LTE Rel-9 and LTE-Advanced in 3GPP

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3GPP TSG-RAN Chairman
Introduction

In 3GPP
- Rel-8 LTE/SAE core specification work has been completed.
- Small improvements are being discussed for Rel-9 LTE/SAE, due to be finalized by end of 2009.
- As LTE Release 10 and beyond, project on LTE-Advanced is on going
  - Study item: LTE-Advanced was approved in March 2008
  - Technology description on LTE-Advanced was submitted to ITU-R WP 5D in June 2009 as a candidate of IMT-Advanced
  - Detailed technical information and self-evaluation results will be provided to ITU-R WP 5D in October

Rel-9 LTE/SAE topics
- Home eNB
- SON (self-organizing networks)
- MBMS
- LCS

LTE-Advanced topics
- Support for wider bandwidth
- Extension of uplink multiple access
- Extension of MIMO techniques
- CoMP (coordinated multiple point transmission and reception)
- Relaying
- Self-evaluation results
LTE Rel-9
Home eNB (HeNB)

- Basic functions for Home eNB are supported in Rel-8.

- HeNB architecture

- CSG (Closed Subscriber Group) control
  - CSG subscription info (allowed CSG ID list) concept in the UE and NW
  - Broadcasting of CSG ID
  - Implementation dependent UE autonomous search for CSG cells
  - No special inbound mobility procedure in Rel-8 to resolve potential PCI confusion
HeNB enhancements in Rel-9

The following enhancements are under discussion:

- **Inbound mobility from macro eNB to HeNB**
  - To resolve PCI confusion at handover (i.e., handover support when different HeNBs neighboring a macro cell are using the same PCI)

- **Support for Hybrid Access modes**
  - Closed access mode: Only UEs belonging to the CSG is entitled to access the cell
  - Hybrid access mode: All UEs are allowed to access the cell, but UEs belonging to the CSG is entitled to access with priority

- **Support of accessibility check in the NW**
  - To provide the support of a secondary access control in the NW in addition to UE’s preliminary access check

- **Local breakout**
  - To reduce load on operator’s core network

- **SON for HeNB**
  - Plug and play
  - Interference coordination

- **Local IP access to home based NW**
- **Local IP access to the Internet**
- **IMS aspect for HeNB**
SON (self-organizing network)

SON is an integral part of LTE. A number of SON features are supported in Rel-8, and work is continuing for Rel-9.

SON solutions can be divided into two categories:

- **Self-configuration**: This function enables the network to automatically perform installation procedure (plug and play)
- **Self-optimisation**: This function enables the network to auto-tune its operational parameters using UE, eNB and performance measurements.

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**Self-Configuration (pre-operational state)**

- **(A) Basic Setup**
  - a-1: configuration of IP address and detection of OAM
  - a-2: authentication of eNB/NW
  - a-3: association to aGW
  - a-4: downloading of eNB software (and operational parameters)

**Self-Optimisation (operational state)**

- **(B) Initial Radio Configuration**
  - b-1: neighbour list configuration
  - b-2: coverage/capacity related parameter configuration

- **(C) Optimization / Adaptation**
  - c-1: neighbour list optimisation
  - c-2: coverage and capacity control
Rel-8 SON features

The following SON features are supported in Rel-8.

- **Self-configuration:**
  - S1 (eNB – core NW) interface dynamic configuration
  - X2 (inter-eNB) interface dynamic configuration
  - Framework for PCI (Physical Cell ID) selection
  - Automatic neighbor cell discovery

- **Self-optimisation:**
  - Basic intra-LTE mobility load balancing
    - Resource-related information exchange between eNBs over X2 I/F
  - Interference management
    - UL interference-related information exchange between eNBs over X2 I/F

- **Other:**
  - Standardized eNB measurements for multi-vendor SON interworking
For Rel-9, the following self-optimisation features are being discussed.

- **Mobility load balancing**
  - Optimisation of cell reselection/ handover parameters to distribute traffic load across the network.

- **Mobility robustness optimisation**
  - Optimisation of cell reselection/ handover parameters to minimise radio link failures due to mobility.

- **Common channel configuration optimisation**
  - Optimisation of common channel configuration, e.g., random access channel configuration based on eNB measurements.

- **Minimisation of drive tests**
  - Logging and reporting of various measurement data (e.g., location information, radio link failure events, throughputs) by the UE and collection of data in a server to minimise drive tests run by operators.

- **Coverage/ capacity optimisation**
  - Optimisation of system parameters to maximise (adjust to the desired balance between) system coverage and capacity.
E-MBMS functionalities

E-MBMS discussion was postponed in Rel-8 due to lack of time and is continued in Rel-9.

Basic Rel-8 L2/L3 architecture is reused in Rel-9.

E-MBMS in Rel-9 will support the following functionalities:
- Broadcast mode and enhanced broadcast mode
- Static MBSFN area (only)
- One cell belongs to only one MBSFN area
- Multiple non overlapping MBSFN areas in a PLMN
- Broadcast transmission only in a shared carrier deployment (no dedicated carrier)
- MBSFN without feedback (i.e. no ACK/ NACK or counting)
- Signalling support, e.g. MCCH over LTE-Uu

Note that the following functionalities are not supported:
- MBMS in Home eNB
- Mobility procedures to support MBMS continuity

<table>
<thead>
<tr>
<th>C/U-plane</th>
<th>Logical Entity</th>
<th>Function</th>
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</table>
| C-plane   | MME (or MBMS GW C-plane) | - Session control
- Session control message filtering for a certain service area (FFS) |
| U-plane   | MBMS GW U-plane       | - U-plane data IP Multicast transmission
- IP Multicast address allocation for each eNB |
Location service (LCS)

Location method candidates in LTE:
- Cell coverage based positioning method
- OTDOA positioning method
- A-GNSS based positioning methods
- U-TDOA positioning method

Applicability of each method is being evaluated.

General LCS architecture:

The necessary support in each interface (LTE-Uu, S1, SLs, SLg) is under discussion in the relevant 3GPP WGs.
Protocol architecture in the following figures are adopted for LCS in LTE.

- LPP (LTE Positioning Protocol) is terminated between UE and E-SMLC
- LPPa (LTE Positioning Protocol Annex) is terminated between eNB and E-SMLC

**Fig.1: Protocol Stack for signaling between UE and E-SMLC**

**Fig.2: Protocol stack for signaling between eNB and E-SMLC**
Other Rel-9 enhancements

- IMS emergency call support
  - Including USIM-less UE support
- PWS (Public Warning System)/ CMAS (Commercial Mobile Alert System) support
  - New SIB to support up to 64 concurrent CMAS notifications
  - S1 procedure modifications to support CMAS transfer
- Vocoder adaptation
  - Based on ECN (RFC3168)
- RLF (Radio Link Failure) enhancements
  - Dedicated configuration of RLF timers
  - GBR bearer handling improvements
- SSAC (service specific access control)
  - Differentiated access control of MMTEL-voice/ video
- CS fallback enhancements
  - Measurement enhancements for faster procedure
  - Simultaneous fallback to CDMA 1xRTT + HRPD
LTE-Advanced
## Schedule for IMT-Advanced

<table>
<thead>
<tr>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
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- **5D meetings**
- **ITU WP5D meetings**
- **WRC-07**
- **SDOs and ARIB etc.**
- **3GPP RAN #38**
- **LTE**
- **LTE Advanced CR phase**
- **WS**
- **2nd WS**
- **Technical specifications**

### Key Milestones:

- **2007:** Spectrum identified
- **2008:** Circular letter
- **2009:** Initial technology submission of LTE-Advanced
- **2010:** Complete submission incl. self-evaluation of LTE-Advanced
- **2011:** Study item approved in 3GPP

**LTE-Advanced** – candidate for IMT-Advanced in 3GPP (3rd Generation Partnership Project)
General Requirements

- LTE-Advanced is an evolution of LTE
- All relevant requirements of LTE are valid also for LTE-Advanced
- LTE-Advanced shall meet or exceed IMT-Advanced requirements within the ITU-R time plan
- Targets of LTE-Advanced are adopted as long term targets

![Diagram showing system performance over time with Rel-8 LTE and LTE-Advanced targets]

IMT-Advanced requirements and time plan
### System Performance Requirements (1)

#### Peak data rate and peak spectrum efficiency

<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>
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<tr>
<td>DL</td>
<td>15</td>
<td>30</td>
<td>15</td>
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<tr>
<td>UL</td>
<td>3.75</td>
<td>15</td>
<td>6.75</td>
</tr>
</tbody>
</table>

*“100 Mbps for high and 1 Gbps for low mobility” is one of the key features as written in Circular Letter (CL)*

#### Peak data rate
- 1 Gbps data rate will be achieved by 4-by-4 MIMO and transmission bandwidth wider than approximately 70 MHz

#### Peak frequency efficiency
- DL: Rel. 8 LTE satisfies IMT-Advanced requirement
- UL: Need to double to satisfy IMT-Advanced requirement
## System Performance Requirements (2)

### Capacity and cell-edge user throughput

<table>
<thead>
<tr>
<th></th>
<th>Ant. Config.</th>
<th>Rel. 8 LTE</th>
<th>LTE-Advanced*</th>
<th>IMT-Advanced**</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Capacity [bps/Hz/cell]</strong></td>
<td></td>
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<tr>
<td>DL</td>
<td>2-by-2</td>
<td>1.69</td>
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<tr>
<td></td>
<td>4-by-2</td>
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<td></td>
<td>4-by-4</td>
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<tr>
<td>UL</td>
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<td>0.74</td>
<td>1.2</td>
<td>–</td>
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<tr>
<td></td>
<td>2-by-4</td>
<td>–</td>
<td>2.0</td>
<td>1.4</td>
</tr>
<tr>
<td><strong>Cell-edge user throughput [bps/Hz/cell/user]</strong></td>
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<td></td>
<td></td>
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<tr>
<td>DL</td>
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<td>0.07</td>
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<tr>
<td></td>
<td>4-by-2</td>
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<td>0.09</td>
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<td></td>
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<td>0.12</td>
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<td>0.04</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>2-by-4</td>
<td>–</td>
<td>0.07</td>
<td>0.03</td>
</tr>
</tbody>
</table>

* For Case 1 scenario in 3GPP  
** For Base Coverage Urban scenario in IMT.EVAL

### DL/UL: Need further improvements to satisfy IMT-Advanced requirements on capacity and cell-edge user throughput

- DL/UL: Need further improvements to satisfy IMT-Advanced requirements on capacity and cell-edge user throughput.
Support of wider bandwidth
- Carrier aggregation to achieve wider bandwidth
- Support of spectrum aggregation
  ➔ Peak data rate, spectrum flexibility

Multiple access and radio parameters
- Rel. 8 LTE based multiple access per component carrier
- Same radio parameters as those of Rel. 8 LTE
  ➔ Backward compatibility

Advanced MIMO techniques
- Extension to up to 8-layer transmission in downlink
- Introduction of single-user MIMO up to 4-layer transmission in uplink
  ➔ Peak data rate, capacity, cell-edge user throughput

Coordinated multipoint transmission and reception (CoMP)
- CoMP transmission in downlink
- CoMP reception in uplink
  ➔ Cell-edge user throughput, coverage, deployment flexibility

Relaying
- Type 1 relays create a separate cell and appear as Rel. 8 LTE eNB to Rel. 8 LTE UEs
  ➔ Coverage, cost effective deployment
Carrier Aggregation for Wider Bandwidth

- Wider bandwidth transmission using carrier aggregation
  - Entire system bandwidth up to, e.g., 100 MHz, comprises multiple basic frequency blocks called component carriers (CCs)
    - Satisfy requirements for peak data rate
  - Each CC is backward compatible with Rel. 8 LTE
    - Maintain backward compatibility with Rel. 8 LTE
  - Carrier aggregation supports both contiguous and non-contiguous spectrum, and asymmetric bandwidth for FDD
    - Achieve flexible spectrum usage

System bandwidth, e.g., 100 MHz

- CC, e.g., 20 MHz

UE capabilities

- 100-MHz case
- 40-MHz case
- 20-MHz case (Rel. 8 LTE)
**Downlink Multiple Access Scheme**

- **Downlink**: OFDMA with component carrier (CC) based structure
  - Priority given to reusing Rel. 8 specification for low-cost and fast development
  - One transport block (TB), which corresponds to channel coding block and retransmission unit, is mapped within one CC
  - Parallel-type transmission for multi-CC transmission
  - Good affinity to Rel. 8 LTE specifications
  - No additional frequency diversity gain from Rel. 8 LTE
Uplink Multiple Access Scheme

- **Uplink:** $N$-times DFT-Spread OFDM
  - Achieve wider band transmission by avoiding physical uplink control channel (PUCCH)
    - Satisfy requirements for peak data rate while maintaining backward compatibility
  - Adopt parallel-type transmission for multi-CC transmission allowing increase in peak-to-average power ratio (PAPR)
    - Reuse Rel. 8 specification for low-cost and fast development

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Diagram:

```
PUCCH region  CC  CC
<p>| | | |</p>
<table>
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<tr>
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<td></td>
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</tbody>
</table>
PUSCH (Physical uplink shared channel)
```

“$N$-times DFT-Spread OFDM”
Advanced MIMO techniques in Downlink

- Extension up to 8-stream transmission
  - Rel. 8 LTE supports up to 4-stream transmission, LTE-Advanced supports up to 8-stream transmission
  
  ➤ Satisfy requirement for peak spectrum efficiency, i.e., 30 bps/Hz

- Specify additional reference signals (RS)
  - Two RSs are specified in addition to Rel. 8 common RS (CRS)
    - Channel state information RS (CSI-RS)
    - UE-specific demodulation RS (DM-RS)
      - UE-specific DM-RS, which is precoded, makes it possible to apply non-codebook based precoding
      - UE-specific DM-RS will enable application of enhanced multi-user beamforming such as zero forcing (ZF) for, e.g., 4-by-2 MIMO

Higher-order MIMO up to 8 streams

Enhanced MU-MIMO

Max. 8 streams

CSI feedback
Introduction of single user (SU)-MIMO up to 4-stream transmission

- Whereas Rel. 8 LTE does not support SU-MIMO, LTE-Advanced supports up to 4-stream transmission
  ➔ Satisfy requirement for peak spectrum efficiency, i.e., 15 bps/Hz

Signal detection scheme with affinity to DFT-Spread OFDM for SU-MIMO

- Turbo serial interference canceller (SIC) is assumed for eNB receiver to achieve higher throughput performance for DFT-Spread OFDM
  ➔ Improve user throughput maintaining single-carrier based signal transmission

Max. 4 streams

SU-MIMO up to 4 streams
Downlink CoMP Transmission

- CoMP transmission schemes in downlink
  - Joint processing (JP)
    - Joint transmission (JT): Downlink physical shared channel (PDSCH) is transmitted from multiple cells with precoding using DM-RS among coordinated cells
    - Dynamic cell selection: PDSCH is transmitted from one cell, and the cell is dynamically selected
  - Coordinated scheduling/beamforming (CS/CB)
    PDSCH is transmitted only from one cell site, and scheduling/beamforming is coordinated among cells

- CSI feedback (FB)
  - Explicit CSI FB (direct channel FB) is investigated to conduct precise precoding, as well as implicit CSI FB (precoding matrix index FB) based on Rel. 8 LTE ➔ Tradeoff between gain and FB signaling overhead

Coherent combining or
dynamic cell selection

Joint transmission/dynamic cell selection

Coordinated scheduling/beamforming
CoMP reception scheme in uplink

- Physical uplink shared channel (PUSCH) is received at multiple cells
- Scheduling is coordinated among the cells
  - Improve especially cell-edge user throughput
- Note that CoMP reception in uplink is implementation matter and does not require change of radio interface

Receiver signal processing at central eNB (e.g., MRC, MMSEC)

Multipoint reception
## Relaying use cases

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Mobility</th>
<th>Hops</th>
<th>Targets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban Hot Spot</td>
<td>Fixed, Nomadic</td>
<td>Two hops</td>
<td>Coverage and Throughput</td>
</tr>
<tr>
<td>Dead Spot</td>
<td>Fixed</td>
<td>Two hops or Multi-hops</td>
<td>Coverage</td>
</tr>
<tr>
<td>Indoor Hot Spot</td>
<td>Fixed, Nomadic</td>
<td>Two hops</td>
<td>Throughput</td>
</tr>
<tr>
<td>Rural Area</td>
<td>Fixed</td>
<td>Two hops</td>
<td>Coverage and Throughput</td>
</tr>
<tr>
<td>Emergency or Temporary Coverage</td>
<td>Nomadic</td>
<td>Two hops or Multi-hops</td>
<td>Coverage and Throughput</td>
</tr>
<tr>
<td>Wireless Backhaul only</td>
<td>Fixed</td>
<td>Two hops or Multi-hops</td>
<td>Coverage or Throughput</td>
</tr>
<tr>
<td>Group Mobility</td>
<td>Mobile</td>
<td>Two hops</td>
<td>Throughput</td>
</tr>
</tbody>
</table>
Type 1 (Layer 3) relaying

- **Type 1 relaying** is assumed as one type of relaying (other types are FFS).
  - Layer 3 (RRC) is terminated in Relay Node for the Uu (Relay Node – UE) interface.
  - L1/L2 signaling (CQI, HARQ, etc) is performed between Relay Node and UE.
  - Un (Donor eNB – Relay Node) transmission is time multiplexed with Uu for UEs connected to the Relay Node.
  - Relay Node has their own PCI (physical cell identity).

→ From a Rel-8 UE, a Relay Node is seen as Rel-8 eNB.

![Diagram of Type 1(Layer 3) relaying](image)

- **Core Node**
- **Donor eNB**
- **Relay Node**
- **UE**

- **SDU assembly**
- **PDU processing**
- **eNB functionality**
- **Decoding**
- **Encoding**
- **Amplifier**

**TDM**

- **Uu**
- **Un** (wireless)

*Diagram showing the flow of data from Core Node to UE via Donor eNB and Relay Node.*
Self-evaluation results

Self-evaluation for LTE-Advanced was conducted in 3GPP

The self-evaluation results shows:

*Baseline configuration exceeding ITU-R requirements with minimum extension*

- LTE release 8 fulfills the requirements in most cases (no extensions needed)
- Minor extensions in some scenarios (Urban Macro/Micro DL)

*More advanced configurations with further enhanced performance*

- Many (18) companies participated in simulations
  - **High reliability**

Self evaluation results will be captured in Technical Report TR 36.912 and provided to ITU-R WP 5D meeting in October.