INSA INSTITUT NATIONAL DES SCIENCES APPLIQUÉES LYON

4TC-Architectures de Réseaux Mobiles
Mobile Network Architectures

Part 4 – Long Term Evolution

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Outline

- Evolution from GSM to UMTS
- UMTS architecture
- UTRAN access network
- UMTS core network
- Radio protocols
- Call and mobility management

Evolution

- Release 99 (Q1 2000): First specification of UMTS
- Release 4 (Q2 2001): All-IP core network
- Release 5 (Q1 2002): IMS and HSDPA
- Release 6 (Q4 2004): HSUPA, MBMS, WLAN integration
- Release 7 (Q4 2007): HSPA+, improvements to QoS and real-time applications
- Release 8 (Q4 2008): First LTE release, OFDMA, all-IP network
- Release 9 (Q4 2009): Core network enhancements, LTE-WiMax inter-operability
- Release 10 (Q1 2011): LTE-Advanced
- Release 11 (Q3 2012): HetNets, IP interconnection with third party service providers

Evolution

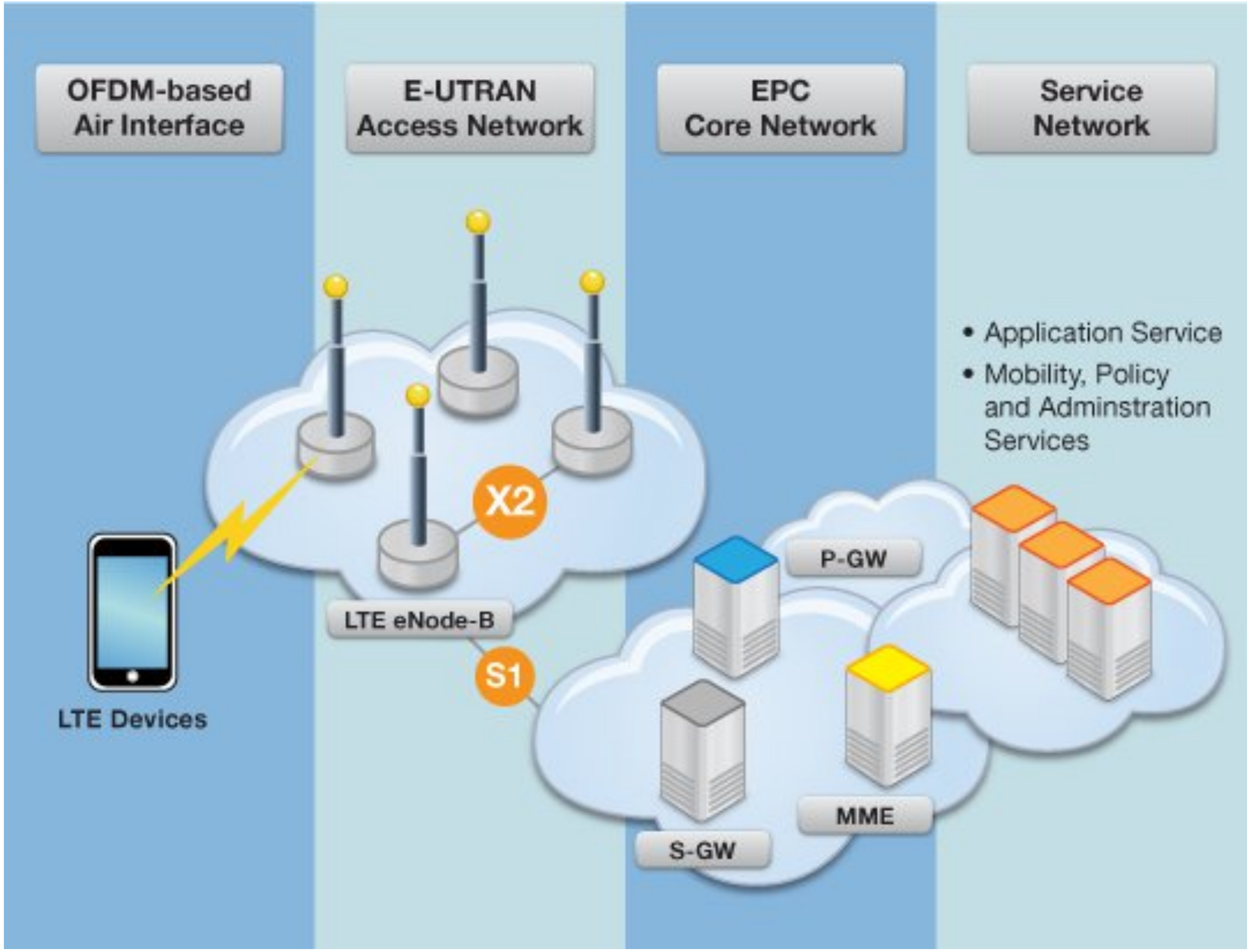
- LTE targets
  - reduced delays (connection establishment and transmission latency)
  - increased user data rates
  - uniformity of service provision (cell-edge users)
  - increased spectral efficiency
  - greater flexibility of spectrum usage
  - simplified network architecture
  - seamless mobility (including inter-technology)
  - reasonable UE power consumption
  - reduced capex/opex

LTE

- New architecture: Evolved Packet System (EPS)
  - Radio part: Long Term Evolution (LTE)
    - includes the Evolved-UTRAN (E-UTRAN)
  - Non-radio part: System Architecture Evolution (SAE)
    - includes the core network – Evolved Packet Core (EPC)

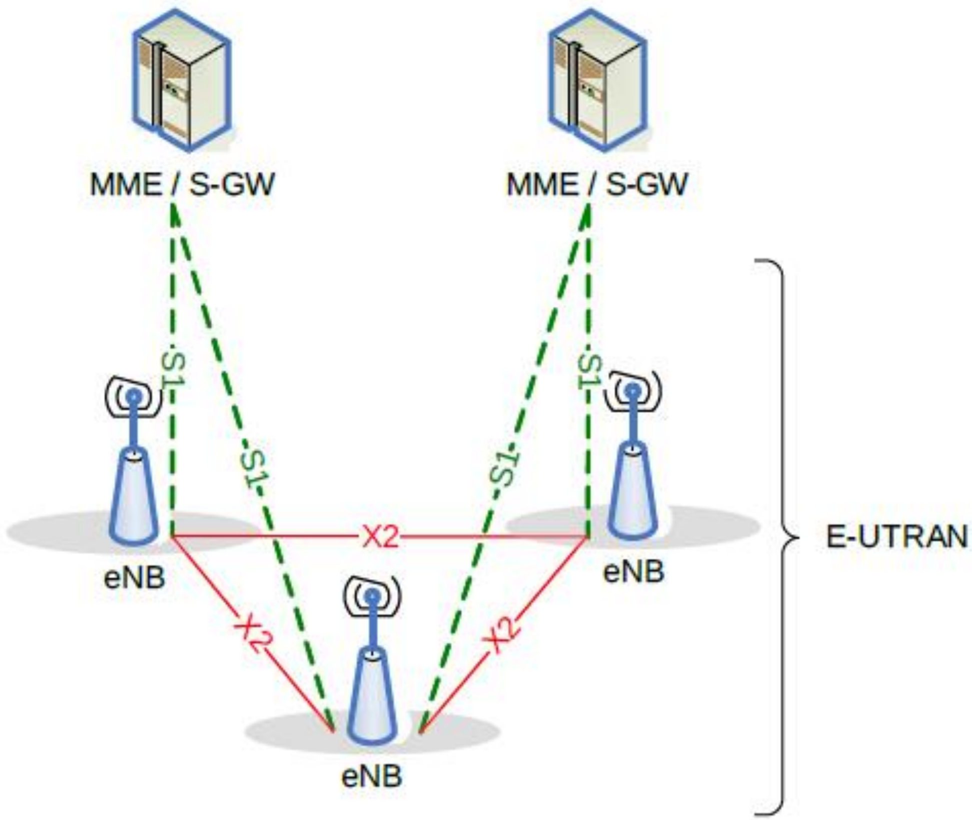
LTE architecture

- Detailed architecture



E-UTRAN

- E-UTRAN Access Network
  - Access stratum protocols, running on the eNodeB

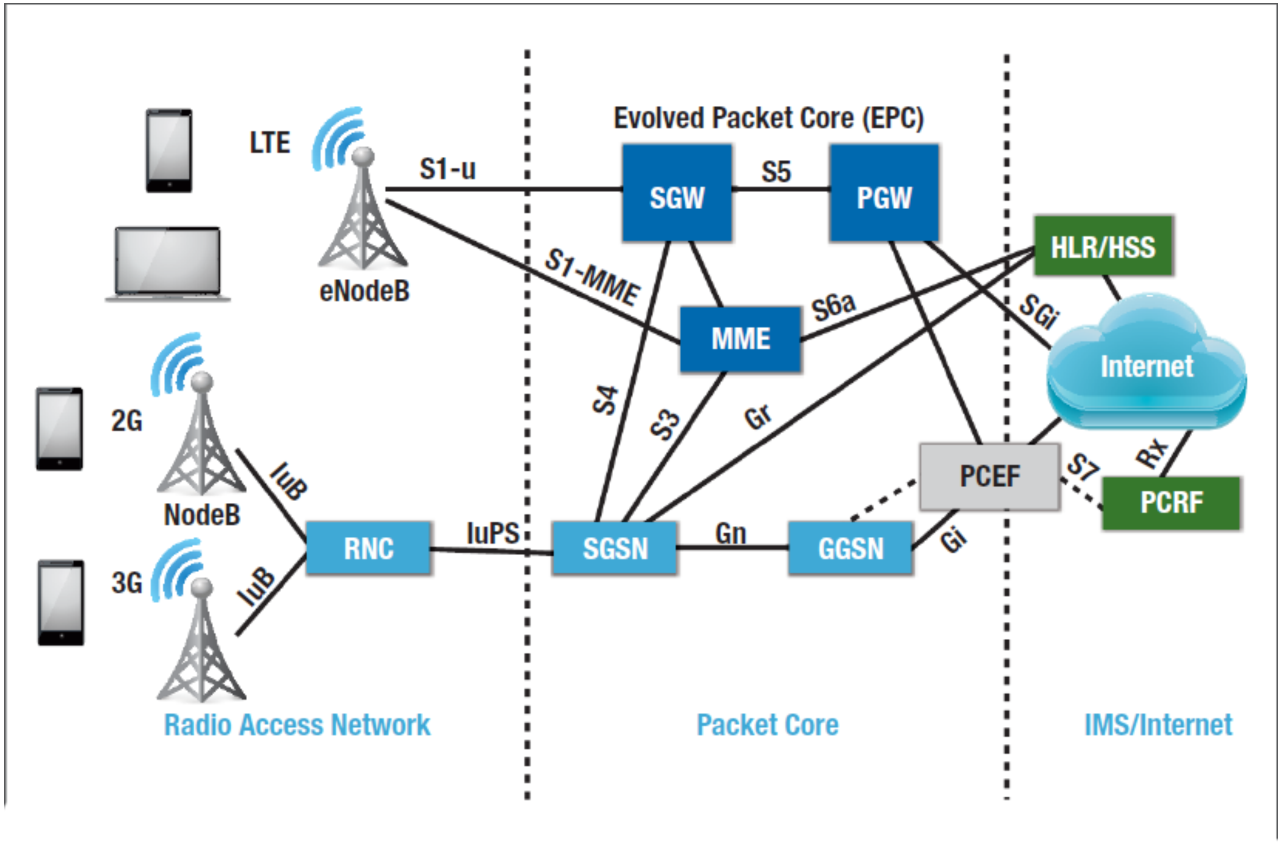


UTRAN

- Evolved Node B - eNodeB
  - Radio resource management – radio bearer control, admission control, mobility control, scheduling, resource allocation
  - Header compression – IP packet header compression (PDCP)
  - Security – the data transmitted over the radio interface is encrypted
  - Positioning - measurements used in the Observed Time Difference of Arrival (OTDOA) positioning method
  - Connectivity to the EPC – transport for signaling and data bearers

Core Network

- Evolved Packet Core



Evolved Packet Core

- Packet Gateway – P-GW
  - IP anchor point for data bearers
  - UE IP address allocation
  - Per-user packet filtering
  - Connectivity to packet data network
  - QoS policy enforcement

Evolved Packet Core

- Serving Gateway – S-GW
  - DL packet buffering for UEs in idle mode
  - Packet routing and forwarding
  - Local mobility anchor for data bearers when UE changes eNodeBs
  - Collects information for charging and legal interception

Evolved Packet Core

- Mobility Management Entity - MME
  - Authentication
  - Tracking area update
  - Idle mode UE reachability
  - S-GW/P-GW selection
  - Bearer management functions (bearer establishment, maintenance and release)

Evolved Packet Core

- Home Subscriber Server - HSS
  - User subscription data (e.g. QoS profile, roaming restrictions)
  - Information about the usable packet data networks
  - Location tracking
  - Identity of current MME
  - Can integrate the Authentication Center

Evolved Packet Core

- Policy Control and Charging Rules Function - PCRF
  - Policy control decision making
  - Control flow-based charging functionalities in P-GW
  - QoS per-flow authorization, in accordance with the user profile

Evolved Packet Core

- Enhanced Serving Mobile Location Center – E-SMLC
  - Overall coordination of the UE positioning process
  - Scheduling of resources required for location estimation
  - Estimates UE position and speed
- Gateway Mobile Location Center - GMLC
  - Support for location-based services

Evolved Packet Core

- Network Entry - An EPC Overview

Evolved Packet Core

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  - UE – eNodeB RRC connection establishment

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Evolved Packet Core

- Network Entry - An EPC Overview
  - UE – eNodeB RRC connection establishment
  - MME selection and signaling bearer set-up
  - Authentication and key establishment with HSS
  - S-GW and P-GW selection
  - Default bearer setup and IP address allocation

Evolved Packet Core

- Network Entry - An EPC Overview
  - UE – eNodeB RRC connection establishment
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  - Authentication and key establishment with HSS
  - S-GW and P-GW selection
  - Default bearer setup and IP address allocation
  - RRC reconfiguration

Back to E-UTRAN

- LTE handover
  - LTE uses user-assisted network controlled handover (as all cellular technologies)
  - UE reports measurements, network decides target cell for handover and when no handover (as all cellular technologies)
  - LTE relies on UE to detect neighboring cells – no need to maintain and broadcast a neighbor list
  - This allows “plug-and-play” capabilities (important for femto-cells) and saves BCH overhead

Back to E-UTRAN

- LTE handover
  - New X2 interface used foe eNB – eNB handover preparation and forwarding of user data
  - Target eNB prepares handover by sending required information to the UE transparently through source eNB
  - Accelerated handover, as UE does not need to read target cell BCH

Back to E-UTRAN

- LTE handover
  - Buffered data is transferred between source eNB and target eNB
  - New data is also forwarded from source eNB to target eNB until path switch (preventing any data loss)
  - UE uses contention free channel access in target cell to accelerate handover
  - RoHC context is not transferred during inter-eNB mobility

Back to E-UTRAN

- More on the X2 interface
  - Established between an eNB and its neighbors, for signaling purposes
  - Full meshed network is not required by the standard
  - Two types of information
    - handover related information
    - load and interference related information

Back to E-UTRAN

- More on the X2 interface
  - Identification if suitable neighbors
    - Through manual configuration
    - Using the Automatic Neighbor Relation Function (ANRF)
  - Load information exchange is essential – flat architecture, no central controller in E-UTRAN
  - Load balancing – low frequency exchanges (every few seconds), to counteract local traffic imbalance
  - Interference management – high frequency messages (period of tens of milliseconds), to optimize the resource allocation process

Back to E-UTRAN

- The Random Access procedure usage
  - UE in RRC_CONNECTED, but not uplink synchronized
  - UE in RRC_CONNECTED, in handover process
  - For positioning purposes in RRC_CONNECTED (as this requires timing advance computation)
  - UE transition from RRC_IDLE to RRC_CONNECTED
  - UE recovering from radio link failure

Back to E-UTRAN

- The Random Access procedure
  - Contention-based
    - No formal guarantee that the access will be provided
  - Contention-free
    - Guaranteed and time bounded access
    - Can be used in the case of incoming (DL) traffic
    - Can be used during handover

Back to E-UTRAN

- The four-steps Random Access procedure

Back to E-UTRAN

- The four-steps Random Access procedure
  - 1. Preamble transmission (UE -> eNB)
    - A total of 64 orthogonal preambles
    - Divided between contention-free and contention-based
    - Each UE randomly picks a preamble (in contention-based) or is assigned one (in contention-free)
    - The preamble contains one bit indicating the quantity of required resources allowing for resource allocation optimization
    - In contention-based, multiple UEs can pick the same preamble

Back to E-UTRAN

- The four-steps Random Access procedure
  - 1. Preamble transmission (UE -> eNB)
  - 2. Random Access Response – RAR (eNB -> UE)
    - Addressed to a Random Access RNTI (RA-RNTI)
    - The RA-RNTI does not identify an UE, but the time-frequency block when the preamble was transmitted
    - All UEs transmitting the same preamble at the same time will receive the RAR
    - Assigns a C-RNTI
    - If no RAR is received, the UE goes back to step 1
    - RAR **does not** solve collisions

Back to E-UTRAN

- The four-steps Random Access procedure
  - 1. Preamble transmission (UE -> eNB)
  - 2. Random Access Response – RAR (eNB -> UE)
  - 3. Layer2/Layer3 message (UE -> eNB)
    - The actual message the UE wants to transmit (RRC connection request, tracking area update, scheduling request, …)
    - Carries the C-RNTI assigned at step 2
    - Contains an initial UE identity (TMSI or random number)
    - In case of collision at step 1, the UEs will collide on message 3
    - One message might be received (capture effect) or none

Back to E-UTRAN

- The four-steps Random Access procedure
  - 1. Preamble transmission (UE -> eNB)
  - 2. Random Access Response – RAR (eNB -> UE)
  - 3. Layer2/Layer3 message (UE -> eNB)
  - 4. Contention Resolution Message
    - Transmitted to a unique UE, identified in message 3
    - UEs losing the contention understand that and restart the procedure

More on handover

- Handover between different radio access technologies – inter-RAT handover
  - LTE deployment mainly in urban areas
  - Rural and suburban areas still covered by legacy networks
  - Development of competing technologies (WiMax, WiFi)
  - Handover is the main cause of call drop

More on handover

- Inter-RAT Handover
  - eNB configures the necessary measurements in the UE using RRC_CONNECTION_RECONFIGURATION messages
  - This sets thresholds for measurement activation
  - Provides the UE with the necessary information (e.g. center frequency and scrambling codes in UMTS)
  - UE does the measures on the other RAT and sends the eNB RRC_MEASUREMENT_REPORT
  - eNB takes handover decision and announces the MME

More on handover

- Inter-RAT Handover
  - The eNB – MME exchange also identifies the target cell in the destination RAT
  - The MME contacts the corresponding entity (e.g. SGSN) to allocate resources
  - When core network mechanisms are done, MME announces the eNB
  - eNB transmits an RRC_MOBILITY_FROM_E-UTRA_COMMAND
  - Mobility anchor in the EPC: S-GW for 3GPP technologies, P-GW for non-3GPP technologies

More on handover

- Example: circuit-switched fall back
  - LTE is all-IP – this means voice can only be done in VoIP
  - VoIP supported by IP Multimedia Subsystem (IMS) services (not the object of this course)
  - IMS services not deployed from phase 1
  - But users still need to be able to call
  - Fall-back on a legacy RAT for CS services

More on handover

- Example: circuit-switched fall back
  - A new interface (SGs) between MME and the MSC in the legacy RAT
  - This interface allows the UE to connect to a CS network while attached to LTE
  - This also allows the legacy RAT to page the UE, while the UE remains in LTE