

LTE QUICK GUIDE

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LTE OVERVIEW

LTE stands for *Long Term Evolution* and it was started as a project in 2004 by telecommunication body known as the Third Generation Partnership Project *3GPP*. *SAE SystemArchitectureEvolution* is the corresponding evolution of the GPRS/3G packet core network evolution. The term LTE is typically used to represent both LTE and SAE.

LTE evolved from an earlier 3GPP system known as the Universal Mobile Telecommunication System *UMTS*, which in turn evolved from the Global System for Mobile Communications *GSM*. Even related specifications were formally known as the evolved UMTS terrestrial radio access *E - UTRA* and evolved UMTS terrestrial radio access network *E - UTRAN*. First version of LTE was documented in Release 8 of the 3GPP specifications.

A rapid increase of mobile data usage and emergence of new applications such as MMOG *MultimediaOnlineGaming*, mobile TV, Web 2.0, streaming contents have motivated the 3rd Generation Partnership Project *3GPP* to work on the Long-Term Evolution *LTE* on the way towards fourth-generation mobile.

The main goal of LTE is to provide a high data rate, low latency and packet optimized radioaccess technology supporting flexible bandwidth deployments. Same time its network architecture has been designed with the goal to support packet-switched traffic with seamless mobility and great quality of service.

LTE Evolution

Year	Event
Mar 2000	Release 99 - UMTS/WCDMA
Mar 2002	Rel 5 - HSDPA
Mar 2005	Rel 6 - HSUPA
Year 2007	Rel 7 - DL MIMO, IMS <i>IPMultimediaSubsystem</i>
November 2004	Work started on LTE specification
January 2008	Spec finalized and approved with Release 8
2010	Targeted first deployment

Facts about LTE

- LTE is the successor technology not only of UMTS but also of CDMA 2000.
- LTE is important because it will bring up to 50 times performance improvement and much better spectral efficiency to cellular networks.
- LTE introduced to get higher data rates, 300Mbps peak downlink and 75 Mbps peak uplink. In a 20MHz carrier, data rates beyond 300Mbps can be achieved under very good signal conditions.
- LTE is an ideal technology to support high data rates for the services such as voice over IP *VOIP*, streaming multimedia, videoconferencing or even a high-speed cellular modem.
- LTE uses both Time Division Duplex *TDD* and Frequency Division Duplex *FDD* mode. In *FDD* uplink and downlink transmission used different frequency, while in *TDD* both uplink and downlink use the same carrier and are separated in Time.
- LTE supports flexible carrier bandwidths, from 1.4 MHz up to 20 MHz as well as both *FDD* and *TDD*. LTE designed with a scalable carrier bandwidth from 1.4 MHz up to 20 MHz which bandwidth is used depends on the frequency band and the amount of spectrum available with a network operator.
- All LTE devices have to support *MIMO* Multiple Input Multiple Output transmissions, which

allow the base station to transmit several data streams over the same carrier simultaneously.

- All interfaces between network nodes in LTE are now IP based, including the backhaul connection to the radio base stations. This is great simplification compared to earlier technologies that were initially based on E1/T1, ATM and frame relay links, with most of them being narrowband and expensive.
- Quality of Service *QoS* mechanism have been standardized on all interfaces 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 hand-over and roaming to existing mobile networks.

Advantages of LTE

- **High throughput:** High data rates can be achieved in both downlink as well as uplink. This causes high throughput.
- **Low latency:** Time required to connect to the network is in range of a few hundred milliseconds and power saving states can now be entered and exited very quickly.
- **FDD and TDD in the same platform:** Frequency Division Duplex *FDD* and Time Division Duplex *TDD*, both schemes can be used on same platform.
- **Superior end-user experience:** Optimized signaling for connection establishment and other air interface and mobility management procedures have further improved the user experience. Reduced latency *to10ms* for better user experience.
- **Seamless Connection:** LTE will also support seamless connection to existing networks such as GSM, CDMA and WCDMA.
- **Plug and play:** The user does not have to manually install drivers for the device. Instead system automatically recognizes the device, loads new drivers for the hardware if needed, and begins to work with the newly connected device.
- **Simple architecture:** Because of Simple architecture low operating expenditure *OPEX*.

LTE - QoS

LTE architecture supports **hard QoS**, with end-to-end quality of service and guaranteed bit rate *GBR* for radio bearers. Just as Ethernet and the internet have different types of *QoS*, for example, various levels of *QoS* can be applied to LTE traffic for different applications. Because the LTE MAC is fully scheduled, *QoS* is a natural fit.

Evolved Packet System *EPS* bearers provide one-to-one 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

LTE BASIC PARAMETERS

This section will summarize the Basic parameters of the LTE:

Parameters	Description
Frequency range	UMTS FDD bands and TDD bands defined in 36.101v860 Table 5.5.1, given below
Duplexing	FDD, TDD, half-duplex FDD
Channel coding	Turbo code
Mobility	350 km/h
Channel Bandwidth <i>MHz</i>	

- 1.4
- 3
- 5
- 10
- 15
- 20

Transmission Bandwidth Configuration NRB :
1resourceblock = 180kHzin1msTTI

- 6
- 15
- 25
- 50
- 75
- 100

Modulation Schemes

UL: QPSK, 16QAM, 64QAM *Optional*

DL: QPSK, 16QAM, 64QAM

Multiple Access Schemes

UL: SC-FDMA *SingleCarrierFrequencyDivisionMultipleAccess* supports 50Mbps+ 20MHzspectrum

DL: OFDM *OrthogonalFrequencyDivisionMultipleAccess* supports 100Mbps+ 20MHzspectrum

Multi-Antenna Technology

UL: Multi-user collaborative MIMO

DL: TxAA, spatial multiplexing, CDD ,max 4x4 array

Peak data rate in LTE

UL: 75Mbps20MHzbandwidth

DL: 150MbpsUECategory4, 2x2MIMO, 20MHzbandwidth

DL: 300MbpsUEcategory5, 4x4MIMO, 20MHzbandwidth

MIMO

UL: 1 x 2, 1 x 4

MultipleInputMultipleOutput

DL: 2 x 2, 4 x 2, 4 x 4

Coverage

5 - 100km with slight degradation after 30km

QoS

E2E QOS allowing prioritization of different class of service

Latency

End-user latency < 10ms

E-UTRA Operating Bands

Following is the table for E-UTRA operating bands taken from LTE Sepecification 36.101v860 Table 5.5.1:

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

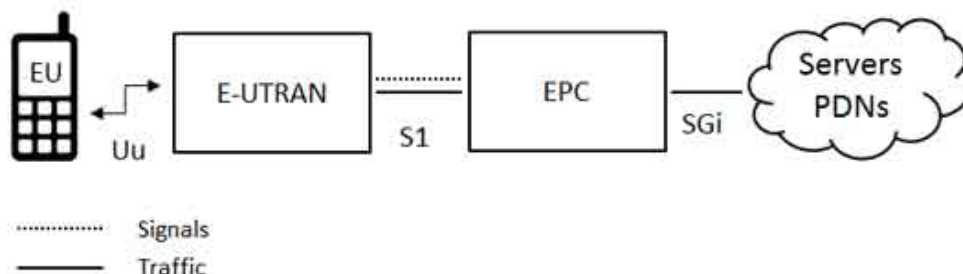
3	1710 MHz – 1785 MHz	1805 MHz – 1880 MHz	FDD
4	1710 MHz – 1755 MHz	2110 MHz – 2155 MHz	FDD
5	824 MHz – 849 MHz	869 MHz – 894 MHz	FDD
6	830 MHz – 840 MHz	875 MHz – 885 MHz	FDD
7	2500 MHz – 2570 MHz	2620 MHz – 2690 MHz	FDD
8	880 MHz – 915 MHz	925 MHz – 960 MHz	FDD
9	1749.9 MHz – 1784.9 MHz	1844.9 MHz – 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

LTE NETWORK ARCHITECTURE

The high-level network architecture of LTE is comprised of following three main components:

- The User Equipment *UE*.
- The Evolved UMTS Terrestrial Radio Access Network *E-UTRAN*.
- The Evolved Packet Core *EPC*.

The evolved packet core communicates with packet data networks in the outside world such as the internet, private corporate networks or the IP multimedia subsystem. The interfaces between the different parts of the system are denoted Uu, S1 and SGi as shown below:



The User Equipment *UE*

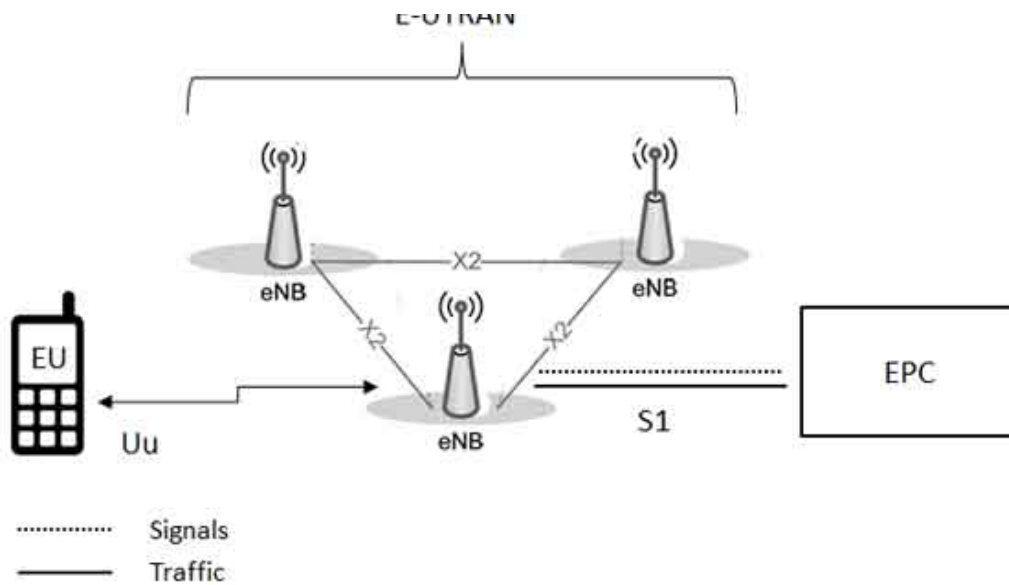
The internal architecture of the user equipment for LTE is identical to the one used by UMTS and GSM which is actually a Mobile Equipment *ME*. The mobile equipment comprised of the following important modules:

- **Mobile Termination *MT*** : This handles all the communication functions.
- **Terminal Equipment *TE*** : This terminates the data streams.
- **Universal Integrated Circuit Card *UICC*** : This is also 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. This keeps information about the user's phone number, home network identity and security keys etc.

The *E-UTRAN* The access network

The architecture of evolved UMTS Terrestrial Radio Access Network *E-UTRAN* has been illustrated below.



The E-UTRAN handles the radio communications between the mobile and the evolved packet core and just has one component, the evolved base stations, called **eNodeB** or **eNB**. Each eNB is a base station that controls the mobiles in one or more cells. The base station that is communicating with a mobile is known as its serving eNB.

LTE Mobile communicates with just one base station and one cell at a time and there are following two main functions supported by eNB:

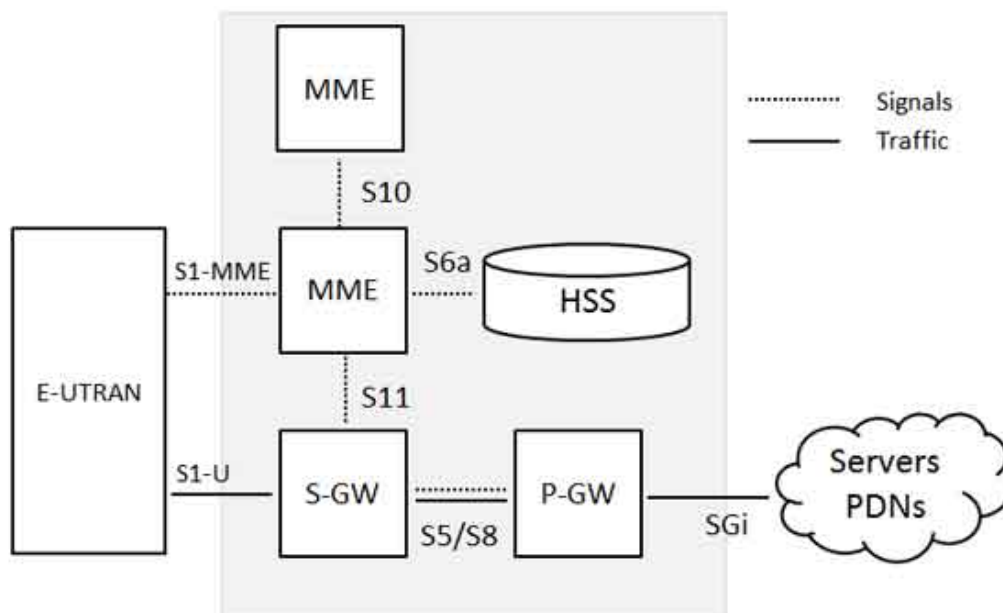
- The eNB sends and receives radio transmissions to all the mobiles using the analogue and digital signal processing functions of the LTE air interface.
- The eNB controls the low-level operation of all its mobiles, by sending them signalling messages such as handover commands.

Each eNB connects with the EPC by means of the S1 interface and it can also be connected to nearby base stations by the X2 interface, which is mainly used for signalling and packet forwarding during handover.

A home eNB *HeNB* is a base station 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 belongs to the closed subscriber group.

The Evolved Packet Core *EPC The core network*

The architecture of Evolved Packet Core *EPC* has been illustrated below. There are few more components which have not been shown in the diagram to keep it simple. These components are like the Earthquake and Tsunami Warning System *ETWS*, the Equipment Identity Register *EIR* and Policy Control and Charging Rules Function *PCRF*.



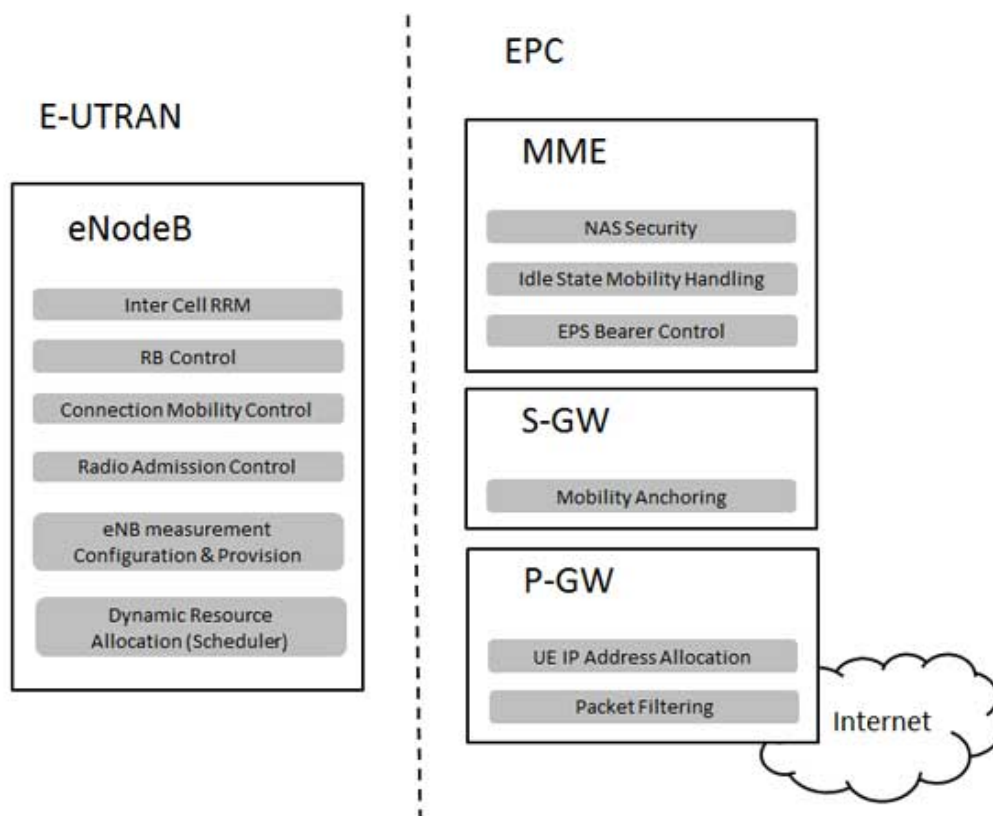
Below is a brief description of each of the components shown in the above architecture:

- The Home Subscriber Server *HSS* component has been carried forward from UMTS and GSM and is a central database that contains information about all the network operator's subscribers.
- The Packet Data Network *PDN* Gateway *P – GW* communicates with the outside world i.e. packet data networks *PDN*, using *SGi* interface. Each packet data network is identified by an access point name *APN*. The *PDN* gateway has the same role as the GPRS support node *GGSN* and the serving GPRS support node *SGSN* with UMTS and GSM.
- The serving gateway *S – GW* acts as a router, and forwards data between the base station and the *PDN* gateway.
- The mobility management entity *MME* controls the high-level operation of the mobile by means of signalling messages and Home Subscriber Server *HSS*.
- The 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*.

The interface between the serving and *PDN* gateways is known as *S5/S8*. This has two slightly different implementations, namely *S5* if the two devices are in the same network, and *S8* if they are in different networks.

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:



2G/3G Versus LTE

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

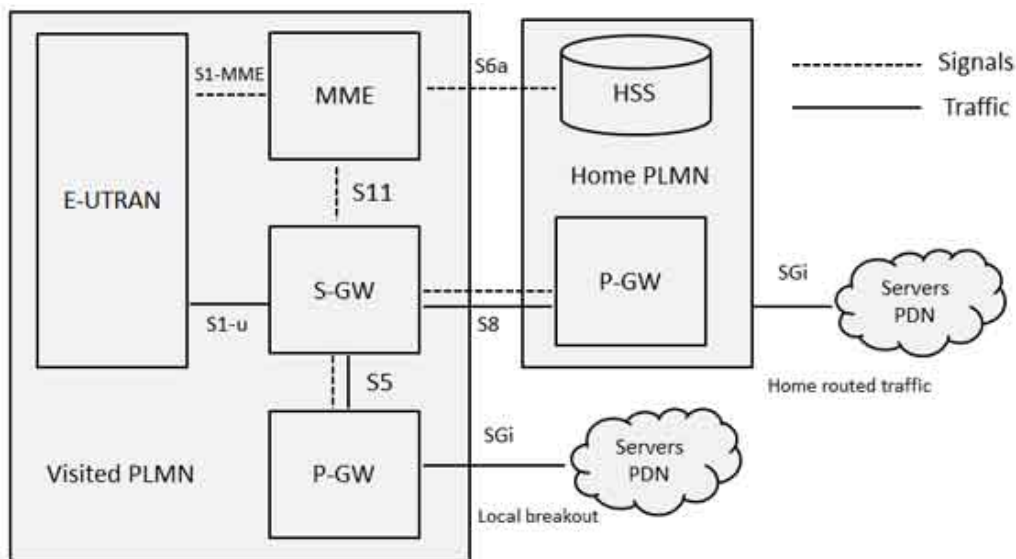
2G/3G	LTE
GERAN and UTRAN	E-UTRAN
SGSN/PDSN-FA	S-GW

GGSN/PDSN-HA	PDN-GW
HLR/AAA	HSS
VLR	MME
SS7-MAP/ANSI-41/RADIUS	Diameter
DiameterGTPc-v0 and v1	GTPc-v2
MIP	PMIP

LTE ROAMING ARCHITECTURE

A network run by one operator in one country is known as a Public Land Mobile Network *PLMN* and when a subscribed user uses his operator's PLMN then it is said Home-PLMN but roaming allows users to move outside their home network and using the resources from other operator's network. This other network is called 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, as shown in below:



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 interface between the serving and PDN gateways is known as S5/S8. This has two slightly different implementations, namely S5 if the two devices are in the same network, and S8 if they are in different networks. For mobiles that are not roaming, the serving and PDN gateways can be integrated into a single device, so that the S5/S8 interface vanishes altogether.

LTE Roaming Charging

The complexities of the new charging mechanisms required to support 4G roaming are much more abundant than in a 3G environment. Few words about both pre-paid and post-paid charging for LTE roaming is given below:

- **Prepaid Charging** - The CAMEL standard, which enables prepaid services in 3G, is not supported in LTE; therefore, prepaid customer information must be routed back to the home network as opposed to being handled by the local visited network. As a result, operators must rely on new accounting flows to access prepaid customer data, such as through their P-Gateways in both IMS and non-IMS environments or via their CSCF in an IMS environment.
- **Postpaid Charging** - Postpaid data-usage charging works the same in LTE as it does in 3G, using versions TAP 3.11 or 3.12. With local breakout of IMS services, TAP 3.12 is required.

Operators do not have the same amount of visibility into subscriber activities as they do in home-routing scenarios in case of local breakout scenarios because subscriber-data sessions are kept within the visited network; therefore, in order for the home operator to capture real-time information on both pre- and postpaid customers, it must establish a Diameter interface between

charging systems and the visited network's P-Gateway.

In case of local breakout of IMS services scenario, the visited network creates call detail records *CDRs* from the S-Gateways, however, these *CDRs* do not contain all of the information required to create a TAP 3.12 mobile session or messaging event record for the service usage. As a result, operators must correlate the core data network *CDRs* with the IMS *CDRs* to create TAP records.

LTE NUMBERING & ADDRESSING

An LTE network area is divided into three different types of geographical areas explained below:

S.N. Area and Description

1 **The MME pool areas**
This is an 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.

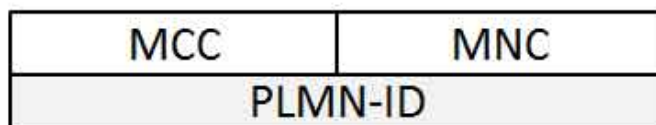
2 **The S-GW service areas**
This is an area served by one or more serving gateways S-GW, through which the mobile can move without a change of serving gateway.

3 **The Tracking areas**
The 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 from UMTS and GSM and will be used to track the locations of mobiles that are on standby mode.

Thus an LTE network will comprise of many MME pool areas, many S-GW service areas and lots of tracking areas.

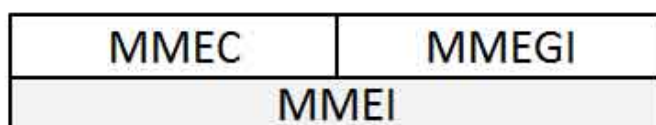
The Network IDs

The network itself will be identified using Public Land Mobile Network Identity *PLMN-ID* which will have a three digit mobile country code *MCC* and a two or three digit mobile network code *MNC*. For example, the Mobile Country Code for the UK is 234, while Vodafone's UK network uses a Mobile Network Code of 15.



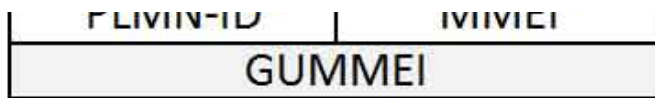
The MME IDs

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.



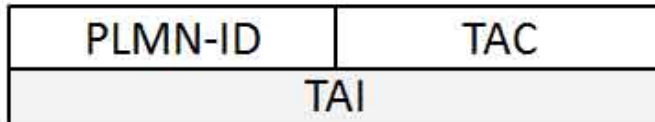
If we combine *PLMN-ID* with the *MMEI* then we arrive at a Globally Unique MME Identifier *GUMMEI*, which identifies an MME anywhere in the world:





The Tracking Area IDs

Each tracking area has two main identities. The tracking area code *TAC* identifies a tracking area within a particular network and if we combining this with the PLMN-ID then we arrive at a Globally Unique Tracking Area Identity *TAI*.



The Cell IDs

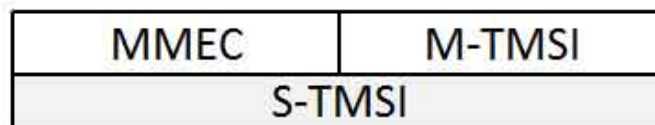
Each cell in the network has three types of identity. The E-UTRAN cell identity *ECI* identifies a cell within a particular network, while the E-UTRAN cell global identifier *ECGI* identifies a cell anywhere in the world.

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

The international mobile equipment identity *IMEI* is a unique identity for the mobile equipment and the International Mobile Subscriber Identity *IMSI* is a unique identity for the UICC and the USIM.

The 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.

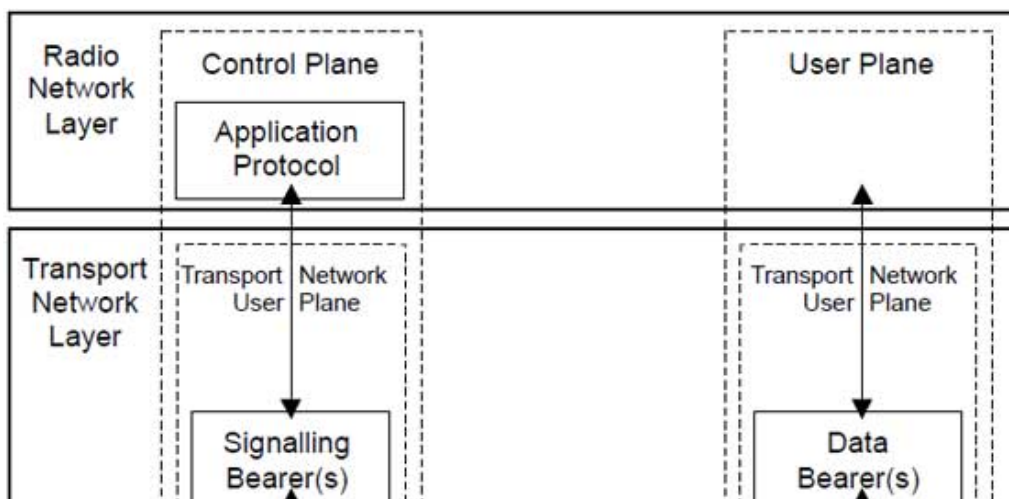


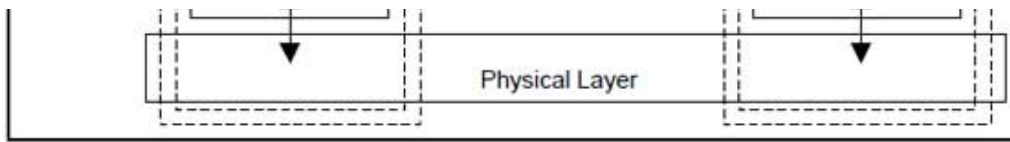
Finally adding the MME group identity and the PLMN identity with S-TMSI results in the Globally Unique Temporary Identity *GUTI*.



LTE RADIO PROTOCOL ARCHITECTURE

The radio protocol architecture for LTE can be separated into **control plane** architecture and **user plane** architecture as shown below:





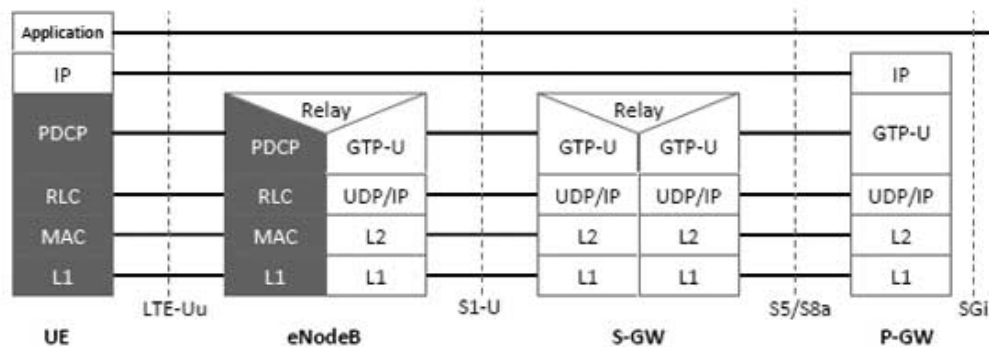
At user plane side, the application creates data packets that are processed by protocols such as TCP, UDP and IP, while in the control plane, the radio resource control *RRC* protocol writes the signalling messages that are exchanged between the base station and the mobile. In both cases, the information is processed by the packet data convergence protocol *PDCP*, the radio link control *RLC* protocol and the medium access control *MAC* protocol, before being passed to the physical layer for transmission.

User Plane

The user plane protocol stack between the e-Node B and UE consists of the following sub-layers:

- *PDCP PacketDataConvergenceProtocol*
- *RLC radioLinkControl*
- *Medium Access Control MAC*

On the user plane, 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. GPRS Tunneling Protocol *GTP* is used on the S1 interface between the eNodeB and S-GW and on the S5/S8 interface between the S-GW and P-GW.



Packets received by a layer are called Service Data Unit *SDU* while the packet output of a layer is referred to by Protocol Data Unit *PDU* and IP packets at user plane flow from top to bottom layers.

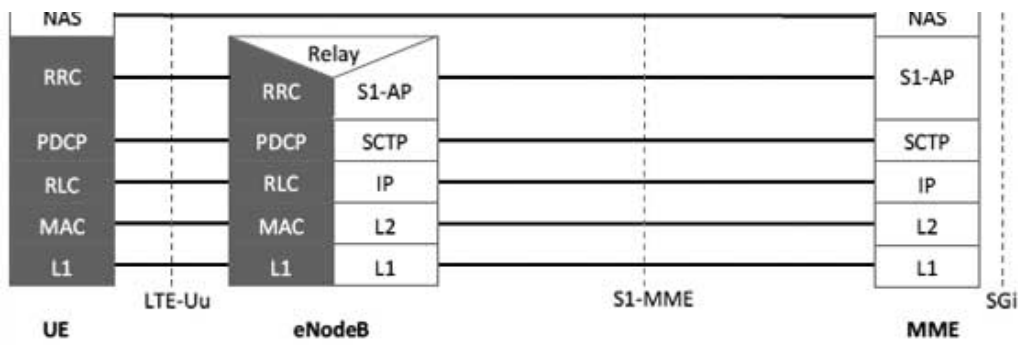
Control Plane

The control plane includes additionally the Radio Resource Control layer *RRC* which is responsible for configuring the lower layers.

The Control Plane handles radio-specific functionality which depends on the state of the user equipment which includes two states: idle or connected.

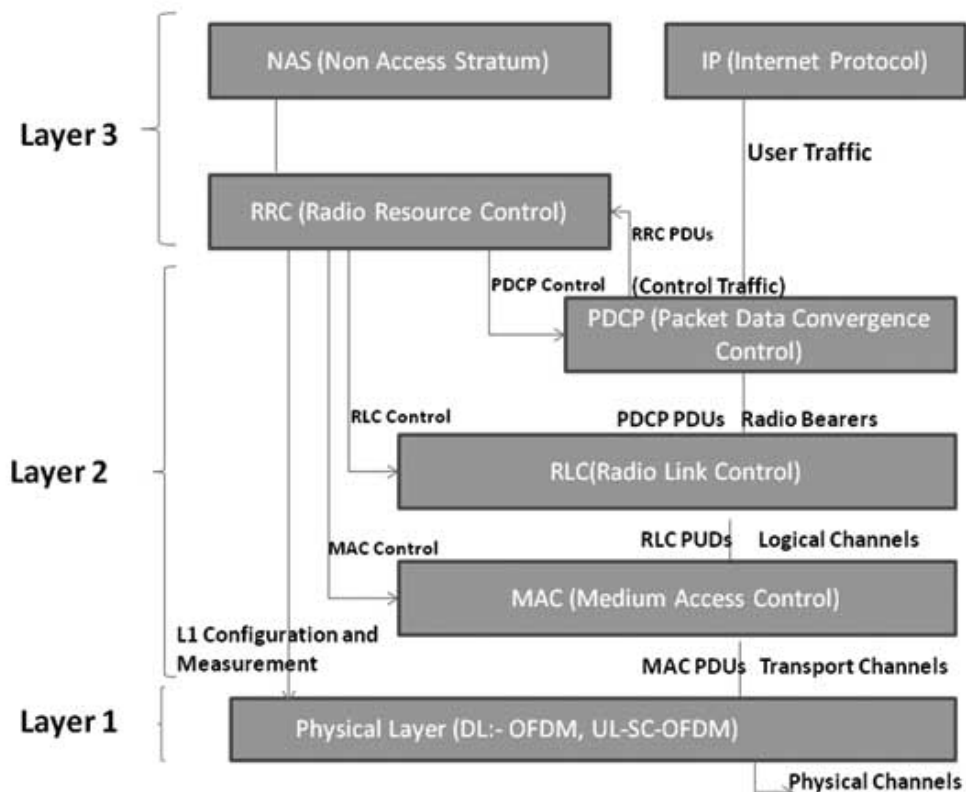
Mode	Description
Idle	The user equipment camps on a cell after a cell selection or reselection process where factors like radio link quality, cell status and radio access technology are considered. The UE also monitors a paging channel to detect incoming calls and acquire system information. In this mode, control plane protocols include cell selection and reselection procedures.
Connected	The UE supplies the E-UTRAN with downlink channel quality and neighbour cell information to enable the E-UTRAN to select the most suitable cell for the UE. In this case, control plane protocol includes the Radio Link Control <i>RRC</i> protocol.

The protocol stack for the control plane between the UE and MME is shown below. The grey region of the stack indicates the access stratum *AS* protocols. The lower layers perform the same functions as for the user plane with the exception that there is no header compression function for the control plane.



LTE PROTOCOL STACK LAYERS

Let's have a close look at all the layers available in E-UTRAN Protocol Stack which we have seen in previous chapter. Below is a more elaborated diagram of E-UTRAN Protocol Stack:



Physical Layer Layer1

Physical Layer carries all information from the MAC transport channels over the air interface. Takes care of the link adaptation *AMC*, power control, cell search *for initial synchronization and handover purposes* and other measurements *inside the LTE system and between systems* for the RRC layer.

Medium Access Layer MAC

MAC layer is responsible for Mapping between logical channels and transport channels, Multiplexing of MAC SDUs from one or different logical channels onto transport blocks *TB* to be delivered to the physical layer on transport channels, de multiplexing of MAC SDUs from one or different logical channels from transport blocks *TB* delivered from the physical layer 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, Logical Channel prioritization.

Radio Link Control RLC

RLC operates in 3 modes of operation: Transparent Mode *TM*, Unacknowledged Mode *UM*, and Acknowledged Mode *AM*.

RLC Layer is responsible for transfer of upper layer PDUs, error correction through ARQ

Only for AM data transfer, Concatenation, segmentation and reassembly of RLC SDUs
 Only for UM and AM data transfer.

RLC is also responsible for re-segmentation 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 of the RRC sublayer include broadcast of System Information related to the non-access stratum NAS, broadcast of System Information related to the access stratum AS, Paging, establishment, maintenance and release of an RRC connection between the UE and E-UTRAN, Security functions including key management, establishment, configuration, maintenance and release of point to point Radio Bearers.

Packet Data Convergence Control PDCP

PDCP Layer is responsible for 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 plane data and control plane data, Integrity protection and integrity verification of control plane data, Timer based discard, duplicate discarding, PDCP is used for SRBs and DRBs mapped on DCCH and DTCH type of logical channels.

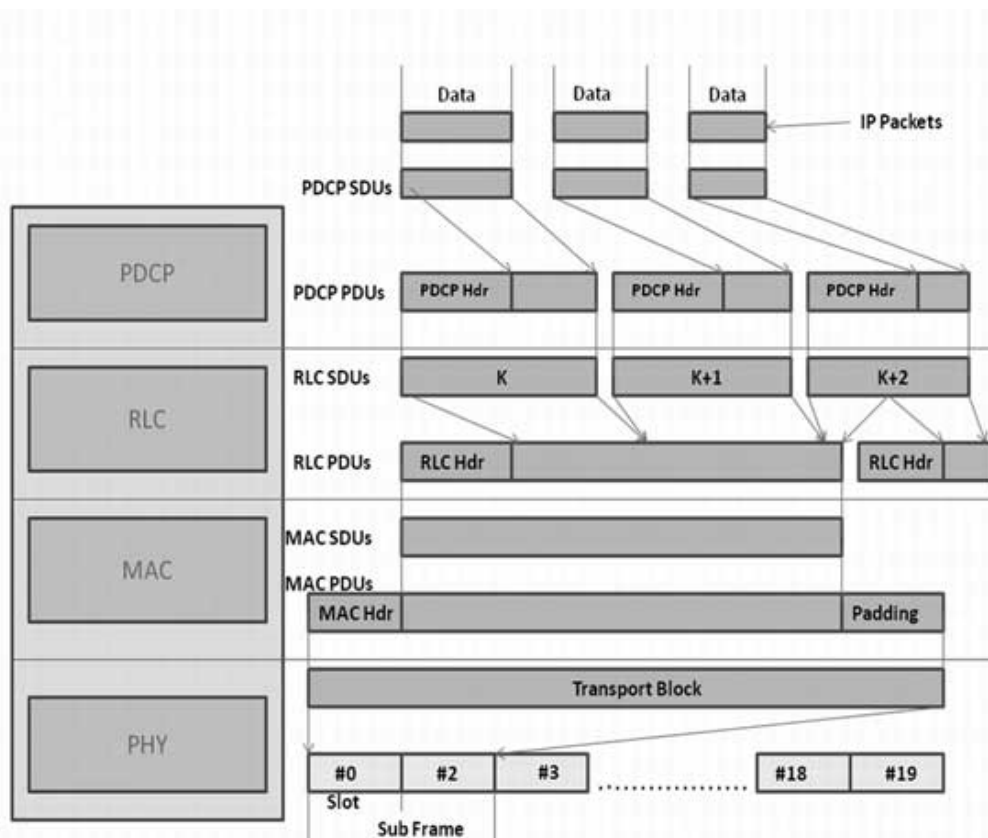
Non Access Stratum NAS Protocols

The non-access stratum NAS protocols form the highest stratum of the control plane between the user equipment UE and MME.

NAS protocols support the mobility of the UE and the session management procedures to establish and maintain IP connectivity between the UE and a PDN GW.

LTE LAYERS DATA FLOW

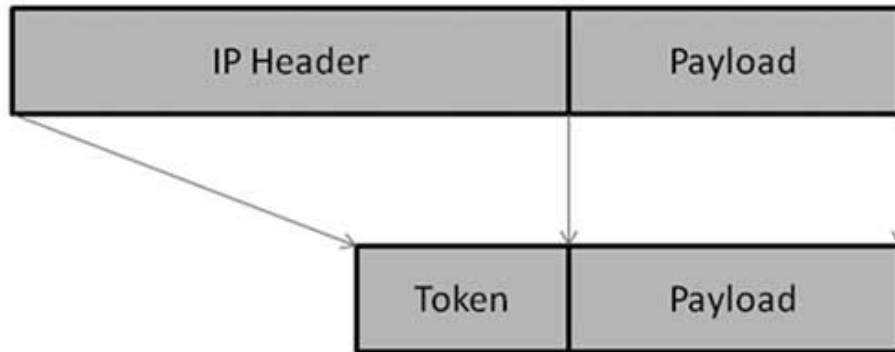
Below is a logical diagram of E-UTRAN Protocol layers with a depiction of data flow through various layers:



Packets received by a layer are called Service Data Unit SDU while the packet output of a layer is referred to by Protocol Data Unit PDU. Let's see the flow of data from top to bottom:

- IP Layer submits PDCP SDUs *IP packets* to the PDCP layer. PDCP layer does header compression and adds PDCP header to these PDCP SDUs. PDCP Layer submits PDCP PDUs *RLCSDUs* to RLC layer.

PDCP Header Compression : PDCP removes IP header *Minimum 20 bytes* from PDU, and adds Token of 1-4 bytes. Which provides a tremendous savings in the amount of header that would otherwise have to go over the air.



- RLC layer does segmentation of these SDUs to make the RLC PDUs. RLC adds header based on RLC mode of operation. RLC submits these RLC PDUs *MACSDUs* to the MAC layer.

RLC Segmentation : If an RLC SDU is large, or the available radio data rate is low *resulting in small transport blocks*, the RLC SDU may be split among several RLC PDUs. If the RLC SDU is small, or the available radio data rate is high, several RLC SDUs may be packed into a single PDU.

- MAC layer adds header and does padding to fit this MAC SDU in TTI. MAC layer submits MAC PDU to physical layer for transmitting it onto physical channels.
- Physical channel transmits this data into slots of sub frame.

LTE COMMUNICATION CHANNELS

The information flows between the different protocols are known as channels and signals. LTE uses several different types of logical, transport and physical channel, which are distinguished by the kind of information they carry and by the way in which the information is processed.

- **Logical Channels** : Define **what type** of information is transmitted over the air, e.g. traffic channels, control channels, system broadcast, etc. Data and signalling messages are carried on logical channels between the RLC and MAC protocols.
- **Transport Channels** : Define **how is** something transmitted over the air, e.g. what are encoding, interleaving options used to transmit data. Data and signalling messages are carried on transport channels between the MAC and the physical layer.
- **Physical Channels** : Define **where is** something transmitted over the air, e.g. first N symbols in the DL frame. Data and signalling messages are carried on physical channels between the different levels of the physical layer.

Logical Channels

Logical channels define what type of data is transferred. These channels define the data-transfer services offered by the MAC layer. Data and signalling messages are carried on logical channels between the RLC and MAC protocols.

Logical channels can be divided into control channels and traffic channels. Control Channel can be either common channel or dedicated channel. A common channel means common to all users in a cell *Point to multipoint* while dedicated channels means channels can be used only by one user *Point to Point*.

Logical channels are distinguished by the information they carry and can be classified in two ways. Firstly, logical traffic channels carry data in the user plane, while logical control channels carry signalling messages in the control plane. Following table lists the logical channels that are used by LTE:

Channel Name	Acronym	Control channel	Traffic channel
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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 Channels

Transport channels define how and with what type of characteristics the data is transferred by the physical layer. Data and signalling messages are carried on transport channels between the MAC and the physical layer.

Transport Channels are distinguished by the ways in which the transport channel processor manipulates them. Following table lists the transport channels that are used by LTE:

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

Data and signalling messages are carried on physical channels between the different levels of the physical layer and accordingly they are divided into two parts:

- Physical Data Channels
- Physical Control Channels

Physical data channels

Physical data channels are distinguished by the ways in which the physical channel processor manipulates them, and by the ways in which they are mapped onto the symbols and sub-carriers used by Orthogonal frequency-division multiplexing *OFDMA*. Following table lists the **physical data channels** that are used by LTE:

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. These are listed in the below table:

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 information that supports the low-level operation of the physical 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 completely invisible to higher layers. Similarly, the physical channel processor creates physical signals, which support the lowest-level aspects of the system.

Physical Control Channels are listed in the below table:

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

The base station also transmits two other physical signals, which help the mobile acquire the base station after it first switches on. These are known as the primary synchronization signal *PSS* and the secondary synchronization signal *SSS*.

LTE OFDM TECHNOLOGY

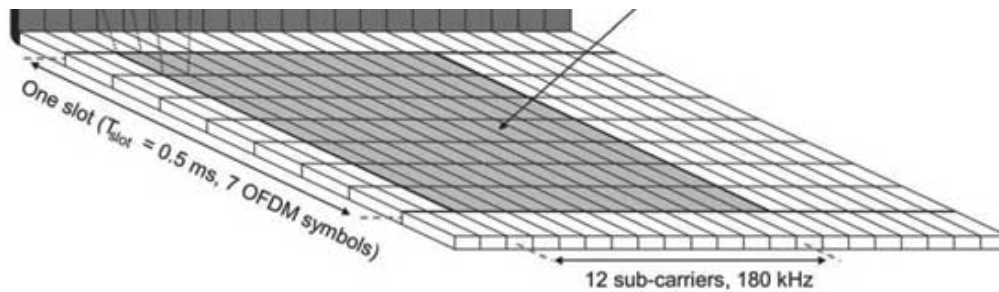
To overcome the effect of multi path fading problem available in UMTS, LTE uses Orthogonal Frequency Division Multiplexing *OFDM* for the downlink - that is, from the base station to the terminal to transmit the data over many narrow band carriers of 180 KHz each instead of spreading one signal over the complete 5MHz carrier bandwidth ie. OFDM uses a large number of narrow sub-carriers for multi-carrier transmission to carry data.

Orthogonal frequency-division multiplexing *OFDM*, is a frequency-division multiplexing *FDM* scheme used as a digital multi-carrier modulation method.

OFDM meets the LTE requirement for spectrum flexibility and enables cost-efficient solutions for very wide carriers with high peak rates. The basic LTE downlink physical resource can be seen as a time-frequency grid, as illustrated in Figure below:

The OFDM symbols are grouped into resource blocks. The resource blocks have a total size of 180kHz in the frequency domain and 0.5ms in the time domain. Each 1ms Transmission Time Interval *TTI* consists of two slots *Tslot*.





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 frequency and time dimensions.

The scheduling mechanisms in LTE are similar to those used in HSPA, and enable optimal performance for different services in different radio environments.

Advantages of OFDM

- The primary advantage of OFDM over single-carrier schemes is its 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 rather than one rapidly-modulated wideband signal.
- The low symbol rate makes the use of a guard interval between symbols affordable, making it possible to eliminate inter symbol interference *ISI*.
- This mechanism also 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 single-carrier system.

Drawbacks of OFDM

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

SC-FDMA Technology

LTE uses a pre-coded version of OFDM called Single Carrier Frequency Division Multiple Access *SC-FDMA* in the uplink. This is to compensate for a drawback with normal OFDM, which has a very high Peak to Average Power Ratio *PAPR*.

High *PAPR* requires expensive and inefficient power amplifiers with high requirements on linearity, which increases the cost of the terminal and drains 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.

LTE GLOSSARY

Term	Description
3GPP	3rd Generation Partnership Project
3GPP2	3rd Generation Partnership Project 2
ARIB	Association of Radio Industries and Businesses
ATIS	Alliance for Telecommunication Industry Solutions
AWS	Advanced Wireless Services
CAPEX	Capital Expenditure

CCSA	China Communications Standards Association
CDMA	Code Division Multiple Access
CDMA2000	Code Division Multiple Access 2000
DAB	Digital Audio Broadcast
DSL	Digital Subscriber Line
DVB	Digital Video Broadcast
eHSPA	evolved High Speed Packet Access
ETSI	European Telecommunications Standards Institute
FDD	Frequency Division Duplex
FWT	Fixed Wireless Terminal
GSM	Global System for Mobile communication
HSPA	High Speed Packet Access
HSS	Home Subscriber Server
IEEE	Institute of Electrical and Electronics Engineers
IPTV	Internet Protocol Television
LTE	Long Term Evolution
MBMS	Multimedia Broadcast Multicast Service
MIMO	Multiple Input Multiple Output
MME	Mobility Management Entity
NGMN	Next Generation Mobile Networks
OFDM	Orthogonal Frequency Division Multiplexing
OPEX	Operational Expenditure
PAPR	Peak to Average Power Ratio
PCI	Peripheral Component Interconnect
PCRF	Policing and Charging Rules Function
PDSN	Packet Data Serving Node
PS	Packet Switched
QoS	Quality of Service
RAN	Radio Access Network
SAE	System Architecture Evolution
SC-FDMA	Single Carrier Frequency Division Multiple Access
SGSN	Serving GPRS Support Node
TDD	Time Division Duplex
TTA	Telecommunications Technology Association
TTC	Telecommunication Technology Committee
TTI	Transmission Time Interval
UTRA	Universal Terrestrial Radio Access
UTRAN	Universal Terrestrial Radio Access Network

WCDMA Wideband Code Division Multiple Access

WLAN Wireless Local Area Network

Processing math: 100%