UTRA-UTRAN Long Term Evolution (LTE) and 3GPP System Architecture Evolution (SAE)

Long Term Evolution of the 3GPP radio technology

3GPP work on the Evolution of the 3G Mobile System started with the RAN Evolution Work Shop, 2 - 3 November 2004 in Toronto, Canada. The Work Shop was open to all interested organizations, members and non members of 3GPP. Operators, manufacturers and research institutes presented more than 40 contributions with views and proposals on the evolution of the Universal Terrestrial Radio Access Network (UTRAN).

A set of high level requirements was identified in the Work Shop:

- Reduced cost per bit
- Increased service provisioning – more services at lower cost with better user experience
- Flexibility of use of existing and new frequency bands
- Simplified architecture, Open interfaces
- Allow for reasonable terminal power consumption

It was also recommended that the Evolved UTRAN should bring significant improvements to justify the standardization effort and it should avoid unnecessary options. On certain aspects, the collaboration with 3GPP SA WGs was found to be essential: the new split between the Access Network and the Core Network, and the characteristics of the throughput that new services would require demanded close architectural coordination.

With the conclusions of this Work Shop and with broad support from 3GPP members, a feasibility study on the UTRA & UTRAN Long Term Evolution was started in December 2004. The objective was "to develop a framework for the evolution of the 3GPP radio-access technology towards a high-data-rate, low-latency and packet-optimized radio-access technology" The study focused on supporting services provided from the PS-domain, involving:

- Related to the radio-interface physical layer (downlink and uplink):
  - e.g. means to support flexible transmission bandwidth up to 20 MHz, introduction of new transmission schemes and advanced multi-antenna technologies
- Related to the radio interface layer 2 and 3:
  - e.g. signalling optimization
- Related to the UTRAN architecture:
  - identify the optimum UTRAN network architecture and functional split between RAN network nodes
- RF-related issues

In adddition, the Next Generation Mobile Networks (NGMN) initiative, led by seven network operators (*) provided a set of recommendations for the creation of networks suitable for the competitive delivery of mobile broadband services. The NGMN goal is "to provide a coherent vision for technology evolution beyond 3G for the competitive delivery of broadband wireless services".

The NGMN long-term objective is to "establish clear performance targets, fundamental recommendations and deployment scenarios for a future wide area mobile broadband network". In a white paper (March 2006), they provided relative priorities of key system characteristics, System recommendations and detailed requirements.

Emphase was also on the IPR side, where the goal was "to adapt the existing IPR regime to provide a better predictability of the IPR licenses (...) to ensure Fair, Reasonable And Non-Discriminatory (FRAND) IPR costs" (NGMN White paper, March 2006).

All RAN WGs participated in the study, with collaboration from SA WG2 in the key area of the network architecture. The first part of the study resulted in agreement on the requirements for the Evolved UTRAN.

As a result, Technical Report (TR) 25.913 contains detailed requirements for the following criteria:

Peak data rate

- Instantaneous downlink peak data rate of 100 Mb/s within a 20 MHz downlink spectrum allocation (5 bps/Hz)
- Instantaneous uplink peak data rate of 50 Mb/s (2.5 bps/Hz) within a 20MHz uplink spectrum allocation)

Control-plane latency

- Transition time of less than 100 ms from a camped state, such as Release 6 Idle Mode, to an active state such as Release 6 CELL_DCH
- Transition time of less than 50 ms between a dormant state such as Release 6 CELL_PCH and an active state such as Release 6 CELL_DCH

Control-plane capacity

- At least 200 users per cell should be supported in the active state for spectrum allocations up to 5 MHz

User-plane latency

- Less than 5 ms in unload condition (ie single user with single data stream) for small IP packet

User throughput

- Downlink: average user throughput per MHz, 3 to 4 times Release 6 HSDPA
- Uplink: average user throughput per MHz, 2 to 3 times Release 6 Enhanced Uplink

Spectrum efficiency

- Downlink: In a loaded network, target for spectrum efficiency (bits/sec/Hz/site), 3 to 4 times Release 6 HSDPA)
- Uplink: In a loaded network, target for spectrum efficiency (bits/sec/Hz/site), 2 to 3 times Release 6 Enhanced Uplink

Mobility

- E-UTRAN should be optimized for low mobile speed from 0 to 15 km/h
- Higher mobile speed between 15 and 120 km/h should be supported with high performance
- Mobility across the cellular network shall be maintained at speeds from 120 km/h to 350 km/h (or even up to 500 km/h depending on the frequency band)

Coverage

- Throughput, spectrum efficiency and mobility targets above should be met for 5 km cells, and with a slight degradation for 30 km cells. Cells range up to 100 km should not be precluded.

Further Enhanced Multimedia Broadcast Multicast Service (MBMS)

- While reducing terminal complexity: same modulation, coding, multiple access approaches and UE bandwidth than for unicast operation.
- Provision of simultaneous dedicated voice and MBMS services to the user.
- Available for paired and unpaired spectrum arrangements.

Spectrum flexibility

- E-UTRA shall operate in spectrum allocations of different sizes, including 1.25 MHz, 1.6 MHz, 2.5 MHz, 5 MHz, 10 MHz, 15 MHz and 20 MHz in both the uplink and downlink. Operation in paired and unpaired spectrum shall be supported

- The system shall be able to support content delivery over an aggregation of resources including Radio Band Resources (as well as power, adaptive scheduling, etc) in the same and different bands, in both uplink and downlink and in both adjacent and non-adjacent channel arrangements. A “Radio Band Resource” is defined as all spectrum available to an operator

Co-existence and Inter-working with 3GPP Radio Access Technology (RAT)

- Co-existence in the same geographical area and co-location with GERAN/UTRAN on adjacent channels.
- E-UTRAN terminals supporting also UTRAN and/or GERAN operation should be able to support measurement of, and handover from and to, both 3GPP UTRAN and 3GPP GERAN.
- The interruption time during a handover of real-time services between E-UTRAN and UTRAN (or GERAN) should be less than 300 msec.

Architecture and migration

- Single E-UTRAN architecture
- The E-UTRAN architecture shall be packet based, although provision should be made to support systems supporting real-time and conversational class traffic
- E-UTRAN architecture shall minimize the presence of "single points of failure"
- E-UTRAN architecture shall support an end-to-end QoS
- Backhaul communication protocols should be optimised

Radio Resource Management requirements

- Enhanced support for end to end QoS
- Efficient support for transmission of higher layers
- Support of load sharing and policy management across different Radio Access Technologies

Complexity

- Minimize the number of options
- No redundant mandatory features

As a consequence the WGs have dedicated normal meeting time to the Evolution activity, as well as separate ad hoc meetings.

RAN WG1 assessed six possible radio interface schemes (evaluations of these technologies against the requirements for the physical layer are collected in TR 25.814).

The wide set of options initially identified by the early LTE work was narrowed down, in December 2005, to a working assumption that the downlink would use Orthogonal Frequency Division Multiplexing (OFDM) and the uplink would use Single Carrier – Frequency Division Multiple Access (SC-FDMA). Although opinions were divided, it was eventually concluded that inter-Node-B macro-diversity would not be employed. More information is given in the report of RAN#30.

Supported downlink data-modulation schemes are QPSK, 16QAM, and 64QAM. The possible uplink data-modulation schemes are (pi/2-shift) BPSK, QPSK, 8PSK and 16QAM.

The use of Multiple Input Multiple Output (MIMO) scheme was agreed, with possibly up to four antennas at the mobile side, and four antennas at the Cell site.

Re-using the expertise from the UTRAN, the same channel coding type than for UTRAN was agreed (turbo codes).

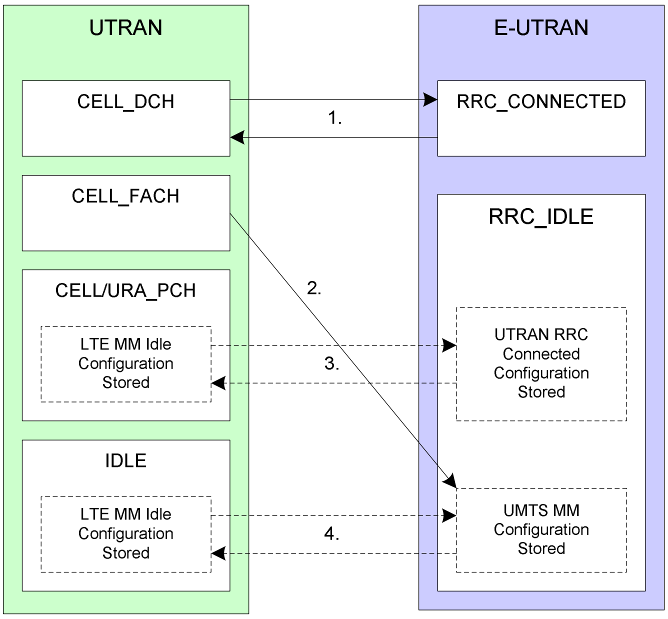
RAN WG2 has also held a first meeting to approach the radio interface protocols of the Evolved UTRAN (link). The initial assumptions were:

- Simplification of the protocol architecture and the actual protocols
- No dedicated channels, and hence a simplified MAC layer (without MAC-d entity)

- Avoiding similar functions between Radio and Core network.

A Transmission Time Interval (TTI) of 1ms was agreed (to reduce signalling overhead and improve efficiency).

RRC States were restricted to RRC_Idle and RRC_Connected States. They are depicted below, in conjunction with the possible legacy UTRAN RRC States (extract of TR 25.813):

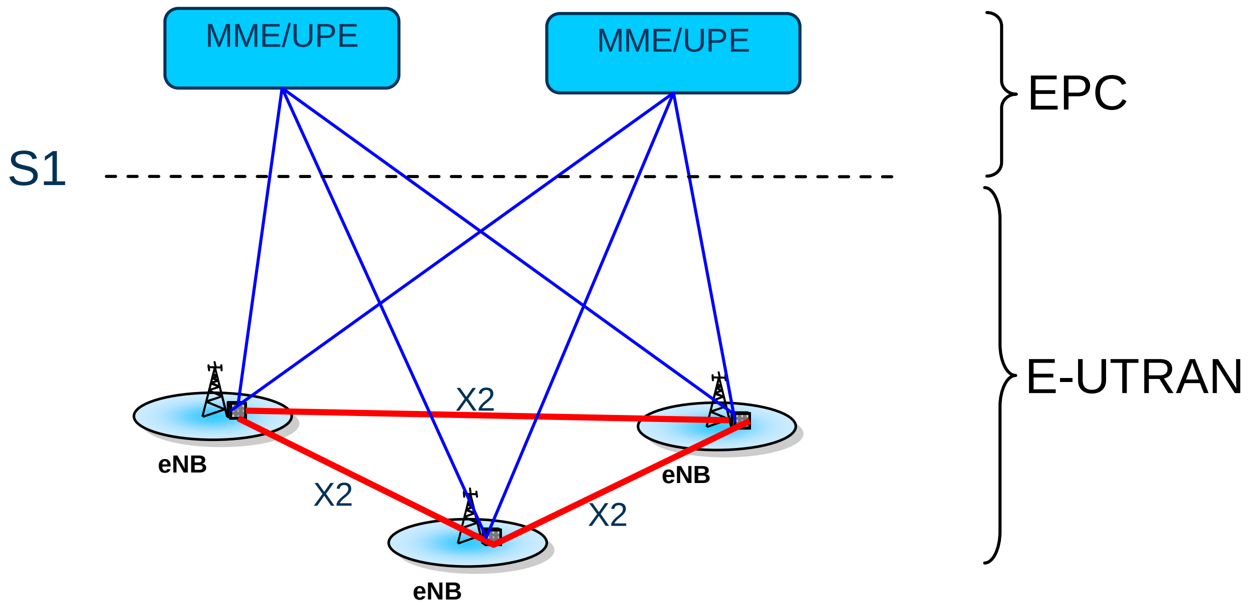


RAN WG3 worked closely with SA WG2 in the definition of the new architecture:

The evolved UTRAN consists of eNBs, providing the evolved UTRA U-plane and C-plane protocol terminations towards the UE. The eNBs are interconnected with each other by means of the *X2 interface*. It is assumed that there always exist an X2 interface between the eNBs that need to communicate with each other, e.g. for support of handover of UEs in LTE_ACTIVE.

The eNBs are also connected by means of the S1 interface to the EPC (Evolved Packet Core). The *S1 interface* support a many-to-many relation between aGWs and eNBs.

E-UTRAN architecture (extract from TR 25.912):



Functional split:

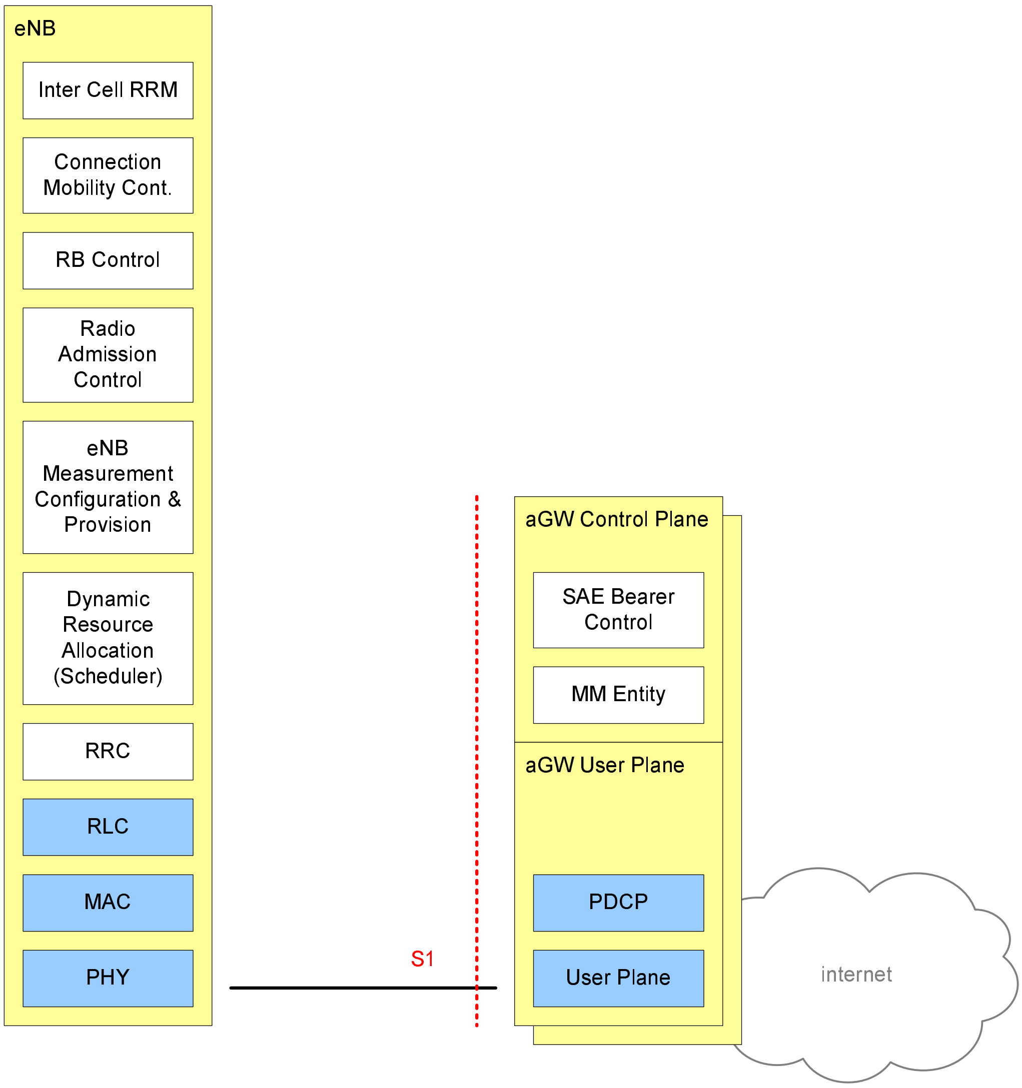
The eNB host the following functions:

- Functions for Radio Resource Management: Radio Bearer Control, Radio Admission Control, Connection Mobility Control, Dynamic Resource Allocation (scheduling).

Mobility Management entity (MME):
- Distribution of paging messages to the eNBs.

User Plane Entity (UPE):
- IP Header Compression and encryption of user data streams;
- Termination of U-plane packets for paging reasons;
- Switching of U-plane for support of UE mobility.

This resulted, in conjuntion with work in RAN WG2, into the following protocol stack and the following function split (extract of TR 25.813):



The Study Item phase was concluded in September 2006. As expected, in particular the E-UTRA system will provide significantly higher data rates than Release 6 WCDMA. The increase in data rate is achieved especially through higher transmission bandwidth and support for MIMO.

In particular, the study showed that simultaneous support for UTRA and E-UTRA UEs in the same spectrum allocation was possible.

It became clear that the solutions chosen for the physical layer and layers 2/3 showed a convergence between paired spectrum and unpaired spectrum solutions for the Long Term Evolution (e.g. initial access, handover procedures, measurements, frame and slot structures).

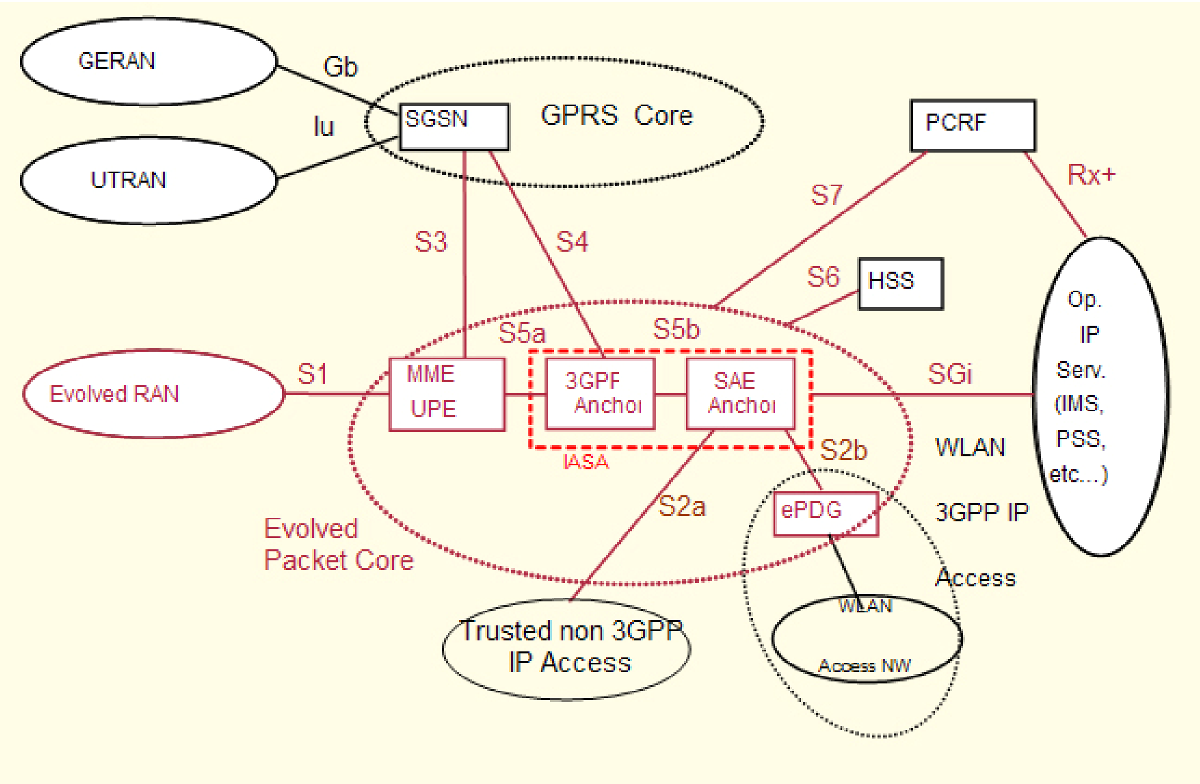
At that point, the Work Item was created to introduce the E-UTRAN into the 3GPP Work Plan.

System Architecture Evolution

SA WG2 started its own Study for the System Architecture Evolution (SAE) whose objective is "to develop a framework for an evolution or migration of the 3GPP system to a higher-data-rate, lower-latency, packet-optimized system that supports, multiple RATs. The focus of this work [is] on the PS domain with the assumption that voice services are supported in this domain". SA2's SAE work is conducted under Work Item "3GPP system architectural evolution", approved in December 2004. It was initiated when it became clear that the future was clearly IP with everything (the "all-IP" network, AIPN - see TS 22.978), and that access to the 3GPP network would ultimately be not only via UTRAN or GERAN but by WiFi, WiMAX, or even wired technologies. Thus SEA has as its main objectives:

- Impact on overall architecture resulting from RAN's LTE work
- Impact on overall architecture resulting from SA1's AIPN work
- Overall architectural aspects resulting from the need to support mobility between heterogeneous access networks

The figure below shows the evolved system architecture, possibly relying on different access technologies (extract of TR 23.882):



New reference points have been defined:

S1: It provides access to Evolved RAN radio resources for the transport of user plane and control plane traffic. The S1 reference point shall enable MME and UPE separation and also deployments of a combined MME and UPE solution.

S2a: It provides the user plane with related control and mobility support between a trusted non 3GPP IP access and the SAE Anchor.

S2b: It provides the user plane with related control and mobility support between ePDG and the SAE Anchor.

S3: It enables user and bearer information exchange for inter 3GPP access system mobility in idle and/or active state. It is based on Gn reference point as defined between SGSNs.

User data forwarding for inter 3GPP access system mobility in active state (FFS).

S4: It provides the user plane with related control and mobility support between GPRS Core and the 3GPP Anchor and is based on Gn reference point as defined between SGSN and GGSN.

S5a: It provides the user plane with related control and mobility support between MME/UPE and 3GPP anchor.

It is FFS whether a standardized S5a exists or whether MME/UPE and 3GPP anchor are combined into one entity.

S5b: It provides the user plane with related control and mobility support between 3GPP anchor and SAE anchor. It is FFS whether a standardized S5b exists or whether 3GPP anchor and SAE anchor are combined into one entity.

S6: It enables transfer of subscription and authentication data for authenticating/authorizing user access to the evolved system (AAA interface).

S7: It provides transfer of (QoS) policy and charging rules from PCRF to Policy and Charging Enforcement Point (PCEP).
The allocation of the PCEP is FFS.

SGi: It is the reference point between the Inter AS Anchor and the packet data network. Packet data network may be an operator external public or private packet data network or an intra operator packet data network, e.g. for provision of IMS services. This reference point corresponds to Gi and Wi functionalities and supports any 3GPP and non-3GPP access systems.

The interfaces between the SGSN in 2G/3G Core Network and the Evolved Packet Core (EPC) will be based on the GTP protocol. The interfaces between the SAE MME/UPE and the 2G/3G Core Network will be based on the GTP protocol.

Future plans

The LTE work should conclude at the September 2007 TSG plenary meetings. The conclusion of the SAE work (item) should follow.

* NGMN members: China Mobile Communications Corporation, KPN Mobile NV, NTT DoCoMo Inc., Orange SA, Sprint Nextel Corporation, T-Mobile International AG & Co KG and, Vodafone Group PLC.

Last update:

2006-10-04: Large revision following the results of the Study Item phase. Functional splits, architecture, functions and results.
2006-01-23: revision to take into account latest developments in 23.882.
2006-01-11: LTE and SAE update completed, bringing this page up to date with latest developments
2006-01-03: updates and inclusion of SAE info (started).
2005-09-19 10h30-CET