Overview of 3GPP LTE

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Cellular Wireless System Evolution

- 1G (Early 1980s)
  - Analog speech communications.
  - Analog FDMA.
  - Ex: AMPS
- 2G (Early 1990s)
  - Digital modulation of speech communications.
  - Advanced security and roaming.
  - TDMA and narrowband CDMA.
  - Ex: GSM, IS-95 (cdmaOne), and PDC
- 3G (Late 1990s)
  - Global harmonization and roaming.
  - Wideband CDMA
  - Ex: UMTS, cdma2000, and TD-SCDMA

Beyond 3G

- International Mobile Telecommunications (IMT)-2000 introduced global standard for 3G.
- Systems beyond IMT-2000 (IMT-Advanced) is set to introduce evolutionary path beyond 3G.
  - Mobile class targets 100 Mbps with high mobility and nomadic/local area class targets 1 Gbps with low mobility.
- 3GPP and 3GPP2 are currently developing evolutionary/revolutionary systems beyond 3G.
  - 3GPP Long Term Evolution (LTE)
  - 3GPP2 Ultra Mobile Broadband (UMB)
- IEEE 802.16-based WiMAX is also evolving towards 4G through 802.16m.

From

http://en.wikipedia.org/wiki/Ultra_Mobile_Broadband

- **UMB (Ultra Mobile Broadband)** is the brand name for the project within 3GPP2 to improve the CDMA2000 mobile phone standard for next generation applications and requirements.
- The system is based upon Internet (TCP/IP) networking technologies running over a next generation radio system, with peak rates of up to 280 Mbit/s.
- Its designers intend for the system to be more efficient and capable of providing more services than the technologies it replaces.
- Commercialization is unlikely as Qualcomm, its main developer, 3GPP2 and major CDMA carriers are concentrating on LTE instead.

Cont.

- To provide compatibility with the systems it replaces, UMB supports handoffs with other technologies including existing CDMA2000 1X and 1xEV-DO systems.
- However 3GPP2 added this functionality to LTE, allowing LTE to become the single upgrade path for all wireless networks.
- According to the technology market research firm ABI Research, Ultra-Mobile Broadband might be "dead on arrival"[2]. No carrier has announced plans to adopt UMB, and most CDMA carriers in Australia, USA, China, Japan and Korea have already announced plans to adopt HSPA or LTE.

From

http://en.wikipedia.org/wiki/High-Speed_Packet_Access

- **High Speed Packet Access (HSPA)** is a collection of mobile telephony protocols that extend and improve the performance of existing UMTS protocols. Two standards, HSDPA and HSUPA, have been established and a further standard, HSPA+, is soon to be released.
  - HSDPA (**High Speed Downlink Packet Access**) provides improved theoretical down-link performance of up to 14.4 Mbit/s.
  - HSUPA (**High Speed Uplink Packet Access**) provides improved up-link performance of up to 5.76 Mbit/s theoretically.

Cont.

- Evolved High Speed Packet Access (HSPA+)
  - HSPA+ is defined in 3GPP release 7.
  - It introduces a simpler IP-centric architecture for the mobile network bypassing most of the legacy equipment.
  - HSPA+ boosts peak data rates to 42 Mbit/s on the downlink and 22 Mbit/s on the uplink.

3GPP Evolution

- Release 99 (Mar. 2000): UMTS/WCDMA
- Rel-5 (Mar. 2002): HSDPA
- Rel-6 (Mar. 2005): HSUPA
- Rel-7 (2007): DL MIMO, IMS (IP Multimedia Subsystem), optimized real-time services (VoIP, gaming, push-to-talk).
- Long Term Evolution (LTE)
  - 3GPP work on the Evolution of the 3G Mobile System started in November 2004.
  - Standardized in the form of Rel-8.
  - Spec finalized and approved in January 2008.
  - Target deployment in 2010.
  - LTE-Advanced study phase in progress.

3GPP2 Evolution

- CDMA2000 1X (1999)
- CDMA2000 1xEV-DO (2000)
- EV-DO Rev. A (2004): VoIP
- EV-DO Rev. B (2006): Multi-carrier
- Ultra Mobile Broadband (UMB)
  - Based on EV-DO, IEEE 802.20, and FLASH-OFDM
    - **IEEE 802.20** or **Mobile Broadband Wireless Access (MBWA)** is an IEEE Standard to enable worldwide deployment of multi-vendor interoperable mobile broadband wireless access networks
  - Spec finalized in April 2007.
  - Commercially available in early 2009.

IEEE 802.16 Evolution

- 802.16 (2002): Line-of-sight fixed operation in 10 to 66 GHz
- 802.16a (2003): Air interface support for 2 to 11 GHz
- 802.16d (2004): Minor improvements to fixes to 16a
- 802.16e (2006): Support for vehicular mobility and asymmetrical link
- 802.16m (in progress): Higher data rate, reduced latency, and efficient security mechanism

Requirements of LTE

- Peak data rate
  - 100 Mbps DL/ 50 Mbps UL within 20 MHz bandwidth.
- Up to 200 active users in a cell (5 MHz)
- Less than 5 ms user-plane latency
- Mobility
  - Optimized for 0 ~ 15 km/h.
  - 15 ~ 120 km/h supported with high performance.
  - Supported up to 350 km/h or even up to 500 km/h.
- Enhanced multimedia broadcast multicast service (E-MBMS)
- Spectrum flexibility: 1.25 ~ 20 MHz
- Enhanced support for end-to-end QoS

LTE Enabling Technologies

- OFDM (Orthogonal Frequency Division Multiplexing)
- Frequency domain equalization
- SC-FDMA (Single Carrier FDMA)
- MIMO (Multi-Input Multi-Output)
- Multicarrier channel-dependent resource scheduling
- Fractional frequency reuse

LTE Enabling Technologies

- Single Carrier FDMA (SC-FDMA)
  - SC-FDMA is a new single carrier multiple access technique which has similar structure and performance to OFDMA.
    - Utilizes single carrier modulation and orthogonal frequency multiplexing using DFT-spreading in the transmitter and frequency domain equalization in the receiver.
  - A salient advantage of SC-FDMA over OFDM/OFDMA is low PAPR (**Peak-to-Average Power Ratio**).
    - Efficient transmitter and improved cell-edge performance.
  - H. G. Myung et al., “Single Carrier FDMA for Uplink Wireless Transmission,” IEEE Vehic. Tech. Mag., vol. 1, no. 3, Sep. 2006
  - A comprehensive tutorial available at http://hgmyung.googlepages.com/scfdma.pdf.

Key Features of LTE

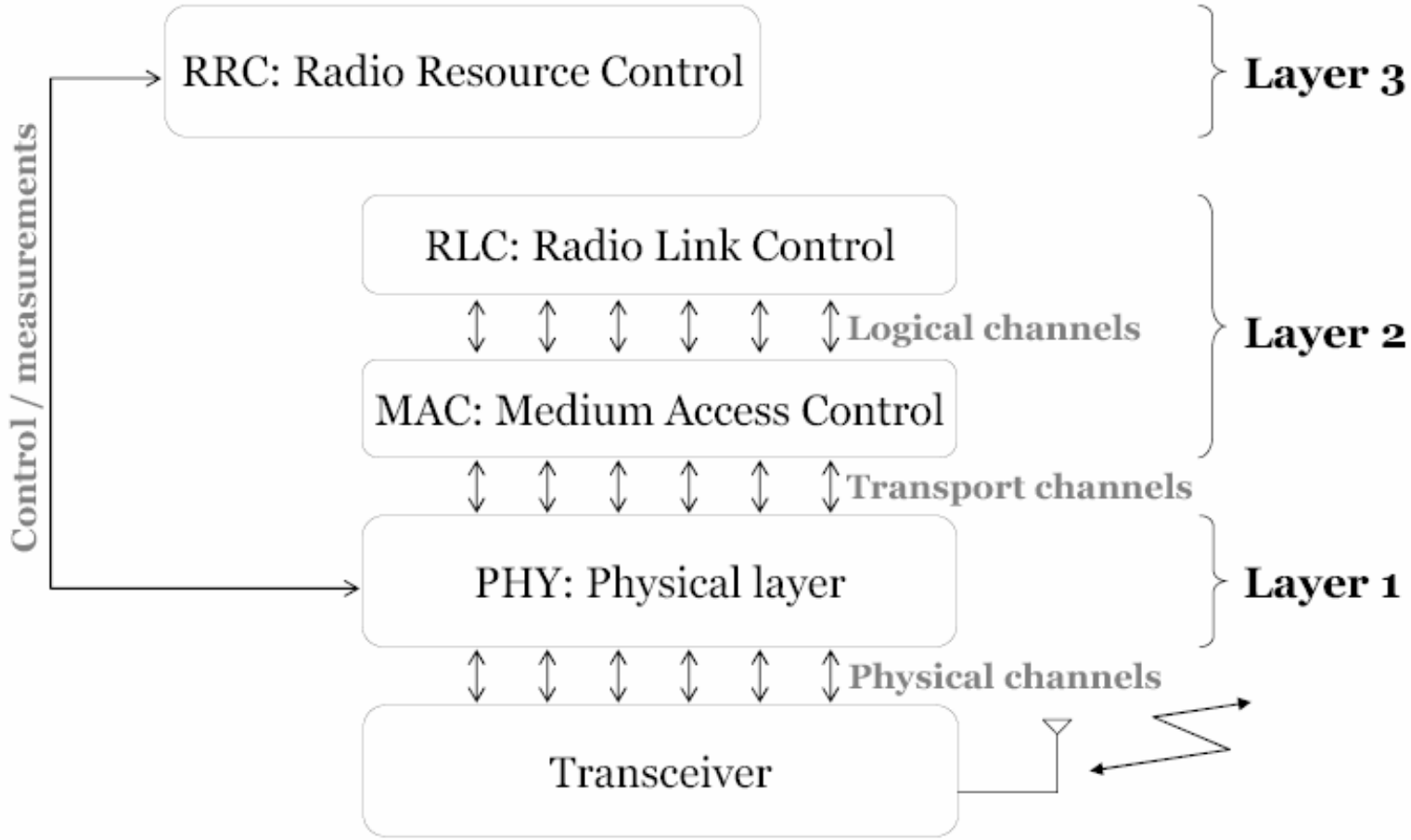
- Multiple access scheme
  - **DL**: OFDMA with CP.
  - **UL**: Single Carrier FDMA (SC-FDMA) with CP.
- Adaptive modulation and coding
  - DL/UL modulations: QPSK, 16QAM, and 64QAM
  - Convolutional code and **Rel-6** turbo code
- Advanced MIMO spatial multiplexing techniques
  - (2 or 4)x(2 or 4) downlink and uplink supported.
  - Multi-user MIMO also supported.
- Support for both FDD and TDD
- H-ARQ (**Hybrid automatic repeat-request**), mobility support, rate control, security, and etc.

LTE Standard Specifications

- Freely downloadable from http://www.3gpp.org/ftp/Specs/html-info/36-series.htm

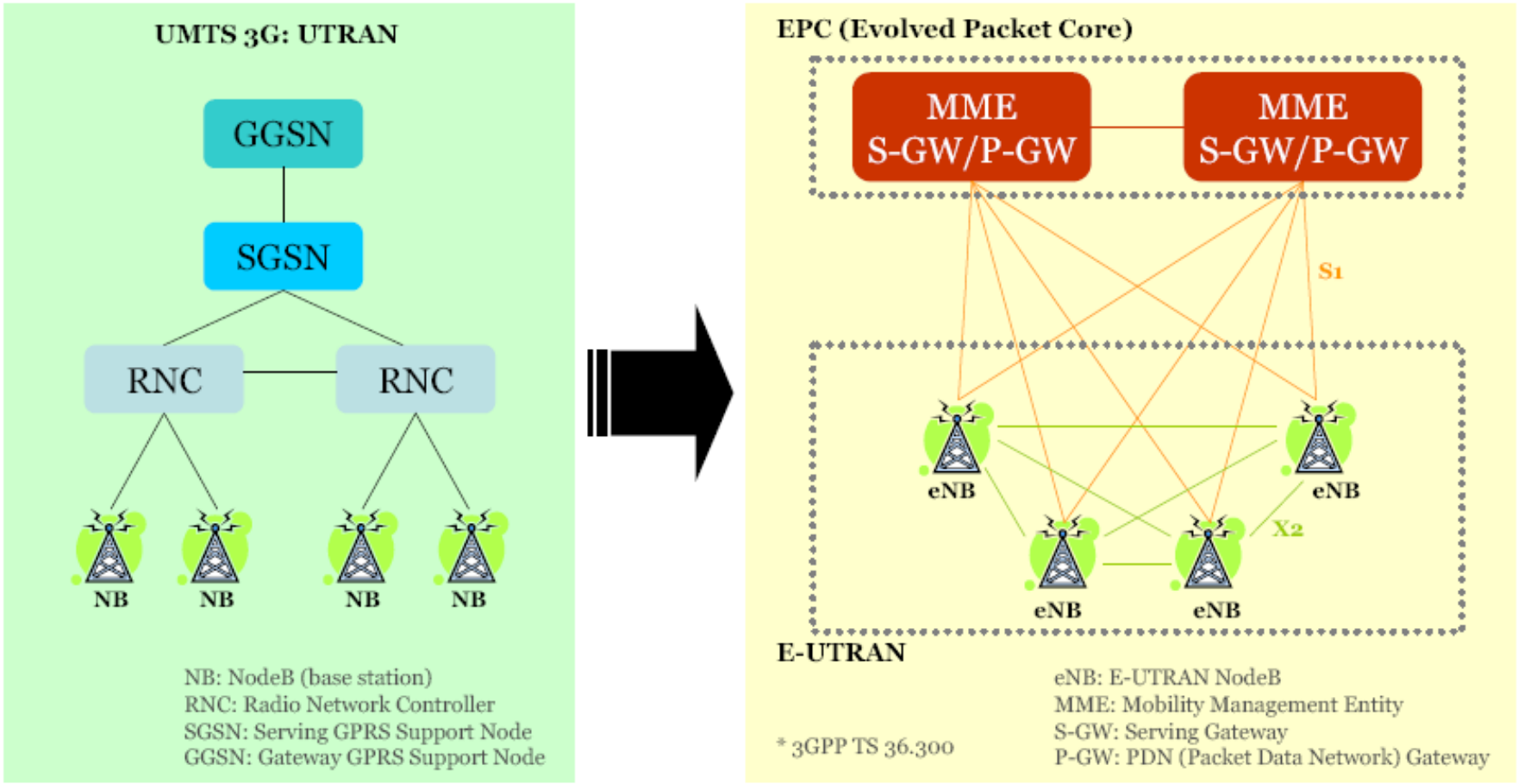
Specification index	Description of contents
TS 36.1xx	Equipment requirements: Terminals, base stations, and repeaters.
TS 36.2xx	Physical layer.
TS 36.3xx	Layers 2 and 3: Medium access control, radio link control, and radio resource control.
TS 36.4xx	Infrastructure communications (UTRAN = UTRA Network) including base stations and mobile management entities.
TS 36.5xx	Conformance testing.

Protocol Architecture



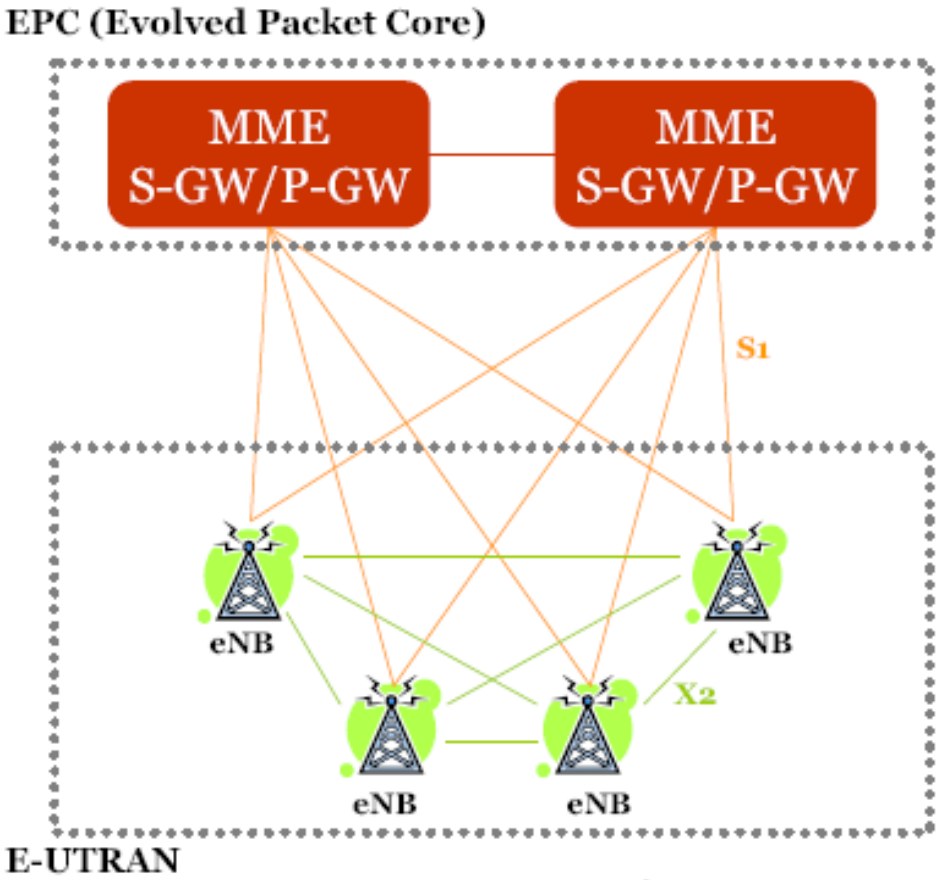
LTE Network Architecture

- E-UTRAN (Evolved Universal Terrestrial Radio Access Network)



LTE Network Architecture

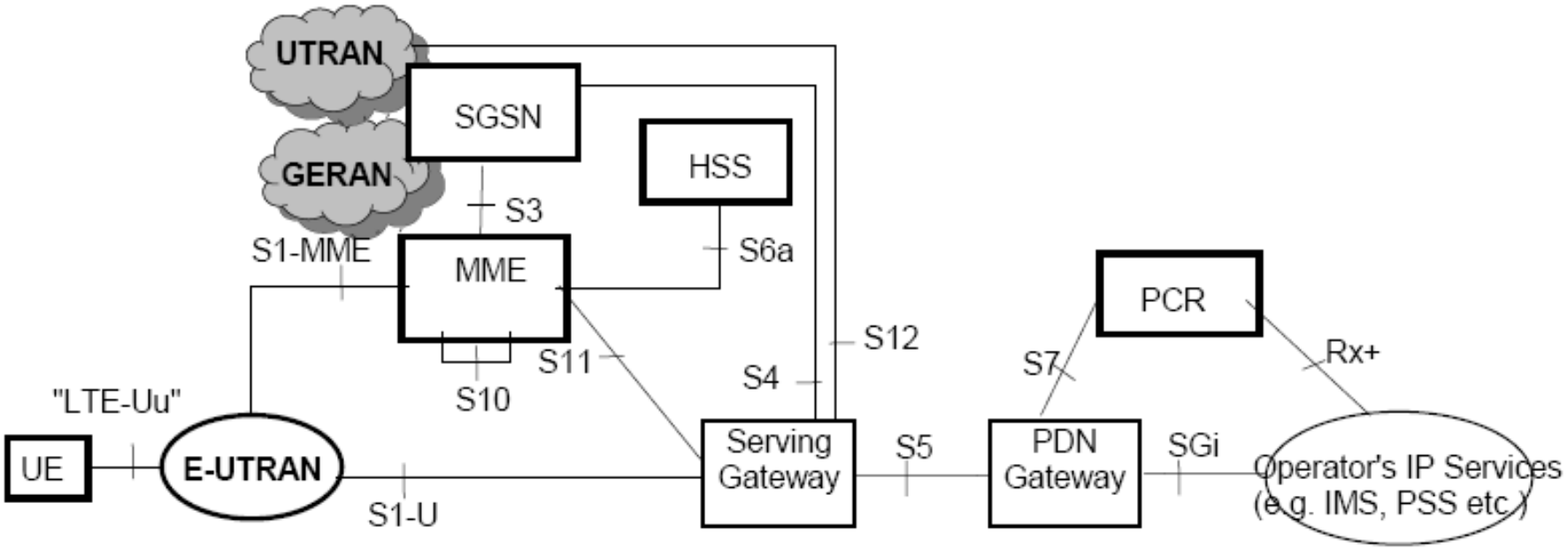
- eNB
  - All radio interface-related functions
- MME
  - Manages mobility, UE identity, and security parameters.
- S-GW
  - Node that terminates the interface towards E-UTRAN.
- P-GW
  - Node that terminates the interface towards PDN.



eNB: E-UTRAN NodeB
MME: Mobility Management Entity
S-GW: Serving Gateway
P-GW: PDN (Packet Data Network) Gateway

* 3GPP TS 36.300

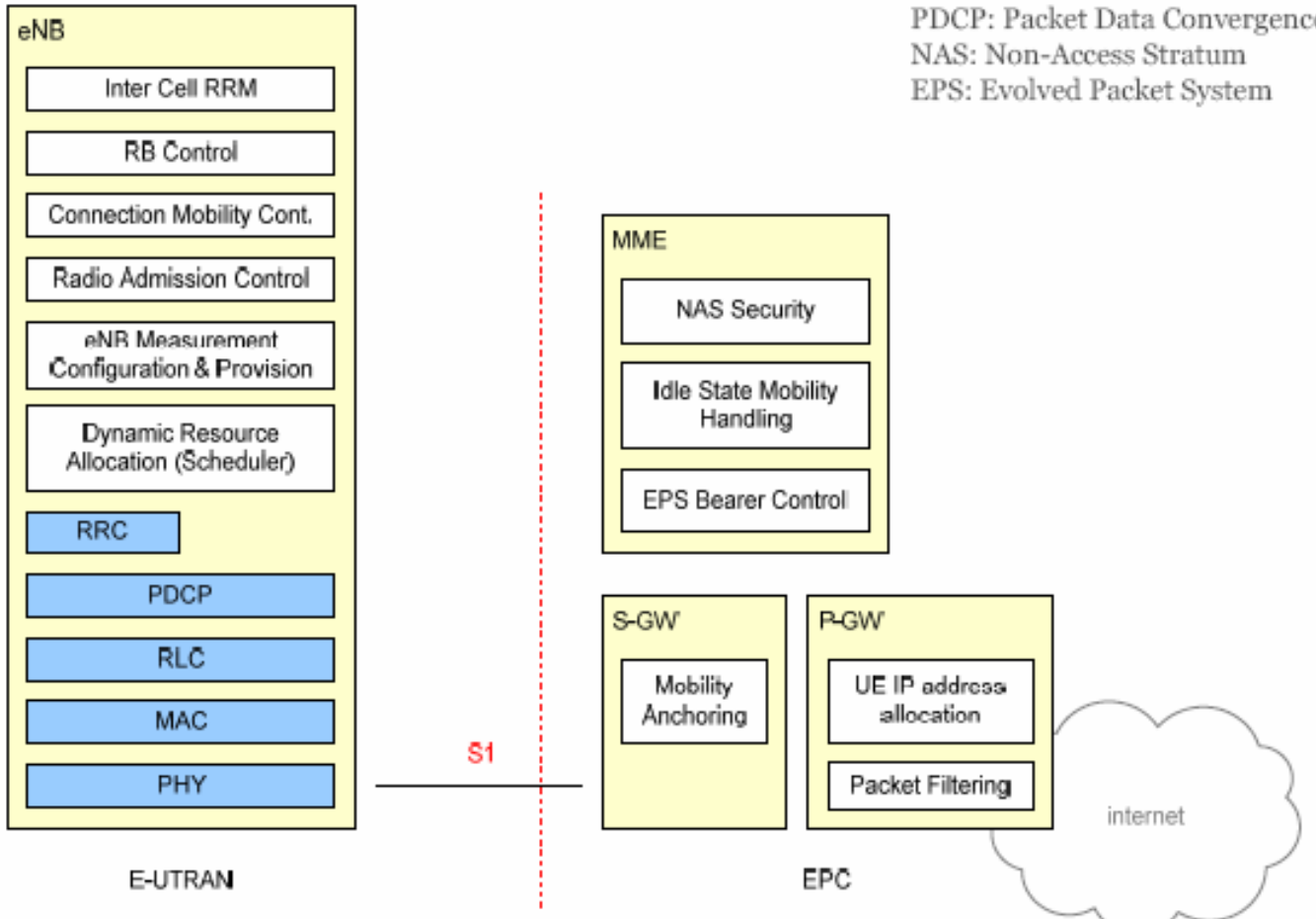
LTE Network Architecture



* Non-roaming architecture
* 3GPP TS 23.401

LTE Network Architecture

RRM: Radio Resource Management
RB: Radio Bearer
RRC: Radio Resource Control
PDCP: Packet Data Convergence Protocol
NAS: Non-Access Stratum
EPS: Evolved Packet System

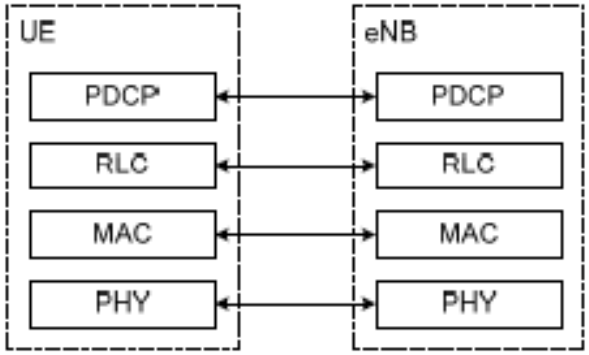


* 3GPP TS 36.300

Evolved Packet Core

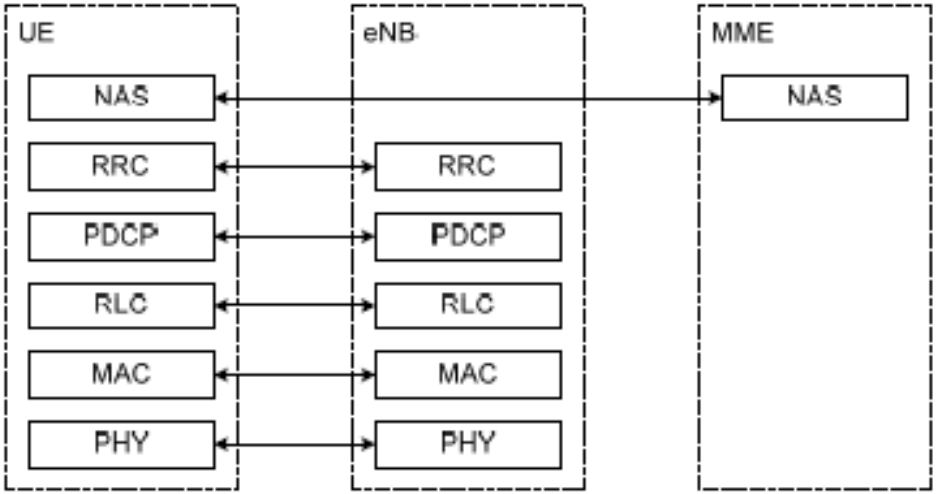
LTE Network Architecture

User-Plane Protocol Stack



PDCP is an abbreviation for Packet Data Convergence Protocol. It is one of the layers of the Radio Traffic Stack in UMTS and performs IP header compression and decompression, transfer of user data and maintenance of sequence numbers for Radio Bearers which are configured for lossless serving radio network subsystem (SRNS) relocation.

Control-Plane Protocol Stack



Non Access Stratum (NAS) is a functional layer in the UMTS protocol stack between Core Network and User Equipment UE. The layer supports signalling and traffic between those two elements.

* 3GPP TS 36.300