RETELE METROPOLITANE SI RURALE

Long Term Evolution Technology (LTE)

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Acknowledgement:
This text does not contain original material. it is a compilation based on several public documents (See Ref. list). Only the text organization belongs to the author.

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1 INTRODUCTION

1.1 Introduction

- There are many types of cellular technologies and services
- Cellular network/telephony is a *radio*-based technology(access part) + fixed network (core part)
- Most used bands are in the 850 MHz, 900 MHz, 1800 MHz, and 1900 MHz

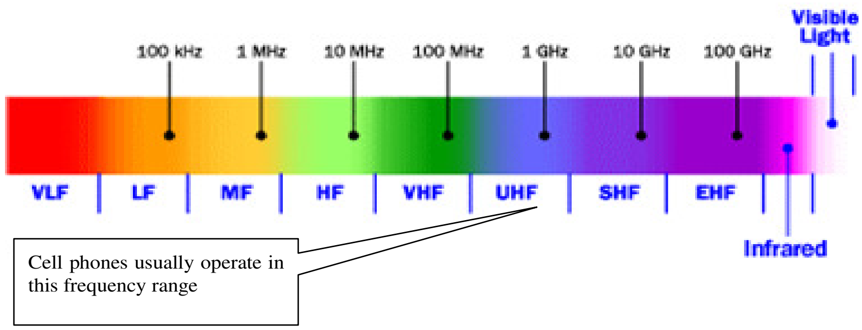

Figure 1-1 Spectral bands

Multiple access schemes

- Frequency Division Multiple Access (FDMA)
  - Frequency channels
- Time Division Multiple Access (TDMA)
  - Temporal channels
- Code Division Multiple Access (CDMA)
  - Use of orthogonal codes to separate different transmissions
  - Each symbol of bit is transmitted as a larger number of bits using the user specific code – Spreading spectrum

1.2 Cellular Technologies General Overview

1G networks
(NMT, C-Nets, AMPS, TACS)

- first analog cellular systems, ~1980s.
- before that, there were radio telephone systems
- conceived and designed for voice calls only with almost no consideration of data services (with the possible exception of built-in modems in some headsets)
- data: 2.4kbps.

(-) Poor Voice Quality ; Poor Battery Life; Large Phone Size; No Security; Limited Capacity

2G networks
(GSM, CDMAOne, D-AMPS) ~1991

- first digital cellular systems, ~1990s (network's switching station are digital)
- voice, data
- improved sound quality, better security and higher total capacity.
- circuit-switched data (CSD), allowing users to place dial-up data calls digitally,
- low data rates on temporal channels (~64kbps)
- SMS service

(-) These systems are unable to handle complex data such as Videos

2.5G networks
(GPRS, CDMA2000 1x)

- enhanced 2G versions with theoretical data rates up to about 144kbit/s.
- GPRS offered the first always-on data service
- 2.5G bridgeds 2G to 3G; it has faster and higher-capacity data transmission
- 2.5G has advances aiming to 3G networks (including packet-switching)
- 2G and 3G have been officially defined as wireless standards by the (ITU); however 2.5G has not been defined like std. and was interim solution- market driven
- 2.5 G includes EDGE (part of the GSM family) and CDMA 2000 1X; at times these technologies are called 3G as they both meet some of the ITU requirements for 3G standards.
- Phone, e-mail, data, camera phones, web brousing – services
- 6-9 mins. to download a 3 mins. Mp3 song

3G networks (~ 2000)
(UMTS FDD and TDD, CDMA2000 1x EVDO, CDMA2000 3x, TD-SCDMA, Arib WCDMA, EDGE, IMT-2000 DECT)

- newer cellular networks that have data rates of 384kbit/s and more.
- UN's ITU IMT-2000 standard requires stationary speeds of 2Mbps and mobile speeds of 384kbps for a "true" 3G.
- 3G systems belong to ITU's Int'l Mobile Telecommunications 2000 (IMT-2000)
- Services:
  - 3G : faster data trs. speeds, greater network capacity, advanced network services
  - Data 144kbps - 2Mbps
  - Video Conferencing / 3D Gaming
  - TV Streaming/ Mobile TV/ Phone Calls
  - Large Capacities and Broadband Capabilities
  - 11 sec – 1.5 min. time to download a 3 min Mp3 song
  - High Speed Web / More Security

- UMTS-HSPA is the world's leading 3G technology.
- by 2015, UMTS-HSPA and LTE 3G expectation
  - ~3.9 billion global subscriptions
  - compared to 569 million CDMA EV-DO subscriptions and 59 million WiMAX subscriptions.

[Note:
HSPA denotes:
HSDPA:

- upgrade of WCDMA (<14 Mbit/s with significantly reduced latency)
- based on shared channel transmission and its key features are shared channel and multi-code transmission, higher order modulation short transmission time interval (TTI), fast link adaptation and scheduling along with fast hybrid automatic repeat request (HARQ).

HSUPA

- WCDMA UL upgrade (3GPP Release 6); it is usually only a software update.
- Enhanced UL adds a new transport channel to WCDMA: Enhanced Dedicated Channel (E-DCH).
  - It supports new applications : VoIP, uploading pictures and sending large e-mail messages.
- The enhanced UL data rate is <5.8 Mbit/s, and also reduces latency.
- improvements are similar to HSDPA: multi-code transmission, short Transmission Time Interval (TTI), fast scheduling and fast HARQ Hybrid Automatic Repeat reQuest

]

3.5G ("beyond 3G")

- 3.5G is not an officially recognized standard by the ITU.
- Interim/ evolutionary step to the next generation of cellular technology that will be known as IMT-Advanced
- IMT-Advanced will comprise the 4G
- 3.5G is also known as *4G Americas* does not use the terms 3.5G (or 2.5G) in respect of the official definitions provided by the ITU.

- The technologies within the GSM family, considered as beyond 3G, include HSPA+ and LTE. These 3.5G technologies are often called *pre-4G* as well.

4G technology

- 4G is defined by the ITU and its Radiocomm Sector (ITU-R) and established as an agreed upon and globally accepted definition in *IMT-Advanced*
- **September 2009, ITU**
    - LTE – Long Term Evolution standardized by the 3GPP
    - WiMAX - 802.16m standardized by the IEEE (i.e. mobile WiMAX)

ITU Requirements for 4G

- all-IP packet switched network
- Peak data rates
    - of up ~ 100 Mbit/s for high mobility
    - up to ~1 Gbps for low mobility (nomadic/local wireless access
- Dynamically share and use the network resources to support more simultaneous users per cell
- Scalable channel bandwidth 5–20 MHz, optionally up to 40 MHz
- Peak link spectral efficiency of *15 bit/s/Hz* in the downlink, and *6.75 bit/s/Hz* in the uplink (meaning that 1 Gbps in the downlink should be possible over less than 67 MHz bandwidth)
- System spectral efficiency of up to 3 bit/s/Hz/cell in the DL and 2.25 bit/s/Hz/cell for indoor usage
- Smooth handovers across heterogeneous networks
- Ability to offer high quality of service for next generation multimedia support
- Specs are so aggressive that no commercialized standard currently meets them.

History

In Release 10, *3rd Generation Partnership Project (3GPP)* addressed the *IMT-Advanced* requirements in a version of LTE, called LTE-Advanced, for which specifications became available in 2011.
WiMAX addressed the *IMT-Advanced* requirements in a version called Mobile WiMAX 2.0, specified in IEEE 802.16m.

WiMAX and Long-Term Evolution (LTE) standards - generally accepted to succeed both CDMA2000 and GSM,

- labeled as "4G technologies,"
- but that's only partially true:
    - they both make use efficient multiplexing scheme (OFDMA, as opposed to the older CDMA or TDMA),
    - however, WiMAX tops at around 40Mbps and LTE at around 100Mbps theoretical speed;
        - they don't fully comply with the planned requirements of 1 Gbps for stationary reception and 100 Mbps for mobile.
    - Practical, real-world commercial networks using WiMAX and LTE range between 4Mbps and 30Mbps.
    - Even though the speeed of WiMAX and LTE is lower than values of IMT-Advanced's standard, they're very different than 3G networks and carriers around the world refer to them as "4G"';
        - The common argument for branding LTE and WiMAX systems as 4G is that they use different frequency bands to 3G technologies
    - Updates to these standards -- **WiMAX 2** and **LTE-Advanced**, respectively -- will increase througput further, but neither has been finalized yet.

Evolution

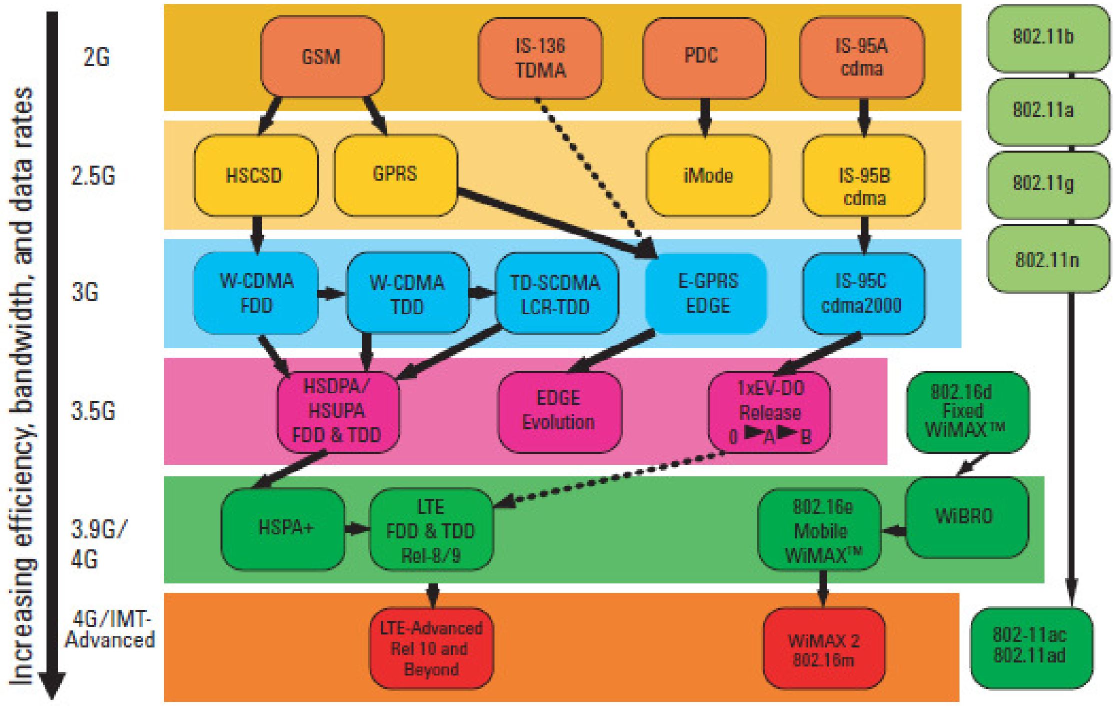

Figure 1-2 Mobile technologies evolution

2 LONG TERM EVOLUTION TECHNOLOGY

2.1 Introduction LTE

- **Evolution: GSM → UMTS→ Earlier 3GPP → LTE**
- LT E started as a project in 2004 by telecom body (3GPP).
- SAE (System Architecture Evolution) is the corresponding evolution of the GPRS/3G packet core network evolution.
- **The term LTE is typically used to represent both LTE and SAE**

- The related specifications were formally known as the evolved UMTS terrestrial radio access (E-UTRA) and evolved UMTS terrestrial radio access network (E-UT RAN).
- **First version of LTE : Release 8 of the 3GPP specs.**

- Why LTE?? : A rapid increase of mobile data usage and emergence of new applications such as *MMOG (Multimedia Online Gaming)*, *mobile TV, Web 2.0, streaming contents* → 3GPP worked on the LTE for 4G mobile.

Main goals:

- high data rate, low latency and packet optimized RAT supporting flexible bandwidth deployments; support packet-switched traffic with seamless mobility and QoS

Evolution:

Mar 2000	Release 99 - UMT S/WCDMA
Mar 2002	Rel 5 - HSDPA
Mar 2005	Rel 6 - HSUPA
Year 2007	Rel 7 - DL MIMO, IMS (IP Multimedia Subsystem)
Nov 2004	Work start on LT E specs
Jan 2008	**Spec finalized and approved with Release 8**
2010	**First deployment**

LTE main characteristics

- ~ **50 times perf.** improvement and much better spectral efficiency to cellular networks.
- **high data rates**: 300 Mbps peak DL and 75 Mbps peak UL
  - data rates > 300Mbps can be achieved in a 20 MHz carrier, under very good signal conditions.
- support for **services** : **VOIP, streaming multimedia, videoconf., high-speed cellular modem**.
- **duplex modes**: both TDD and FDD mode.
- supports **flexible carrier bandwidths**, from 1.4 - 20 MHz as well as both FDD and T DD.
  - scalable carrier bandwidth from 1.4 MHz up to 20 MHz ; the bandwidth used depends on the frequency band and the amount of spectrum available with a network operator.
- All LTE **devices have to support MIMO transmissions**,
  - (BS can transmit several data streams over the same carrier simultaneously).
- **All I/Fs between network nodes in LTE are IP based,** including the backhaul connection to the radio base stations.
  - Significant simplification compared to earlier technologies initially based on E1/T 1, ATM and frame relay links, with most of them being narrowband and expensive.

- **QoS mechanism** have been standardized on all I/Fs to ensure that the requirement of voice calls for a constant delay and bandwidth, can still be met when capacity limits are reached.
- Works with **GSM/EDGE/UMTS** systems utilizing existing 2G and 3G spectrum and new spectrum.
- Supports **handover and roaming** to existing mobile networks.

LTE Advantages

- **High throughput**

- **Low latency** (time required to connect to the network is ~ 10^2 ms and power saving states can now be entered and exited very quickly.
- **FDD and TDD in the same platform**:
- **Superior QoE :** Optimized signaling for connection establishment and other air interface and mobility management procedures have further improved the user experience. Reduced latency (to 10 ms) for better user experience.
- **Seamless connection to existing networks such as GSM, CDMA and WCDMA**.
- **Plug and play**: no need to manually install drivers for devices.
  - The system automatically recognizes the device, loads new drivers for the hardware if needed, and begins to work with the newly connected device.
- **More simple architecture**: → low operating expenditure (OPEX).

LTE - QoS

- LTE supports E2E **hard QoS,** with guaranteed bit rate (GBR) for radio bearers.
- **Various levels of QoS** can be applied to LT E traffic for different applications.
- Because the LT E **MAC is fully scheduled**, QoS is a natural fit.

- **Evolved Packet System (EPS)** bearers provide 1-to-1 correspondence with RLC radio bearers and provide support for Traffic Flow Templates (TFT).
  - There are four types of EPS bearers:
    - **GBR Bearer:** resources permanently allocated by admission control
    - **Non-GBR Bearer** no admission control
    - **Dedicated Bearer** associated with specific TFT (GBR or non-GBR)
    - **Default Bearer** Non GBR, **catch-all** for unassigned traffic

2.2 LTE Basic Parameters

Table 2-1 LTE basic parameters

Parameters	**Description**	
Frequency range	UMTS FDD bands and TDD bands defined in 36.101(v860) T able 5.5.1, g iven below	
Duplexing	FDD, TDD, half-duplex FDD	
Mobility	350 km/h	
Channel Bandwidth (MHz)	1.4; 3; 5; 10; 15; 20	
T ransmission Bandwidth Config uration NRB: (1 resource block = 180kHz in 1ms T T I)	6;15;25;50;75;100	
Coverage	5 - 100km with slig ht deg radation after 30km	
QoS	E2E QOS allowing prioritization of different class of service	
Latency	End-user latency < 10mS	

E-UTRA Operating Bands

Table 2-2 E-UTRA operating bands taken from LT E Sepecification 36.101(v860)

E-UTRA Operating Band	Uplink (UL) operating band BS receive UE transmit	Downlink (DL) operating band BS transmit UE receive	Duplex Mode
	F_{UL_low} – F_{UL_high}	F_{DL_low} – F_{DL_high}	
1	1920 MHz – 1980 MHz	2110 MHz – 2170 MHz	FDD
2	1850 MHz – 1910 MHz	1930 MHz – 1990 MHz	FDD
3	1710 MHz – 1785 MHz	1805 MHz – 1880 MHz	FDD
4	1710 MHz – 1755 MHz	2110 MHz – 2155 MHz	FDD
5	824 MHz – 849 MHz	869 MHz – 894MHz	FDD
6	830 MHz – 840 MHz	875 MHz – 885 MHz	FDD
7	2500 MHz – 2570 MHz	2620 MHz – 2690 MHz	FDD
8	880 MHz – 915 MHz	925 MHz – 960 MHz	FDD
9	1749.9 MHz – 1784.9 MHz	1844.9 MHz – 1879.9 MHz	FDD
10	1710 MHz – 1770 MHz	2110 MHz – 2170 MHz	FDD
11	1427.9 MHz – 1447.9 MHz	1475.9 MHz – 1495.9 MHz	FDD
12	698 MHz – 716 MHz	728 MHz – 746 MHz	FDD
13	777 MHz – 787 MHz	746 MHz – 756 MHz	FDD
14	788 MHz – 798 MHz	758 MHz – 768 MHz	FDD
17	704 MHz – 716 MHz	734 MHz – 746 MHz	FDD
...			
33	1900 MHz – 1920 MHz	1900 MHz – 1920 MHz	TDD
34	2010 MHz – 2025 MHz	2010 MHz – 2025 MHz	TDD
35	1850 MHz – 1910 MHz	1850 MHz – 1910 MHz	TDD
36	1930 MHz – 1990 MHz	1930 MHz – 1990 MHz	TDD
37	1910 MHz – 1930 MHz	1910 MHz – 1930 MHz	TDD
38	2570 MHz – 2620 MHz	2570 MHz – 2620 MHz	TDD
39	1880 MHz – 1920 MHz	1880 MHz – 1920 MHz	TDD
40	2300 MHz – 2400 MHz	2300 MHz – 2400 MHz	TDD

2.3 LTE Network Architecture [1],[3]

Three main components:

- **User Equipment** (UE).
- **Evolved UMTS Terrestrial Radio Access Network** (E-UTRAN).
- **Evolved Packet Core (EPC).**
  - o EPC communicates with packet data networks in the outside world such as the internet, private corporate networks or the IP multimedia subsystem.

The interfaces : **Uu, S1 and SGi**

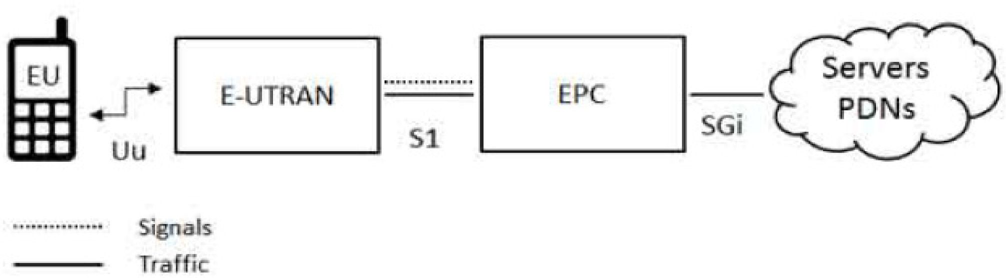

Figure 2-1 High level LTE architecture

2.3.1 User Equipment (UE)

- The EU internal architecture of the user equipment for LTE is identical to the one used by UMTS and GSM, i.e. Mobile Equipment (ME).
- Modules:

- **Mobile Termination (MT):** handles all the communication functions.
- **T erminal Equipment (T E):** terminates the data streams.
- **Universal Integ rated Circuit Card (UICC):** known as the SIM card for LTE equipments.
  - It runs an application known as the **Universal Subscriber Identity Module (USIM).**

- A **USIM** stores user-specific data very similar to 3G SIM card. T his keeps information about the user's phone number, home network identity and security keys etc.

[GSM Mobile terminal – reminder

- physical equipment used by a PLMN subscriber to connect to the network.
- it comprises the **Mobile Equipment (ME)** + **Subscriber Identity Module (SIM).**
- ihe ME is part of the **Mobile Termination (MT)**
- which, depending on the application and services, may also include various types of **Terminal Equipment (TE)** and associated **Terminal Adapter (TA).**

MT = TE (e.g laptop) + TA+ MS (i.e SIM +ME)

Identification principles - summary

MS equipment and subscriber- distinctly identified

ME has an **IMEI** unique **("International Mobile Equipment Identity")** – equipment Id (Can be checked for stolen equipment)

Subcriber Identification: several addresses (different points of view)**:**

- **MS-ISDN ("Mobile Subscriber ISDN Number")** - number (address) used to call MS from PSTN, ISDN
- **IMSI ("International Mobile Subscriber Identity")** – unique number in the context of the mobile network
- **TMSI ('Temporar Mobile Subscriber Identity")** - temporary number assigned to the subscriber by the GSM system

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2.3.2 E-UTRAN (The access network)

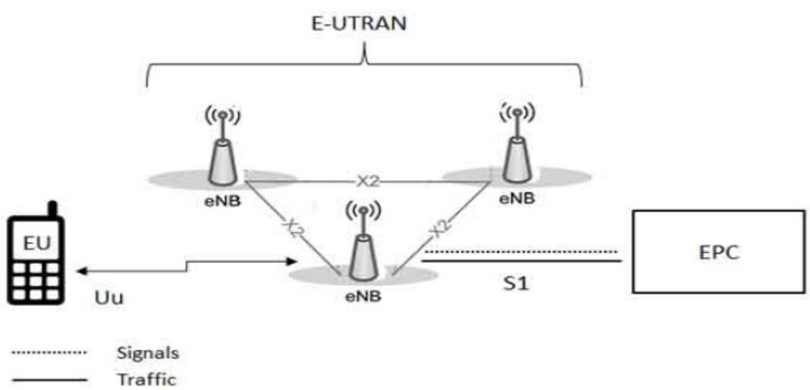

Figure 2-2 E-UTRAN components

- **E-UTRAN handles the radio communications between the mobile and EPC**
  - has *one component,* the *evolved base stations*, called **eNodeB** or **eNB**.
  - Each eNB is a BS that controls the mobiles *in one or more cells.*
- The BS that is communicating with a mobile is known as its **serving eNB**.
- LTE Mobile communicates with just one BS and one cell at a time
- Two main eNB functions:
  - sends and receives radio transmissions to mobiles using the analogue and DSP functions of the LTE air I/F.

- controls the low-level operation of all its mobiles, by sending them signalling messages such as handover commands.
- Each eNB is connected to
  - EPC by S1 I/F
  - (it can be) to nearby base stations by the X2 I/F (used for signalling and packet forwarding during handover).
- A **home eNB (HeNB)** is a BS that has been purchased by a user to provide femtocell coverage within the home.
  - A home eNB belongs to a closed subscriber group (CSG) and can only be accessed by mobiles with a USIM that also belong s to the closed subscriber g roup.

2.3.3 Evolved Packet Core (EPC) (core network)

Figure 2-3 shows a simplified picture of EPC architecture.

Several components have not been shown in the diagram to keep it simple e.g.
Earthquake and Tsunami Warning System (ETWS),
Equipment Identity Register (EIR)
Policy Control and Charg ing Rules Function (PCRF))

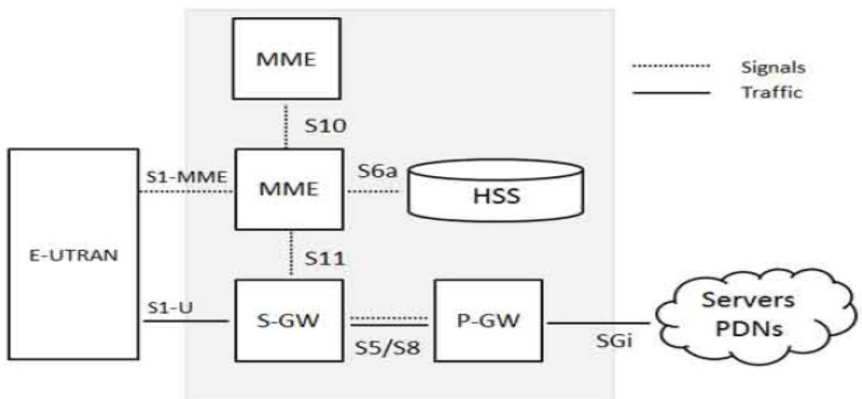

Figure 2-3 Simplified EPC architecture

Description:

- ***Home Subscriber Server (HSS)***
  - continuation of HLR - UMTS and GSM
  - is a central database that contains information about all the network operator's subscribers.

- ***Packet Data Network (PDN) Gateway (P-GW)*** communicates with the outside world i.e. using SGi interface.
  - Each packet data network is identified by an *access point name (APN).*
  - PDN gateway role – is similar as the
    - *GPRS support node (GGSN)* and

- ***Serving gateway (S-GW)*** *acts as a router,* and forwards data between the BS and the PDN gateway.
    - Similar role to the *serving GPRS support node (SGSN)* with UMTS and GSM.

- ***Mobility management entity (MME)***
  - controls the high-level operation of the mobile by means of signalling messages and HSS
-
- ***Policy Control and Charging Rules Function (PCRF)***
  - is a component which is not shown in the above diagram but it is responsible for *policy control decision-making*, as well as for controlling the flow-based charging functionalities in the *Policy Control Enforcement Function* (PCEF), which resides in the P-GW.
- **S5/S8 is the I/F between the serving and PDN gateways.**

- This has two slightly different implementations,
  - S5 if the two devices are in the same network
  - S8 if they are in different networks.

2.3.3.1 Functional split between the E-UTRAN and the EPC

Following diagram shows the functional split between the E-UTRAN and the EPC for an LTE network:

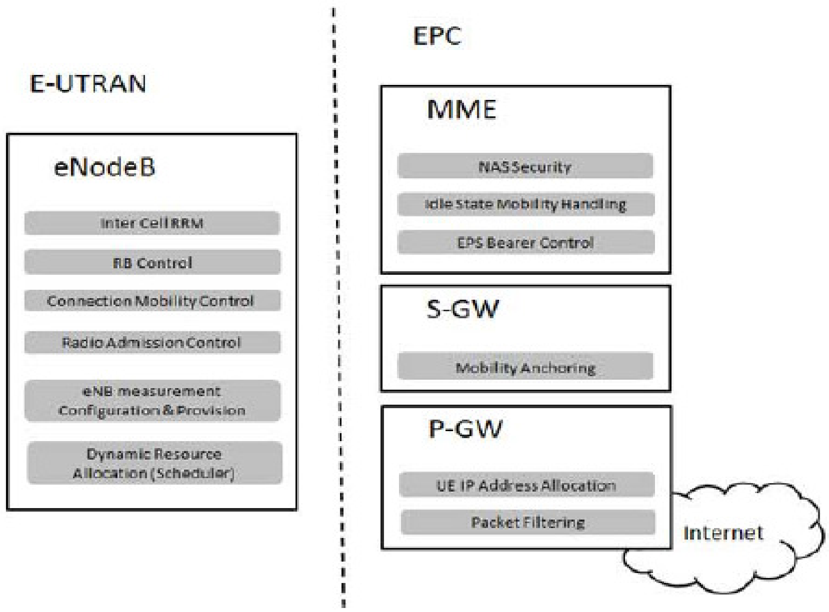

Figure 2-4 Main functions of E-UTRAN and EPC

2.3.3.2 2G/3G Versus LTE

Following table compares various important Network Elements & Signaling protocols used in 2G/3G and LTE

Table 2-3 2G/3G versus LTE

2G/3G	LTE
GERAN and UTRAN	E-UTRAN
SGSN/PDSN-FA	S-GW
GGSN/PDSN-HA	PDN-GW
HLR/AAA	HSS
VLR	MME
SS7-MAP/ANSI-41/RADIUS	Diameter
DiameterGTPc-v0 and v1	GTPc-v2
MIP	PMIP

2.3.4 LTE Roaming Architecture (summary)

- Roaming = the user moves and uses the resources of other PLMN (Visited-PLMN).

- A roaming user is connected to the E-UTRAN, MME and S-GW of the ***visited LTE network.***
- **However, LTE/SAE allows the P-GW of either the visited or the home network to be used**

- The home network's P-GW allows the user to access the home operator's services even while in a visited network.
- A P-GW in the visited network allows a "local breakout" to the Internet in the visited network.
- The I/F between the *serving* and *PDN gateways* is as S5/S8.
    - slightly different implementations,
        - S5 if the two devices are in the same network,
        - S8 if they are in different networks.

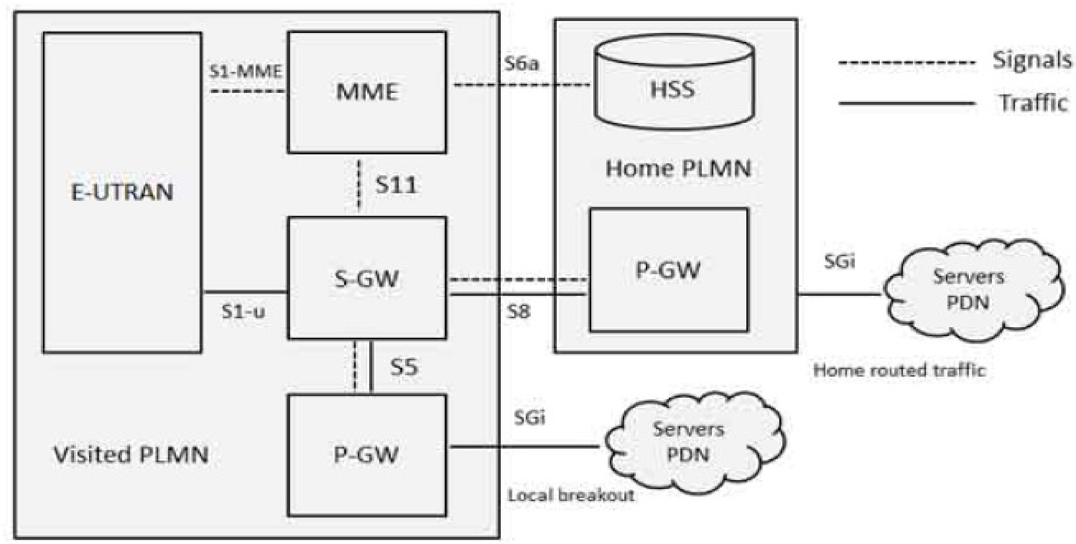

Figure 2-5 LTE Roaming architecture

2.3.5 LTE Numbering and Addressing

An LT E network area is divided into three different types of geographical areas

MME pool areas

- area through which the mobile can move without a change of serving MME
- every MME pool area is controlled by one or more MMEs on the network.

S-GW service areas

- area served by n ≥1 serving S-GW, through which the mobile can move without a change of serving GW

Tracking areas

- MME pool areas and the S-GW service areas are both made from smaller, non-overlapping units known as tracking areas (TAs).
- They are similar to the location and routing areas of UMTS and GSM and will be used to track the locations of mobiles that are on standby mode.

Network IDs

- The network is identified using ***Public Land Mobile Network Identity (PLMN-ID)*** having
    - three digit mobile country code (MCC)
    - and a two or three digit mobile network code (MNC).
    - **PLMN-ID = MCC, MNC**

For example, the

MCC for the UK = 234; Vodafone's UK network MNC = 15.

MME IDs
Each MME has three main identities.

- An **MME code (MMEC)** uniquely identifies the MME within all the pool areas.
- A group of MMEs is assigned an ***MME Group Identity (MMEGI)*** which works along with MMEC to make MME identifier (MMEI).
- A **MMEI** uniquely identifies the MME within a particular network.
- **MMEI = MMEGI, MMEC**

If we **combine PLMN-ID with the MMEI** then we arrive at a ***Globally Unique MME Identifier (GUMMEI),*** which identifies an MME anywhere in the world:

- **GUMMEI = PLMN-ID, MMEI**

The Tracking Area IDs
Each tracking area has **two main identities.**

- tracking area code (TAC) identifies a tracking area within a particular network
- and if we combine this with the PLMN-ID then we get a ***Globally Unique Tracking Area Identity (TAI).***

The Cell IDs

- Each cell in the network has **three types of identity**.
- ***E-UT RAN cell identity (ECI)*** identifies a cell within a particular network,
- ***E-UT RAN cell global identifier (ECGI)*** identifies a cell anywhere in the world.
- The physical cell identity, which is a number from 0 to 503 and it distinguishes a cell from its immediate neighbours.

The Mobile Equipment ID

- ***International Mobile Equipment Identity (IMEI)*** is a unique identity for the mobile equipment
- ***International Mobile Subscriber Identity (IMSI)*** is a unique identity for the UICC and the USIM.
- ***M temporary mobile subscriber identity (M-TMSI)*** identifies a mobile to its serving MME.

Adding the MME code in M-TMSI results in a ***S temporary mobile subscriber identity (S-TMSI),*** which identifies the mobile within an MME pool area.

- **S-TMSI= MMEC, M-TMSI**

Finally adding the MME group identity and the PLMN identity with S-TMSI results in the
Globally Unique Temporary Identity (GUTI).

- **GUTI= PLMN-ID, MMEGI, S-TMSI**

2.3.6 Mobile IP (MIP) – and Proxi MIP - reminder

MIPv4 Functional entities:

1. ***Mobile Node (MN).***

- A **host or router** that **changes its point of attachment** from one network or subnetwork to another.
- Note: MN may change its location without changing its IP address;
    - it may continue to communicate with other Internet nodes at any location using its (constant) IP address, assuming link layer connectivity to a point of attachment is available(this is L2 mobility)

2. ***Home Agent.***

A router on a **MN home network** that tunnels datagrams for delivery to the MN when it is away from home, and maintains current location information for the mobile node.

3. ***Foreign Agent.***

A **router on a MN's visited network** providing routing services to the MN while registered. FA detunnels and delivers datagrams to the MN that were tunneled by the mobile node's HA

For datagrams sent by a MN the FA may serve as a default router for registered MNs.

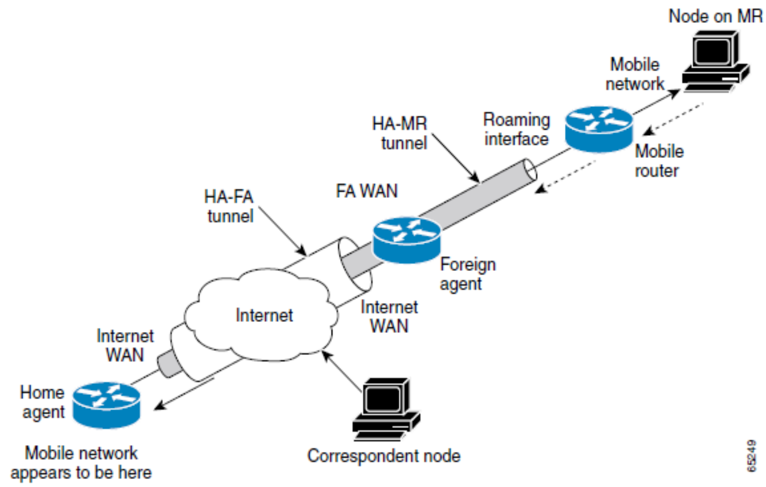

Figure 2-6 Mobile IP principle (CISCO- presentation)

MIPv4 drawbacks (ang others): triangle routing

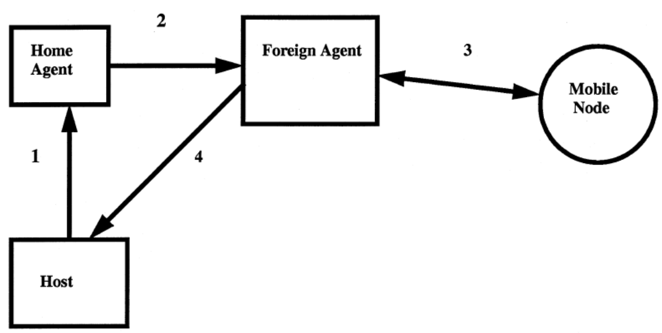

Figure 2-7 MIP Triangle routing

MIPv6- significant enhancement

Use some of the IPv6 new features

- **Address Autoconfiguration**
  - Stateless autoconfiguratoin
    - Network Prefix + Interface ID
  - Stateful autoconfiguration
    - DHCPv6
- **Neighbor Discovery**
  - Discover each other's presence and find routers
  - Determine each other's link-layer addresses
  - Maintain reachability information
- **Extension Headers**
  - Routing header
    - For route optimization
  - Destination Options header
    - For mobile node originated datagrams

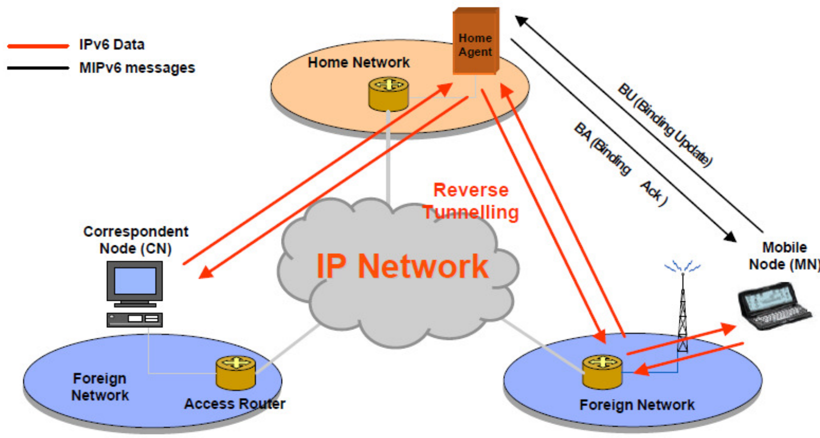

Figure 2-8 Mobile IPv6 – Routing through HA [5]

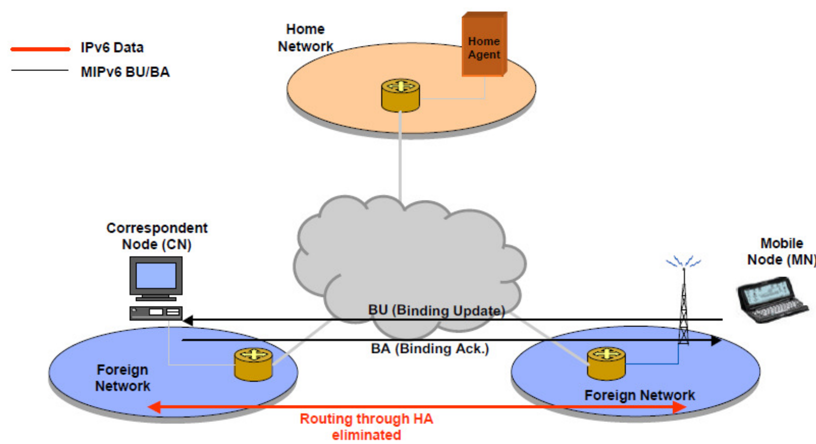

Figure 2-9 Mobile IPv6 – Route Optimisation [5]

Proxi Mobile IPv6

Problems with MIP:

- Clients must implement MIP in the kernel (**MIP mobility is basically *host-based***).
  - difficult to implement kernel changes
  - difficult to deploy (clients need software upgrade to get MIP support)
- *Handoff* procedure is not efficient
  - large delay.
- Security concerns (MIP support in the kernel provides an additional attack vector).

PMIPv6 solution:

•PMIPv6 (RFC5213) is completely *transparent* to mobile nodes (use of a „proxy" to do the handoff work).

•PMIPv6 is meant to be used in *localized networks* with limited topology where handoff signalling delays are minimal.

PMIPv6: RFC 5213, 2008
Main characteristics:

- Network-based mobility management enables IP mobility for a host **without requiring its participation in any mobility-related signaling.**
- The **network is responsible for managing IP mobility** on behalf of the host.
- The **mobility entities in the network are responsible for tracking the movements of the host** and initiating the required mobility signaling on its behalf.

From RFC 5213:

- MIPv6 requires client functionality in the IPv6 stack of a MN.
- Signaling between the MN - HA enables the creation and maintenance of a binding between the MN's home address and its care-of address.
- Mobility [RFC3775] requires the IP host to send IP mobility mgmt. signaling messages to the HA.

- Network-based mobility is another approach to solving the IP mobility
- No - host involvement, by extending MIPv6 [RFC3775] signaling between a **network node** and a HA .
- A proxy mobility agent in the network performs the signaling with the HA and does the mobility mgmt. on behalf of the MN
- This protocol is referred to as Proxy Mobile IPv6 (PMIPv6).

Notations (PIMv6):

- **Local Mobility Domain (LMD):**
- PMIP-enabled network containing 1 LMA and multiple MAGs.

- **Local Mobility Anchor (LMA):**
  - ***similar to the home agent (HA) in MIP***
  - all traffic from and to MN is routed through the LMA.
  - maintains a set of routes for each MN connected to the LMD

- **Mobile Access Gateway (MAG):**
  - MAG ***assumes the role of the MIP client in MIP.***
  - performs the mobility signalling on behalf of the MNs attached to its access links
  - The MAG is usually the access router (first hop router) for the MN
- **Mobile Node (MN):** Any device that connects through a wireless network (WLAN, WiMAX, MBWA, G3/G4) to the LMD

- **Corresponding Node (CN):** Any node in the Internet or also in the LMD communicating with an MN

- **NetLMM:**
  - Network based Localized Mobility Management (IETF WG for network-based mobility support)

- **Binding Cache:** Cache maintained by the LMA that contains BCEs.
- **Binding Cache Entry (BCE**):
  - Entry in the LMA's binding cache, having the fields MN-ID, MAG proxy-CoA and MN-prefix.
- **Binding Update List:**
  - Cache maintained by the MAG that contains information about the attached MNs.

- **Proxy Binding Update (PBU):**
  - PMIP signalling packet sent by the **MAG -> LMA** to indicate a new MN.
  - PBU fields : MN-ID (e.g. MN MAC), MAG address (proxy-CoA) and handoff indicator to signal if the MN-attachment is a new one or a handoff from another MAG.

- **Proxy Binding Acknowledge (PBA):**
  - Response to a PBU **LMA →MAG.**
  - The PBA contains the MN-ID, the MAG address and the prefix assigned to the MN
  -
- **Proxy care of address (proxy-CoA):** IP address of public interface of MAG.
  - The proxy-CoA is the tunnel endpoint address on the MAG.
  - The LMA encapsulates packets destined to the MN into a tunnel packet with destination address = proxy-CoA.
  -
- **Mobile Node Identifier (MN-ID):** Unique identifier of mobile node, e.g. one of its MAC addresses.
- **Home Network Prefix**: Prefix assigned to the MN by the LMA.

PMIPv6 deployment use cases

- WLAN-based campus-style networks: PMIPv6 provides transparent handoff for mobile nodes in campus networks.
- Advanced 3G/4G networks Replace GTP (GPRS tunneling protocol) by PMIP, thus reduce the costs and management in the network.

General PMIPv6 configuration [5]

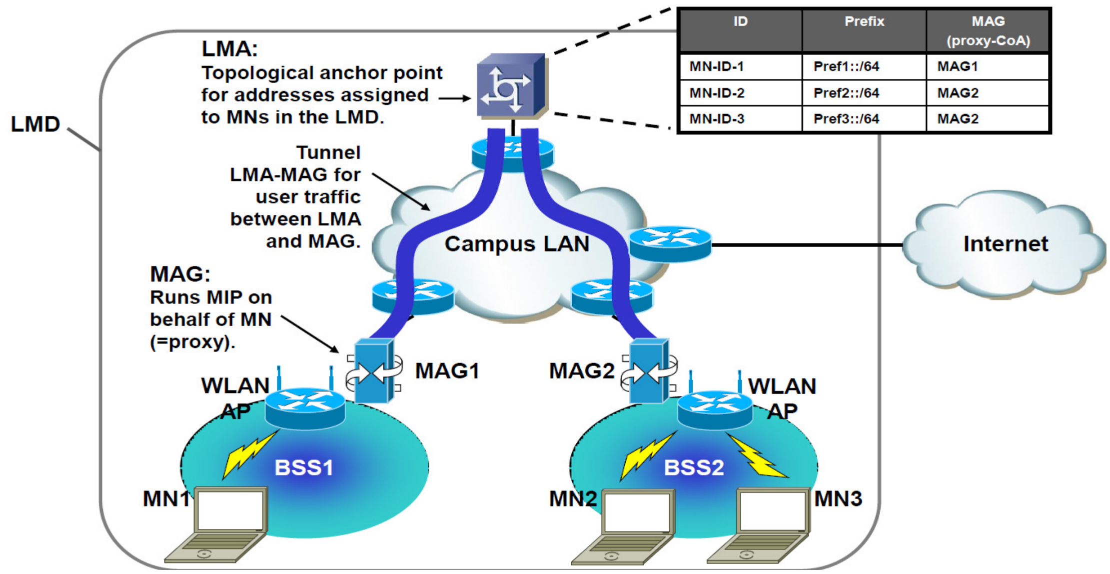

Figure 2-10 General PMIPv6 configuration

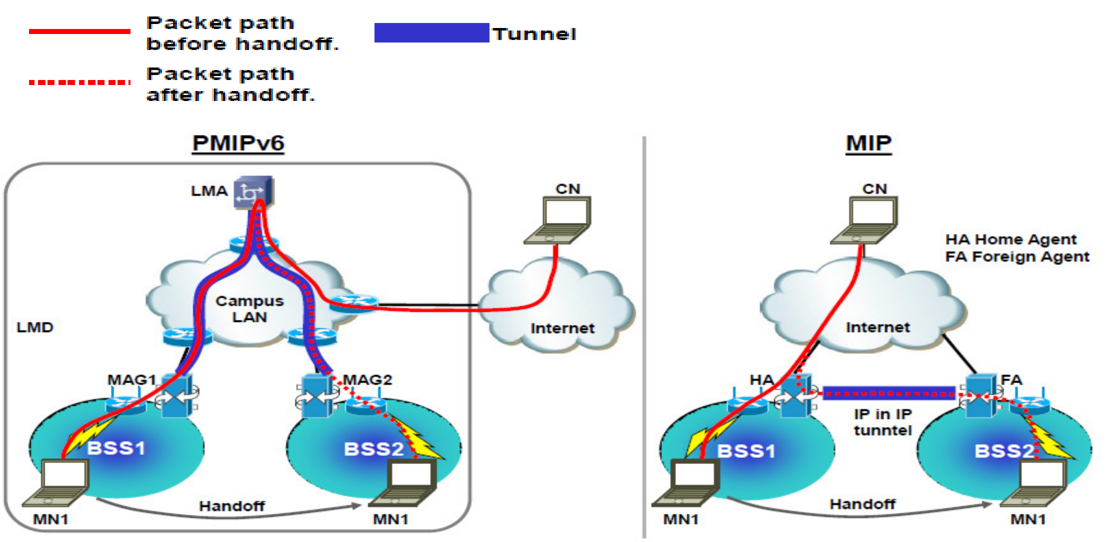

Figure 2-11 PMIPv6 versus MIP, [6]

2.3.7 LTE – Radio Protocol Architecture

Main Refs: [1] [2]

Control plane + User plane

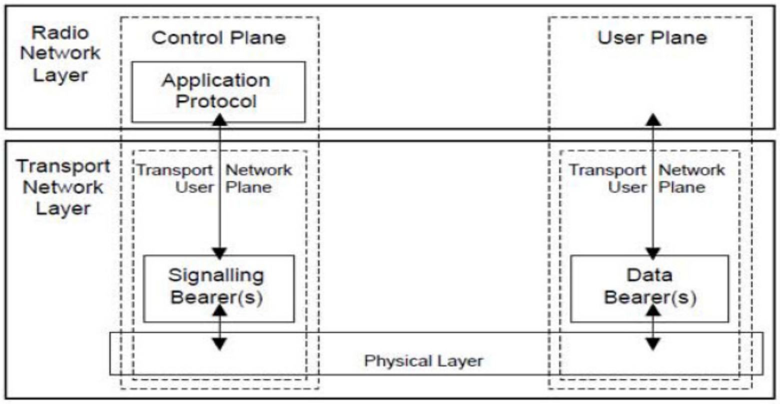

Figure 2-12 LTE Radio Protocol Architecture [1-2]

User plane : data packets – where the stack is : appl., TCP, UDP, IP, etc
Control plane: *Radio resource control (RRC)* protocol – via signalling messages BS- MN

In both cases, the information is processed by the

- *Packetdata Convergence protocol (PDCP)*
- Radio link control (RLC) protocol and
- Medium access control (MAC) protocol.

2.3.7.1 User Plane

- PDCP (Packet Data Converg ence Protocol)
- RLC (radio Link Control)
- Medium Access Control (MAC).

- Packets in the core network (EPC) are encapsulated in a specific EPC protocol and tunneled
- between the P-GW and the eNodeB.
- Different tunneling protocols are used depending on the interface.
- On the S1 and S5/S8 I/Fs it is used GPRS Tunneling Protocol (GTP)
- SDUs and PDUs are defined in details in the standards

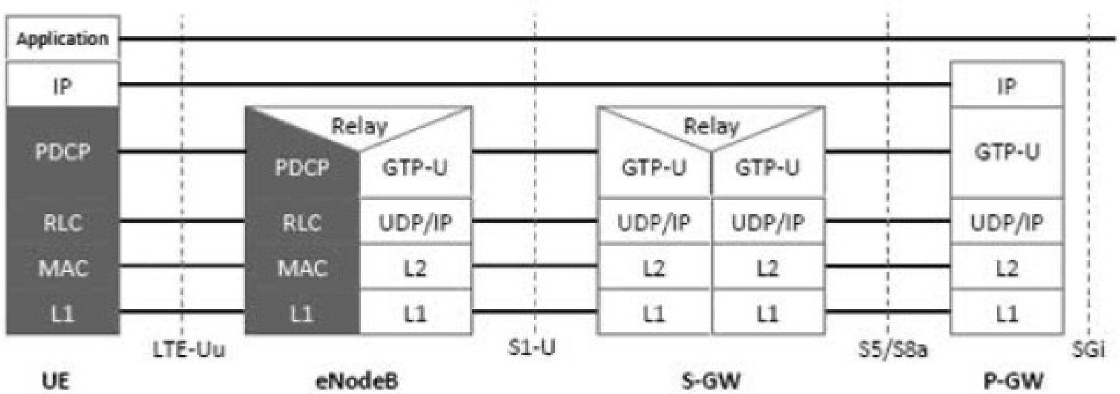

Figure 2-13 User Plane stack

2.3.7.2 Control Plane(CPl)

CPl includes additionally the *Radio Resource Control layer (RRC)*, responsible for configuring the lower layers. CPl handles radio-specific functionality which depends on the UE state (idle or connected)

Idle

- UE associates itself to a cell (following a cell selection or reselection process based on parameters like radio link quality, cell status and also on radio access technology

- UE also monitors a paging channel to detect incoming calls and acquires system information.
- CPl runs cell selection and reselection procedures.

Connected

- UE supplies the E-UT RAN with DL channel quality and neighbor cell information to enable the E-UT RAN to select the most suitable cell for the UE.
    - o CPl protocol includes the Radio Link Control (RRC) protocol.
- The lower layers : the same functions as for the user plane but no no header compression function
-

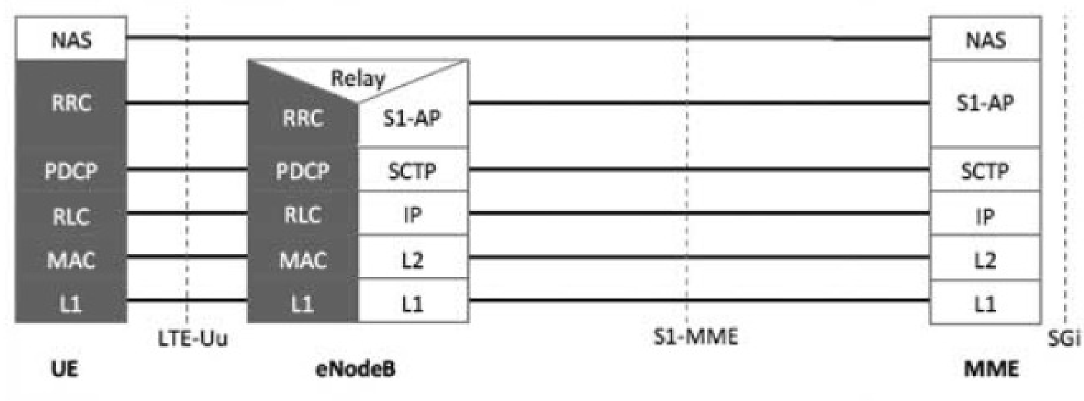

Figure 2-14 Control Plane stack

Grey zone – access stratun

Stream Control Transmission Protocol (SCTP)- RFC 2960

Designed initiually to transport PSTN signaling messages over IP networks, but is capable of broader applications.

SCTP: is a reliable transport on top of IP a

SCTP services offered to its users:

- acknowledged error-free non-duplicated transfer of user data,
- data fragmentation to conform to discovered path MTU size,
- sequenced delivery of user messages within multiple streams, with an option for order-of-arrival delivery of individual user   messages,
- optional bundling of multiple user messages into a single SCTP packet
- network-level fault tolerance through supporting of multi-homing at either or both ends of an association.
- the design includes appropriate congestion avoidance behaviour and resistance to flooding and masquerade attacks.

2.3.7.3 LTE – E-UTRAN Protocol stack layers

Physical Layer (L1)

- carries MAC transport channels info from the over the air interface.
- link adaptation (AMC), power control, cell search (for initial synchro and handover purposes)
- L1 measurements (inside the LT E system and between systems) for the RRC layer.

Medium Access Layer (MAC)

- mapping : logical channels and transport(Phy) channels
- multiplexing of MAC SDUs from one or different logicalchannels onto transport blocks (TB) to be delivered to PHY on transport channels
- demultiplexing of MAC SDUs from one or different logical channels from transport blocks (TB) delivered from the PHY on transport channels
- scheduling information reporting
- error correction through HARQ

- priority handling between UEs by means of dynamic scheduling
- priority handling between Logical channels of one UE, LogicalChannel prioritization.

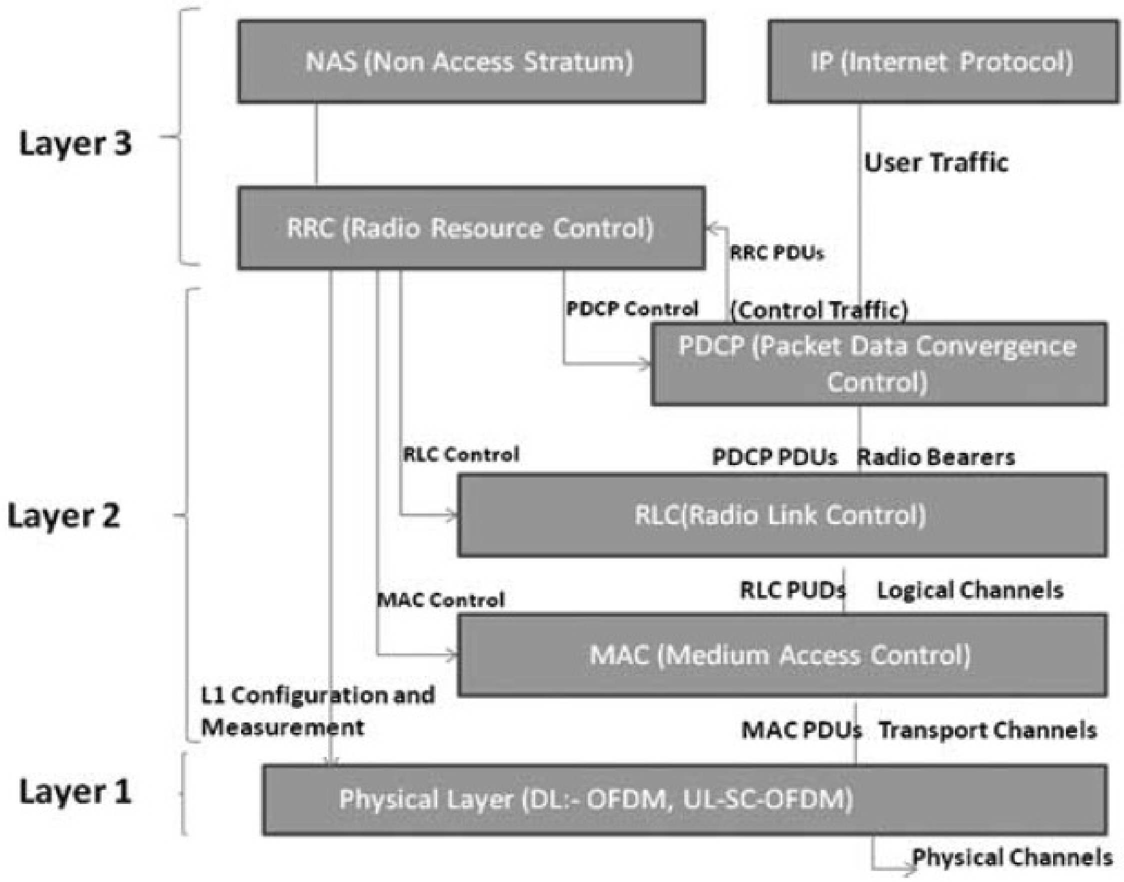

Figure 2-15 Protocol stack layers

Radio Link Control (RLC)
Operation modes:

- **Transparent (TM)**
- **Unacknowledged (UM)**
- **Acknowledged (AM).**

Functions:

- RLC Layer transfers the upper layer PDUs
- error correction throug h ARQ (Only for AM)
- concatenation, segmentation and reassembly of RLC SDUs (Only for UM and AM data transfer).
- for re-seg mentation of RLC data PDUs (Only for AM data transfer)
- reordering of RLC data PDUs (Only for UM and AM data transfer)
- duplicate detection (Only for UM and AM data transfer), RLC
- SDU discard (Only for UM and AM data transfer)
- RLC re-establishment
- and protocol error detection (Only for AM data transfer).

Radio Resource Control (RRC)
The main services and functions

- broadcast of System Information related to the
  - nonaccess stratum (NAS)
  - access stratum (AS)
- paging
- establishment, maintenance and release of an RRC connection between the UE and E-UT RAN
- security

Packet Data Convergence Control (PDCP)

- Header compression and decompression of IP data
- Transfer of data (user plane or control plane)
- Maintenance of PDCP Sequence Numbers (SNs)
- In-sequence delivery of upper layer PDUs at re-establishment of lower layers
- Duplicate elimination of lower layer SDUs at re-establishment of lower layers for radio bearers mapped on RLC AM
- Ciphering and deciphering of user DPl and CPl data
- Integ rity protection and integrity verification of control plane data
- Timer based discard, duplicate discarding
- PDCP is used for SRBs and DRBs mapped on DCCH and DT CH type of logicalchannels.

Non Access Stratum (NAS) Protocols

- they form the highest stratum of the CPl between the user equipment (UE) and MME.
- support the mobility of the UE and the session management procedures to establish and maintain IP connectivity between the UE and a PDN GW.

2.3.7.4 LTE – Layers Data Flow

- IP Layer submits PDCP SDUs (IP Packets) to the PDCP layer.
- PDCP layer
  - o does header compression and adds PDCP header to these PDCP SDUs.
  - o submits PDCP PDUs (RLC SDUs) to RLC layer.

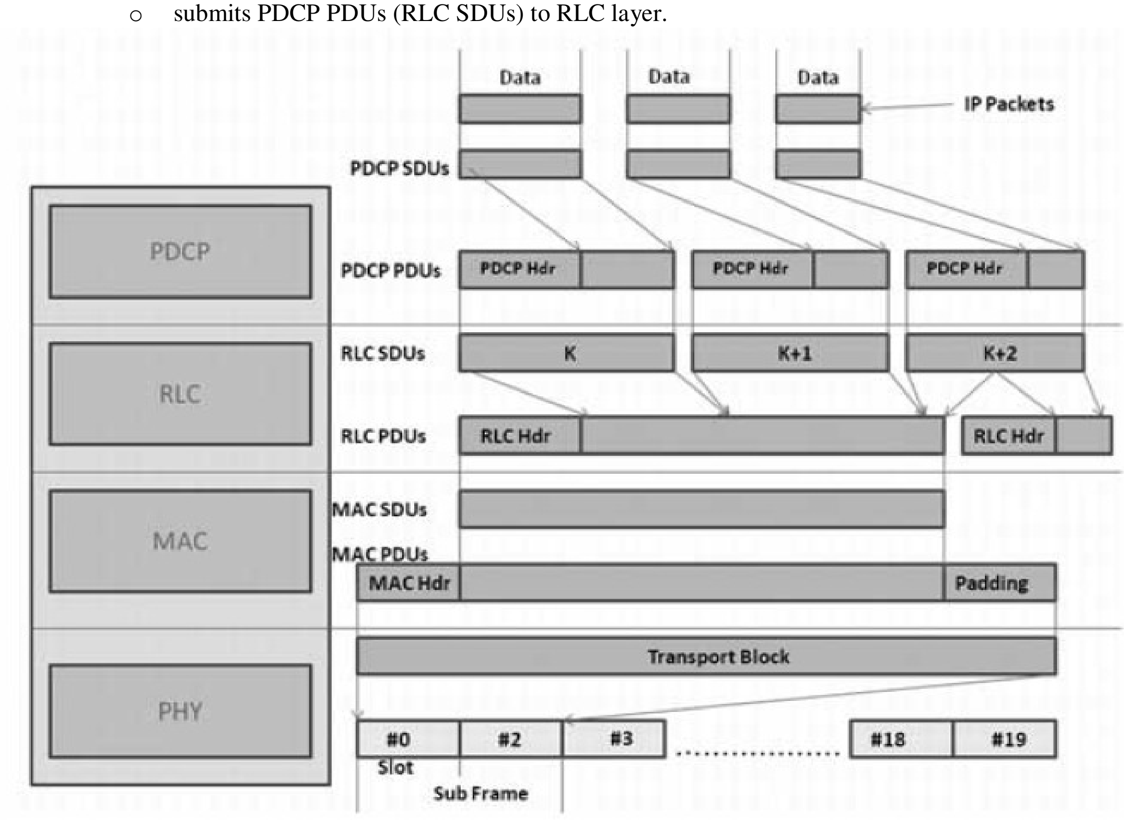

Figure 2-16 Data Plane PDUs at various layers

PDCP Header Compression:
PDCP removes IP header (Minimum 20 bytes) from PDU, and adds Token of 1-4 bytes (Overhead savings)

RLC layer

- may aply segmentation of the SDUS to make smaller RLC PDUs.
- May pack sdus in larger PDUs
- adds header based on RLC mode of operation.
- submits these RLC PDUs (MAC SDUs) to the MAC layer.

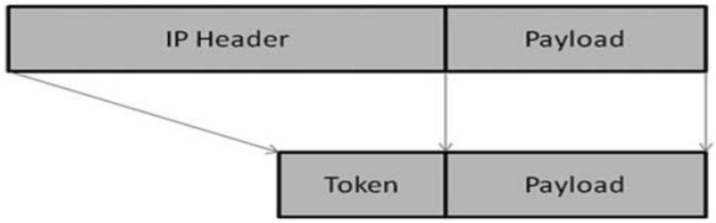

Figure 2-17 Header Compression

2.3.7.5 LTE – Communication Channels [3]

LT E uses several different types of logical, transport and physical channel, for different info types and processing

Logical Channels:
- Define info **type** which is transmitted over the air, e.g . traffic/control channels, system broadcast, etc.
- Data and sgn. messages are carried on logical channels between the RLC and MAC

Transport Channels:
- Define **howis** data transmitted over the air
  - e.g . what are encoding, interleaving options used to transmit data
- Defined between the MAC and PHY

Physical Channels:
- Define **whereis** something transmitted over the air, e.g . first N symbols in the DL frame.
- Data and sgn. messages are carried on PHY channels between the different levels of the PHY

Logical Channels (LC)
- These channels define the data-transfer services offered by the MAC layer.
- LCs can be divided into *control* channels and *traffic* channels.
  - *Control Channel* : common channel or dedicated channel.
    - common channel means that can be used by all users in a cell (PMP)
    - dedicated channel - means a channel that can be used only by one user (Point to Point).
  - *Traffic Channel* : carry data in the user plane

Table 2-4 Logical Channels

Channel Name	Acronym	Control channel	Traffic channel
Broadcast Control Channel	BCCH	X	
Paging Control Channel	PCCH	X	
Common Control Channel	CCCH	X	
Dedicated Control Channel	DCCH	X	
Multicast Control Channel	MCCH	X	
Dedicated Traffic Channel	DTCH		X
Multicast Traffic Channel	MTCH		X

Transport Channeles
- define *how* and with *what type of characteristics* the data is transferred by the PHY layer.
- are distinguished by the ways in which the transport channel processor manipulates them.

Table 2-5 Transport Channels

Channel Name	Acronym	Downlink	Uplink
Broadcast Channel	BCH	X	
Downlink Shared Channel	DL-SCH	X	
Paging Channel	PCH	X	
Multicast Channel	MCH	X	
Uplink Shared Channel	UL-SCH		X
Random Access Channel	RACH		X

Physical Channels

- Physical Data Channels
- Physical Control Channels

Physical data channels

They are distinguished by the ways in which the PHY channel processor manipulates them, and by the ways in which they are mapped onto the symbols and sub-carriers used by OFDMA)

Table 2-6 Physical Data Channels

Channel Name	Acronym	Downlink	Uplink
Physical downlink shared channel	PDSCH	X	
Physical broadcast channel	PBCH	X	
Physical multicast channel	PMCH	X	
Physical uplink shared channel	PUSCH		X
Physical random access channel	PRACH		X

The **transport channel** processor composes several types of control information, to support the low-level operation of the physical layer.

Table 2-7 Transport channels

Field Name	Acronym	Downlink	Uplink
Downlink control information	DCI	X	
Control format indicator	CFI	X	
Hybrid ARQ indicator	HI	X	
Uplink control information	UCI		X

Physical Control Channels

- The *transport channel processor* also creates control info that supports the low-level operation of the PHY layer and sends this information to the *physical channel processor* in the form of physical control channels.
- The information travels as far as the transport channel processor in the receiver, but is invisible to higher layers.
- Similarly, the physical channel processor creates physical signals, which support the lowest-level aspects of the system.

Table 2-8 Physical Control Channels

Channel Name	Acronym	Downlink	Uplink
Physical control format indicator channel	PCFICH	X	
Physical hybrid ARQ indicator channel	PHICH	X	
Physical downlink control channel	PDCCH	X	
Relay physical downlink control channel	R-PDCCH	X	
Physical uplink control channel	PUCCH		X

2.3.7.6 LTE - OFDM and SC Technology

OFDM

- LTE uses OFDM (based on digital multi-carrier modulation method) for the DL to overcome the effect of multi path fading problem available in UMTS
    - to transmit the data over many narrow band careers of 180 KHz each
- OFDM meets the LTE requirement for spectrum flexibility and enables cost-efficient solutions for very wide carriers with high peak rates.
- The basic LTE DL PHY resource can be seen as a time-frequency grid,
- The OFDM symbols are grouped into resource blocks.
    - Theresource blocks have a total size of 180kHz in the frequency domain and 0.5ms in the time domain.
    - Each 1ms Transmission Time Interval (TT I) consists of two slots (T slot)

- Each user is allocated a number of so-called resource blocks in the time.frequency grid.
- The more resource blocks a user gets, and the higher the modulation used in the resource elements, the higher the bit-rate.
- Which resource blocks and how many the user gets (at a given point in time) depend on advanced scheduling mechanisms in the F-T dimensions (similar to WiMAX scheduling) .
- The scheduling mechanisms in LTE are similar to those used in HSPA, and enable optimal performance for different services in different radio environments.

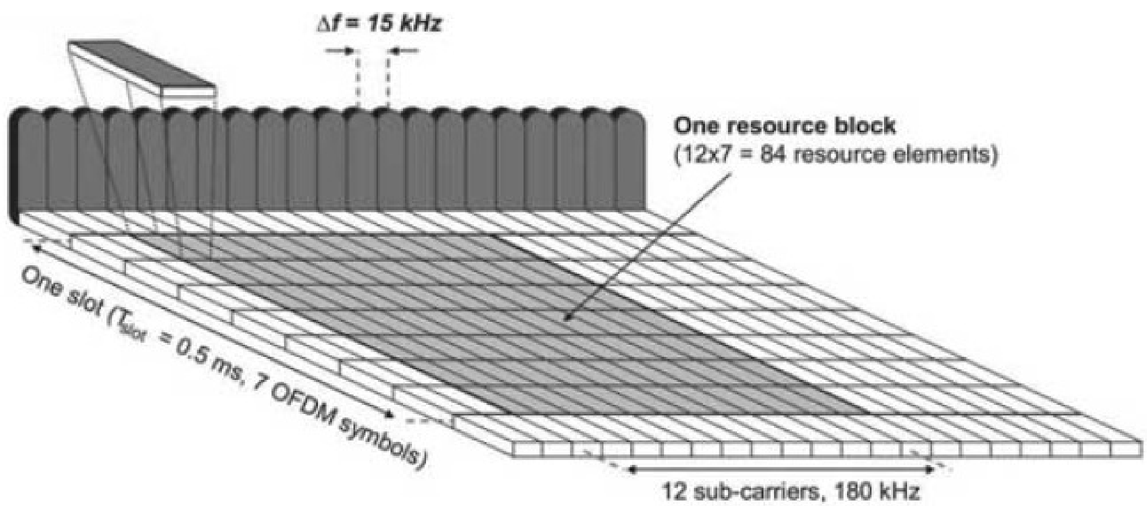

Figure 2-18 OFDM in LTE [3]

OFDM Advantages (over SC)

- Ability to cope with severe channel conditions (for example, attenuation of high frequencies in a long copper wire, narrowband interference and frequency-selective fading due to multipath) without complex equalization filters.
    - Channel equalization is simplified because OFDM may be viewed as using many slowly-modulated narrowband signals
- The low symbol rate → use of a guard interval between symbols affordable, making it possible to eliminate inter symbol interference (ISI).
    - facilitates the design of single frequency networks (SFNs), where several adjacent transmitters send the same signal simultaneously at the same frequency, as the signals from multiple distant transmitters may be combined constructively, rather than interfering as would typically occur in a traditional SC system.

OFDM Drawbacks

High peak-to-average ratio
Sensitive to frequency offset, hence to Doppler-shift as well.

SC-FDMA Technolog y

- LTE uses in the UL *Single Carrier Frequency Division Multiple Access (SC-FDMA)*
- to compensate for a drawback with OFDM, which has a very high *Peak to Avg.Power Ratio (PAPR)*
- High PAPR requires
    - expensive and inefficient power amplifiers with high requirements on linearity
    - increases the cost of the terminal and consumes the battery faster.

- SC-FDMA solves this problem by grouping together the resource blocks in such a way that reduces the need for linearity, and so power consumption, in the power amplifier.
- A low PAPR also improves coverage and the cell-edge performance.

Scheduler [11]

It is a key component for the achievement of a fast adjusted and efficiently utilized radio resource.

The Transmission Time Interval (TTI) is set to only 1 ms.

During each TTI the eNB scheduler shall:

- consider the physical radio environment per UE.
    - The UEs report their perceived radio quality, as an input to the scheduler to decide which Modulation and Coding scheme to use.
    - The solution relies on rapid adaptation to channel variations, employing HARQ (Hybrid Automatic Repeat Request) with soft-combining and rate adaptation.

- prioritize the QoS service requirements amongst the UEs. LTE supports both delay sensitive real-time services as well as datacom services requiring high data peak rates.
- inform the UEs of allocated radio resources.
    - The eNB schedules the UEs both on the downlink and on the uplink.
    - For each UE scheduled in a TTI the user data will be carried in a *Transport Block (TB).*
    - DL there can be a maximum of two TBs generated per TTI per UE – if spatial multiplexing is used.
    - The TB is delivered on a transport channel.

In LTE the number of channels is decreased compare to UMTS. For the user plane there is only one shared transport channel in each direction. The TB sent on the channel, can therefore contain bits from a number of services, multiplexed together.

2.4 Integration LTE- 2G/3G

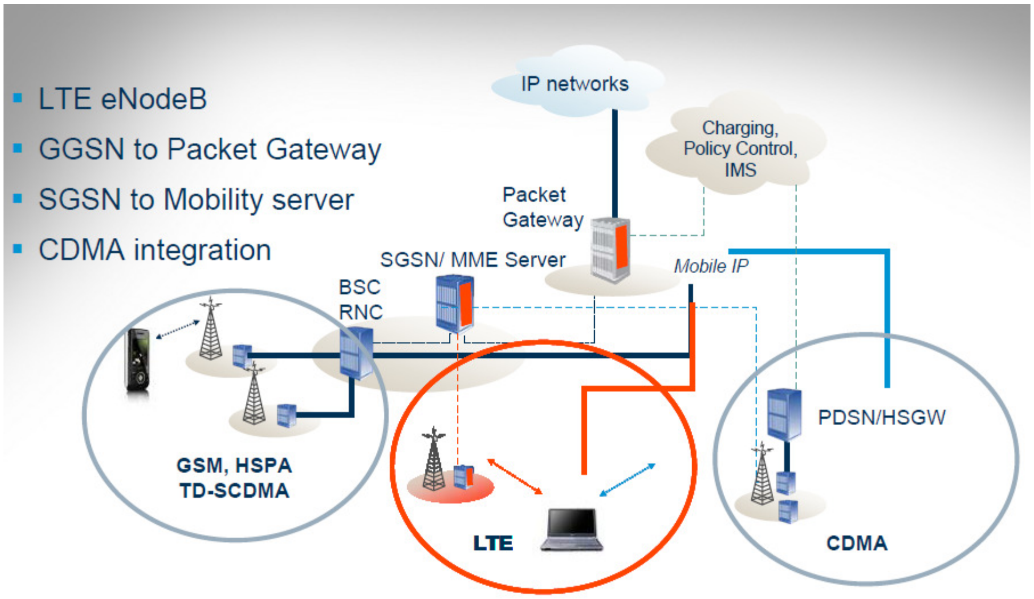

Figure 2-19 Integration of LTE with 2G/3G technologies

2.5 LTE- Advanced (3GPP)

Refs. [10-13]
LTE-Advanced is is an **evolutionary step** in the continuing development of LTE
(LTE release 10, 11, 12)

The core significant goals for LTE-Advanced are:

- The data rate with peak ***uplink of 500Mbps and peak downlink of 1Gbps***.
- Provide ***spectrum efficiency*** with more than ***three times*** that provided by LTE.
- Offer *spectrum efficiency* in uplink ***15 bps/Hz*** and in downlink ***30 bps/Hz.***
- The spectrum using the capability to backing the scalable bandwidth and the ***aggregation of spectrum*** where noncontiguous spectrum is need to using.
- The link latency in case from idle status to connected status are a ***smaller than 50msec*** and ***less than 5msec*** for one-way in single packet transferring.
- The ***throughput of edge*** *of* user cell to be ***doubles*** that in LTE.
- The ***average throughput*** of any user is to be ***triple*** **that** in LTE.
- ***The mobility environments is the similar that used in LTE***
- LTE-Advanced can provide ***compatibility by interworking with 3GPP and LTE.***

The core part in the E-UTRAN architecture is still the enhanced Node B (eNodeB or eNB) providing:

- air interface with user plane and control plane protocol terminations towards the UE.
- Each eNBs is a logical component serving one or several E-UTRAN cells
- and the interface interconnecting the eNBs is called the X2 interface.
-
- Additionally, Home eNBs (HeNBs, also called femtocells), which are eNBs of lower cost for
- indoor coverage improvement, can be connected to the EPC directly or via a gateway that provides additional support for a large number of HeNBs.1
- Further, 3GPP is considering *relay nodes* and sophisticated relaying strategies for network performance enhancement.
- The targets of this new technology are increased coverage, higher data rates, and better QoS performance and fairness for different users.

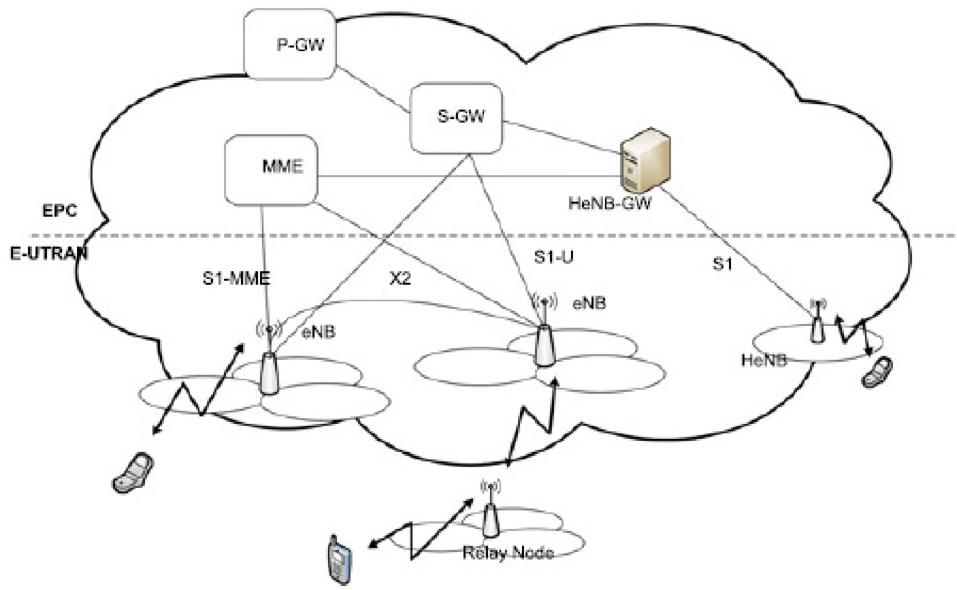

Figure 2-20 LTE-Advanced E-UTRAN architecture [5]

Protocols

User plane:

- Packet Data Convergence Protocol (PDCP)
- Radio Link Control (RLC)
- Medium Access Control (MAC),
- Physical Layer (PHY) protocols.

Control plane stack additionally includes the Radio Resource Control (RRC) protocols.

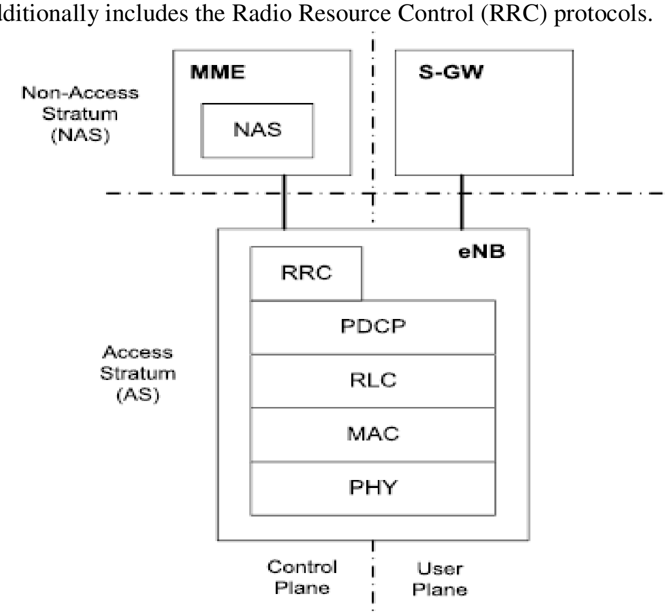

Figure 2-21 LTE-A Protocol stack

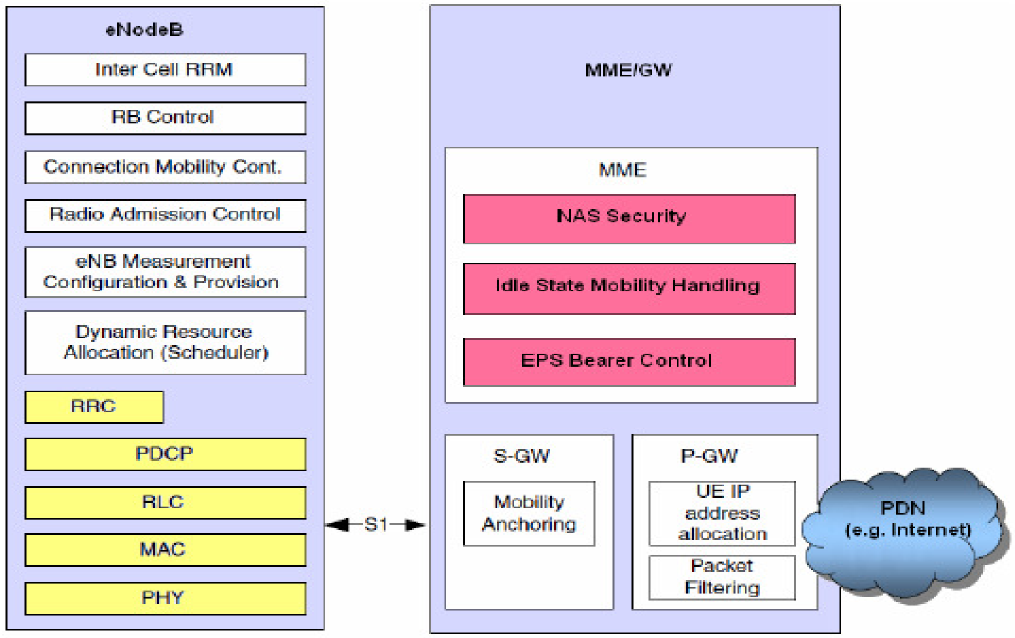

Figure 2-22 Functions splitting between MME/GW and eNodeB

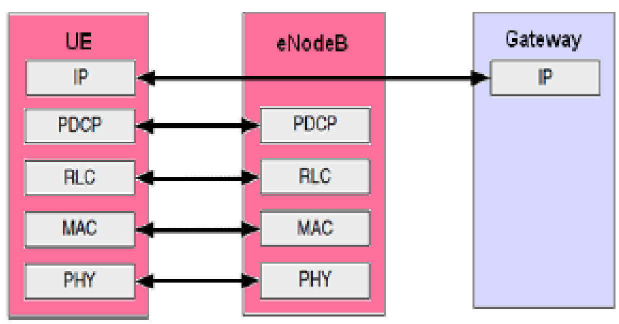

Figure 2-23 User plane stack

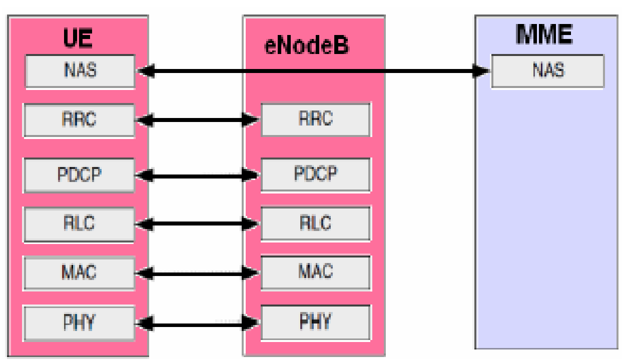

Figure 2-24 Control plane stack [8]

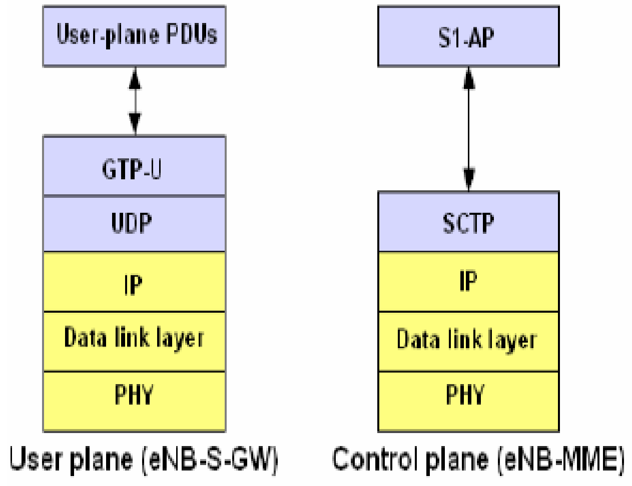

Figure 2-25 S1 interface user and control planes

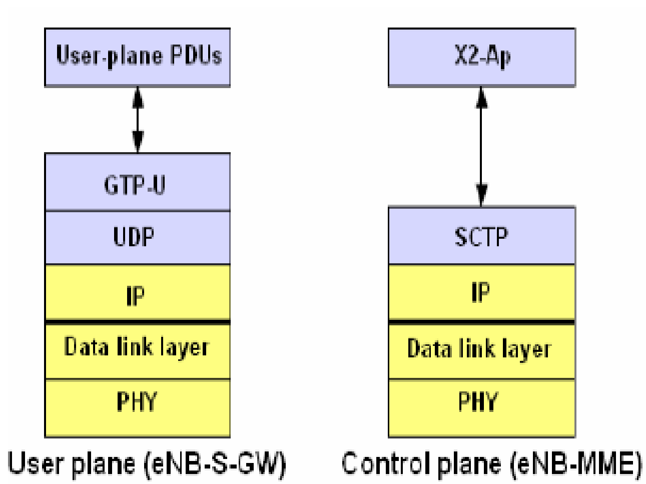

Figure 2-26 X2 interface user and control planes

2.6 Recent Evolutions

1999

Release	Stage 3: Core specs complete	Main feature of Release
Rel-99	March 2000	UMTS 3.84 Mcps (W-CDMA FDD & TDD)
Rel-4	March 2001	1.28 Mcps TDD (aka TD-SCDMA)
Rel-5	June 2002	HSDPA
Rel-6	March 2005	HSUPA (E-DCH)
Rel-7	Dec 2007	HSPA+ (64QAM DL, MIMO, 16QAM UL). LTE & SAE Feasibility Study, EDGE Evolution
Rel-8	Dec 2008	LTE Work item – OFDMA air interface SAE Work item – New IP core network UMTS Femtocells, Dual Carrier HSDPA
Rel-9	Dec 2009	Multi-standard Radio (MSR), Dual Carrier HSUPA, Dual Band HSDPA, SON, LTE Femtocells (HeNB) LTE-Advanced feasibility study, MBSFN
Rel-10	March 2011	LTE-Advanced (4G) work item, CoMP Study Four carrier HSDPA
Rel-11	Sept 2012	CoMP, eDL MIMO, eCA, MIMO OTA, HSUPA TxD & 64QAM MIMO, HSDPA 8C & 4x4 MIMO, MB MSR
Rel-12	Sept 2014	3DL CA, LTE-Direct, Active Antenna Systems, small cells...
Rel-13	Dec 2015	Being defined from Sept 2014: LTE-U? 4 carrier aggregation?

2015

Figure 2-27 EVolution of UMTS specifications

Release 10 LTE-Advanced

Release 10 LTE enhancements

Carrier aggregation for wider bandwidths

Uplink transmission scheme

Downlink transmission scheme

Relaying

Other Release 10 enhancements

Enhanced inter-cell interference coordination (eICIC)

Minimization of drive test

Machine-type communications (MTC)

New frequency bands

New UE categories

Release 11 LTE-Advanced enhancements

New frequency bands

Release 11 features for LTE and UTRA

Further self-optimizing network (SON) enhancements

Enhancement of minimization of drive test (MDT) for E-UTRAN and UTRAN

Network energy saving for E-UTRAN

RF requirements for multi-band and multi-standard radio

Further enhancements to H(e)NB mobility

Release 11 features for LTE

Network-based positioning support in LTE

Service continuity improvements for MBMS for LTE

Further enhanced non CA-based ICIC for LTE

LTE RAN enhancements for diverse data applications

Relays for LTE

Signaling and procedure for interference avoidance for in-device coexistence

Coordinated multi-point transmission (CoMP)

Enhanced downlink control channels for LTE-Advanced

Public safety broadband high power UE for Band 14, Region 2

Improved minimum performance requirements for E-UTRA: interference rejection

Additional special subframe configuration for LTE TDD

Release 11 carrier aggregation

Release 12 radio evolution

New frequency bands

Carrier aggregation scenarios

Release 12 work items

Dual connectivity for LTE

Further enhancements for H(e)NB Mobility—Part 3

RF and EMC requirements for active antenna systems (AAS)

Machine-type communications (MTC)

WLAN/3GPP radio interworking

LTE TDD-FDD joint operation including carrier aggregation

Further MBMS operations support for E-UTRAN

E-UTRA small cell enhancements—physical layer aspects

Inter-eNB CoMP for LTE

LTE device-to-device proximity services

Network-assisted interference cancellation and suppression for LTE

Verification of radiated multi-antenna reception performance of UEs in LTE/UMTS

Performance requirements of 8 Rx antennas for LTE uplink

Release 12 study items

Study on mobile relay for E-UTRA

Study on 3D-channel model for elevation beamforming/FD-MIMO studies for LTE

Study on group communication for LTE

Verification of radiated multi-antenna reception performance of UEs: MIMO OTA

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4 ACRONYMS:

3GPP	Third Generation Partnership Project
AMPS	Advanced Mobile Phone System
ARIB	Association of Radio Industries and Businesses
BS	Base Station
CDMA	Code Division Multiple Access
D-AMPS	Digital AMPS
DECT	Digital Enhanced Cordless Telecommunications
DL	Downlink
DSL	Dig ital Subscriber Line
DSP	Digital Signal Processing
EDGE	Enhanced Data Rates for GSM Evolution
EPC	Evolved Packet Core
EVDO	Enhanced Voice-Data Optimized or Enhanced Voice-Data Only
E-UT RAN	Evolved - UMTS Terrestrial Radio Access Network
ETSI	European T elecommunications Standards Institute
FDD	Frequency Division Duplex
FDM	Frequency Division Multiplexing
FDMA	Frequency Division Multiple Access
GSM	Global System for Mobile Communication
GPRS	General Packet Radio Service
HSPA	High Speed Packet Access (HSDPA + HSUPA)
HSDPA	High Speed Downlink Packet Access
HSS	Home Subscriber Server
HSUPA	High Speed Uplink Packet Access
HARQ	Hybrid Automatic Repeat reQuest
IMT-dvanced	International Mobile Telecommunications-Advanced
LTE	Long Term Evolution
LTE-A	Long Term Evolution - Advanced
ME	Mobile equipment
MIMO	Multiple Input Multiple Output
MIP	Mobile IP
MBMS	Multimedia Broadcast Multicast Service
MME	Mobility Management Entity
MN	Mobile Node
MT	Mobile Terminal
NAS	Non- Access Stratum
NMT	Nordic Mobile Telephony
NGMN	Next Generation Mobile Networks
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
PAPR	Peak to Averag e Power Ratio
PDCP	Packet Data Convergence Protocol
PSTN	Public Switched Telephone Network
RAN	Radio Access Network
RAT	Radio Access Technology
RRC	Radio Resources Control
SAE	System Architecture Evolution
SGSN	Serving GPRS Support Node
TDD	Time Division Duplex
TDM	Time Division Multiplexing
TDMA	Time Division Multiple Access
TD-SCDMA	Time Division Synchronous Code Division Multiple Access
TTI	Transmission T ime Interval
UE	User Equipment
UL	Uplink

UMTS	Universal Mobile Telecom System
USIM	Universal Subscriber Identity Module
UTRA	UMTS terrestrial radio access
UTRAN	UMTS terrestrial radio access network
WIMAX	Worldwide Interoperability for Microwave Access
WCDMA	Wideband Code Division Multiple Access