LTE systems: overview
Outline

1. Standard status
2. Signal structure
3. Signal generation
4. Physical layer procedures
5. System architecture
6. References
Long Term Evolution


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3GPP - Series 36:

RF processing aspects
Physical layer [layer 1]
MAC, RRC [layer 2,3]

Peak rate: 150, 300 Mbps (MIMO Downlink), 75 Mbps (Uplink)
FDD (Half or Full duplex): (time)frame structure 1
TDD: (time)frame structure 2

**Bandwidths**: 1.4 - 20 MHz

**Carriers** for FDD and TDD: several bandwidths in 698 – 915 MHz, 1.4 GHz, 1.7 – 2 GHz, 2.3 – 2.5GHz

**Downlink** resource allocation: OFDMA x frame

**Uplink** resource allocation: SC-OFDM x frame

The downlink and uplink (time, frequency) grids are composed by **resource blocks** of 12 sub-carriers (frequency spacing of 15 kHz – 180 kHz) x 0.5 ms, equal to 1 (time)slot.

A user is assigned a rectangular set of resource blocks.
Radio frame 1 = 10 ms

Slot number

Subframe

resource block (RB)

resource element = 1 sub-carrier x 1 OFDMA symbol time

N subcarriers
Radio frame 2 = 2 half-frames = 2 x 5 ms

Subframe

Slot number

0 1

resource block (RB)

resource element = 1 sub-carrier x 1 SC-OFDM symbol time

Several uplink/downlink divisions of subframes

DwPTS, GP, UpPTS

N subcarriers

0 4 9

DwPTS, GP, UpPTS
Main operations for downlink signal generation (multiple antennas)
## Encoding

<table>
<thead>
<tr>
<th>Channels</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>UL-SCH, DL-SCH (UL-, DL- Shared)</td>
<td>Turbo parallel code, $R = 1/3$</td>
</tr>
<tr>
<td>PCH (Paging), MCH (Multicast)</td>
<td></td>
</tr>
<tr>
<td>BCH (Broadcast)</td>
<td>Tailbiting convolutional code, $R = 1/3$</td>
</tr>
</tbody>
</table>

## Modulation: QPSK, 16-QAM, 64-QAM
Physical layer procedures

- **Synchronization**
  - Cell search
  - Timing

- **Power control**
  - **Downlink:** energy per resource element
  - **Uplink:** average power over an SC-FDMA symbol

- **Random access**

- **Reporting of several measurements / indicators:**
  - e.g. channel quality indication (CQI)

- **Link adaptation:** AMC (adaptive modulation and coding).
E-UTRAN: eNBs providing the E-UTRA user plane (PDCP/RLC/MACPHY) and control plane (RRC) protocol for the UEs.

eNBs are interconnected with each other by means of X2 interface.

eNBs are connected by means of the S1-MME interface to the MME (Mobility Management Entity) and to the Serving Gateway (S-GW) by means of the S1-U (EPC, Evolved Packet Core).
Main functions

**eNB**
- Functions for Radio Resource Management: Radio Bearer Control, Radio Admission Control, Connection Mobility, Control, Dynamic allocation of resources to UEs in both uplink and downlink (scheduling);
- Routing of User Plane data towards Serving Gateway;
- Scheduling and transmission of paging, broadcast and ETWS messages (originated from the MME);
- Measurement and reporting configuration for mobility and scheduling;

**MME**
- RRC sublayer
  - Broadcast of System Information related to the non-access stratum (NAS) or access stratum (AS);
  - Paging;
  - Establishment, maintenance and release of an RRC connection between the UE and E-UTRAN;
  - Security functions including key management;
  - Establishment, configuration, maintenance and release of point to point Radio Bearers;
  - Mobility functions including handover;
  - QoS management functions;
  - UE measurement reporting and control of the reporting;

**RLC sublayer**
- Error Correction through ARQ, concatenation, segmentation and reassembly of RLC SDUs;
- Protocol error detection and recovery;
System architecture

MME
- NAS signalling;
- Inter CN node signalling for mobility between 3GPP access networks;
- Idle mode UE Reachability (including control and execution of paging retransmission);
- MME selection for handovers with MME change;
- Roaming;
- Authentication;
- Bearer management functions including dedicated bearer establishment;
- Support for ETWS message transmission.

Serving Gateway (S-GW)
- The local Mobility Anchor point for inter-eNB handover;
- Mobility anchoring for inter-3GPP mobility;
- Lawful Interception;
- Packet routing and forwarding;

PDN Gateway (P-GW)
- Per-user based packet filtering (by e.g. deep packet inspection);
- Lawful Interception;
- UE IP address allocation;
The purpose of **radio resource management** (RRM) is to ensure the efficient use of the available radio resources. It includes:

- Radio Bearer Control (RBC)
- Radio Admission Control (RAC)
- Connection Mobility Control (CMC)
- Dynamic Resource Allocation (DRA) - Packet Scheduling (PS)
- Inter-cell Interference Coordination (ICIC)
- Load Balancing (LB)
References

[1] 3GPP TS 36.201: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer; General description”.
[5] 3GPP TS 36.302: "Evolved Universal Terrestrial Radio Access (E-UTRA); Services provided by the physical layer”