 MHz</td>
<td>TDD</td>
</tr>
</tbody>
</table>

### Spectrum band to be standardized by Sep. 2011
- UMTS/LTE 3500MHz
- Extending 850 MHz Upper Band (814 – 849 MHz)

### Spectrum band to be standardized by Sep. 2012
- LTE-Advanced Carrier Aggregation of Band 3 and Band 7
- LTE Advanced Carrier Aggregation of Band 4 and Band 17
- LTE Advanced Carrier Aggregation of Band 4 and Band 13
- LTE Advanced Carrier Aggregation of Band 4 and Band 12
- LTE Advanced Carrier Aggregation of Band 5 and Band 12
- LTE Advanced Carrier Aggregation of Band 20 and Band 7
- LTE Advanced Carrier Aggregation Band 2 and Band 17
- LTE Advanced Carrier Aggregation Band 4 and Band 17
- LTE Advanced Carrier Aggregation Band 5 and Band 5
- LTE Advanced Carrier Aggregation Band 5 and Band 17
- LTE Advanced Carrier Aggregation in Band 41
- LTE Advanced Carrier Aggregation in Band 38
- LTE Downlink FDD 716-728MHz
- LTE E850 - Lower Band for Region 2 (non-US)
- LTE for 700 MHz digital dividend
- Study on Extending 850MHz
- Study on Interference analysis between 800~900 MHz bands
- Study on UMTS/LTE in 900 MHz band
Conclusions

LTE Release 8
- Specification completed and stable
- Commercially deployed and committed to deploy by many operators all over the world

LTE Release 9
- Small enhancements of LTE Release 8
- Specification completed and stable

LTE Release 10
- Stage 3 frozen and stabilized
- Accepted as a technology of IMT-Advanced by ITU-R WP5D
- Materials and specifications submitted to ITU-R WP5D for ITU-R recommendation M.[IMT.RSPEC]

LTE Release 11
- Started with many Work Items and Study Items for further enhancements of LTE Release 10
Thank You

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