4G and LTE

(1) High level architecture of UMTS and GSM.

LTE was designed by a collaboration of national and regional telecommunications standards bodies known as the Third Generation Partnership Project (3GPP) and is known in full as 3GPP long term evolution. LTE evolved from an earlier 3GPP system known as the Universal Mobile Telecommunication system (UMTS), which in turn evolved from Global system for Mobile communications (GSM)

A mobile phone network is officially known as a public land mobile network (PLMN), and is run by a network operator such as Vodafone or Verizon.

UMTS & GSM share a common n/w architecture. There are three main components, namely the core network, the radio access n/w & the mobile phone.

The Core network contains two domains.

The Circuit Switched (CS) domain transports phone calls across the geographical region that the n/w operator is covering, in the same way as a traditional fixed-line telecommunication system. It communicates with the public switched telephone network (PSTN) so that users can make calls to land lines and with the Circuit Switched domains of other network operators..

The packet switched (PS) domain transports data stream, such as web pages & emails, b/w the user and external packet data networks (PDNs) such as the internet.

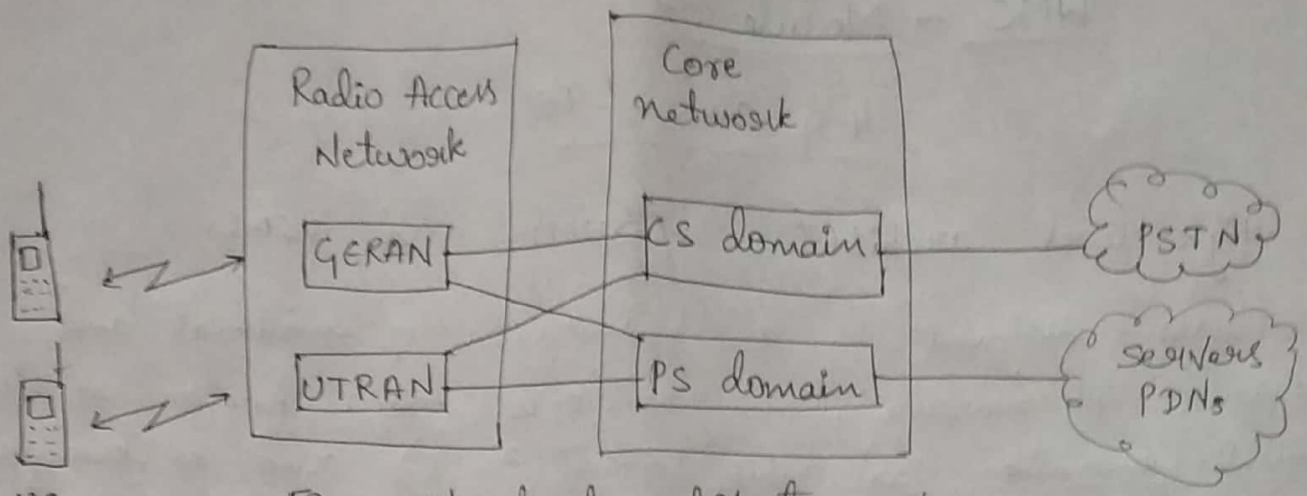


Fig: High level architecture of UMTS & GSM.

The two domains transport their information in very different ways. The CS domain uses a technique known as circuit switching, in which it sets aside a dedicated two-way connection for each individual phone call so that it can transport the information with a constant data rate and minimal delay. The technique is effective, but is rather inefficient. It is inappropriate for data transfers, in which data rate can vary widely. To deal with the problem, the PS domain uses a different technique, known as packet switching. Here, a data stream is divided into packets, each of which is labelled with the address of the required destination device. Within the network, routers read the address labels of the incoming data packets and forward them towards the corresponding destinations. The network's resources are shared amongst all the users, so this technique is more efficient than circuit switching.

The radio access network handles the core network's radio communications with the user. There are actually two separate radio access networks, namely the GSM edge radio access network (GERAN) and the UMTS terrestrial radio access network (UTRAN). These use the different radio communication techniques of GSM & UMTS but share a common core network between them.

The user device that is known officially as the User Equipment (UE) and colloquially as the mobile. It communicates with the radio access network over the air interface. The direction from network to mobile is known as the downlink (DL) or forward link and the direction from mobile to network is known as the uplink (UL) or reverse link

A mobile can work outside the coverage area of its network operator by using the resources from two public land mobile networks: the visited n/w, where the mobile is located & the operator's home n/w. This situation is known as roaming.

(2) Capacity of a Mobile Telecommunication System.

In 1948, Claude Shannon discovered a theoretical limit on the data rate that can be achieved from any communication system.

$$C = B \log_2(1 + SINR)$$

SINR → signal to interference plus noise ratio, in other words the power at the receiver due to the required signal, divided by the power due to noise & interference.

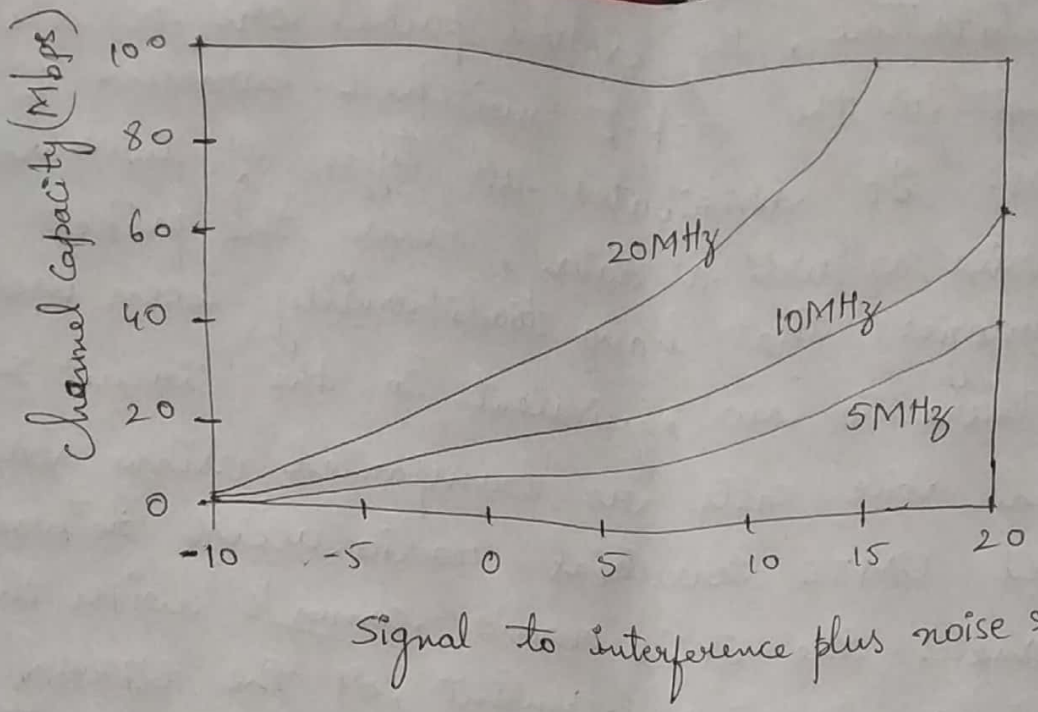
B is the bandwidth of the communication s/m in Hz

C is the channel capacity in bits s^{-1}

It is theoretically possible for a communication s/m to send data from a transmitter to receiver without any errors at all, provided the data rate is less than the ~~Cap~~ channel capacity. In a mobile comm s/m, C is the maximum data rate that one cell can handle and equals the combined data rate of all the mobiles in the cell.

The results are shown below, using bandwidth 5, 10 & 20 Hz. The vertical axis shows the channel capacity in million bits per second (Mbps), while the horizontal axis shows the signal to interference plus noise ratio in decibels (dB).

$$SINR(dB) = 10 \log_{10}(SINR)$$



(3) High level architecture of LTE.

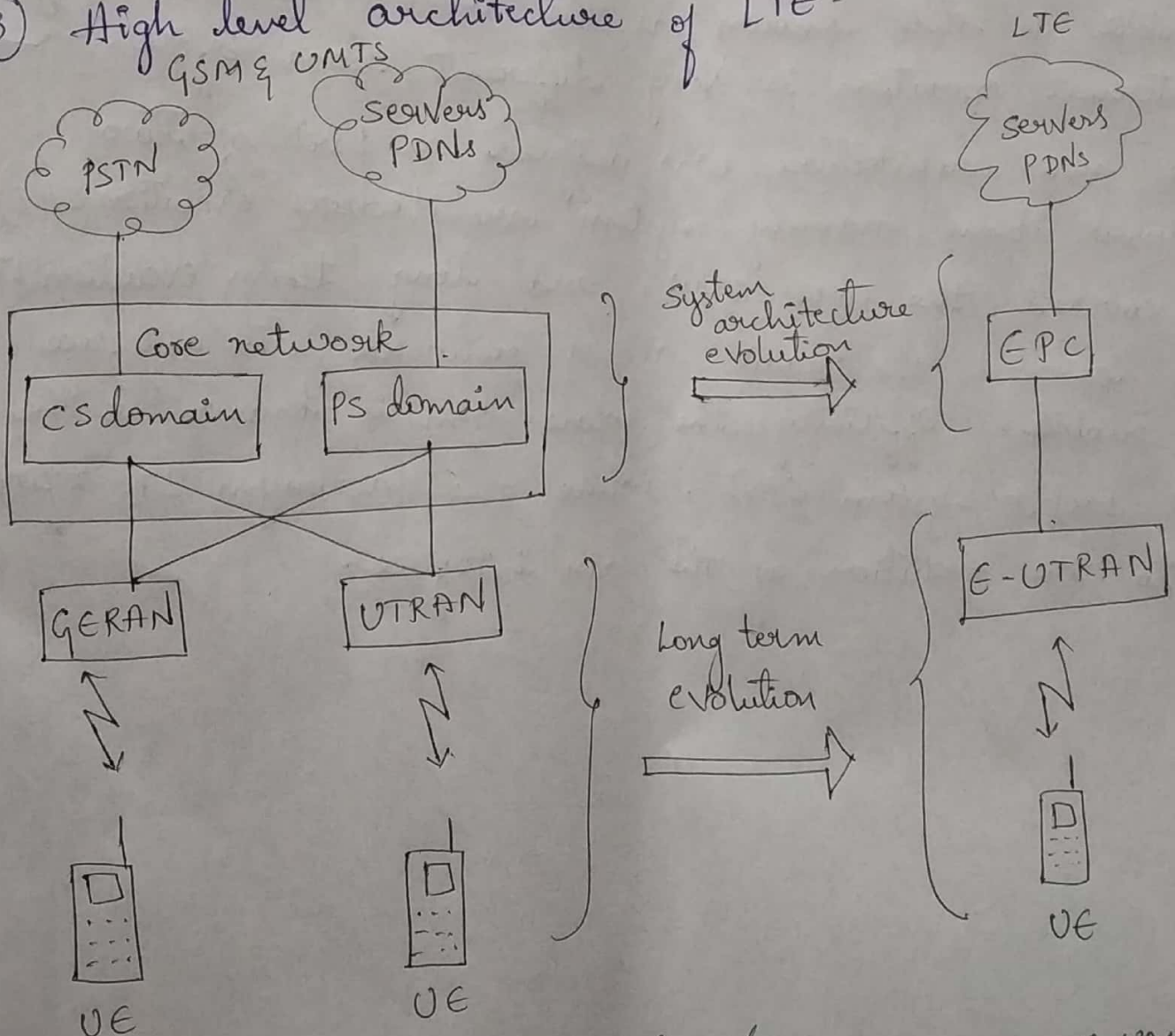


Fig: Evolution of the s/m architecture from GSM & UMTS to LTE.

In the new architecture, the evolved packet core (EPC) is a direct replacement for the packet switched domain of UMTS and GSM. It distributes all types of information to the user, voice as well as data, using the packet switching technologies that have traditionally been used for data alone. There is no equivalent to the circuit switched domain: instead, voice calls are transported using voice over IP. The evolved UMTS terrestrial radio access network (E-UTRAN) handles the EPC's radio comm's with the mobile, so is a direct replacement for the UTRAN. The mobile is still known as the user equipment, though its internal operation is very different from before.

The new architecture was designed as part of two 3GPP work items, namely system architecture evolution (SAE), which covered the core n/w, and long term evolution (LTE) which covered the radio access network, air interface and mobile. Officially, the whole s/m is known as the evolved packet system (EPS), while the acronym LTE refers only to the evolution of the air interface.

(4) From LTE to LTE-Advanced.

(i) The ITU Requirements for 4G.

The design of LTE took place at the same time as an initiative by the International Telecommunication Union (ITU). In the late 1990s, the ITU had helped to drive the development of 3G technologies by publishing a set of requirement for a 3G mobile communication system, under the name International Mobile Telecommunications (IMT) 2000.

The ITU launched a similar process in 2008, by publishing a set of requirements for a fourth generation (4G) Comm s/m under the name IMT-Advanced. ACC to these requirements, the peak data rate of a compatible system should be at least 600 Mbps on the downlink and 270 Mbps on the uplink, in a bandwidth of 40MHz.

(ii) Requirements of LTE-Advanced.

LTE-Advanced was required to deliver a peak data rate of 1000 Mbps in the downlink, and 500 Mbps in uplink. In practice, the system has been designed so that it can eventually deliver peak data rates of 3000 & 1500 Mbps respectively, using a total bandwidth of 100 MHz that is made from five separate components of 20MHz each.

(iii) 4G Communication Systems.

The ITU announced in October 2010 that two systems met the requirements of IMT-advanced. One system was LTE-Advanced, while the other was an enhanced version of WiMAX under IEEE specification 802.16m, known as mobile WiMAX 2.0.

Qualcomm had originally intended to develop a 4G successor to cdma2000 under the name Ultra Mobile Broadband (UMB). However this system did not possess two of the advantages that its predecessor had done. Firstly, it was not backwards compatible with cdma2000, in the way that Cdma2000 had been with IS-95. Secondly, it was no longer the only system that could operate in the narrow bandwidths that dominated North America, due to the flexible bandwidth support of LTE.

(iv) The Meaning of 4G

Originally ITU intended that the term 4G should only be used for systems that met the requirements of IMT-Advanced. LTE did not do so and neither did mobile WiMAX 1.0. Because of this, the engineering community came to describe these systems as 3.9G. These considerations did not, however, stop the marketing community from describing LTE and mobile WiMAX 1.0 as 4G technologies. There is a clear technical transition in the move from UMTS to LTE, which does not exist in the move from LTE to LTE-Advanced.

(5) 3GPP specification series used by UMTS & LTE

The specifications for LTE are produced by the Third Generation Partnership Project, in the same way as the specifications of UMTS & GSM.

3GPP specifications releases for UMTS & LTE

Release	Date frozen	New features
R99	March 2000	WCDMA air interface
R4	March 2001	TD-SCDMA air interface
R5	June 2002	HSDPA, IP multimedia subsystem
R6	March 2005	HSUPA
R7	December, 2007	Enhancements to HSPA
R8	December, 2008	LTE, SAE
R9	December 2009	Enhancements to LTE & SAE
R10	March 2011	LTE-Advanced
R11	September 2012	Enhancements to LTE-Advanced.

3GPP specification series used by UMTS & LTE.

series	Scope.
21	High level requirements.
22	stage 1 service specifications
23	stage 2 service & architecture specifications.
24	Non access stratum protocols.
25	WCDMA & TD-SCDMA air interfaces & radio access n/w
26	Codecs
27	Data terminal equipment.
28	Tandem free operation of speech codecs.
29	Core network protocols.
30	Programme management
31	UICC and USIM
32	operations, administration, maintenance, provisioning and charging.
33	security
34	UE test specifications
35	security algorithms
36	LTE air interface & radio access network
37	Multiple radio access technologies.