3GPP Long-Term Evolution / System Architecture Evolution Overview

September 2006

Ulrich Barth

ALCATEL

All rights reserved © 2006, Alcatel

Outline

3G-LTE Introduction

- Motivation
- Workplan
- Requirements

LTE air-interface

LTE Architecture

SAE Architecture

ALCATEL

All rights reserved © 2006, Alcatel

3GPP Evolution

- 2G: Started years ago with GSM: Mainly voice
- 2.5G: Adding Packet Services: GPRS, EDGE
- 3G: Adding 3G Air Interface: UMTS
- 3G Architecture:
  - Support of 2G/2.5G and 3G Access
  - Handover between GSM and UMTS technologies
- 3G Extensions:
  - HSDPA/HSUPA
  - IP Multi Media Subsystem (IMS)
  - Inter-working with WLAN (I-WLAN)
- Beyond 3G:
  - Long Term Evolution (LTE)
  - System Architecture Evolution (SAE)
  - Adding Mobility towards I-WLAN and non-3GPP air interfaces

ALCATEL

All rights reserved © 2006, Alcatel

Motivation for LTE

- **Need for PS optimised system**
  - Evolve UMTS towards packet only system
- **Need for higher data rates**
  - Can be achieved with HSDPA/HSUPA
  - and/or new air interface defined by 3GPP LTE
- **Need for high quality of services**
  - Use of licensed frequencies to guarantee quality of services
  - Always-on experience (reduce control plane latency significantly)
  - Reduce round trip delay (→ 3GPP LTE)
- **Need for cheaper infrastructure**
  - Simplify architecture, reduce number of network elements
  - Most data users are less mobile

ALCATEL

All rights reserved © 2006, Alcatel

LTE history - Workplan

Kick-off in RAN LTE workshop: Toronto, Nov. 2004

Study Item: TR feasibility on system level (Dec 2004 – June 2006)

- TR 25.913: Requirements for E-UTRAN
- TR 25.813: EUTRA and EUTRAN radio interface protocol aspects
- TR 25.814: Physical layer aspects for E-UTRA
- TR 25.912: Feasibility Study for Evolved UTRA and UTRAN

Detailed standard work: - June 2007

First products deployed … 2010

ALCATEL

All rights reserved © 2006, Alcatel

RAN-LTE concept: Requirements

3GPP TR 25.913

- **Service related requirements:**
  - support of available and future advanced services VoIP
  - higher peak data rates (e.g. 100 Mbps DL, 50 Mbps UL)
  - U-Plane /C-Plane latency: transit time (<10ms); setup times (<100ms)
- **Radio related requirements:**
  - improved "cell edge rates" and spectral efficiency (e.g. 2-4 x Rel6)
  - improved inner cell average data throughputs (MIMO needed)
  - Scaleable bandwidth - 1.25, 1.6, 2.5, 5, 10, 15, 20 MHz
- **Cost related requirements: reduced CAPEX and OPEX imply**
  - less complexity in RAN (architecture, signaling procedures/protocols)
  - economic usage of backhaul capacity; simplified and unified transport (IP)
- **Compatibility Requirements:**
  - interworking with legacy 3G and cost effective migration

ALCATEL

All rights reserved © 2006, Alcatel

Outline

3G-LTE Introduction

LTE air-interface

- Modulation / Multiple Access
- Multiple Antenna Schemes
- Scheduling

LTE Architecture

SAE Architecture

ALCATEL

All rights reserved © 2006, Alcatel

Modulation / Multiple Access

- **Downlink: OFDM / OFDMA**
  - Allows simple receivers in the terminal in case of large bandwidth
  - #subcarriers scales with bandwidth (76 ... 1201)
  - frequency selective scheduling in DL (i.e. OFDMA)
  - Adaptive modulation and coding (up to 64-QAM)
- **Uplink: SC-FDMA (Single Carrier - Frequency Division Multiple Access)**
  - A FFT-based transmission scheme like OFDM
  - But with better PAPR (Peak-to-Average Power Ratio)
  - The total bandwidth is divided into a small number of frequency blocks to be assigned to the UEs (e.g., 15 blocks for a 5 MHz bandwidth)
  - With Guard Interval (Cyclic Prefix) for easy Frequency Domain Equalisation (FDE) at receiver

ALCATEL
All rights reserved © 2006, Alcatel

3GPP LTE PHY

- TTI length: 1ms, comprising 2 subframes; concatenation possible
- DL parameters from 25.814 (Aug. 06)

Table 7.1.1-1 - Parameters for downlink transmission scheme

Transmission BW		1.25 MHz	2.5 MHz	5 MHz	10 MHz	15 MHz	20 MHz
Sub-frame duration		0.5 ms					
Sub-carrier spacing		15 kHz					
Sampling frequency		1.92 MHz (1/2 × 3.84 MHz)	3.84 MHz	7.68 MHz (2 × 3.84 MHz)	15.36 MHz (4 × 3.84 MHz)	23.04 MHz (6 × 3.84 MHz)	30.72 MHz (8 × 3.84 MHz)
FFT size		128	256	512	1024	1536	2048
Number of occupied sub-carriers†, ††		76	151	301	601	901	1201
Number of OFDM symbols per sub frame (Short/Long CP)		7/6					
CP length (μs/samples)	Short	(4.69/9) × 6, (5.21/10) × 1*	(4.69/18) × 6, (5.21/20) × 1	(4.69/36) × 6, (5.21/40) × 1	(4.69/72) × 6, (5.21/80) × 1	(4.69/108) × 6, (5.21/120) × 1	(4.69/144) × 6, (5.21/160) ×1
	Long	(16.67/32)	(16.67/64)	(16.67/128)	(16.67/256)	(16.67/384)	(16.67/512)

†Includes DC sub-carrier which contains no data

ALCATEL

All rights reserved © 2006, Alcatel

3GPP LTE PHY – Multiple Antenna Schemes

Well-integrated part in LTE from the beginning

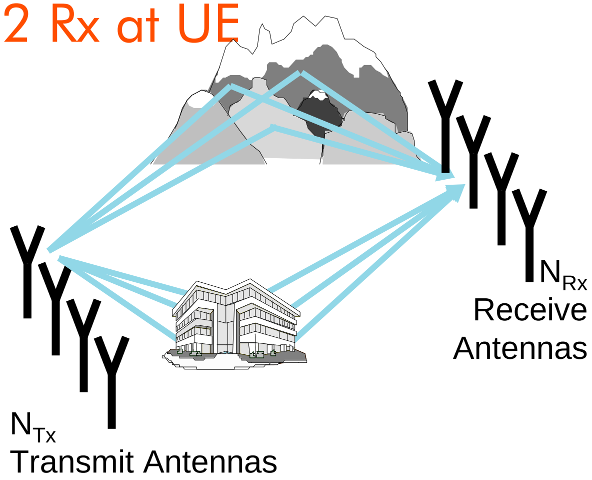
- Minimum antennas requirement: 2 at eNodeB, 2 Rx at UE

Beamforming

- Improves throughput at cell edge

Spatial Multiplexing → MIMO

- Needs good channel conditions
  - high SNR to enable good channel estimation
  - rich scattering environment, high spatial diversity, but NLOS !
- Improves throughput in cell center



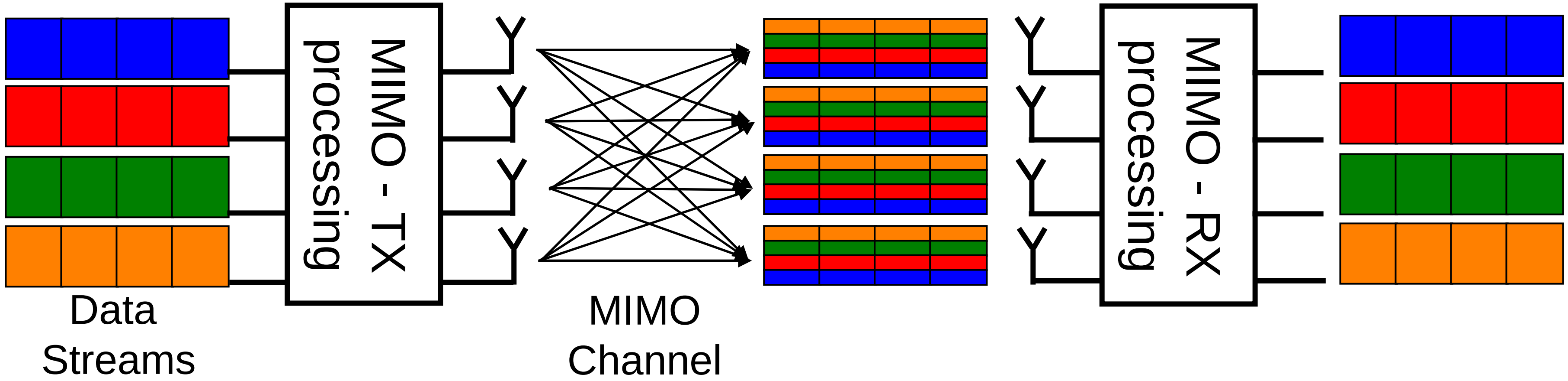
Multi-Antena Diversity

- Fall back solution if channel conditions don't allow MIMO

All rights reserved © 2006, Alcatel

3GPP LTE PHY - MIMO Basics

- Transmission of several independent data streams in parallel over uncorrelated antennas (i.e. separated by ≥ 10 λ)
  ⇒ increased data rate
- The radio channel consists of N_{Tx} x N_{Rx} (ideally uncorrelated) paths
- Theoretical maximum rate increase factor = Min (N_{Tx}, N_{Rx})
  (in a rich scattering environment; no gain in a line-of-sight environment)



- multiple codewords (MCW): each stream / antenna has its own FEC coding
  → "Per Antenna" (PAxx) schemes

ALCATEL
All rights reserved © 2006, Alcatel

3GPP LTE PHY - Scheduling

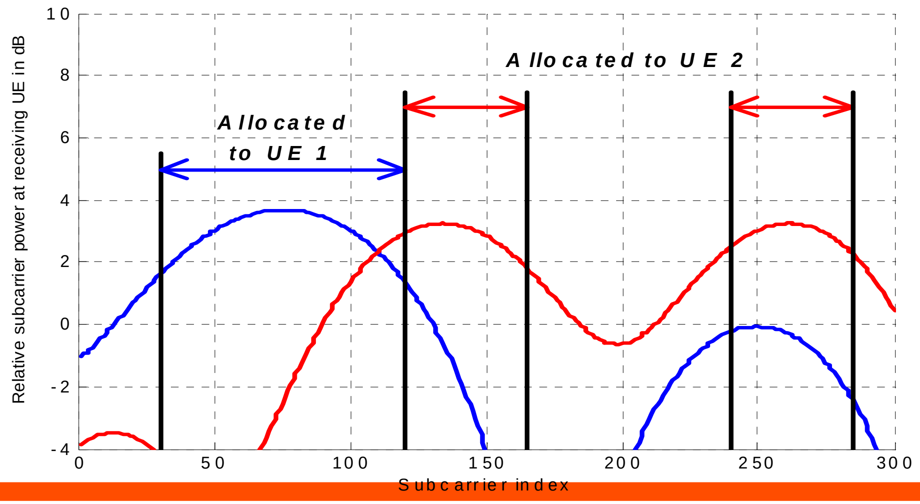
- Resource Block Size: 12 subcarriers → 100 RB in 20 MHz

Frequency diverse scheduling

- UEs are allocated to distributed resource blocks (combs)

Frequency selective scheduling - user specific

- Each UE is allocated its individual best part of the spectrum
- Best use of the spectrum ⇒ OFDM exploits channel capacity
- Sufficient feedback information on channel conditions from UE required



All rights reserved © 2006, Alcatel

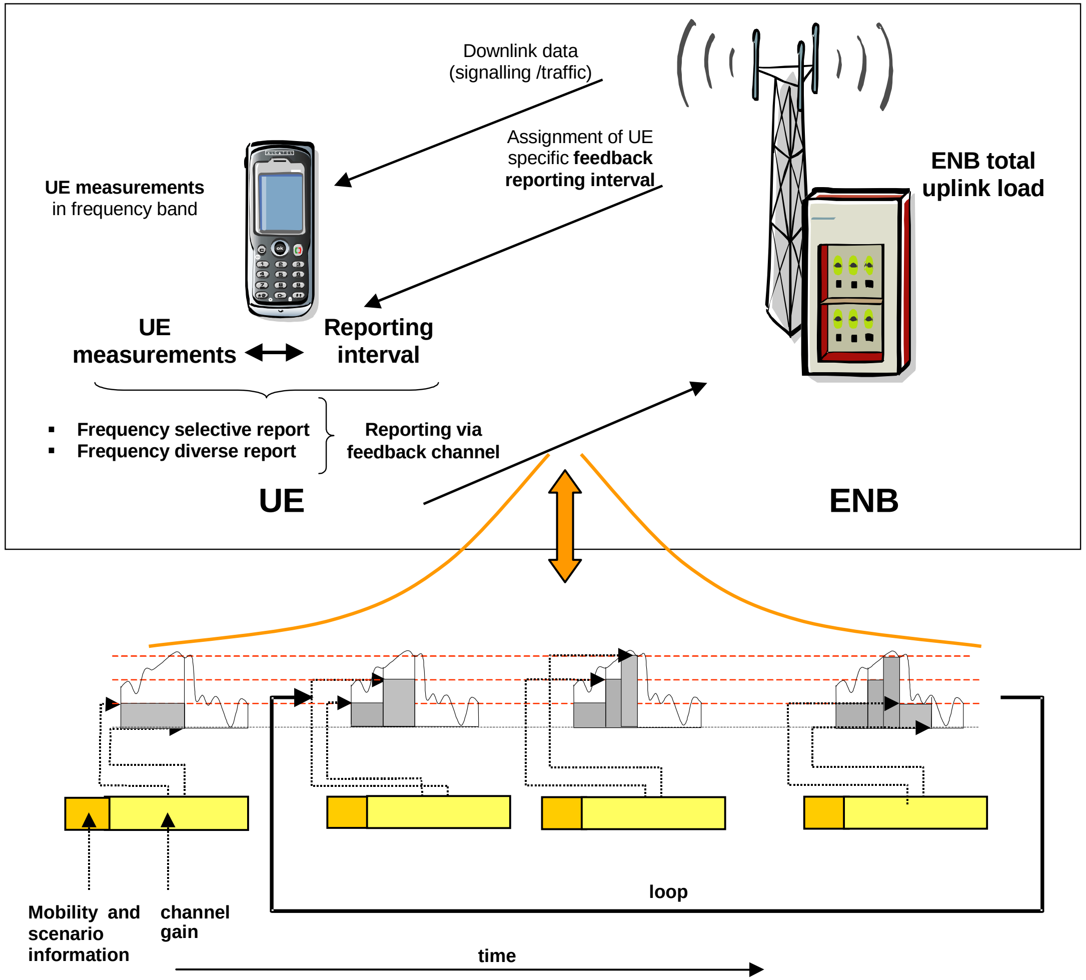
3GPP LTE PHY - Feedback Channel Concept

UE: Reports the finest possible granularity

- **The reporting scheme and granularity depend on the radio channel quality variation!**

ENB: Receives mobility and quality information

- **Incremental feedback information forms a rough picture of the radio channel with the first report(s). The granularity gets finer and finer with each report.**



ALCATEL

All rights reserved © 2006, Alcatel

Outline

3G-LTE Introduction

LTE air-interface

LTE Architecture

- Node Architecture
- User plane
- Control plane

SAE Architecture

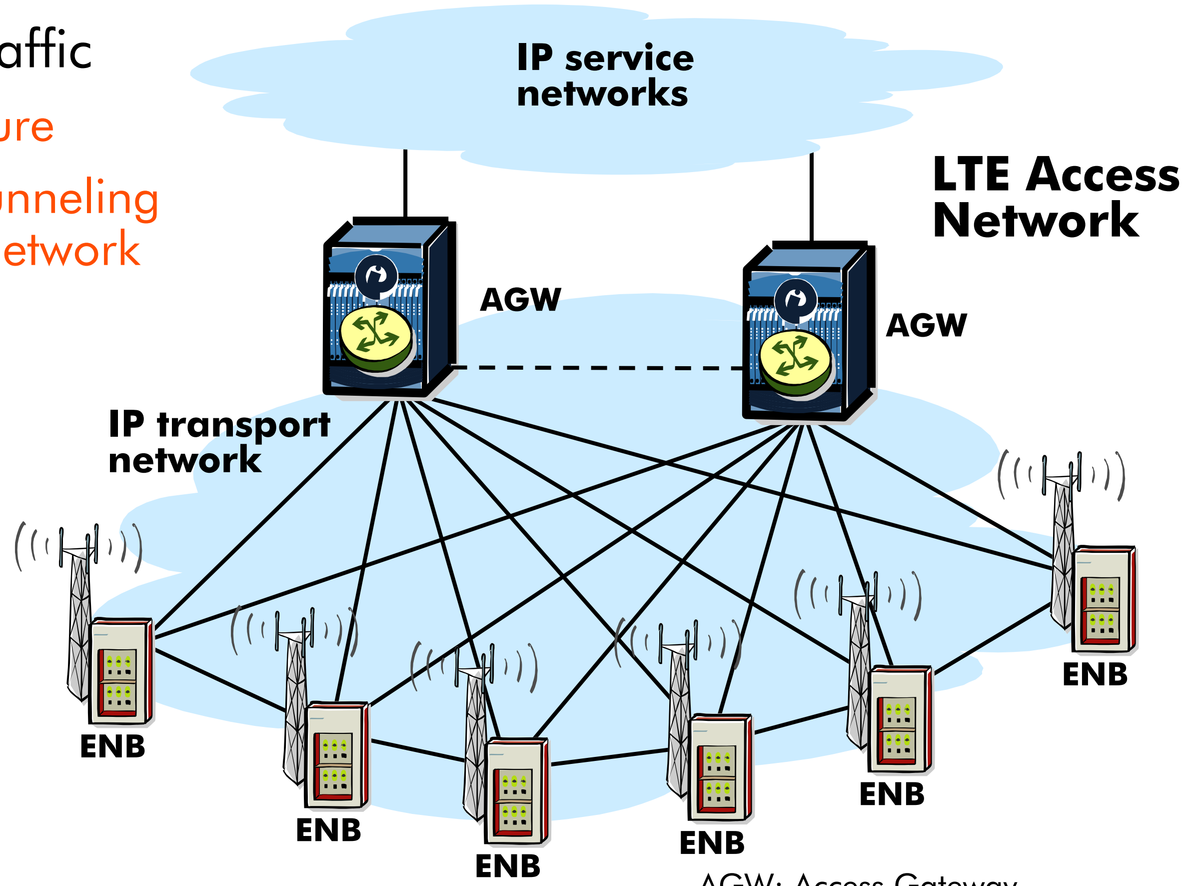
ALCATEL

All rights reserved © 2006, Alcatel

Network Architecture for LTE

Architecture for User Plane Traffic

- Cost efficient 2 node architecture
- Fully meshed approach with tunneling mechanism over IP transport network
  - Iu Flex approach
- Access Gateway (AGW)
- Enhanced Node B (ENB)

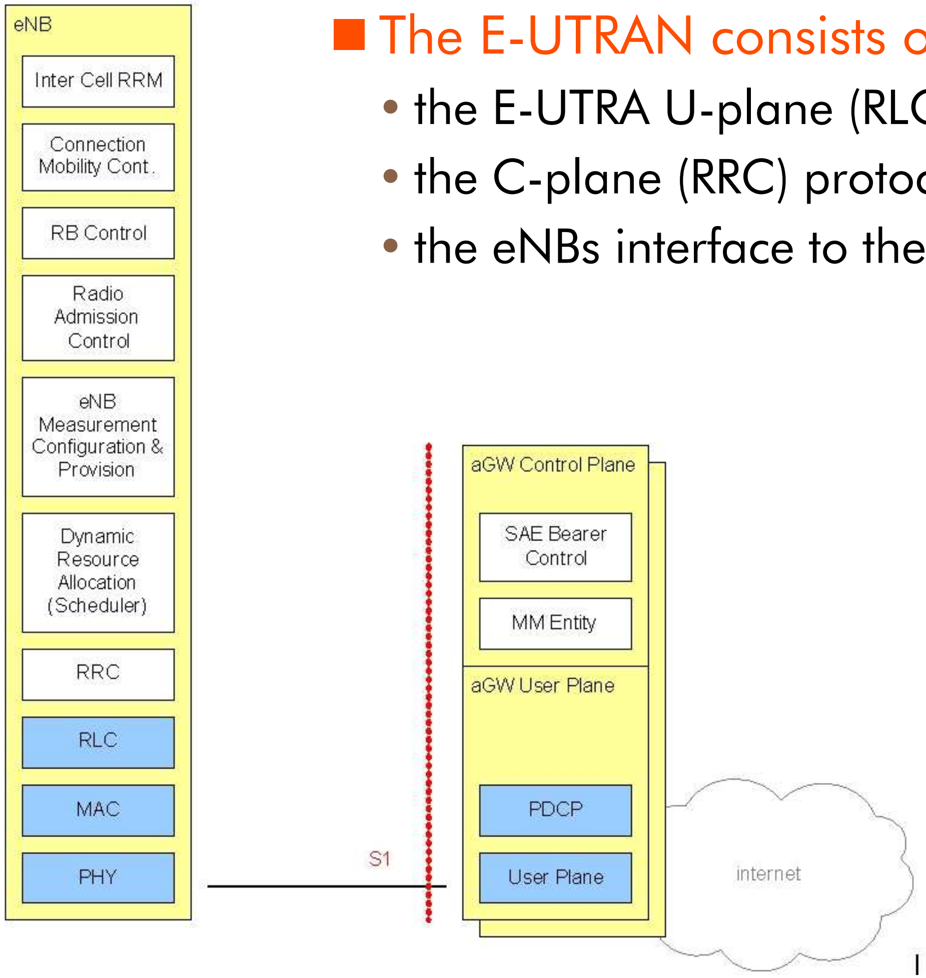


AGW: Access Gateway
ENB: Enhanced Node B

ALCATEL
All rights reserved © 2006, Alcatel

E-UTRAN Architecture

[25.912]



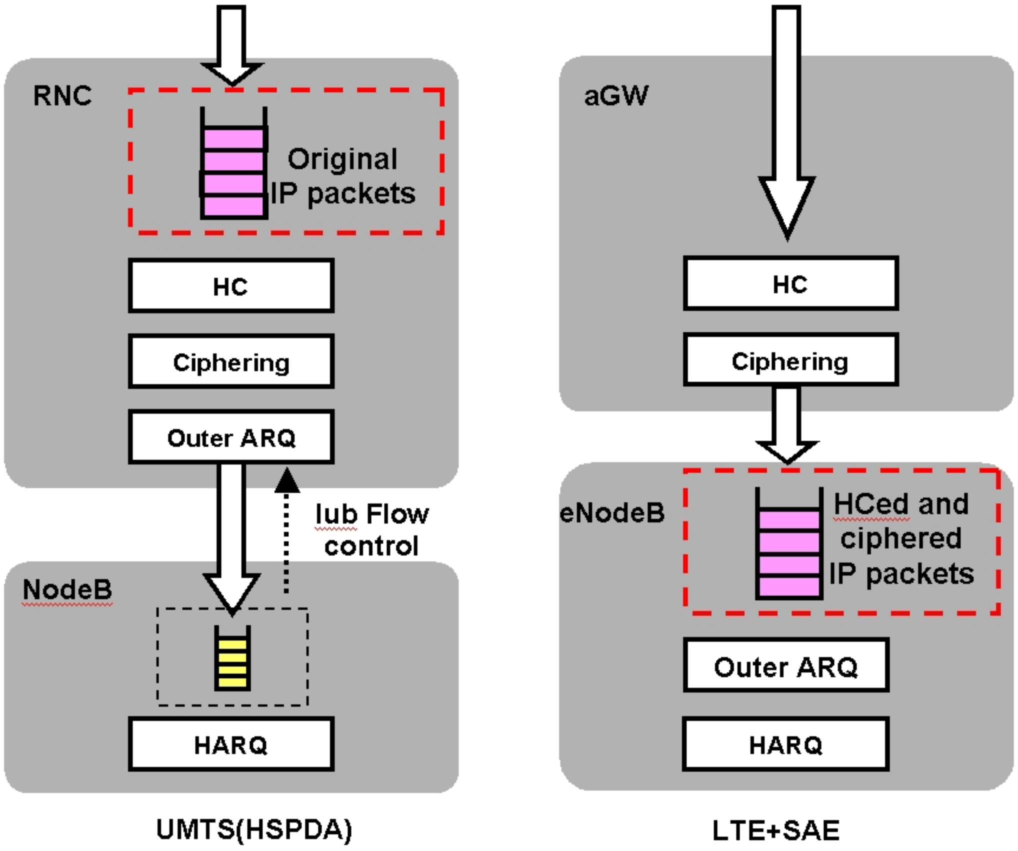
- The E-UTRAN consists of eNBs, providing
  - the E-UTRA U-plane (RLC/MAC/PHY) and
  - the C-plane (RRC) protocol terminations towards the UE.
  - the eNBs interface to the aGW via the S1
- eNodeB
  - All Radio-related issues
  - Decentralized mobility management
  - MAC and RRM
  - Simplified RRC
- aGW
  - Paging origination
  - LTE_IDLE mode management
  - Ciphering of the user plane
  - Header Compression (ROHC)

ALCATEL

All rights reserved © 2006, Alcatel

E-UTRAN Architecture: U-plane

Differences between UMTS (HSDPA) and LTE/SAE

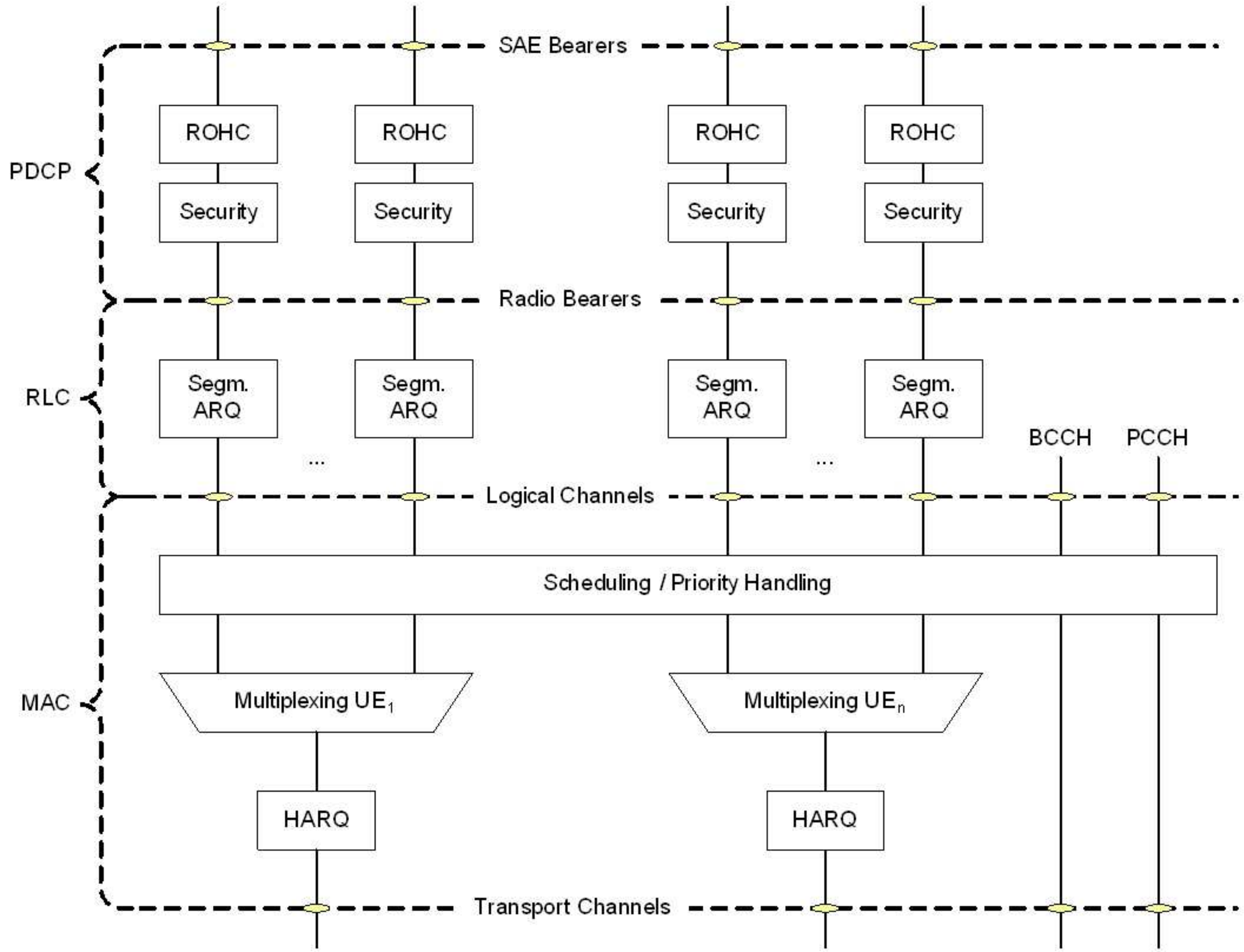


ALCATEL

All rights reserved © 2006, Alcatel

Layer 2 Structure (eNB and aGW)

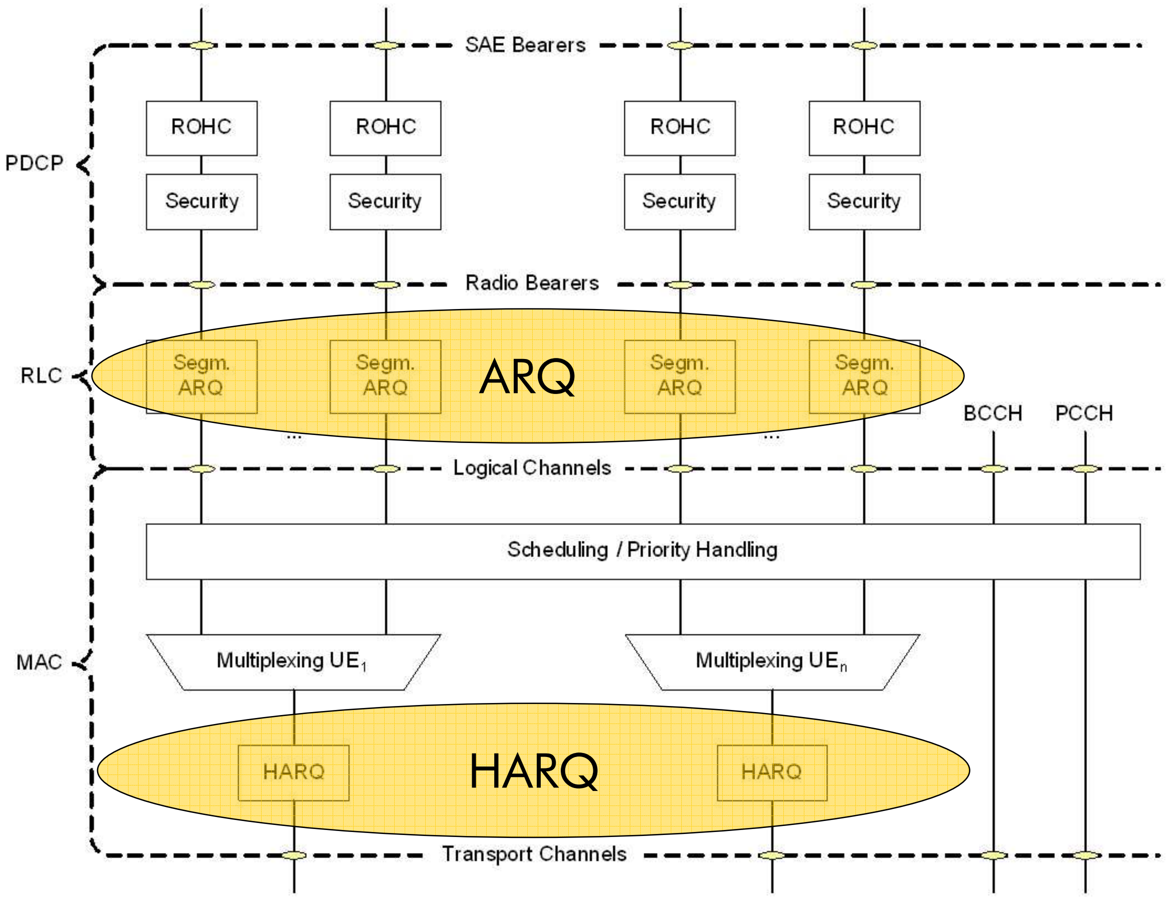
[25.912]



ALCATEL

All rights reserved © 2006, Alcatel

ARQ and HARQ



- The ARQ functionality provides error correction by retransmissions in acknowledged mode at Layer 2.
- The HARQ functionality ensures delivery between peer entities at Layer 1.

All rights reserved © 2006, Alcatel

ARQ and HARQ

[25.813]

HARQ characteristics

- N-process Stop-And-Wait HARQ is used
- The HARQ is based on ACK/NACKs
- In the downlink asynchronous retransmissions with adaptive transmission parameters are supported
- In the uplink HARQ is based on synchronous retransmissions

ARQ characteristics

- The ARQ retransmits RLC SDUs (IP packets)
- ARQ retransmissions are based on HARQ/ARQ interactions

HARQ/ARQ interactions

- ARQ uses knowledge obtained from the HARQ about the transmission/reception status of a Transport Block

ALCATEL

All rights reserved © 2006, Alcatel

E-UTRAN C-Plane: Distributed RRM

- Radio Bearer Control (RBC)
- Radio Admission Control (RAC)
- Connection Mobility Control (CMC)
- Dynamic Resource Allocation (scheduling) (DRA)
- Radio Configuration (RC)

References for Distributed RRM

- R2-052905 RRM for Architecture Option C in the Control Plane and Option A in the User Plane
- R3-051248 Definition of Multi- and Intra-cell RRM
- R3-060029 Handling of RRM in a Decentralized RAN Architecture

ALCATEL

All rights reserved © 2006, Alcatel

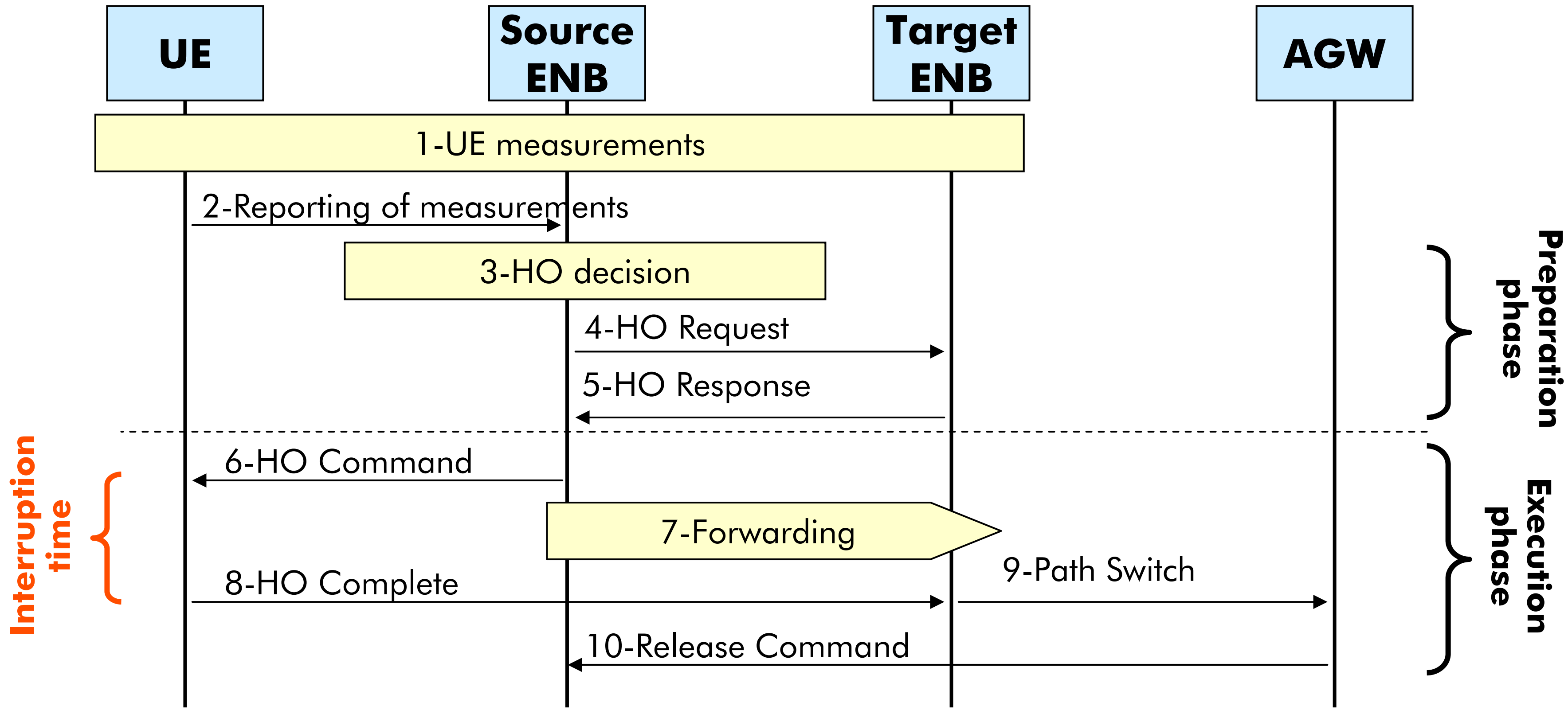
E-UTRAN C-Plane: Intra-LTE Handover

- Network controlled handover: decision taken by Source ENB
- Preparation phase
  - preparation of Target eNodeB by context transfer prior to HO command
  - Break before make approach
  - core network not involved during preparation phase
- Temporary forwarding of UP data from Source ENB to Target ENB
- Path switching at AGW
  - after establishment of new connection between UE and Target ENB
  - no temporary buffering at AGW
- Performance
  - short interruption time in the range of 30 ms
  - same handover procedure applicable for real-time (delay sensitive) and non real-time (non delay sensitive) services
  - suitable for lossless and seamless handovers

ALCATEL

All rights reserved © 2006, Alcatel

E-UTRAN C-Plane: Intra-LTE Handover



All rights reserved © 2006, Alcatel

Outline

3G-LTE Introduction

LTE air-interface

LTE Architecture

SAE Architecture

- Objectives
- Node Architecture

ALCATEL

All rights reserved © 2006, Alcatel

System Architecture Evolution

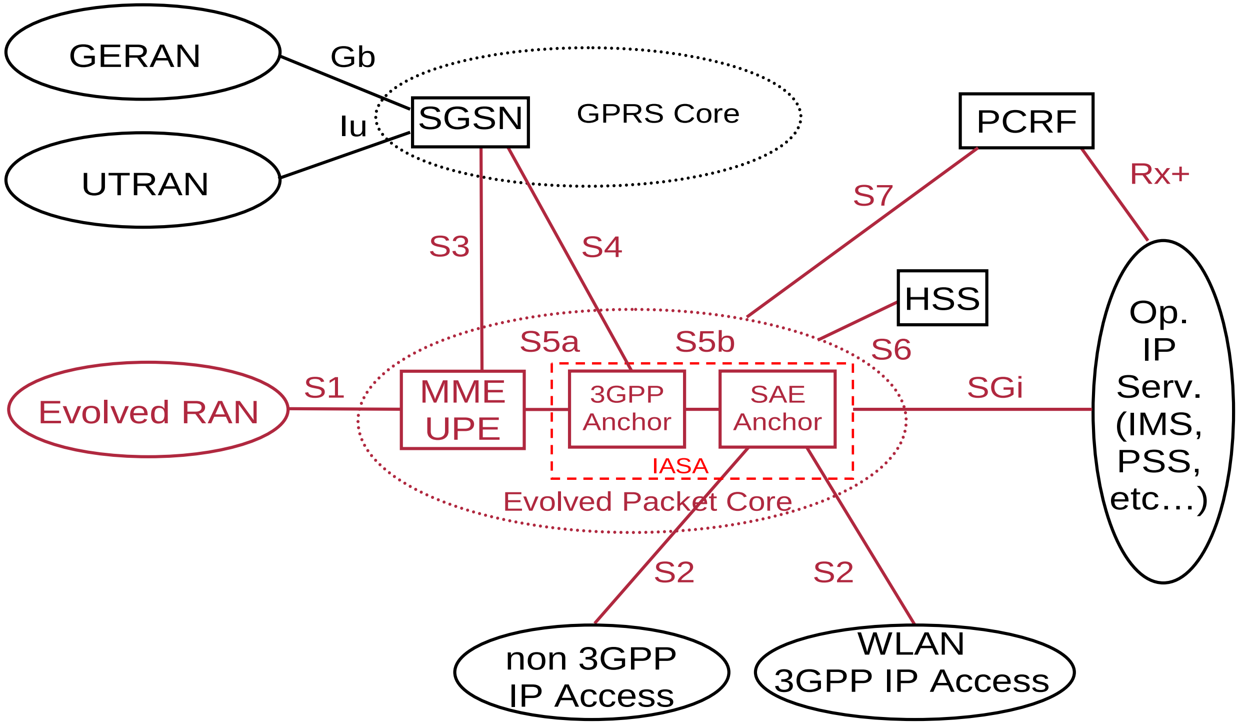
Objectives

- New core network architecture to support the high-throughput / low-latency LTE access system
  - Simplified network architecture
- All IP network
  - All services are via PS domain only, No CS domain
- Support mobility between multiple heterogeneous access system
  - 2G/3G, LTE, non 3GPP access systems (e.g. WLAN, WiMAX)
  - Inter-3GPP handover (GPRS <> E-UTRAN): Using GTP-C based interface for exchange of Radio info/context to prepare handover
  - Inter 3GPP non-3GPP mobility: Evaluation of host based (MIPv4, MIPv6, DSMIPv6) and network based (NetLMM, PMIPv4, PMIPv6) protocols

ALCATEL

All rights reserved © 2006, Alcatel

SAE Architecture: Baseline

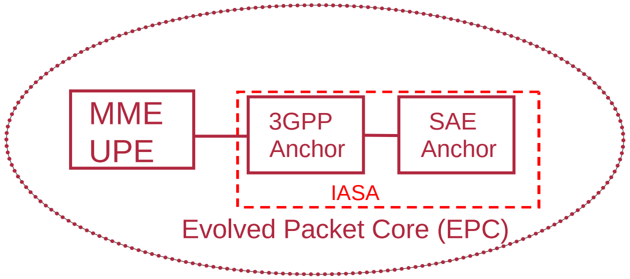


* Color coding: red indicates new functional element / interface

Figure 4.2-1: Logical high level architecture for the evolved system [3GPP TR 23.882]

All rights reserved © 2006, Alcatel

SAE Architecture: Functions per Element

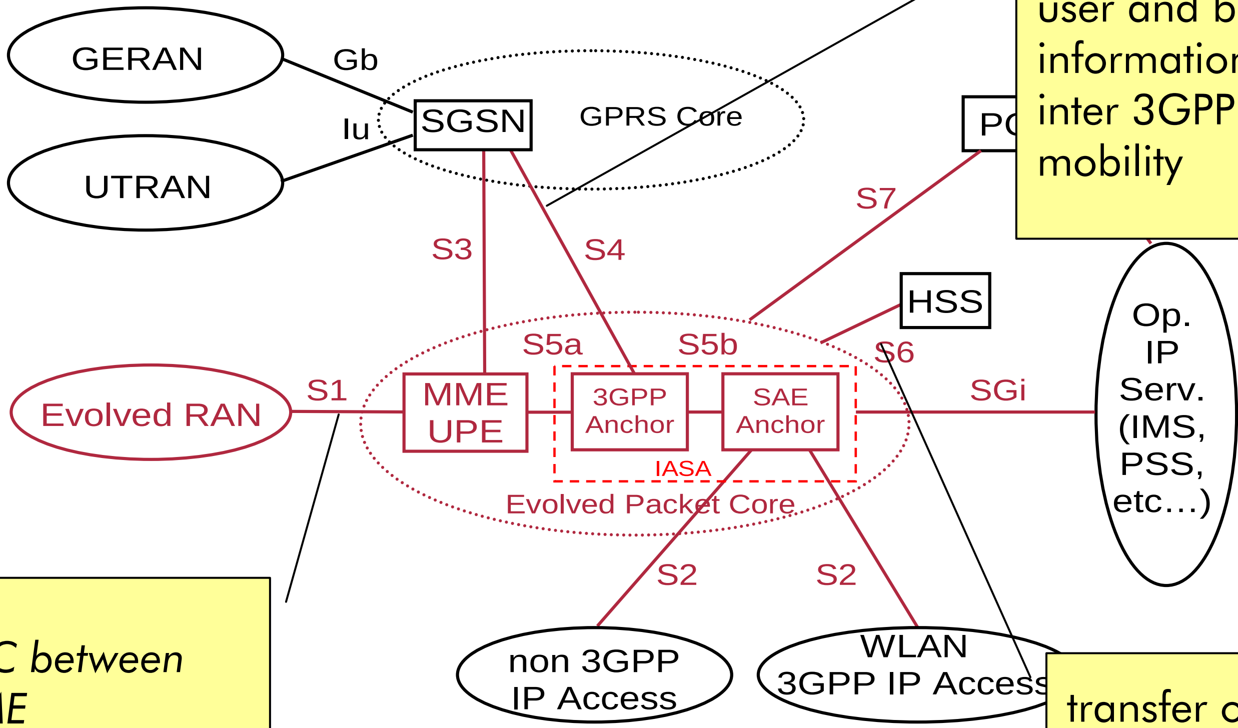


- **MME (Mobility Management Entity):**
  - Manages and stores the UE control plane context, generates temporary Id, UE authentication, authorisation of TA/PLMN, mobility management
- **UPE (User Plane Entity):**
  - Manages and stores UE context, DL UP termination in LTE_IDLE, ciphering, mobility anchor, packet routing and forwarding, initiation of paging
- **3GPP anchor:**
  - Mobility anchor between 2G/3G and LTE
- **SAE anchor:**
  - Mobility anchor between 3GPP and non 3GPP (I-WLAN, etc)

ALCATEL

All rights reserved © 2006, Alcatel

SAE Architecture: Interfaces



ndicates new functional element / interface

.2-1: Logical high level architecture for the evolved system [3

user and bearer information exchange for inter 3GPP access system mobility

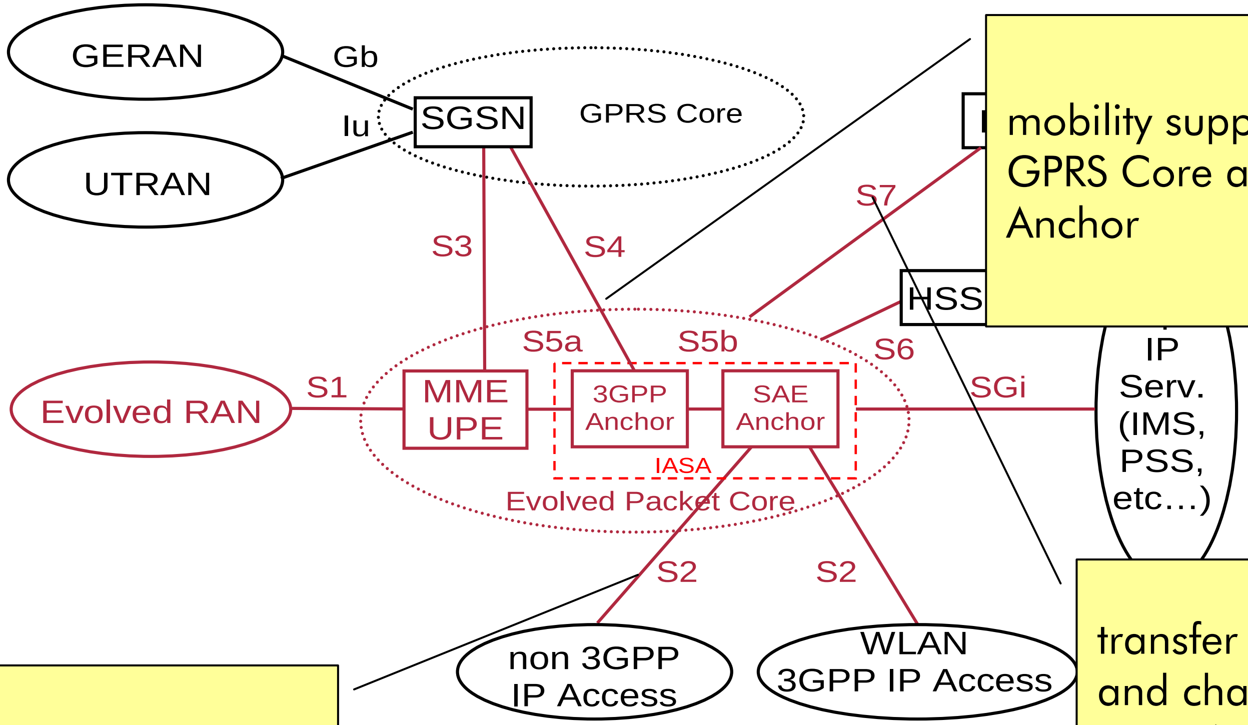
C-Plane: S1-C between eNB and MME
U-Plane: S1-U between eNB and UPE

transfer of subscription and authentication data for user access to the evolved system (AAA interface).

ALCATEL

All rights reserved © 2006, Alcatel

SAE Architecture: Interfaces



mobility support between GPRS Core and Inter AS Anchor

transfer of (QoS) policy and charging rules from PCRF (Policy and Charging Rule Function)

mobility support between WLAN 3GPP IP access or non 3GPP IP access and Inter AS Anchor

es new functional element / interface

Logical high level architecture for the evolved system [3GP

ALCATEL

All rights reserved © 2006, Alcatel

Thank You

Ulrich.Barth@Alcatel.de

All rights reserved © 2006, Alcatel