INDEX

1 BASICS OF MOBILE COMMUNICATION

1.1 LEARNING OBJECTIVES

On completion of this chapter trainee will be able to understand Basic of Mobile communication. Topics covered will be:-

- Cellular Concept
- Fundamentals of GSM
- GSM Specifications
- GSM Architecture

1.2 CELLULAR CONCEPT

Traditional mobile service was structured similar to television broadcasting. One very powerful transmitter located at the highest spot in an area would broadcast in a radius of up to fifty kilometers. The Cellular concept structured the mobile telephone network in a different way. Instead of using one powerful transmitter many low-powered transmitter were placed throughout a coverage area. In a cellular system, the covering area of an operator is divided into cells. A cell corresponds to the covering area of one transmitter or a small collection of transmitters. The cellular concept employs variable low power levels, which allows cells to be sized according to subscriber density and demand of a given area. As the population grows, cells can be added to accommodate that growth. Frequencies used in a cell will be reused several cells away. The distance between the cells using the same frequency must be sufficient to avoid interference. The frequency reuse will increase considerably the capacity in number of users.

1.2.1 CELL SYSTEM

A cell is the basic geographic unit of cellular system. The term cellular comes from the honeycomb areas into which a coverage region is divided. Cells are base stations transmitting over small geographic areas that are represented as hexagons as shown in Figure. Each cell size varies depending upon landscape. Because of constraint imposed by natural terrain and man-made structures, the true shape of cell is not a perfect hexagon. In order to work properly, a cellular system must verify the following two main conditions:

The power level of a transmitter within a single cell must be limited in order to reduce the interference with the transmitters of neighboring cells.

Neighboring cells can not share the same channels. In order to reduce the interference, the frequencies must be reused only within a certain pattern.

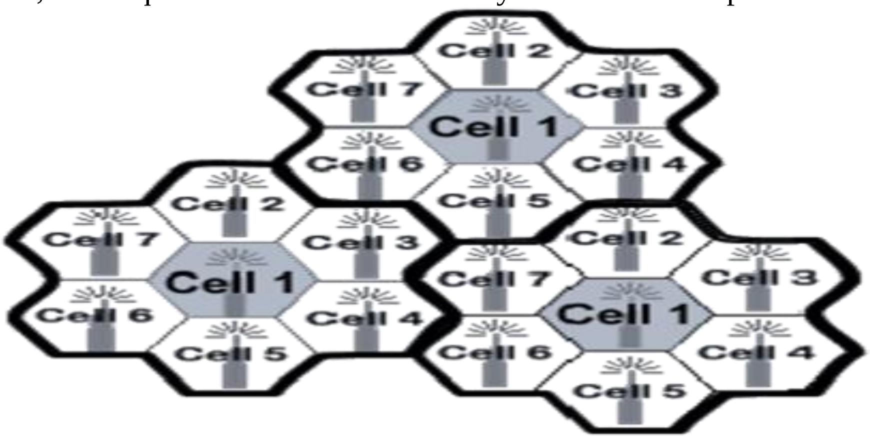

Figure 1: Cell System

1.3 CLUSTER

The spectrum allocated for a cellular network is limited. As a result there is a limit to the number of frequencies or channels that can be used. The cells are grouped into clusters. Group of cells in which no frequencies are reused is termed as a cluster.

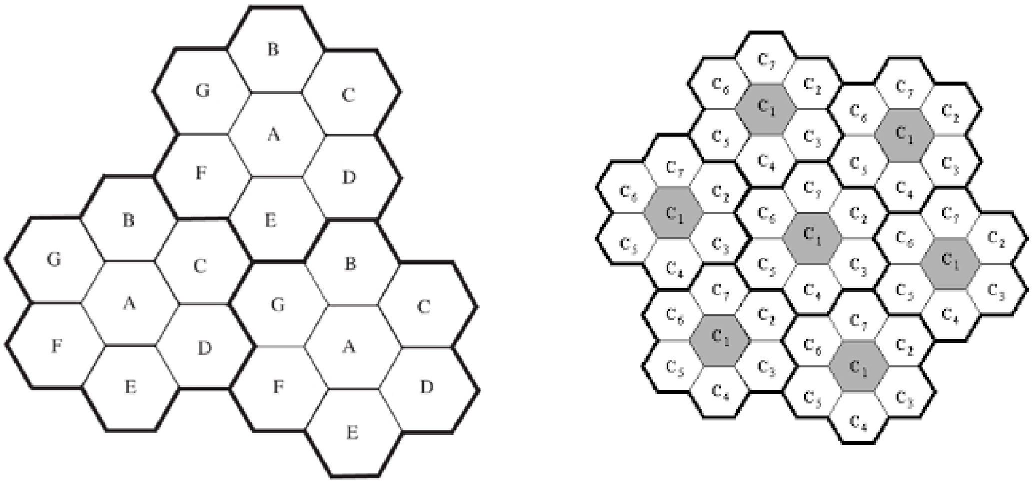

Figure 2: CLUSTER

1.3.1 TYPES OF CELLS

The density of population in a country is so varied that different types of cells are used:

A. MACRO CELLS

The macro cells are large cells for remote and sparsely populated areas.

B. MICRO CELLS

These cells are used for densely populated areas. By splitting the existing areas into smaller cells, the number of channels available is increased as well as the capacity of the cells. The power level of the transmitters used in these cells is then decreased, reducing the possibility of interference between neighboring cells.

C. PICO CELLS

Pico cells are small cells whose diameter is only few dozen meters; they are used mainly in indoor applications. It can cover e.g. a floor of a building or an entire building like shopping centers, Airports etc.

D. SELECTIVE CELLS

It is not always useful to define a cell with a full coverage of 360 degrees. In some cases, cells with a particular shape and coverage are needed. These cells are called selective cells. Typical examples of selective cells are the cells that may be located at the entrances of tunnels where coverage of 360 degrees is not needed. In this case, a selective cell with coverage of 120 degrees is used.

E. UMBRELLA CELLS

A freeway crossing very small cells produces an important number of handovers among the different small neighboring cells in case of a fast moving mobile subscriber. In order to solve this problem, the concept of umbrella cells is introduced. An umbrella cell covers several micro cells. The power level inside an umbrella cell is increased comparing to the power levels used in the micro cells that form the umbrella cell. When the speed of the mobile is too high, the mobile is handed over to the umbrella cell. The mobile will then stay longer in the same cell (in this case the umbrella cell). This will reduce the number of handovers and the work of the network.

1.3.2 CELL SECTORING

One way of reducing the level of interference is to use directional antenna at base stations, with each antenna illuminating a sector of the cell, and with a separate channel set allocated to each sector. There are two commonly used methods of Sectorisation either using 120˚ sector or 60˚ sector, both of which reduce the number of prime interference sources.

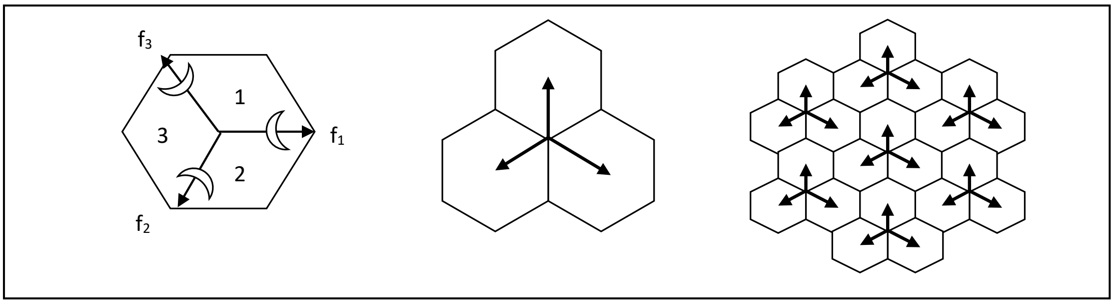

Figure 3: Sectorization

The three sector case is generally used with a seven cell pattern, giving an overall requirement for 21 channel sets as shown in Figure above.

1.3.3 FEATURES OF DIGITAL CELLULAR SYSTEM:

A. SMALL CELLS: A cellular system uses many base stations with relatively small coverage radii (on the order of a 100 m to 30 km).

B. FREQUENCY REUSEF: The spectrum allocated for a cellular network is limited. As a result there is a limit to the number of channels or frequencies that can be used. For this reason each frequency is used simultaneously by multiple base-mobile pairs. This frequency reuse allows a much higher subscriber density per MHz of spectrum than other systems.

C. SMALL, BATTERY-POWERED HANDSET: In addition to supporting much higher densities than previous systems, this approach enables the use of small, battery-powered handsets with a radio frequency that is lower than the large mobile units used in earlier systems.

D. PERFORMANCE OF HANDOVERS: In cellular systems, continuous coverage is achieved by executing a “handover” (the seamless transfer of the call from one base station to another) as the mobile unit crosses cell boundaries. This requires the mobile to change frequencies under control of the cellular network.

1.4 FUNDAMENTALS OF GSM

A cellular mobile communications system uses a large number of low-power wireless transmitters to create cells the basic geographic service area of a wireless communications system. Variable power levels allow cells to be sized according to the subscriber density and demand within a particular region. As mobile users travel from cell to cell, their conversations are "handed over" between cells in order to maintain seamless service. Channels (frequencies) used in one cell can be reused in another cell some distance away. Cells can be added to accommodate growth, creating new cells in uncovered areas or overlaying cells in existing areas.

The important objectives of the mobile communication are:-

- Any time Anywhere communication
- Mobility & Roaming
- High capacity & subscriber density

- Efficient Use of Radio Spectrum
- Seamless Network Architecture
- Low Cost
- Innovative Services
- Standard Interface

1.4.1 DIFFERENT GENERATIONS:

TECHNOLOGY	1G	2G	2.5G	3G	4G
First Design	1970	1980	1985	1990	2000
Implementation	1982	1991	1999	2002	2010?
Service	Analog Voice	Digital Voice, SMS	Package Data	Broadband data up to 2 Mb/s	IP-oriented unlimited multimedia data
Standards	AMPS	TDMA, CDMA, GSM	GPRS,EDGE	EVDO, W-CDMA, HSDPA	WiMAX, HSOPA
Data Bandwidth	1.9 kbps	14.4 kbps	384 kbps	2 mbps	200 mbps

Table 1. Different Generations

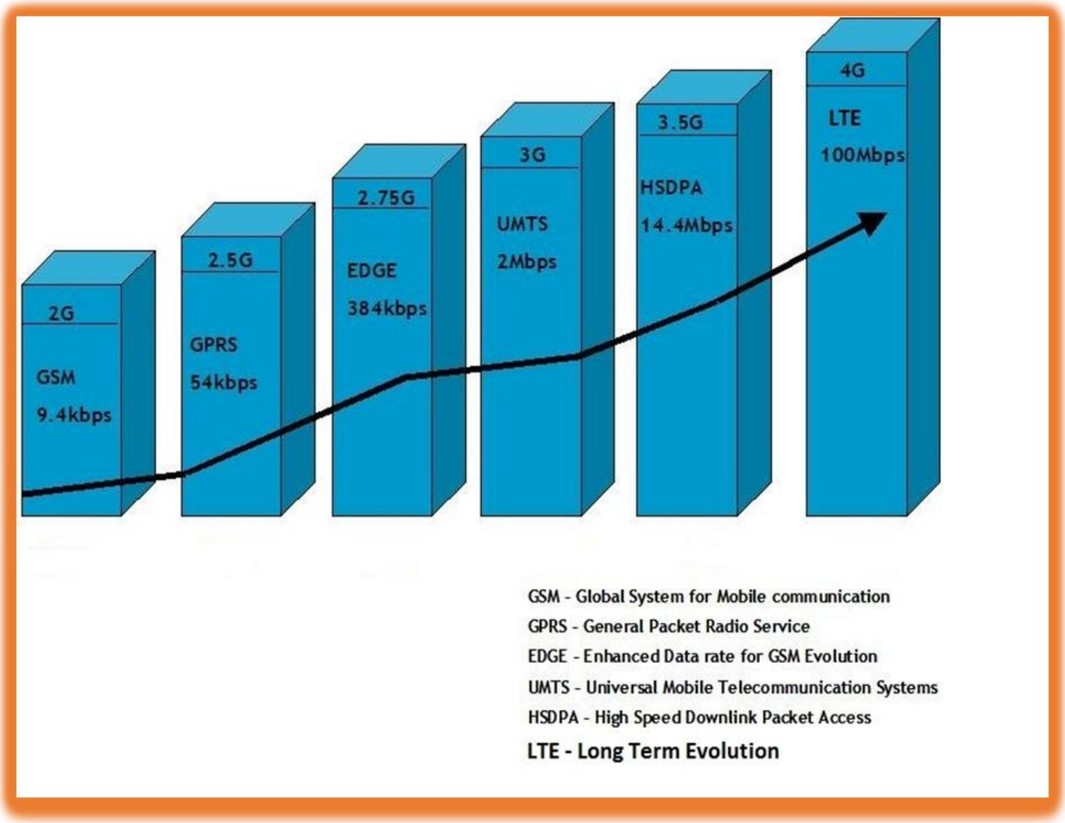

Figure 4: Different Generations

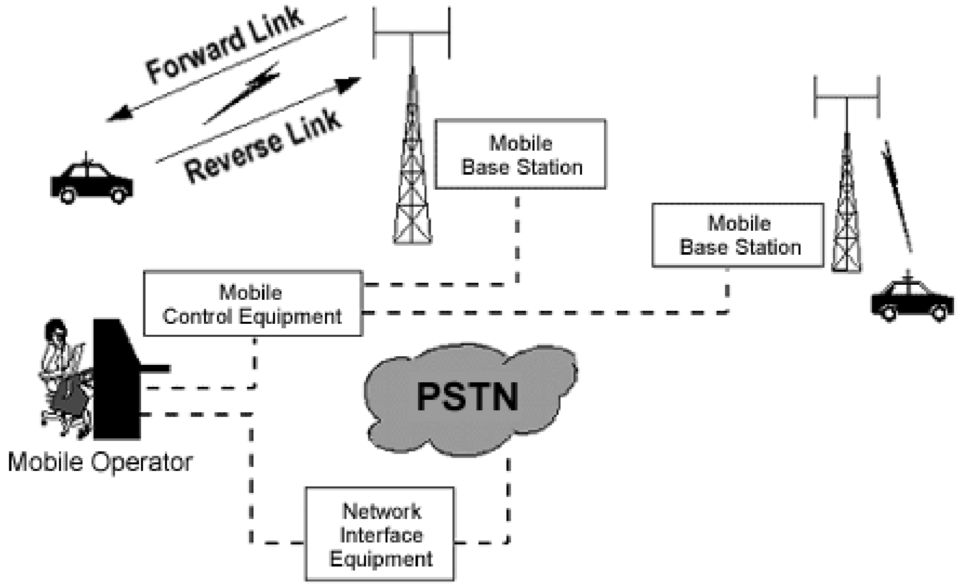

Figure 5: Basic Mobile Telephone Service Network

1.4.2 DUPLEXING METHODOLOGY:

Duplexing is the technique by which the send and receive paths are separated over the medium, since transmission entities (modulator, amplifiers, demodulators) are involved.

There are two types of duplexing:

A) Frequency Division Duplexing FDD

B) Time Division Duplexing TDD

A. Frequency Division Duplexing (FDD)

Different Frequencies are used for send and receive paths and hence there will be a Forward band and reverse band. Duplexer is needed if simultaneous transmission (send) and reception (receive) methodology is adopted .Frequency separation between forward band and reverse band is constant.

B. Time Division Duplexing (TDD)

TDD uses different time slots for transmission and reception paths. Single radio frequency can be used in both the directions instead of two as in FDD. No duplexer is required. Only a fast switching synthesizer, RF filter path and fast antenna switch are needed. It increases the battery life of mobile phones.

GSM use Frequency Division Duplexing.

1.4.3 FREQUENCY BANDS AND CHANNEL ARRANGEMENT

STANDARD OR PRIMARY GSM 900 BAND,P-GSM

For Standard GSM 900 Band, the system is required to operate in the following frequency band:

- 890 - 915 Mhz: Mobile Transmit, Base Receive
- 935 - 960 Mhz: Base Transmit, Mobile Receive

DCS 1800 Band: For DCS 1800

The system is required to operate in the following band:

- 1710 - 1785 MHz: Mobile Transmit, Base Receive
- 1805 - 1880 MHz: Base Transmit, Mobile Receive

Parameters	Standard or Primary GSM 900 Band	1800 Band
Uplink Frequency	890-915 MHz	1710 - 1785 MHz
Downlink frequency	935-960 MHz	1805 – 1880 MHz
Duplex Distance	45 MHz	95 MHz
Carrier separation	200 KHz	200 KHz
Frequency Channels	124	374
Voice coder bit rate	13 Kbps	13 Kbps
Modulation	GMSK	GMSK
Air transmission Rate	270.8333 Kbps	270.8333 Kbps
Access Method	FDMA/TDMA	FDMA/TDMA
Speech Coder	RPE-LTP	RPE-LTP
Duplexing	FDD	FDD

Table 2. GSM Specifications

1.5 GSM NETWORK STRUCTURE

Every telephone network needs a well-designed structure in order to route incoming called to the correct exchange and finally to the called subscriber. In a mobile network, this structure is of great importance because of the mobility of all its subscribers. In the GSM system, the network is divided into the following partitioned areas.

- GSM service area
- PLMN service area
- MSC service area
- Location area
- Cells.

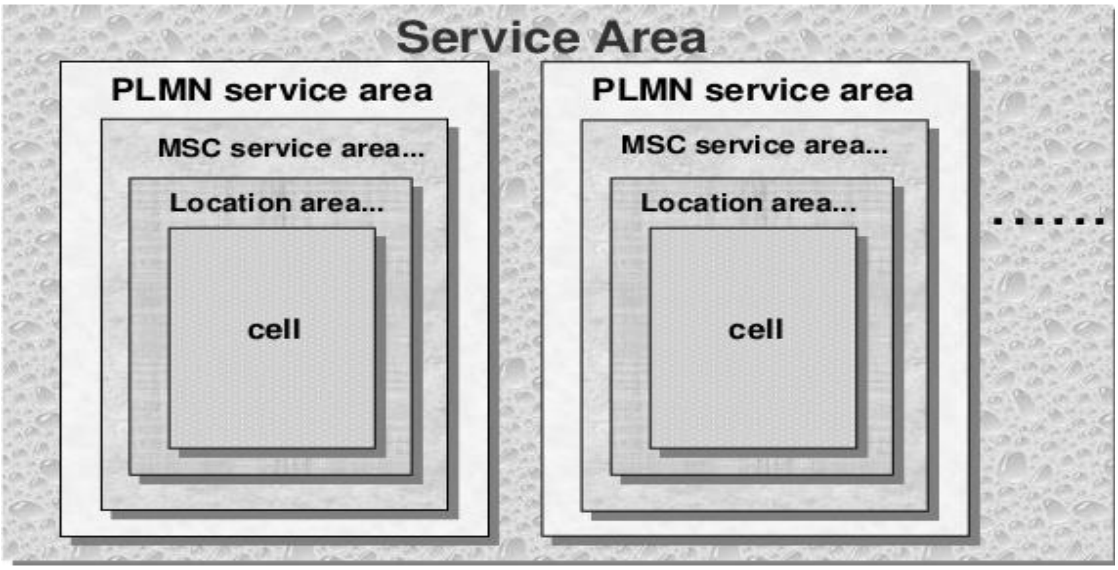

Figure 6: GSM- Network Structure

1.5.1 GSM NETWORK SYSTEM

GSM system basically designed as a combination of three major subsystems:

- Base Station Subsystem (BSS)
- Network Switching Subsystem (NSS)
- Operation Support Subsystem (OSS)

1.5.2 GSM NETWORK ELEMENTS

The major network elements are MS, Base Station Controller (BSC), Base Transceiver Station (BTS) and Mobile Service Switching Centre (MSC) and the four databases associated with MSC namely HLR, VLR, EIR and AUC.

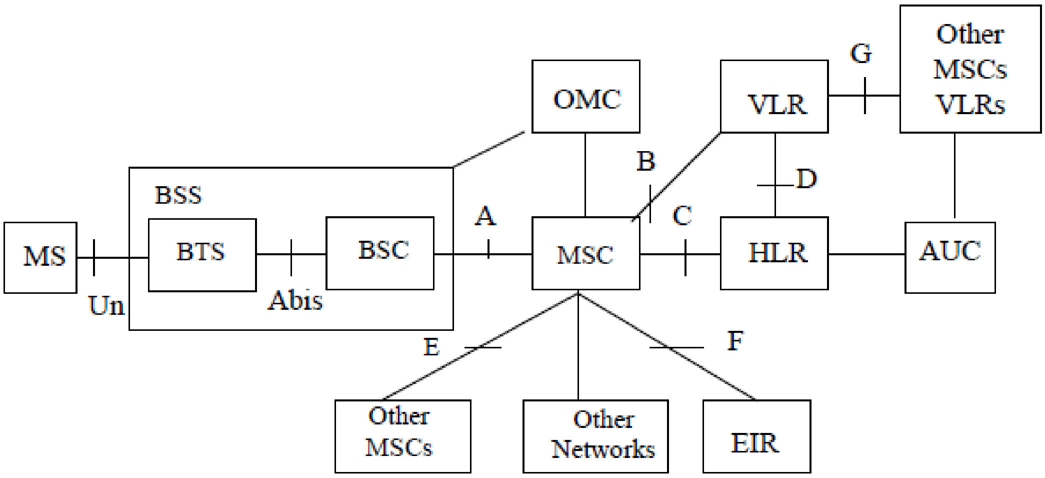

Figure 7: GSM- Architecture

Mobile Station (MS)

The MS includes radio equipment and the SIM (Subscriber Identity Module) that a subscribe needs in order to access the services provided by the GSM PLMN. The MS may include provisions for data communication as well as voice. A mobile transmits and receives message to and from the GSM system over the air interface to establish and continue connections through the system.

Each ME (Mobile Equipment) is identified by an International Mobile Equipment Identity (IMEI) that is permanently stored in the mobile unit. Upon request, the MS sends this number over the signalling channel to the MSC. The IMEI can be used to identify mobile units that are reported stolen or operating incorrectly.Just as the IMEI identities the mobile equipment, other numbers are used to identify the mobile subscriber.The Mobile Subscriber ISDN Number (MSISDN) is the number that the calling party dials in order to reach the subscriber. It is used by the land network to route calls toward an appropriate MSC. The international mobile subscribe identity (IMSI) is the primary identity of the subscriber within the mobile network and is permanently assigned to him. The GSM system can also assign a Temporary Mobile Subscriber Identity (TMSI) to identity a mobile. This number can be periodically changed by the system and protect the subscriber from being identified by those attempting to monitor the radio channel.

These are five different categories of mobile telephone units specified by the European GSM system: 20W, 8W, 5W, 2W, and 0.8W. GSM subscribers are provided with a SIM card with its unique identification at the very beginning of the service. By divorcing the subscriber ID from the equipment ID, the subscriber may never own the GSM mobile equipment set. The subscriber is identified in the system when he inserts the SIM card in the mobile equipment. This provides an enormous amount of flexibility to the subscribers since they can now use any GSM-specified mobile equipment. Thus with a SIM card the idea of “Personalize” the equipment currently in use and the respective information used by the network (location information) needs to be updated. The smart card SIM is portable between Mobile Equipment (ME) units. The user only needs to take his smart card on a trip. He can then rent a ME unit at the destination, even in another country, and insert his own SIM. Any calls he makes will be charged to his home GSM account. Also, the GSM system will be able to reach him at the ME unit he is currently using.

The SIM is a removable SC, the size of a credit card, and contains an integrated circuit chip with a microprocessor, random access memory (RAM), and read only memory (ROM). It is inserted in the MS unit by the subscriber when he or she wants to use the MS to make or receive a call. As stated, a SIM also comes in a modular form that can be mounted in the subscriber's equipment. When a mobile subscriber wants to use the system, he or she mounts their SIM card and provide their Personal Identification Number (PIN), which is compared with a PIN stored within the SIM. If the user enters three incorrect PIN codes, the SIM is disabled.

Base Transceiver Station (BTS)

The BSS is a set of BS equipment (such as transceivers and controllers) that is in view by the MSC through a single A interface as being the entity responsible for communicating with MSs in a certain area. The radio equipment of a BSS may be composed of one or more cells. A BSS may consist of one or more BS. The interface between BSC and BTS is designed as an A-bis interface. The BSS includes two types of machines: the BTS in contact with the MSs through the radio interface and the BSC, the latter being in contact with the MSC. The function split is basically between transmission equipment, the BTS, and managing equipment at the BSC. A BTS compares radio transmission and reception devices, up to and including the antennas, and also all the signal processing specific to the radio interface. A single transceiver within BTS supports eight basic radio channels of the same TDM frame. A BSC is a network component in the PLMN that function for control of one or more BTS. It is a functional entity that handles common control functions within a BTS.

A BTS is a network component that serves one cell and is controlled by a BSC. BTS is typically able to handle three to five radio carriers, carrying between 24 and 40 simultaneous communication. Reducing the BTS volume is important to keeping down the cost of the cell sites.

An important component of the BSS that is considered in the GSM architecture as a part of the BTS is the Transcoder/Rate Adapter Unit (TRAU). The TRAU is the equipment in which coding and decoding is carried out as well as rate adoption in case of data. Although the specifications consider the TRAU as a subpart of the BTS, it can be sited away from the BTS (at MSC), and even between the BSC and the MSC.

The interface between the MSC and the BSS is a standardized SS7 interface (A-interface) that, as stated before, is fully defined in the GSM recommendations. This allows the system operator to purchase switching equipment from one supplier and radio equipment and the controller from another. The interface between the BSC and a remote BTS likewise is a standard the A-bis. In splitting the BSS functions between BTS and BSC, the main principle was that only such functions that had to reside close to the radio transmitters/receivers should be placed in BTS. This will also help reduce the complexity of the BTS.

Base Station Controller (BSC)

The BSC, as discussed, is connected to the MSC on one side and to the BTS on the other. The BSC performs the Radio Resource (RR) management for the cells under its control. It assigns and release frequencies and timeslots for all MSs in its own area. The BSC performs the inter-cell handover for MSs moving between BTS in its control. It also reallocates frequencies to the BTSs in its area to meet locally heavy demands during peak hours or on special events. The BSC controls the power transmission of both BSSs and MSs in its area. The minimum power level for a mobile unit is broadcast over the BCCH.

The BSC provides the time and frequency synchronization reference signals broadcast by its BTS. The BSC also measures the time delay of received MS signals relative to the BTS clock. If the received MS signal is not centred in its assigned timeslot at the BTS, The BSC can direct the BTS to notify the MS to advance the timing such that proper synchronization takes place. The BSC may also perform traffic concentration to reduce the number of transmission lines from the BSC to its BTS.

Mobile Switching Center (MSC)

The network and the switching subsystem together include the main switching functions of GSM as well as the databases needed for subscriber data and mobility management (VLR). The main role of the MSC is to manage the communications between the GSM users and other telecommunication network users. The basic switching function performed by the MSC is to coordinate setting up calls to and from GSM users. The MSC has interface with the BSS on one side (through which MSC VLR is in contact with GSM users) and the external networks on the other (ISDN/PSTN/PSPDN). The main difference between a MSC and an Exchange in a fixed network is that the MSC has to take into account the impact of the allocation of RRs and the mobile nature of the subscribers and has to perform, in addition, at least, activities required for the location registration and handover. The MSC is a telephony switch that performs all the switching functions for MSs located in a geographical area as the MSC area. The MSC must also handle different types of numbers and identities related to the same MS and contained in different registers: IMSI, TMSI, ISDN number, and MSRN. In general identities are used in the interface between the MSC and the MS, while numbers are used in the fixed part of the network, such as, for routing.

As stated, the main function of the MSC is to coordinate the set-up of calls between GSM mobile and PSTN users. Specifically, it performs functions such as paging, resource allocation, location registration, and encryption. Specifically, the call-handling function of paging is controlled by MSC. MSC coordinates the set-up of call to and from all GSM subscribers operating in its areas. The dynamics allocation of access resources is done in coordination with the BSS. More specifically, the MSC decides when and which types of channels should be assigned to which MS. The channel identity and related radio parameters are the responsibility of the BSS; The MSC provides the control of interworking with different networks. It is transparent for the subscriber authentication procedure. The MSC supervises the connection transfer between different BSSs for MSs, with an active call, moving from one call to another. This is ensured if the two BSSs are connected to the same MSC but also when they are not. In this latter case the procedure is more complex, since more than one MSC in involved. The MSC performs billing on calls for all subscribers based in its areas. When the subscriber is roaming elsewhere, the MSC obtains data for the call billing from the visited MSC. Encryption parameters transfers from VLR to BSS to facilitate ciphering on the radio interface are done by MSC. The exchange of signalling information on the various interface toward the other network elements and the management of the interface themselves are all controlled by the MSC. Finally, the MSC serves as a SMS gateway to forward SMS messages from Short Message Service Center (SMSC) to the subscribers and from the subscribers to the SMSCs. It thus acts as a message mailbox and delivery system.

Visitor Location Register (VLR)

The VLR is collocated with an MSC. A MS roaming in an MSC area is controlled by the VLR responsible for that area. When a MS appears in a LA, it starts a registration procedure. The MSC for that area notices this registration and transfers to the VLR the identity of the LA where the MS is situated. A VLR may be in charge of one or several MSC LA's. The VLR constitutes the databases that support the MSC in the storage and retrieval of the data of subscribers present in its area. When an MS enters the MSC area borders, it signals its arrival to the MSC that stores its identity in the VLR. The information necessary to manage the MS is contained in the HLR and is transferred to the VLR so that they can be easily retrieved if so required. The data contained in the VLR and in the HLR are more or less the same. Nevertheless the data are present in the VLR only as long as the MS is registered in the area related to that VLR. Data associated with the movement of mobile are IMSI, MSISDN, MSRN, and TMSI. The terms permanent and temporary, in this case, are meaningful only during that time interval. Some data are mandatory, others are optional.

Home Location Register (HLR)

The HLR is a database that permanently stores data related to a given set of subscribers. The HLR is the reference database for subscriber parameters. Various identification numbers and addresses as well as authentication parameters, services subscribed, and special routing information are stored. Current subscriber status including a subscriber's temporary roaming number and associated VLR if the mobile is roaming, are maintained.

The HLR provides data needed to route calls to all MS-SIMs home based in its MSC area, even when they are roaming out of area or in other GSM networks. The HLR provides the current location data needed to support searching for and paging the MS-SIM for incoming calls, wherever the MS-SIM may be. The HLR is responsible for storage and provision of SIM authentication and encryption parameters needed by the MSC where the MS-SIM is operating. It obtains these parameters from the AUC. The HLR maintains record of which supplementary service each user has subscribed to and provides permission control in granting services. The HLR stores the identification of SMS gateways that have messages for the subscriber under the SMS until they can be transmitted to the subscriber and receipt is knowledge. Some data are mandatory, other data are optional. Both the HLR and the VLR can be implemented in the same equipment in an MSC (collocated). A PLMN may contain one or several HLRs.

Authentication Center (AUC)

The AUC stores information that is necessary to protect communication through the air interface against intrusions, to which the mobile is vulnerable. The legitimacy of the subscriber is established through authentication and ciphering, which protects the user information against unwanted disclosure. Authentication information and ciphering keys are stored in a database within the AUC, which protects the user information against unwanted disclosure and access. In the authentication procedure, the key Ki is never transmitted to the mobile over the air path, only a random number is sent. In order to gain access to the system, the mobile must provide the correct Signed Response (SRES) in answer to a random number (RAND) generated by AUC.

Also, Ki and the cipher key Kc are never transmitted across the air interface between the BTS and the MS. Only the random challenge and the calculated response are transmitted. Thus, the value of Ki and Kc are kept secure. The cipher key, on the other hand, is transmitted on the SS7 link between the home HLR/AUC and the visited MSC, which is a point of potential vulnerability. On the other hand, the random number and cipher key is supposed to change with each phone call, so finding them on one call will not benefit using them on the next call. The HLR is also responsible for the "authentication" of the subscriber each time he makes or receives a call. The AUC, which actually performs this function, is a separate GSM entity that will often be physically included with the HLR. Being separate, it will use separate processing equipment for the AUC database functions.

Equipment Identity Register (EIR)

EIR is a database that stores the IMEI numbers for all registered ME units. The IMEI uniquely identifies all registered ME. There is generally one EIR per PLMN. It interfaces to the various HLR in the PLMN. The EIR keeps track of all ME units in the PLMN. It maintains various lists of message. The database stores the ME identification and has nothing do with subscriber who is receiving or originating call. There are three classes of ME that are stored in the database, and each group has different characteristics.

- White List: contains those IMEIs that are known to have been assigned to valid MS's. This is the category of genuine equipment.
- Black List: contains IMEIs of mobiles that have been reported stolen.
- Grey List: contains IMEIs of mobiles that have problems (for example, faulty software, wrong make of the equipment, etc.). This list contains all MEs with faults not important enough for barring.

Interworking Function (IWF)

GSM provides a wide range of data services to its subscribers. The GSM system interface with various public and private data networks. It is the job of the IWF to provide this interfacing capability. The IWF, which in essence is a part of MSC, provides the subscriber with access to data rate and protocol conversion facilities so that data can be transmitted between GSM Data Terminal Equipment (DTE) and a land-line DTE.

Echo Canceller (EC)

EC is used on the PSTN side of the MSC for all voice circuits. The EC is required at the MSC PSTN interface to reduce the effect of GSM delay when the mobile is connected to the PSTN circuit. The total round-trip delay introduced by the GSM system, which is the result of speech encoding, decoding and signal processing, is of the order of 180 ms. Normally this delay would not be an annoying factor to the mobile, except when communicating to PSTN as it requires a two-wire to four-wire hybrid transformer in the circuit. This hybrid is required at the local switching office because the standard local loop is a two-wire circuit. Due to the presence of this hybrid, some of the energy at its four-wire receive side from the mobile is coupled to the four-wire transmit side and thus retransmitted to the mobile. This causes the echo, which does not affect the land subscriber but is an annoying factor to the mobile. The standard EC cancels about 70 ms of delay. During a normal PSTN (land-to-land call), no echo is apparent because the delay is too short and the land user is unable to distinguish between the echo and the normal telephone "side tones" However, with the GSM round-trip delay added and without the EC, the effect would be irritating to the MS subscriber.

Operation and Maintenance Center

The OMC provides alarm-handling functions to report and log alarms generated by the other network entities. The maintenance personnel at the OMC can define that criticality of the alarm. Maintenance covers both technical and administrative actions to maintain and correct the system operation, or to restore normal operations after a breakdown, in the shortest possible time.

The fault management functions of the OMC allow network devices to be manually or automatically removed from or restored to service. The status of network devices can be checked, and tests and diagnostics on various devices can be invoked. For example, diagnostics may be initiated remotely by the OMC. A mobile call trace facility can also be invoked. The performance management functions included collecting traffic statistics from the GSM network entities and archiving them in disk files or displaying them for analysis. Because a potential to collect large amounts of data exists, maintenance personal can select which of the detailed statistics to be collected based on personal interests and past experience. As a result of performance analysis, if necessary, an alarm can be set remotely.

The OMC provides system change control for the software revisions and configuration data bases in the network entities or uploaded to the OMC. The OMC also keeps track of the different software versions running on different subsystems of the GSM.

1.5.3 GSM IDENTITIES

International Mobile Subscriber Identity (IMSI)

An IMSI is assigned to each authorized GSM user. It consists of a mobile country code (MCC), mobile network code (MNC), and a PLMN unique mobile subscriber identification number (MSIN). The IMSI is not hardware-specific. Instead, it is maintained on a SC by an authorized subscriber and is the only absolute identity that a subscriber has within the GSM system. The IMSI consists of the MCC followed by the NMSI and shall not exceed 15 digits.

Temporary Mobile Subscriber Identity (TMSI)

A TMSI is a MSC-VLR specific alias that is designed to maintain user confidentiality. It is assigned only after successful subscriber authentication. The correlation of a TMSI to an IMSI only occurs during a mobile subscriber's initial transaction with an MSC (for example, location updating). Under certain condition (such as traffic system disruption and malfunctioning of the system), the MSC can direct individual TMSIs to provide the MSC with their IMSI.

Mobile Station ISDN Number (MSISDN)

The MS international number must be dialled after the international prefix in order to obtain a mobile subscriber in another country. The MSISDN numbers is composed of the country code (CC) followed by the National Significant Number (NSN), which shall not exceed 15 digits.

The Mobile Station Roaming Number (MSRN)

The MSRN is allocated on temporary basis when the MS roams into another numbering area. The MSRN number is used by the HLR for rerouting calls to the MS. It is assigned upon demand by the HLR on a per-call basis. The MSRN for PSTN/ISDN routing shall have the same structure as international ISDN numbers in the area in which the MSRN is allocated. The HLR knows in what MSC/VLR service area the subscriber is located. At the reception of the MSRN, HLR sends it to the GMSC, which can now route the call to the MSC/VLR exchange where the called subscriber is currently registered.

International Mobile Equipment Identity (IMEI)

The IMEI is the unique identity of the equipment used by a subscriber by each PLMN and is used to determine authorized (white), unauthorized (black), and malfunctioning (gray) GSM hardware. In conjunction with the IMSI, it is used to ensure that only authorized users are granted access to the system. An IMEI is never sent in cipher mode by MS.

1.6 CONCLUSION

Mobile Communication will always useful as it has mobility , the newer antenna system MIMO will play very important role in modern day communication.

2 MIGRATION TO MOBILE TECHNOLOGIES UPTO 5G

2.1 LEARNING OBJECTIVES

After completion of this chapter participant will able to understand about:

- Migration upto 5G Network Architecture
- 2G/3G Architecture
- LTE Radio Network E UTRAN
- LTE Network Elements
- 5G Network Architecture

2.2 MOBILE GENERATIONS

- 1 G - First Generation - Analog - Only mobile voice services - AMPS, NMT-450, TACS etc. (Cellular Revolution)
- 2 G - Second Generation - Digital - Mostly for voice services & data delivery possible – GSM, CDMA (IS-95), DAMPS (IS-136), ETDMA, PDC etc (Breaking Digital Barrier).
- 3 G - Third Generation - Voice & Data - Mainly for data services where voice services will also be possible (Breaking Data Barrier)
- 4 G - Fourth Generation - The Fourth Generation of mobile communication upgrade existing communication networks and is expected to provide a comprehensive and secure IP based solution where facilities such as voice, data and streamed multimedia will be provided to users on an "Anytime, Anywhere" basis and at much higher data rates compared to previous generations.
- 5 G - Fifth Generation -The most important for 5G technologies are 802.11 Wireless Local Area Networks (WLAN) and 802.16 Wireless Metropolitan Area Networks (WMAN), Ad-hoc Wireless Personal Area Network (WPAN) and Wireless networks for digital Communication.

2.3 OVERVIEW OF GPRS

The existing GSM networks are based on circuit switching techniques. For data services that are based on Internet Protocol (IP) such as e-mail and web browsing, GSM circuit switching is inefficient.

GSM Release '97 has introduced the General Packet Radio Service (GPRS) which maintains the GSM BSS access technologies but provides packet switched data services to the mobile station (MS).

2.3.1 GPRS STANDARDIZATION

The ETSI standardization work on GPRS Phase 1 was officially finalized in Q1/1998. It includes point-to-point (PTP) services and the complete basic GPRS infrastructure. Air interface, mobility management, security, limited QoS, SMS service, GPRS support nodes, and the GPRS backbone are all part of Phase 1.

The ETSI standardization work on GPRS Phase 2 was frozen with GSM Release 99. Some work items were included in the GSM Release 98. Phase 2 adds additional services like enhanced QoS support and point-to-multipoint (PTM) connections. Some main point of GPRS phase 2 are the support of:

- IPv4 and IPv6
- BSS co-ordination of radio resource allocation for class A GPRS services

- Enhanced QoS support in GPRS
- Charging and billing for GPRS – AoC
- Charging and billing for GPRS – Pre-paid
- Point-to-multipoint (PTM) services

Access to ISPs and intranets in GPRS Phase 2, separation of GPRS bearer establishment and ISP service environment set-up

In GSM Release 4 (frozen March 2001) and GSM Release 5 (frozen June 2002), QoS enhancements for the GPRS backbone were introduced to support packet switched real-time services (on the long run). This goes hand-in-hand with the introduction of the IP Multimedia Subsystem (IMS). The Nokia IP Multimedia Subsystem can be combined with terminals supporting downloadable applications, creating exciting opportunities for application developers and operators to develop and offer new IP multimedia services in GPRS and 3G networks. Further information on network details is available in the architecture module.

At the end of the year 2002, more that 120 operators are commercially offering GPRS and more than 40 operators are testing GPRS or building up a GPRS

Key points

GPRS uses a packet-based switching technique, which will enhance GSM data services significantly, especially for bursty Internet/intranet traffic.

Some application examples:

- Bus, train, airline real-time information
- Locating restaurants and other entertainment venues based on current Location
- Lottery
- E-commerce
- Banking
- E-mail
- Web browsing

The main advantages of GPRS for users:

- Instant access to data as if connected to an office LAN
- Charging based on amount of data transferred (not the time connected)
- Higher transmission speeds

The main advantages for operators:

- Fast network roll-out with minimum investment
- Excess voice capacity used for GPRS data
- Smooth path to 3G services

In circuit switching, each time a connection is required between two points, a link between the two points is established and the needed resources are reserved for the use of that single call for the complete duration of the call.

In packet switching, the data to be transferred is divided up into packets, which are then sent through the network and re-assembled at the receiving end.

The GPRS network acts in parallel with the GSM network, providing packet switched connections to the external networks. The requirements of a GPRS network are the following:

The GPRS network must use as much of the existing GSM infrastructure with the smallest number of modifications to it.

Since a GPRS user may be on more than one data session, GPRS should be able to support one or more packet switched connections.

To support the budgets of various GPRS users, it must be able to support different Quality of Service (QoS) subscriptions of the user.

The GPRS network architecture has to be compatible with future 3rd and 4th generation mobile communication systems.

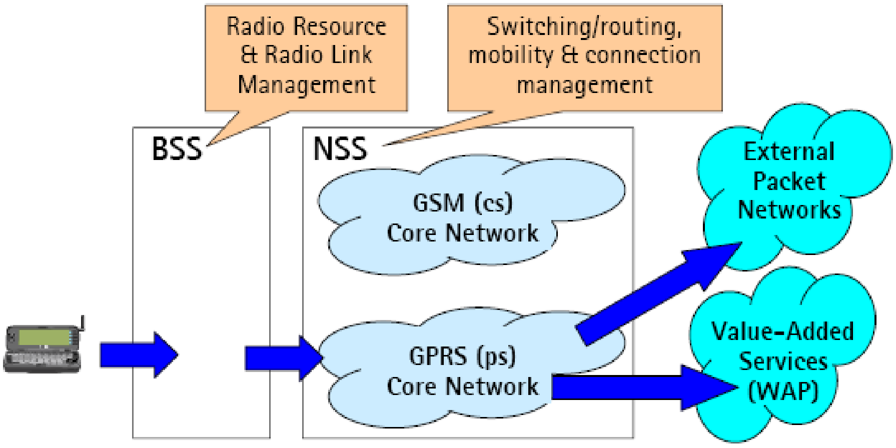

Figure 8: GPRS Architecture

It should be able to support both point-to-point and point-to-multipoint data connections.

It should provide secure access to external networks.

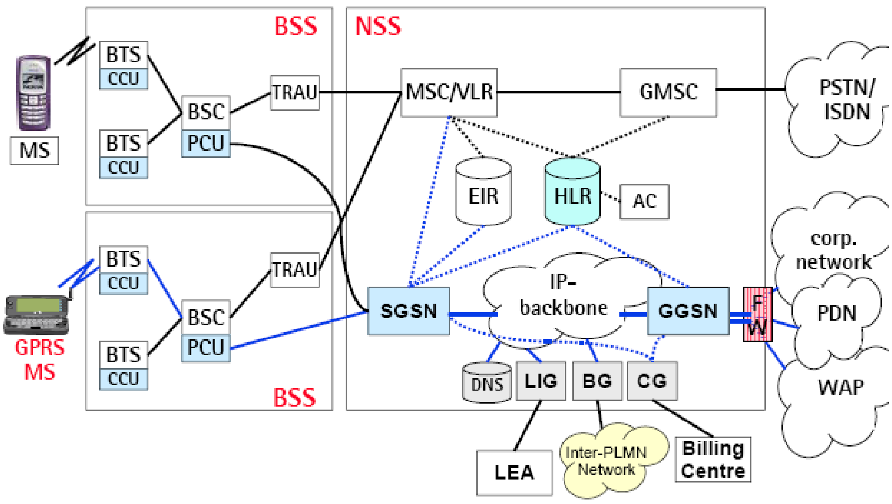

Figure 9: GSM GPRS Architecture

Figure shows the architecture of a GPRS network. The GPRS system brings some new network elements to an existing GSM network. These elements are:

- Packet Control Unit (PCU)
- Serving GPRS Support Node (SGSN): the MSC of the GPRS network
- Gateway GPRS Support Node (GGSN): gateway to external networks
- Border Gateway (BG): a gateway to other PLMN Intra-PLMN backbone: an IP based network inter-connecting all the GPRS elements
- Charging Gateway (CG)
- Legal Interception Gateway (LIG)
- Domain Name System (DNS)

- Firewalls: used wherever a connection to an external network is required.

Not all of the network elements are compulsory for every GPRS network.

2.3.2 PACKET CONTROL UNIT (PCU)

The PCU separates the circuit switched and packet switched traffic from the user and sends them to the GSM and GPRS networks respectively. It also performs most of the radio resource management functions of the GPRS network. The PCU can be either located in the BTS, BSC, or some other point between the MS and the MSC. There will be at least one PCU that serves a cell in which GPRS services will be available. Frame Relay technology is being used at present to interconnect the PCU to the GPRS core.

2.3.3 CHANNEL CODEC UNIT (CCU)

The CCU is realised in the BTS to perform the Channel Coding (including the coding scheme algorithms), power control and timing advance procedures.

2.3.4 SERVING GPRS SUPPORT NODE (SGSN)

The SGSN is the most important element of the GPRS network. The SGSN of the GPRS network is equivalent to the MSC of the GSM network. There must at least one SGSN in a GPRS network. There is a coverage area associated with a SGSN. As the network expands and the number of subscribers increases, there may be more than one SGSN in a network. The SGSN has the following functions:

- Protocol conversion (for example IP to FR)
- Ciphering of GPRS data between the MS and SGSN
- Data compression is used to minimise the size of transmitted data units
- Authentication of GPRS users
- Mobility management as the subscriber moves from one area to another, and possibly one SGSN to another
- Routing of data to the relevant GGSN when a connection to an external network is required
- Interaction with the NSS (that is, MSC/VLR, HLR, EIR) via the SS7 network in order to retrieve subscription information
- Collection of charging data pertaining to the use of GPRS users
- Traffic statistics collections for network management purposes.

2.3.5 GATEWAY GPRS SUPPORT NODE (GGSN)

The GGSN is the gateway to external networks. Every connection to a fixed external data etwork has to go through a GGSN. The GGSN acts as the anchor point in a GPRS data connection even when the subscriber moves to another SGSN during roaming. The GGSN may accept connection request from SGSN that is in another PLMN. Hence, the concept of coverage area does not apply to GGSN. There are usually two or more GGSNs in a network for redundancy purposes, and they back up each other up in case of failure. The functions of a GGSN are given below:

- Routing mobile-destined packets coming from external networks to the relevant SGSN
- Routing packets originating from a mobile to the correct external network
- Interfaces to external IP networks and deals with security issues
- Collects charging data and traffic statistics
- Allocates dynamic or static IP addresses to mobiles either by itself or with the help of a DHCP or a RADIUS server

- Involved in the establishment of tunnels with the SGSN and with other external networks and VPN.

From the external network's point of view, the GGSN is simply a router to an IP sub-network. This is shown below. When the GGSN receives data addressed to a specific user in the mobile network, it first checks if the address is active. If it is, the GGSN forwards the data to the SGSN serving the mobile. If the address is inactive, the data is discarded. The GGSN also routes mobile originated packets to the correct external network.

2.4 THE EDGE

EDGE, or the Enhanced Data Rate for Global Evolution, is the new mantra in the Global Internet Connectivity scene. EDGE is the new name for GSM 384. The technology was named GSM 384 because of the fact that it provided Data Transmission at a rate of 384 Kbps. It consists of the 8 pattern time slot, and the speed could be achieved when all the 8 time slots were used. The idea behind EDGE is to obtain even higher data rates on the current 200 KHz GSM carrier, by changing the type of the modulation used.

Now, this is the most striking feature. EDGE, as being once a GSM technology, works on the existing GSM or the TDMA carriers, and enables them to many of the 3G services.

Although EDGE will have a little technical impact, since its fully based on GSM or the TDMA carriers, but it might just get an EDGE over the upcoming technologies, and of course, the GPRS. With EDGE, the operators and service providers can offer more wireless data application, including wireless multimedia-mail (Web Based), Web Infotainment, and above all, the technology of Video Conferencing. Now all these technologies that were named earlier, were the clauses of the IMT-UMTS 3G Package. But, with EDGE, we can get all these 3G services on our existing GSM phones, which might just prove to be a boon to the user.

The current scenario clearly states that EDGE will definitely score higher than GPRS. The former, allows its users to increase the data speed and throughput capacity, to around 3-4 times higher than GPRS.

Secondly, it allows the existing GSM or the TDMA carriers to give the sophisticated 3G services. And with 1600 Million subscribers of GSM in over 170 countries, offer the full Global Roaming, anywhere between India to Japan and to San Fransisco.

- Based on an 8 PSK modulation, it allows higher bit rate across the air Interface.
- One Symbol for every 3 bits. Thus, EDGE Rate = 3x GPRS Rate.

2.5 UMTS HSPA AND 3GPP STANDARDS

3G HSPA provides a major improvement in performance to the 3G UMTS mobile telecommunications system. It provides additional facilities that are added on to the basic 3GPP UMTS standard.The top data rates for HSPA compete well with the 4G LTE technology. As such the 3G infrastructure usage was prolonged and enabled many operators to maximise the use of their investment before having to add the capability for 4G.

The evolution of UMTS-HSPA happens in stages referred to as 3GPP Releases. The upgrades and additional facilities were introduced at successive releases of the 3GPP standard.

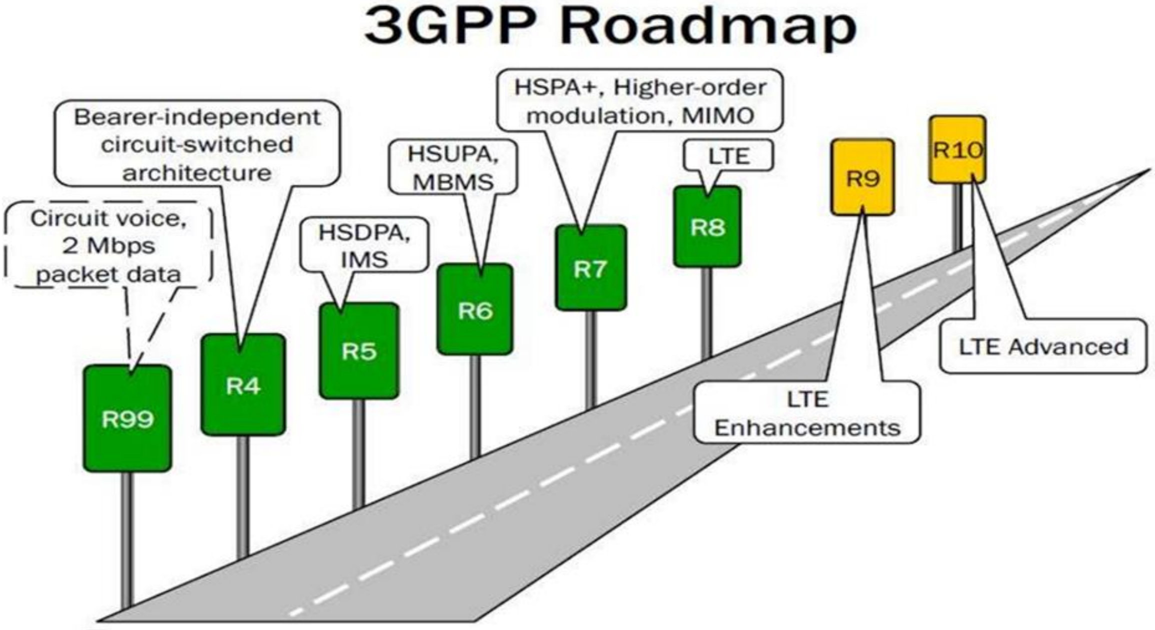

Figure 10: 3GPP UMTS Evolution

- **Release 4:** This release of the 3GPP standard provided for the efficient use of IP, a facility that was required because the original Release 99 focussed on circuit switched technology. Accordingly this was a key enabler for 3G HSDPA.

- **Release 5:** This release included the core of HSDPA itself. It provided for downlink packet support, reduced delays, a raw data rate (i.e. including payload, protocols, error correction, etc) of 14 Mbps and gave an overall increase of around three over the 3GPP UMTS Release 99 standard.

- **Release 6:** This included the core of HSUPA with an enhanced uplink with improved packet data support. This provided reduced delays, an uplink raw data rate of 5.74 Mbps and it gave an increase capacity of around twice that offered by the original Release 99 UMTS standard. Also included within this release was the MBMS, Multimedia Broadcast Multicast Services providing improved broadcast services, i.e. Mobile TV.

- **Release 7:** This release of the 3GPP standard included downlink MIMO operation as well as support for higher order modulation up to 64-QAM in the uplink and 16-QAM in the downlink. However it only allows for either MIMO or the higher order modulation. It also introduced protocol enhancements to allow the support for Continuous Packet Connectivity (CPC).

- **Release 8:** This release of the standard occurred during the course of 2008 and it defines dual carrier operation as well as allowing simultaneous operation of the high order modulation schemes and MIMO. Further to this, latency is improved to keep it in line with the requirements for many new applications being used.

- **Release 9:** 3GPP Release 9 occurred during 2009 and included facilities for HPSA including 2x2MIMO in the uplink and a 10MHz bandwidth in the downlink. The uplink carriers may be from different bands.

- **Release 10:** HSPA Release 10 utilises up to 4-carriers, i.e. 20 MHz bandwidth which may be from two separate bands. In addition to this 2x2 MIMO in the downlink provides data rates up to 168 Mbps. This figure equates to that obtained for LTE Release 8 when using comparable bandwidth and antennas configurations.

- **Release 11:** Release 11 occurred during 2011 / 2012. It provided the facility for 40MHz bandwidth in the uplink along with up to 4x4 MIMO. The downlink was upgraded to accommodate 64-QAM modulation and MIMO.

2.6 HSPA: HIGH SPEED PACKET ACCESS

High speed packet access, HSPA is an upgrade to 3G UMTS to provide very high higher data rates in both uplink and downlink.3G UMTS enabled mobile communications to move from voice-centric systems to data centric ones. However the speeds that could be supported we nowhere near sufficient to enable Internet surfing and video downloads. To overcome this 3G UMTS was upgraded with high speed packet access, HSPA to provide a major leap in performance and make it suitable to cover its requirements.

Initially the downlink was addressed using high speed downlink packet access, HSDPA and then upgrades were added to the uplink with high speed uplink packet access.

Further upgrades were added later with dual carrier and MIMO capabilities to raise the data speeds hugely above those first envisaged for 3G.

2.7 EVOLVED HSPA / HSPA+

Once the basic HSPA was running, further evolutions were implemented in the form of Evolved HSPA / HSPA+ / HSPA Evolution.As data usage increased still further, HSPA was improved in a series of revisions to provide what was termed Evolved HSPA, HSPA+ or even HSPA Evolution.

The overall Evolved HSPA / HSPA+ involved a series of enhancements that improved not only the data speed, but also reduced latency and gave an overall improvement in performance.

To achieve these enhancements were made to the radio access network as well as backhaul along with an on-going improvement to the network itself.

2.7.1 HSPA+ IN 3GPP RELEASES

The definition of HSPA+ / Evolved HSPA have been included in Releases 7 and 8 of the 3GPP standards.

- ***3GPP Release 7:*** This release of the 3GPP standard included downlink MIMO operation as well as support for higher order modulation up to 64 QAM in the uplink and 16 QAM in the downlink. However it only allows for either MIMO or the higher order modulation. It also introduced protocol enhancements to allow the support of more users that are in a "continuously on" state.

- ***3GPP Release 8:*** This release of the standard defines dual carrier operation as well as allowing simultaneous operation of the high order modulation schemes and MIMO. Further to this, latency is improved to keep it in line with the requirements for many new applications being used.

2.7.2 HSPA+ DATA RATE COMPARISON WITH LTE

The next migration of the cellular services beyond HSPA+ is known as LTE. Using a completely new air interface based around the use of OFDM rather than W-CDMA which is used for UMTS, HSPA and HSPA+, it offers even higher data traffic rates. It is then anticipated that it will be used as the basis for the next generation, i.e. 4G systems.

It is however worth comparing the maximum data rates offered by both HSPA+ and LTE.

CHANNEL BANDWIDTH (MHZ)	HSPA+ DATA RATE (MBPS)	LTE DATA RATE (MBPS)
5	42	37
10	84	73
20	--	150

Table 3. HSPA+ data rate comparison

Although the basic comparisons appear to show that LTE will offer few advantages, there are several other features of LTE that mean that it is a preferable option for the long term. LTE enables wider bandwidths and the OFDM modulation enables data transmissions to be made more resilient to multipath and other propagation effects.

2.8 LTE: LONG TERM EVOLUTION

LTE Long Term Evolution was the 4G successor to 3G UMTS that provided improved speeds and performance. Providing much higher data speeds and greatly improved performance as well as lower operating costs, the scheme started to be deployed in its basic form around 2008.

Initial deployments gave little improvement over 3G HSPA and were sometimes dubbed 3.5G or 3.99G, but soon the full capability of LTE was realised it provided a full 4G level of performance.

The first deployments were simply known as LTE, but later deployments were designated 4G LTE Advanced and later still 4G LTE Pro.

Not only was the radio access network improved for 4G LTE, but the network architecture was overhauled enabling lower latency and much better interconnectivity between elements of the radio access network, RAN.

2.8.1 LTE EVOLUTION

It was 3GPP release 8 when LTE was introduced for the very first time. All the releases following only enhanced the technology.

Although there are major step changes between LTE and its 3G predecessors, it is nevertheless looked upon as an evolution of the UMTS / 3GPP 3G standards. Although it uses a different form of radio interface, using OFDMA / SC-FDMA instead of CDMA, there are many similarities with the earlier forms of 3G architecture and there is scope for much re-use.

In determining what is LTE and how does it differ from other cellular systems, a quick look at the specifications for the system can provide many answers. LTE can be seen for provide a further evolution of functionality, increased speeds and general improved performance.

COMPARISON WITH OTHER MOBILE COMMUNICATIONS TECHNOLOGIES				
	WCDMA (UMTS)	**HSPA HSDPA / HSUPA**	**HSPA+**	**LTE**
Max downlink speed bps	384 k	14 M	28 M	100M
Max uplink speed bps	128 k	5.7 M	11 M	50 M
Latency round trip time approx	150 ms	100 ms	50ms (max)	~10 ms
3GPP releases	Rel 99/4	Rel 5 / 6	Rel 7	Rel 8
Approx years of initial roll out	2003 / 4	2005 / 6 HSDPA 2007 / 8 HSUPA	2008 / 9	2009 / 10
Access methodology	CDMA	CDMA	CDMA	OFDMA / SC-FDMA

Table 4. Comparison With Other Mobile Communications Technologies

In addition to this, LTE is an all IP based network, supporting both IPv4 and IPv6.

2.8.2 LTE SPECIFICATION OVERVIEW

It is worth summarizing the key parameters of the 3G LTE specification. In view of the fact that there are a number of differences between the operation of the uplink and downlink, these naturally differ in the performance they can offer.

These highlight specifications give an overall view of the performance that LTE will offer. It meets the requirements of industry for high data download speeds as well as reduced latency - a factor important for many applications from VoIP to gaming and interactive use of data. It also provides significant improvements in the use of the available spectrum

LTE BASIC SPECIFICATIONS	
PARAMETER	**DETAILS**
Peak downlink speed 64QAM (Mbps)	100 (SISO), 172 (2x2 MIMO), 326 (4x4 MIMO)
Peak uplink speeds (Mbps)	50 (QPSK), 57 (16QAM), 86 (64QAM)
Data type	All packet switched data (voice and data). No circuit switched.
Access schemes	OFDMA (Downlink) SC-FDMA (Uplink)
Modulation types supported	QPSK, 16QAM, 64QAM (Uplink and downlink)
Spectral efficiency	Downlink: 3 - 4 times Rel 6 HSDPA Uplink: 2 -3 x Rel 6 HSUPA
Channel bandwidths (MHz)	1.4, 3, 5, 10, 15, 20
Duplex schemes	FDD and TDD
Mobility	0 - 15 km/h (optimised), 15 - 120 km/h (high performance)
Latency	Idle to active less than 100ms Small packets ~10 ms

Table 5. LTE Basic Specifications

2.9 LTE ENHANCEMEN

The initial enhancements were included to LTE in release 9. These were in fact the improvements which were left behind from release 8 or perhaps provided some minor improvements. These improvements are listed below with brief description.

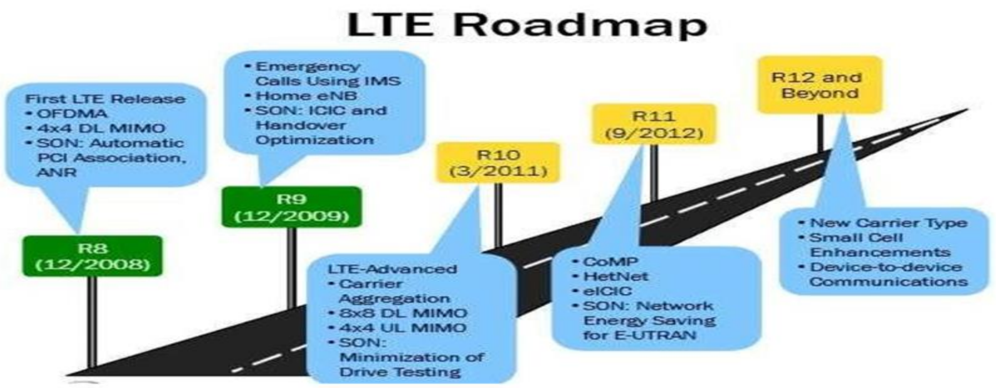

Figure 11: 3GPP LTE Enhancement

PWS (Public Warning System): Public should always receive timely and accurate alerts related to natural disasters or other critical situations. Commercial Mobile Alert System (CMAS) was introduced in release 9 in addition to ETWS introduced in release 8
Femto Cell: Femto cell is basically a small cell used in offices or homes and connected to providers' networks through landline broadband connection. 3G Femto cells are deployed around world and in order for LTE users to take advantage of femto cell, new requirements were added to release 9.
MIMO Beam forming: Beamforming is used to increase cell edge throughput by directing beam towards specific UE by position estimation at eNB. In release 8, LTE supported single layer beam forming based on user-specific Reference Symbols. In release 9, single layer beam forming has been extended to multilayer beam forming
Self Organizing Networks (SON): SON means self installation, optimization and healing of networks in order to reduce manual work and cost associated with technical support. The idea of SON was introduced in release 8 though the focus was more towards eNBsself configuration where as in release 9, requirements for self optimization were also added.
eMBMS: With Multimedia broadcast Multicast Services (MBMS), operators have capability to broadcast services over LTE network. The idea is not novel to the LTE and has been used in legacy networks as well but for LTE, the MBMS channel has evolved from data rate and capacity perspective. The MBMS was already defined at physical layer in release8 but with release 9, higher layer and network layer aspects were completed
LTE Positioning: Three position methods are specified in LTE release 9 i.e. Assisted GPS (A-GPS), Observed Time difference of arrival (OTDOA) and Enhanced Cell ID (E-CID). The goal is to improve the accuracy of user locations in case of emergency scenarios where the user itself is unable to disclose his whereabouts

2.10 4G : LTE ADVANCED

The basic LTE, long term evolution cellular services were launched around 2010 with some advance deployments well before this. It was never envisaged that this initial form of LTE would provide the full performance intended. This required some additional elements that were in what was termed LTE Advanced.

LTE Advanced, LTE-A incorporated a number of new techniques that enabled the system to provide very much higher data rates, and also much better performance, particularly at cell edges and other areas where performance would not normally have been so good.

LTE Advanced took a few more years to fully develop and roll out across the networks, but when introduced it enabled its many advanced features to provide significant improvements over basic LTE.

International Telecommunication Union using Radio (ITU-R) defined 4G mobile technology as IMT-Advanced (International Mobile telecommunication Advanced). LTE-Advanced specifications in release 10 includes significant features and improvements to fulfil ITU IMT-Advanced requirements which sets higher speeds than what UE can achieve from 3GPP release 8 specifications.

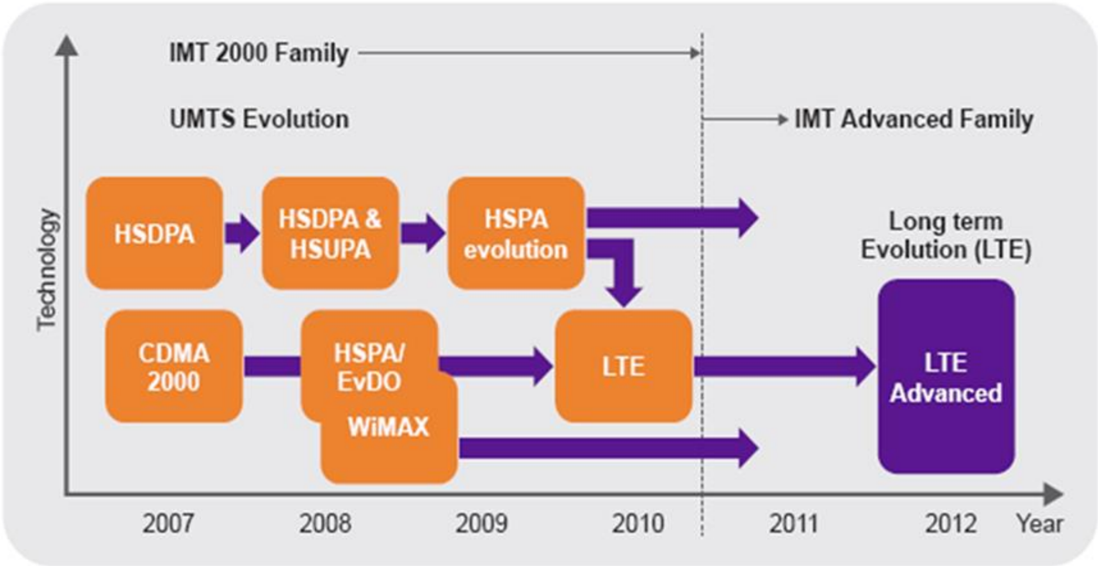

Figure 12: IMT 2000 & IMT Advanced

Some key requirements laid down by IMT-Advanced are as below

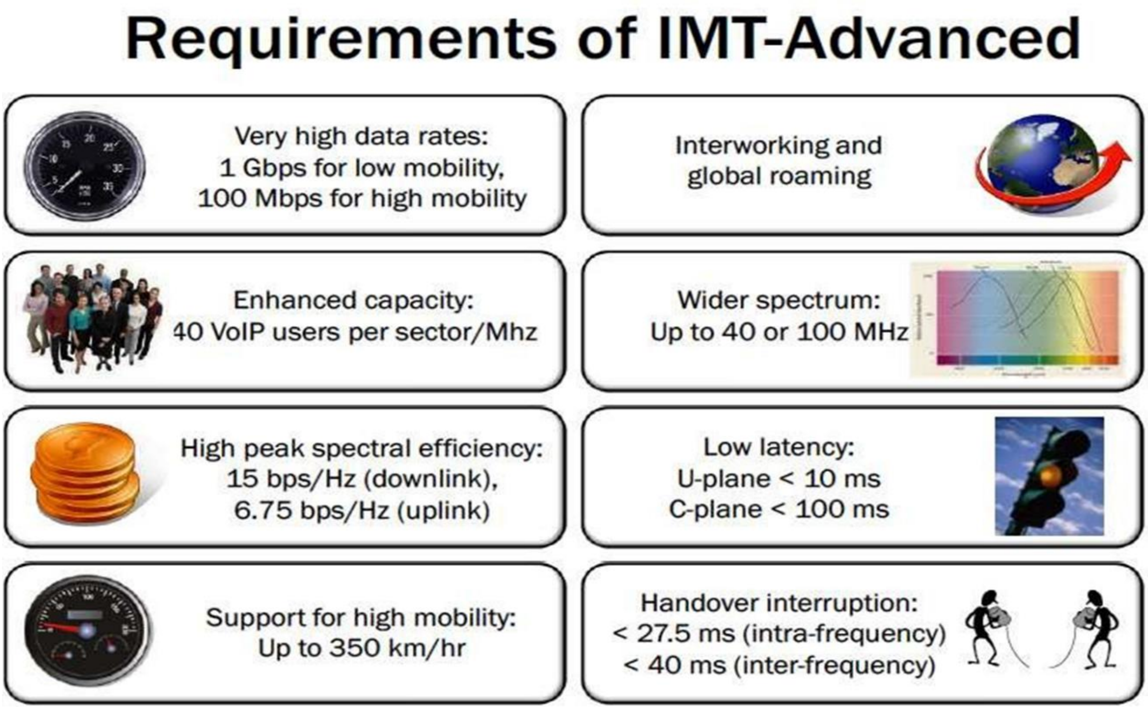

Figure 13: Key Requirement of IMT-Advanced

2.10.1 RADIO TECHNOLOGY EVOLUTION TO 4G

OFDM forms the basis of the radio access technology. Along with it there is OFDMA (Orthogonal Frequency Division Multiple Access) along with SC-FDMA (Single Channel Orthogonal Frequency Division Multiple Access). These will be used in a hybrid format. However the basis for all of these access schemes is OFDM.

LTE uses separate multiple-access technologies for the downlink (base station to mobile) and the uplink (mobile to base station). It employs Orthogonal FDMA (OFDMA) for the downlink and Single-Carrier FDMA (SC-FDMA) for the uplink.

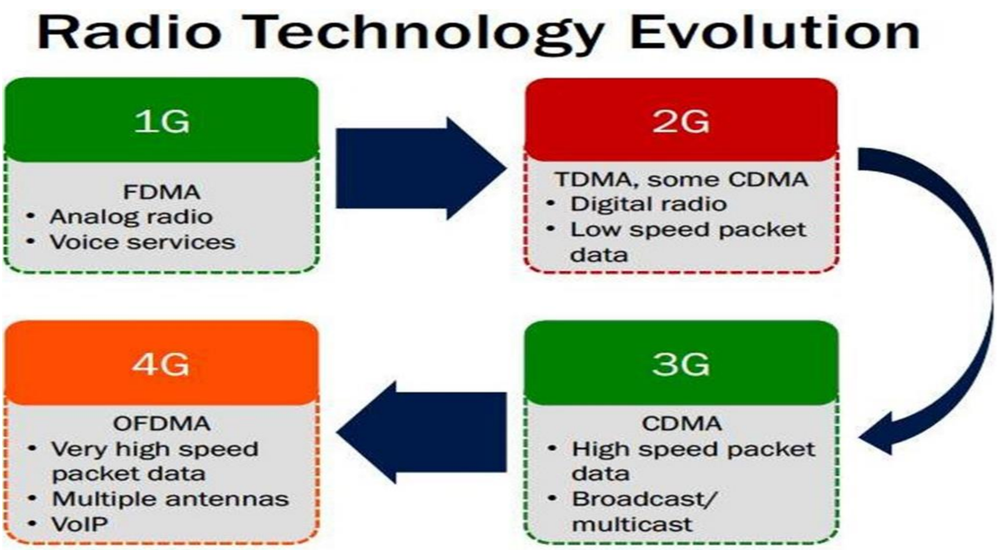

Figure 14: Radio Technology Evolution

2.10.2 NETWORK ARCHITECTURE EVOLUTION

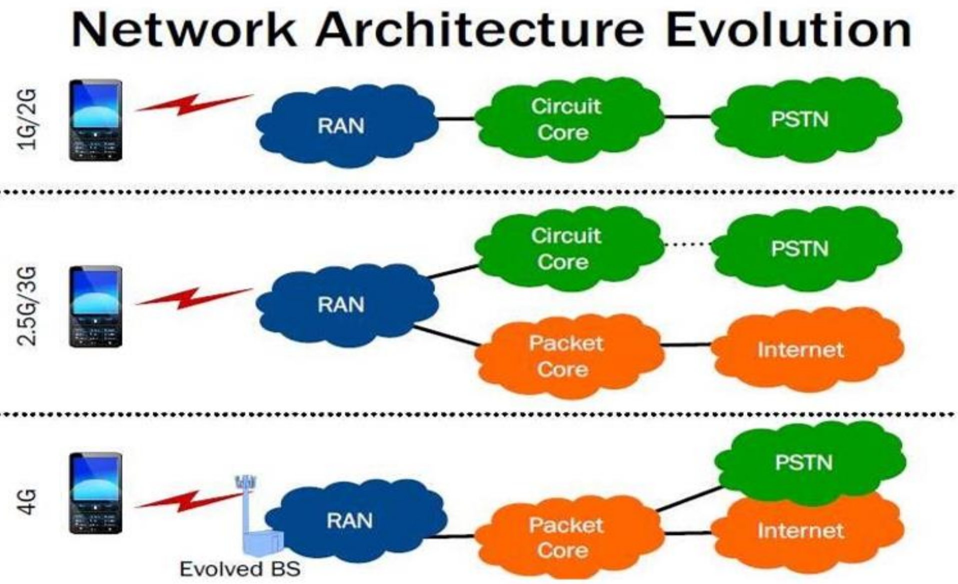

Figure 15: Network Architecture Evolution

2.10.3 FOLLOWING ARE SOME SIGNIFICANT IMPROVEMENTS IN RELEASE 10

Enhanced Uplink multiple access:

Release 10 introduces clustered SC-FDMA in uplink. Release 8 SC-FDMA only allowed carriers along contiguous block of spectrum but LTE-Advanced in release 10 allows frequency-selective scheduling in uplink

MIMO enhancements:

LTE-Advanced allows upto 8x8 MIMO in downlink and on the UE side it allows 4X4 in uplink direction.

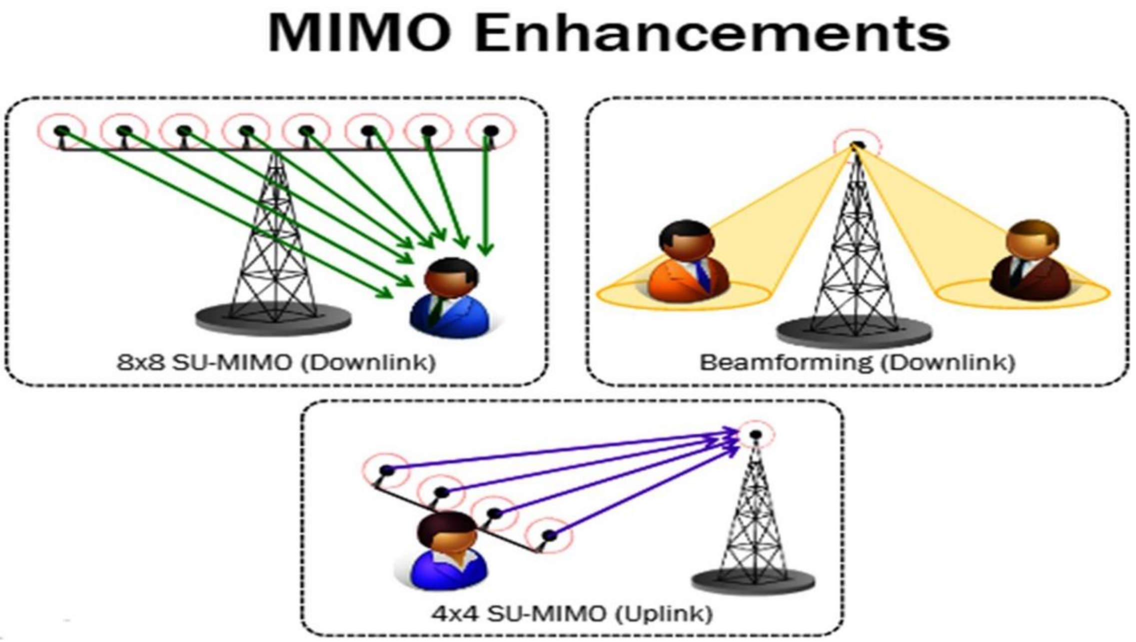

Figure 16: MIMO Enhancement

Relay Nodes:

In order to decrease coverage loop holes, Relay nodes are one of the features proposed in release 10. The relay nodes or low power enbs extending the coverage of main eNB in low coverage environment. The relay nodes are connected to Donor eNB (DeNB) through Un interface.

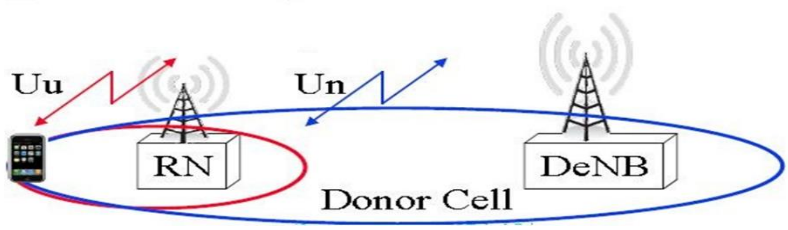

Figure 17: Relay Node

Enhanced inter-cell interference coordination (eICIC)

eICIC introduced in 3GPP release 10 to deal with interference issues in Heterogeneous Networks (HetNet). eICIC mitigates interference on traffic and control channels. eICIC uses power, frequency and also time domain to mitigate intra-frequency interference in heterogeneous networks.

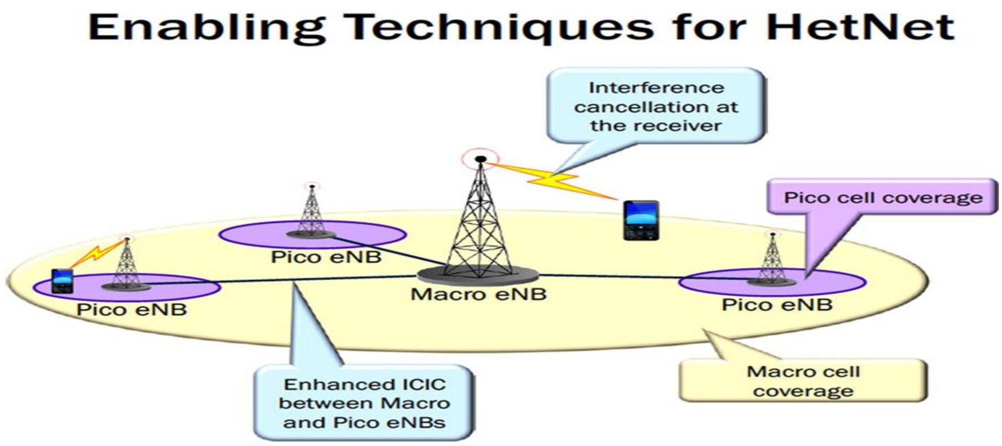

Figure 18: eICIC

ICIC: An eNB sends a "load information" message to the neighbore NB about interference level per physical resource block. The neighbor adjusts DL power levels at those blocks

Almost Blank Subframes (ABS): Only control channels and cell-specific pilots, no user data. Allows UEs in CRE region to mitigate macro-cell interference = eICIC

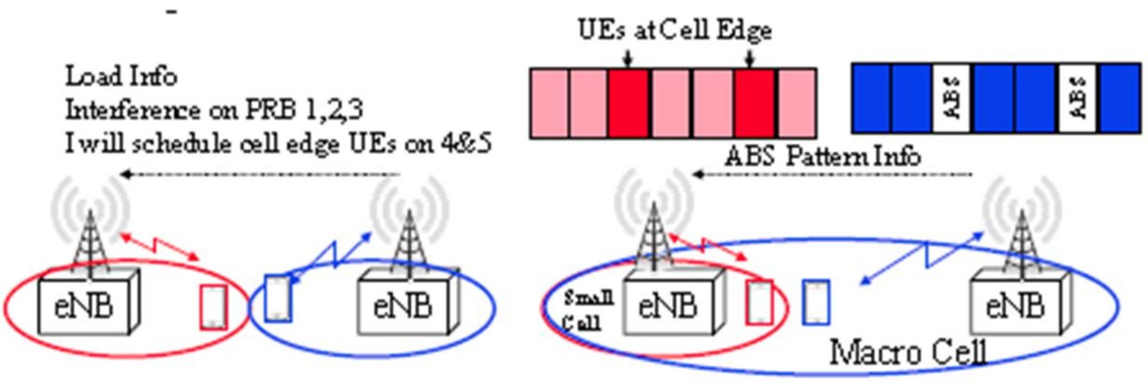

Figure 19: ICIC

Carrier Aggregation (CA):

CA introduced in release 10 is a cost effective way for operators to utilize their fragmented spectrum spread across different or same bands in order to improve end user throughput as required by IMT-Advanced. Carrier Aggregation increases the channel bandwidth by combining multiple RF carriers. Each individual RF carrier is known as a Component Carrier.

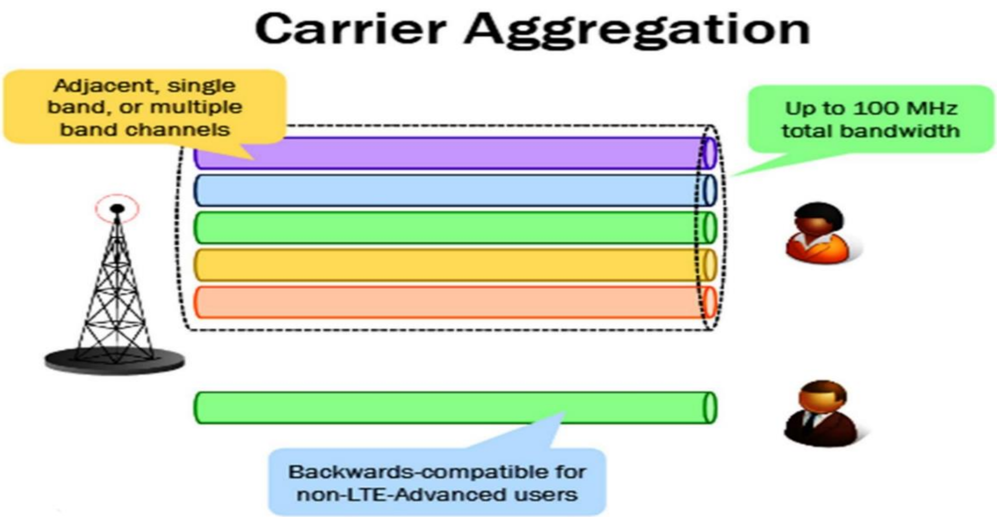

Figure 20: Carrier Aggregation

The release 10 version of the 3GPP specifications defines signalling to support up to 5 Component Carriers. i.e. a maximum combined channel bandwidth of 100 MHz. Component Carriers do not need to be adjacent and can be located in different operating bands. The release 10 version of the 3GPP specifications defines individual Component Carriers to be backwards compatible so they can be used by release 8 and release 9 devices.

Figure 21: Goals of CA

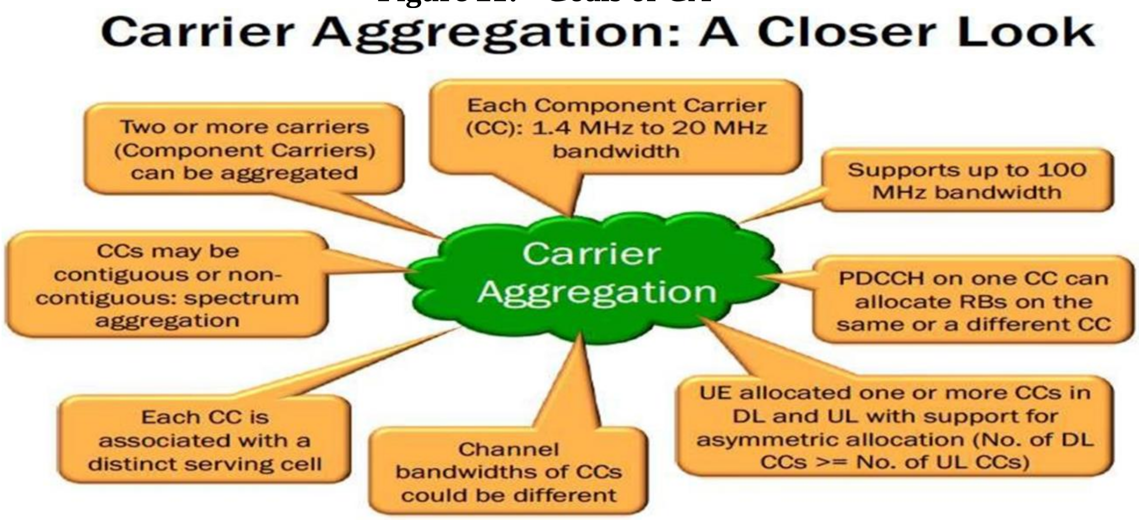

Figure 22: Carrier Aggregation summary

Support for Heterogeneous Networks:

The combination of large macro cells with small cells results in heterogeneous networks. Release 10 intended to layout the detail specification for heterogeneous networks.

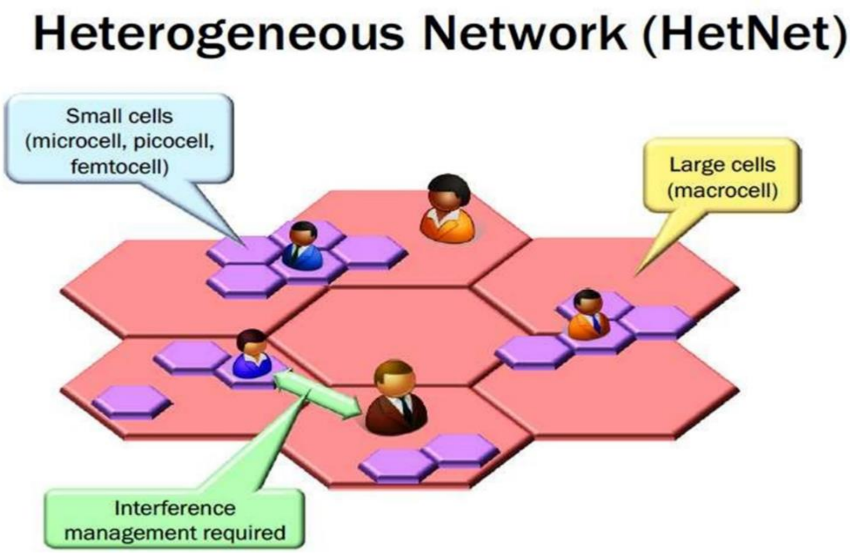

Figure 23: Network Architecture Evolution

Coordinated Multi-Point transmission (CoMP):

Coordinated Multi-Point (CoMP) transmission in the down link and reception in the uplink are LTE-Advanced solutions to help improve the cell edge throughput and spectrum efficiency performance.

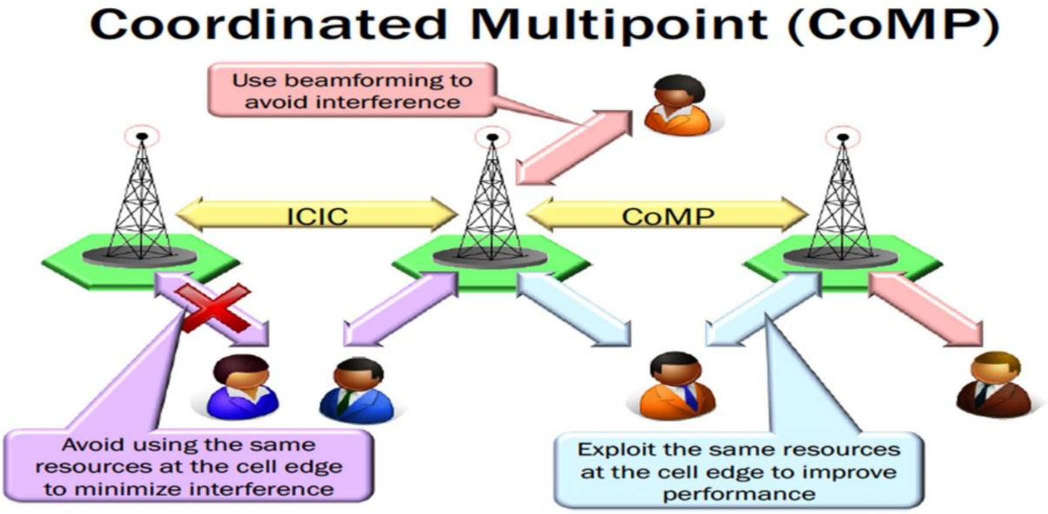

Figure 24: COMP

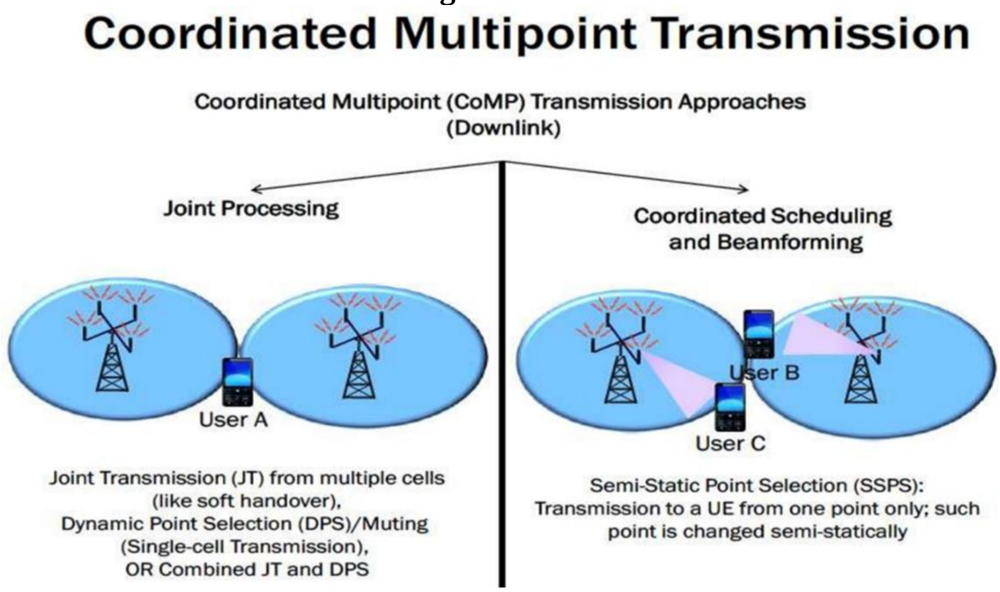

Figure 25: Coordinated Multipoint Transmission

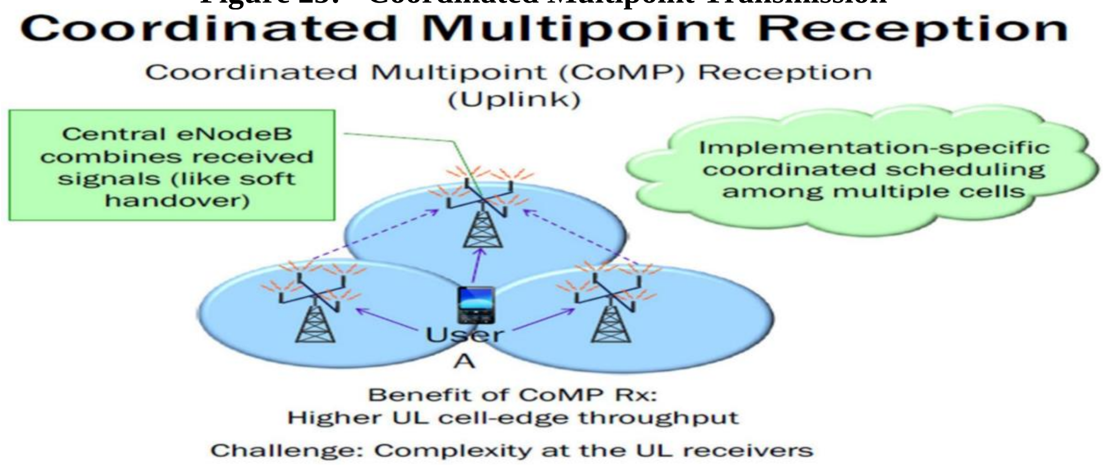

Figure 26: Coordinated Multipoint Reception

SON Improvements:

Release 10 provides enhancements to SON features introduced in release 9 which also considers self healing procedures.

2.11 ENHANCEMENT TO LTE ADVANCE

Release 11 includes enhancements to LTE Advanced features standardized in release 10. Some of the important enhancements are listed below .

2.11.1 CARRIER AGGREGATION ENHANCEMENTS:

Following are the major enhancements to carrier aggregation in release 11

- Multiple timing advances (TAs) for uplink carrier aggregation
- Non contiguous intra band carrier aggregation
- physical layer changes for carrier aggregation support in TDD LTE

2.11.2 COORDINATED MULTIPOINT TRANSMISSION AND RECEPTION (COMP):

With CoMP the transmitter can share data load even if they are not collocated. Though they are connected by high speed fiber link

ePDCCH:

New enhanced PDCCH introduced in 3GPP release 11 to increase control channel capacity. ePDCCH uses PDSCH resources for transmitting control information unlike release 8 PDCCH which can only use control region of subframes

Network based Positioning:

In release 11, support for uplink positioning is added by utilizing sounding reference signals for time difference measurements taken by many eNBs.

2.12 5G NETWORK ARCHITECTURE

2.12.1 5G SYSTEM ARCHITECTURE

The 5G System (SGS) includes the 5G Core Network (CN), the 5G Access Network (AN) and the User Equipment (UE).The 5G Core Network provides connectivity to the internet and to application servers. The 5G Access Network can be a 3GPP Next Generation Radio Access Network (NG RAN), or a non-3GPP Access Network.

Figure 27: 5G System Architecture

2.12.2 5G DEPLOYMENT OPTIONS

With an already deployed 4G RAN/EPC in the field and a new 5G RAN/NG-Core deployment underway, we can't ignore the issue of transitioning from 4G to 5G (an issue the IP-world has been grappling with for 20 years). 3GPP officially spells out multiple deployment options, which can be summarized as follows.

- Standalone 4G / Stand-Alone 5G
- Non-Standalone (4G+5G RAN) over 4G's EPC
- Non-Standalone (4G+5G RAN) over 5G's NG-Core

The second of the three options, which is generally referred to as "NSA", involves 5G base stations being deployed alongside the existing 4G base stations in a given geography to provide a data-rate and capacity boost. In NSA, control plane traffic between the user equipment and the 4G Mobile Core utilizes (i.e., is forwarded through) 4G base stations, and the 5G base stations are used only to carry user traffic. Eventually, it is expected that operators complete their migration to 5G by deploying NG Core and connecting their 5G base stations to it for Standalone (SA) operation. NSA and SA operations are illustrated in Figure

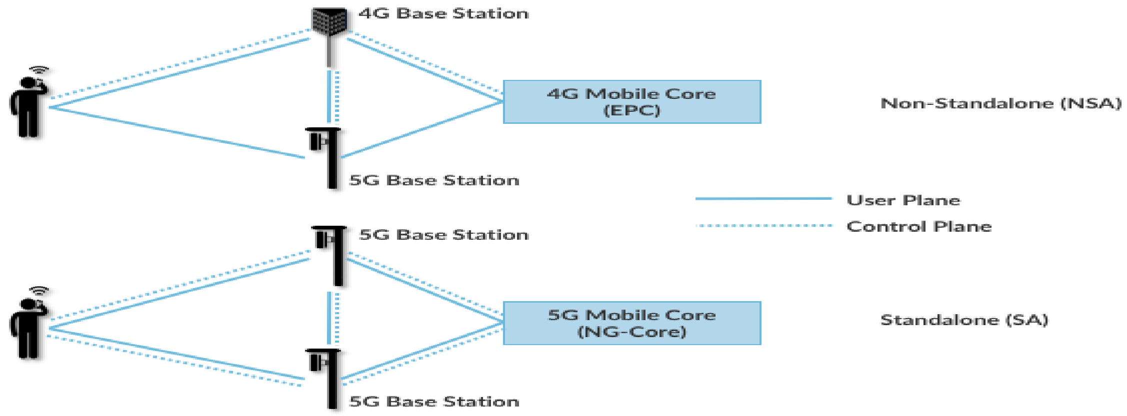

Figure 28: SA and Non SA Deployment

2.13 CONCLUSION

The 5G Network is the need of hour , as 4G Network has reached to its maximum capabilities and it is difficult to manage latency in it, 5G is required for AI services.

3 VARIOUS 3GPP RELEASES AND STANDARDS

3.1 LEARNING OBJECTIVES

After completion of this chapter participant will able to understand about:

- 3GPP Specifications
- HSAP and HSPA+ Standards
- Various releases
- HSPA and HSPA+ technology
- Migration to 4G

3.2 THIRD-GENERATION PARTNERSHIP PROJECT (3GPP)

The cellular technologies specified by 3GPP are the most widely deployed in the world, with the number of users passing 5 billion. Third Generation Partnership Project (3GPP) was formed by standards-developing organizations from all regions of the world. This solved the problem of trying to maintain parallel development of aligned specifications in multiple regions. The present organizational partners of 3GPP are ARIB (Japan), CCSA (China), ETSI (Europe), ATIS (USA), TTA (Korea) and TTC (Japan).

ETSI (European Telecommunications Standards Institute) in early 1998 had selected Wideband CDMA (WCDMA) as the technology for UMTS (Universal Mobile Telecommunications System) in the paired spectrum (FDD) and TD-CDMA (Time Division CDMA) for the unpaired spectrum (TDD). There was also a decision to harmonize the parameters between the FDD and the TDD components.

3GPP consists of several Technical Specifications Groups (TSGs). 3GPP TSG RAN is the technical specification group that has developed WCDMA, its evolution HSPA, as well as LTE, and is in the forefront of the technology.

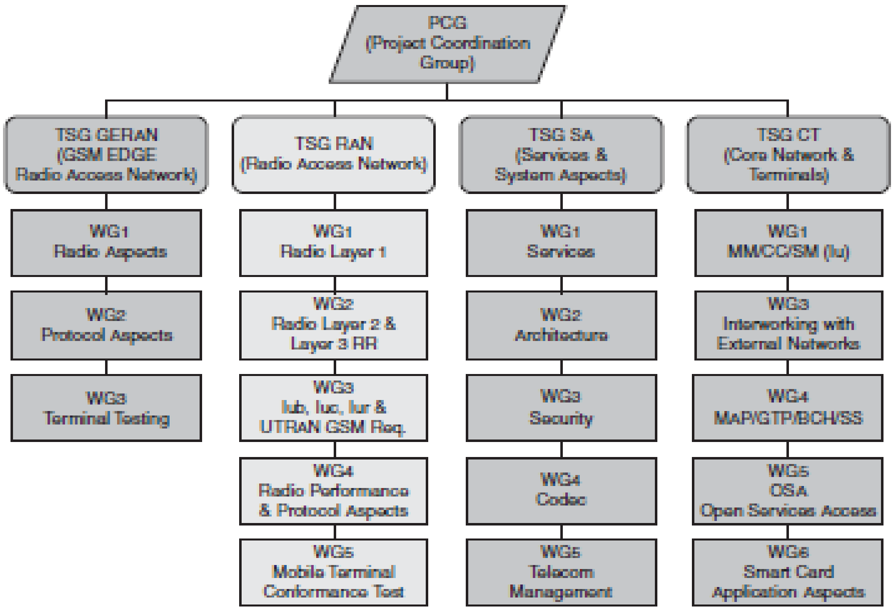

Figure 29: 3GPP organization.

TSG RAN consists of five working groups (WGs):

- RAN WG1 dealing with the physical layer specifications.
- RAN WG2 dealing with the layer 2 and layer 3 radio interface specifications.

- RAN WG3 dealing with the fixed RAN interfaces, for example interfaces between nodes in the RAN, but also the interface between the RAN and the core network.
- RAN WG4 dealing with the radio frequency (RF) and radio resource management (RRM) performance requirements.
- RAN WG5 dealing with the terminal conformance testing.

The work in 3GPP is carried out with relevant ITU recommendations in mind and the result of the work is also submitted to ITU. The organizational partners are obliged to identify regional requirements that may lead to options in the standard. Examples are regional frequency bands and special protection requirements local to a region. The specifications are developed with global roaming and circulation of terminals in mind. This implies that many regional requirements in essence will be global requirements for all terminals, since a roaming terminal has to meet the strictest of all regional requirements. Regional options in the specifications are thus more common for base stations than for terminals.

The specifications of all releases can be updated after each set of TSG meetings, which occur 4 times a year. The 3GPP documents are divided into releases, where each release has a set of features added compared to the previous release. The features are defined in Work Items agreed and undertaken by the TSGs. The releases up to Release 17 and some main features of those are shown in Figure. The date shown for each release is the day the content of the release was frozen. For historical reasons, the first release is numbered by the year it was frozen (1999), while the following releases are numbered 4, 5, etc. For the WCDMA Radio Access developed in TSG RAN, Release 99 contains all features needed to meet the IMT-2000 requirements as defined by ITU. There are circuit-switched voice and video services, and data services over both packet switched and circuit-switched bearers. The first major addition of radio access features to WCDMA is Release 5 with High Speed Downlink Packet Access (HSDPA) and Release 6 with Enhanced Uplink. With HSPA, UTRA goes beyond the definition of a 3G mobile system and also encompasses broadband mobile data. With the studies of an Evolved UTRAN (LTE) and the related System Architecture Evolution (SAE), further steps are taken in terms of broadband capabilities.

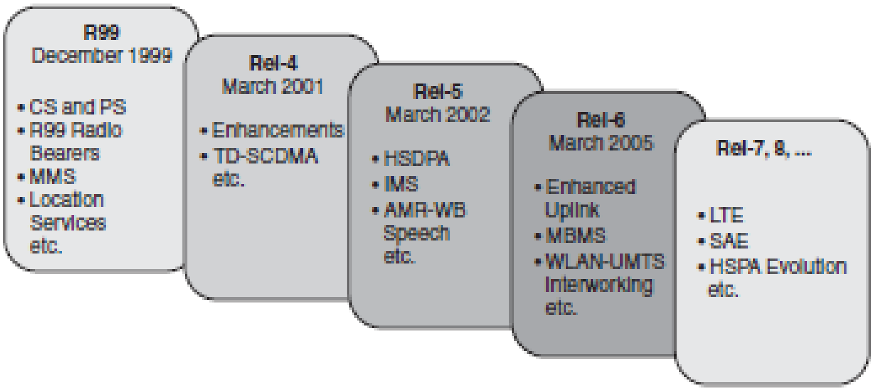

Figure 30: Releases of 3GPP specifications for UTRA

3.3 3GPP SPECIFICATIONS:

3GPP specifications are the actual documents that define the system. At a high level, the specifications are organized into releases, each of which is a version of the system with a particular set of features. 3GPP maintains the specifications for all the releases of UMTS in parallel. This allows it to add new features to the system as part of each new release, while making the occasional technical correction to the older, more stable releases that are used by manufacturers. Each release is developed over a period of months or even years, but the most important event happens when the release is frozen. After it has been frozen, there are no more changes to a release's technical features, although some issues such as the details of the protocols and the conformance tests will usually lag behind. Technical corrections can of course continue for a long time after freezing. The first release of UMTS was release99, which was frozen in March 2000. This release specified a 3G telecommunication system based on the core network of GSM, but with a new air interface that used wideband code division multiple access (W-CDMA).The plan was then to have one release per year, using a numbering scheme of release00, release 01 and so on. However, it was soon realized that this was too ambitious, so the numbering scheme was changed to uncouple it from the calendar year, and the next release became known as release 4. Using this scheme, release99 is synonymous with release3, while the numbers1 and 2 are reserved for draft specifications.

Within each release, the different specifications are organized into series, each of which covers a different part of the system. Series 21 to 36 describe UMTS, including aspects of the system that are common with GSM. Other series refer to features that are unique to GSM: series 00 to 13 were used up to release 99, and series 41 to 55 are for release 4 onwards. Individual specifications have document numbers like (for example) TS 25.331 v 6.12.0. Here, TS stands for technical specification – there are also documents that do not actually define any part of the system, which are known as technical reports and denoted TR; 25 is the series number; 331 is the specification number within that series; 6 is the release number; 12 is the technical version number (which is incremented after technical changes to a specification); and 0 is the editorial version number (incremented after non-technical changes). This particular specification describes the radio resource control (RRC) protocol.

There are several hundred specifications altogether, which can be downloaded from the 3GPP website, www.3gpp.org.

3.4 HSPA AND HSPA+

We are at the dawn of a new decade that will bring to mass market the mobile broadband innovations introduced over the last several years. 3G technology has shown us the power and potential of always-on, everyplace network connectivity and has ignited a massive wave of industry innovation that spans devices, applications, Internet integration, and new business models. Already used by hundreds of millions of people, mobile broadband connectivity is on the verge of becoming ubiquitous. It will do so on a powerful foundation of networking technologies, including GSM with EDGE, HSPA, and LTE. Through constant innovation, Universal Mobile Telecommunications System (UMTS) with High Speed Packet Access (HSPA) technology has established itself as the global, mobile broadband solution. Building on the phenomenal success of Global System for Mobile Communications (GSM), the GSM-HSPA ecosystem has become the most successful communications technology family ever. Through a process of constant improvement, the GSM family of technologies has not only matched or exceeded the capabilities of all competing approaches, but has significantly extended the life of each of its member technologies.

UMTS-HSPA, in particular, has many key technical and business advantages over other mobile wireless technologies. Operators worldwide are now deploying both High Speed Downlink Packet Access (HSDPA) and High Speed Uplink Packet Access (HSUPA), the combination of the two technologies called simply HSPA. HSPA is the most capable cellular data technology ever developed and deployed. HSPA, already widely available, follows the successful deployment of UMTS networks around the world and is now a standard feature. HSPA is strongly positioned to be the dominant mobile-data technology for the next five to ten years. To leverage operator investments in HSPA, the 3GPP (Third Generation Partnership Project) standards body has developed a series of enhancements to create "HSPA Evolution," also referred to as "HSPA+." HSPA Evolution represents a logical development of the Wideband Code Division Multiple Access (WCDMA) approach.

Technology Name	Type	Characteristics	Typical Downlink Speed	Typical Uplink Speed
GSM	TDMA	Most widely deployed cellular technology in the world. Provides voice and data service via GPRS/EDGE.		
EDGE	TDMA	Data service for GSM networks. An enhancement to original GSM data service called GPRS.	70 kbps to 135 kbps	70 kbps to 135 kbps
Evolved EDGE	TDMA	Advanced version of EDGE that can double and eventually quadruple throughput rates, halve latency and increase spectral efficiency.	175 kbps to 350 kbps expected (Single Carrier) 350 kbps to 700 kbps expected (Dual Carrier)	150 kbps to 300 kbps expected
UMTS	CDMA	3G technology providing voice and data capabilities. Current deployments implement HSPA for data service.	200 to 300 kbps	200 to 300 kbps
HSPA	CDMA	Data service for UMTS networks. An enhancement to original UMTS data service.	1 Mbps to 4 Mbps	500 kbps to 2 Mbps
HSPA+	CDMA	Evolution of HSPA in various stages to increase throughput and capacity and to lower latency.	1.5 Mbps to 7 Mbps	1 Mbps to 4 Mbps
LTE	OFDMA	New radio interface that can use wide radio channels and deliver extremely high throughput rates. All communications handled in IP domain.	4 Mbps to 24 Mbps (in 2 x 20 MHz)	
LTE-Advanced	OFDMA	Advanced version of LTE designed to meet IMT-Advanced requirements.		

Table 6. Characteristics of 3GPP Technologies

The development of GSM and UMTS-HSPA happens in stages referred to as 3GPP releases, and equipment vendors produce hardware that supports particular versions of each specification. It is important to realize that the 3GPP releases multiple technologies. For example, Release 17 optimized efficiency and performance of 5G NR, but also significantly enhanced GSM data functionality with Evolved EDGE. A summary of the different 3GPP releases is as follows:

- Release 99: First deployable version of UMTS. Enhancements to GSM data (EDGE). Majority of deployments today are based on Release 99.Provides support for GSM/EDGE/GPRS/WCDMA radio-access networks.
- Release 4: Multimedia messaging support. First steps toward using IP transport in the core network.
- Release 5: HSDPA First phase of IMS. Full ability to use IP-based transport instead of just Asynchronous Transfer Mode (ATM) in the core network.
- Release6:HSUPA Enhanced multimedia support through Multimedia Broadcast/Multicast Services (MBMS). Performance specifications for advanced receivers. WLAN integration option. IMS enhancements. Initial VoIP capability.
- Release 7: Provides enhanced GSM data functionality with Evolved EDGE. Specifies HSPA Evolution (HSPA+), which includes higher order modulation and MIMO. Provides fine-tuning and incremental improvements of features from previous releases. Results include performance enhancements, improved spectral efficiency, increased capacity, and better resistance to interference. Continuous Packet Connectivity (CPC) enables efficient "always-on" service and enhanced uplink UL VoIP capacity, as well as reductions in call set-up delay for PoC. Radio enhancements to HSPA include 64 QAM in the downlink DL and 16 QAM in the uplink. Also includes optimization of MBMS capabilities through the multicast/broadcast, single-frequency network (MBSFN) function.
- Release 8: Comprises further HSPA Evolution features such as simultaneous use of MIMO and 64 QAM. Includes work item for dual-carrier HSPA (DC-HSPA) wherein two WCDMA radio channels can be combined for a doubling of throughput performance. Specifies OFDMA-based 3GPP LTE. Defines EPC.
- Release 9: It includes HSPA and LTE enhancements including HSPA multi-carrier operation.
- Release 10: It specify LTE-Advanced that meets the requirements set by ITU's IMT-Advanced project.
- Release 11: Advanced IP Interconnection of Services. Service layer interconnection between national operators/carriers as well as third party application providers. Heterogeneous networks (HetNet) improvements, Coordinated Multi-Point operation (CoMP). In-device Co-existence (IDC).
- Release 12: Enhanced Small Cells (higher order modulation, dual connectivity, cell discovery, self-configuration), Carrier aggregation (2 uplink carriers, 3 downlink carriers, FDD/TDD carrier aggregation), MIMO (3D channel modeling, elevation beam forming, massive MIMO), New and Enhanced Services (cost and range of MTC, D2D communication, eMBMS enhancements).
- Release 13: LTE in unlicensed, LTE enhancements for Machine-Type Communication. Elevation Beam forming / Full-Dimension MIMO, Indoor positioning. LTE-Advanced Pro.

- Release 14: Energy Efficiency, Location Services (LCS), Mission Critical Data over LTE, Mission Critical Video over LTE, Flexible Mobile Service Steering (FMSS), Multimedia Broadcast Supplement for Public Warning System (MBSP), enhancement for TV service, massive Internet of Things, Cell Broadcast Service (CBS).
- Release 15: First NR ("New Radio") release. Support for 5G Vehicle-to-x service, IP Multimedia Core Network Subsystem (IMS), Future Railway Mobile Communication System.
- Release 16: The 5G System - Phase 2: 5G enhancements, NR-based access to unlicensed spectrum (NR-U), Satellite access.
- Release 17: TSG RAN: Several features that continue to be important for overall efficiency and performance of 5G NR: MIMO, Spectrum Sharing enhancements, UE Power Saving and Coverage Enhancements. RAN1 will also undertake the necessary study and specification work to enhance the physical layer to support frequency bands beyond 52.6GHz, all the way up until 71 GHz.

TSG SA groups focused on further enhancements to the 5G system and enablers for new features and services:

Enhanced support of: non-public networks, Industrial Internet of Things, edge computing in 5GC, access traffic steering, switch and splitting support, network automation for 5G, network slicing, advanced V2X service, devices having multiple USIMs, proximity-based services in 5GS,5G multicast-broadcast services, Unmanned Aerial Systems (UAS), satellite access in 5G, 5GC location services, Multimedia Priority Service.

3.5 UMTS EVOLUTIONTO LTE:

The evolution of UMTS-HSPA happens in stages referred to as 3GPP Releases. A summary of the different 3GPP releases towards LTE is as follows:

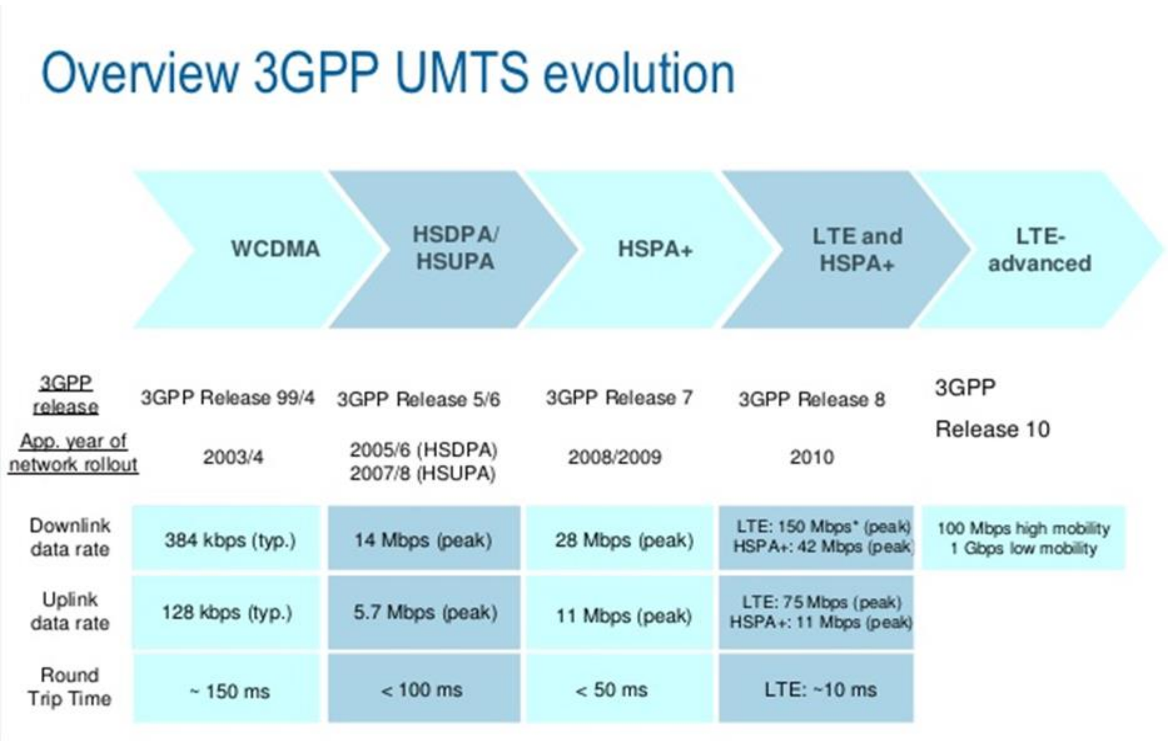

Figure 31: 3GPP UMTS Evolution

Release 99: First deployable version of UMTS. Enhancements to GSM data (EDGE). Majority of deployments today are based on Release 99.Provides support for GSM/EDGE/GPRS/WCDMA radio-access networks.

Release 4: Multimedia messaging support. First steps toward using IP transport in the core network.

Release 5: HSDPA. First phase of IMS. Full ability to use IP-based transport instead of just Asynchronous Transfer Mode (ATM) in the core network.

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Release 8 and 9: The initial enhancements were included to LTE in release 9. These were in fact the improvements which were left behind from release 8 or perhaps provided some minor improvements. These improvements are listed below with brief description.

Release 10.

Enhanced Uplink multiple accesses: Release 10 introduces clustered SC-FDMA in uplink. Release 8 SC-FDMA only allowed carriers along contiguous block of spectrum but LTE-Advanced in release 10 allows frequency-selective scheduling in uplink

MIMO enhancements: LTE-Advanced allows upto 8x8 MIMO in downlink and on the UE side it allows 4X4 in uplink direction.

Release 11 Release 11 includes enhancements to LTE Advanced features standardized in release 10. Some of the important enhancements are listed below .

Carrier Aggregation enhancements: Following are the major enhancements to carrier aggregation in release 11

- Multiple timing advances (TAs) for uplink carrier aggregation
- Non contiguous intra band carrier aggregation
- physical layer changes for carrier aggregation support in TDD LTE

- **Coordinated multipoint transmission and reception (CoMP):** With CoMP the transmitter can share data load even if they are not collocated. Though they are connected by high speed fiber link

- **ePDCCH:** New enhanced PDCCH introduced in 3GPP release 11 to increase control channel capacity. ePDCCH uses PDSCH resources for transmitting control information unlike release 8 PDCCH which can only use control region of subframes

- **Network based Positioning:** In release 11, support for uplink positioning is added by utilizing Sounding reference signals for time difference measurements taken by many eNBs.

- **Minimization of drive test (MDT):** Drive tests are always expensive. To decrease dependency on drive tests, new solutions introduced which are independent of SON though much related. MDT basically relies on information provided by UE.

- **RAN overload control for Machine type communication:** For machine type devices new mechanism has been specified in release 11 where network in case of mass communication from devices can bar some devices to send connection request to network

- **In Device Co Existence:** Now a days, all mobile devices would usually carry multi radio transceivers like for LTE, 3G, Bluetooth, WLAN etc. Now this co existence results in interference. To mitigate this interference, release 11 has specified solutions as mentioned below

    - DRX based time domain solutions
    - Frequency domain solutions
    - UE autonomous denials

Smartphone Battery saving technique: Many applications on smart phones generate background traffic which consumes battery power. Release 11 specifies a method where UE can inform network whether it needs to be operated in battery saving mode or normal mode and based on UE request network can modify DRX parameters.

Release 12 Release 12 includes further enhancement to LTE Advanced features standardized in release 10 and 11. Some of the important enhancements are listed below

- **Small cells enhancements:** Small cells were supported since beginning with features like ICIC and eICIC in release 10. Release 12 introduces optimization and enhancements for small cells including deployments in dense areas. Dual connectivity i.e. inter-site carrier aggregation between macro and small cells is also a focus area

- **Carrier aggregation enhancements:** Release 12 now allows carrier aggregation between co-located TDD and FDD carriers. In addition to carrier aggregation between TDD and FDD, there are also now three carrier aggregations possible for total of 60 Mhz spectrum aggregated

- **Machine Type communication (MTC):** Huge growth is expected in machine type communication in coming years which can result in tremendous network signalling, capacity issues. To cope with this, new UE category is defined for optimized MTC operations

- **Wifi integration with LTE:** With integration between LTE and Wifi, operators will have more control on managing WiFi sessions. In release 12, the intent is to specify mechanism for steering traffic and network selection between LTE and WiFI

- **LTE in unlicensed spectrum:** An LTE operation in unlicensed spectrum is one of the study items in release 12. Operations in Bandwidth rich unlicensed spectrum brings many benefits to operators like increase in network capacity, load and performance

Release 13 Release 13 and beyond: LTE ADVANCED PRO

3GPP publishes its specifications in the form of releases. These releases are published regularly. A new release is published when a set of essential new features are developed and finalized. Often a set of such releases is given a marketing name. As shown in Figure, Rel. 8, 9 is called LTE; Rel. 10, 11, 12, LTE-Advanced; and Rel. 13 and beyond, LTE-A Pro.

LTE-A Pro is the marketing name for a set of releases that cellular standards body 3GPP (3rd Generation Partnership Project) publishes.3GPP has devised a set of advanced features to continue enhancing the capabilities of 4G LTE as part of Rel. 13 and onwards. This upgrade in capabilities has been called "LTE-Advanced Pro (LTE-A Pro)," which you may also see referred to as 4.5G or Pre-5G.

Figure 32: LTE Advanced PRO

Some of the important enhancements are listed below

Carrier aggregation enhancements: The goal in release 13 is to support carrier aggregation of upto 32 CC (component carriers) where as in release 10, the carrier aggregation was introduced with support of only upto 5 CC.

Enhancements for Machine-Type communication (MTC): Continuing from release 12, there are further enhancements in MTC, a new low complexity UE category is being defined to provide support for reduced bandwidth, power and support long battery life.

LTE in unlicensed enhancements: The focus in release 13 is the aggregation of primary cell from licensed spectrum with secondary cell from unlicensed spectrum to meet the growing traffic demand

Indoor Positioning: In release 13 there is work going on improving existing methods of indoor positioning and also exploring new positioning methods to improve indoor accuracy

Enhanced multi-user transmission techniques: Release 13 also covers potential enhancements for downink multiuser transmission using superposition coding

MIMO enhancements: Upto 8 antenna MIMO systems are currently supported, the new study in this release will look into high-order MIMO systems with up to 64 antenna ports.

3.6 BEYOND REL. 13

5G NR and LTE-A Pro are evolved in parallel. Rel. 15 introduces 5G NR, a new unified radio interface that significantly improves performance, efficiency and scalability of cellular networks.

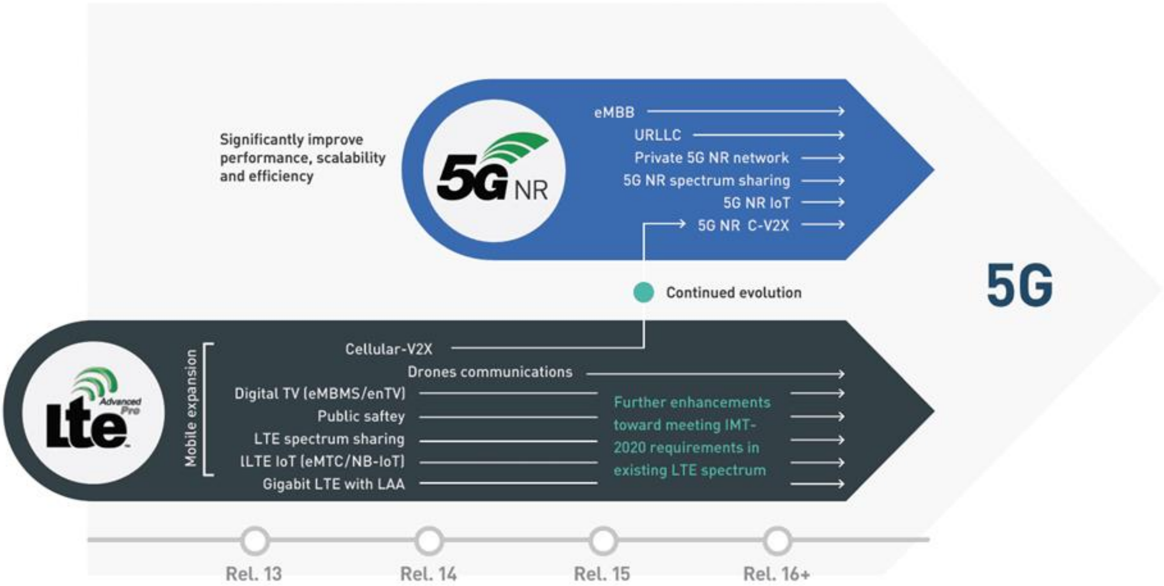


Figure 33: 5G NR and LTE-A Pro are evolving in parallel

3.7 INTRODUCTION TO 5G

5G is the 5th generation mobile network. It is a new global wireless standard after 1G, 2G, 3G, and 4G networks. 5G enables a new kind of network that is designed to connect virtually everyone and everything together including machines, objects, and devices.

5G wireless technology is meant to deliver higher multi-Gbps peak data speeds, ultra low latency, more reliability, massive network capacity, increased availability, and a more uniform user experience to more users. Higher performance and improved efficiency empower new user experiences and connects new industries.

3.8 5G STANDARDIZATION

As of 3G, the generational designation corresponds to a standard defined by the 3rd Generation Partnership Project (3GPP). Even though its name has "3G" in it, the 3GPP continues to define the standards for 4G and 5G, each of which corresponds to a sequence of releases of the standard. Release 15 is considered the demarcation point between 4G and 5G. Complicating the terminology, 4G was on a multi-release evolutionary path referred to as Long Term Evolution (LTE). 5G is on a similar evolutionary path, with several expected releases over its lifetime.5G is defined by ITU-R as IMT-2020.

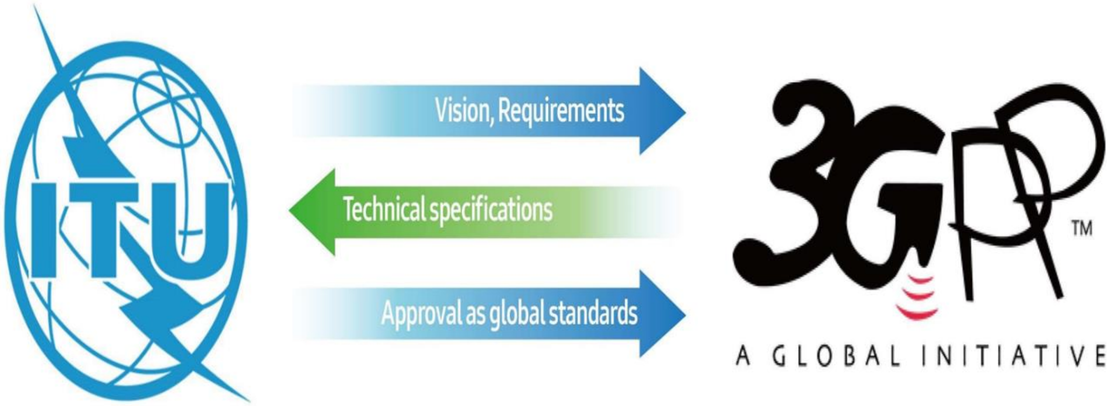


Figure 34: 5G Standardisation

3.9 CONCLUSION

5G is going to future technology as it has low latency and high efficiency.

4 VARIOUS PHASES OF BSNL CMTS TENDER

4.1 LEARNING OBJECTIVES

After completion of this chapter participant will able to understand about:

- Various phases of BSNL CMTS Tenders

4.2 INTRODUCTION

In this chapter we will have details of various phases of CMTS tender by BSNL in North, South, East and West zones since BSNL started its mobile services and highlights of current CTMS tender. Network capacity phase wise vendor wise in various phases of GSM projects in BSNL(in lakhs)

For CMTS , tenders are done by BSNL CO New Delhi on zonal basis (North, East, West, South)

4.3 BSNL TENDER DIFFERENT PHASES

4.3.1 PHASE –I

This was the first tender of the BSNL CMTS , the tender was intended to procure GSM lines. The supply in North and East zone was made by M/s Ericsson, in south by M/s Motorola and in west by M/s Lucent through ITI. The supply was of 2G –GSM equipment only.

4.3.2 PHASE –II AND II+

This was the second tender of the BSNL CMTS , the tender was intended to add- the capacity of GSM/GPRS lines. The supply in North and East zone was made by M/s Ericsson, in south by M/s Motorola and in west by M/s Lucent through ITI. The supply was of 2G –GSM/GPRS equipment. The bidder were same as in phase-I

4.3.3 PHASE –III AND III+

This was the add-on of second tender of the BSNL CMTS , the tender was intended to supply the extra capacity of GSM/GPRS lines. The supply in North and East zone was made by M/s Ericsson, in south by M/s Motorola, West zone has not got any supply in this phase. The supply was of 2G –GSM/GPRS equipment. The bidder were same as in phase-I/II except in west zone

4.3.4 PHASE –IV ,IV+, IV++, IV+++

This was the new tender of the BSNL CMTS in 2004, the tender was intended to supply the extra capacity of GSM/GPRS lines. The supply in South and East zone was made by M/s Nortel, in North by M/s Nokia, West zone has not got any supply in this phase. The supply was of 2G –GSM/GPRS equipment. In phase IV+, IV++ and IV +++ Ercisson and Motorola were the suppliers.

4.3.5 PHASE –V, V.1 AND V.2, V.2

This was the new tender of the BSNL CMTS in 2006, the tender was intended to supply the IMPCS 2G/3G COMBO network. Phase-V.1-17.5 million, Phase-V.2 - 14 million, Phase-V.3 - 14 million Total 45.5 million lines. The supply in North and East zone was made by M/s Ericson, in South by M/s Huawei, West zone has supply from M/s Alcatel in this phase. The supply was of 2G –GSM/GPRS equipment. In phase IV+, IV++ and IV +++ Ercisson and Motorola were the suppliers. The details is as follows

SR. NO.	COMPONENT		PERCENTAGE OF WEIGHTAGE FOR DIFFERENT PHASES		
			V.1	V.2	V.3
1.	CS & PS CORE NETWORK ELEMENTS	MGW & MSC-S	20	20	20
		3G SGSN & GGSN	10	10	10
		HLR, HSS	10	10	10
2.	GERAN		40	30	20
3.	UTRAN		20	30	40

Table 7. Details of Component for Phase V supply

Phase V.2 was for USO site supply for

4.3.6 PHASE VII, VII+

This was the new tender of the BSNL CMTS in 2011-12, the tender was intended to supply the 2G/3G COMBO network. In Phase-VII the supplier was ZTE on pan India Basis Circles were authorized to is Purchase Order (PO) by BSNLCO New Delhi as per APO issued by Corporate office. The total supply was of 150 Lakhs (15 million) lines.

4.3.7 PHASE VIII.4

This was the new tender of the BSNL CMTS in 2015-16, the tender was intended to supply the 2G/3G COMBO network along with upgradation and supply of 4G equipment. In Phase-VII the supplier was ZTE in North and East , Nokia in South and West. Basis Circles were authorized to is Purchase Order (PO) by BSNLCO New Delhi as per APO issued by Corporate office. The supplies detail is as follows

Vendor	Capacity	Vendor	Capacity	Vendor	Capacity	Vendor	Capacity
ZTE NORTH	2G-55.453G-71.854G-13.09	ZTE EAST	2G-21.32 3G-35.80 4G-16.22	Nokia SOUTH	2G-41.81 3G-55.49 4G-30.16	Nokia WEST	2G-71.51 3G-88.60 4G-26.90

Table 8. Vendor and Capacity in Phase VIII.4

4.3.8 PHASE IX

Phase IX project for deployment of 4G network in BSNL, the tender is in the planning phase. The tender is mainly for setting and upgrading to 4G Network.

Sl No.	Phase/ Zone	North		East		South		West		Total Phase wise
		Vendor	Capacity	Vendor	Capacity	Vendor	Capacity	Vendor	Capacity	
1	Ph I	Ericsson	4.20	Ericsson	1.51	Motorola	5.78	ITI/Lucent	4.08	15.57
2	PH II & II+	Ericsson	6.38	Ericsson	3.30	Motorola	8.03	ITI/Lucent	6.82	24.53
3	PH II+	Ericsson	2.71	Ericsson	1.17	Motorola	3.46	-	0.00	7.34
4	Pilot project redeployment		0.00	Ericsson	0.41		0.00		0.00	0.41
5	PH III	Ericsson	6.81	Ericsson	3.13	Motorola	10.93	-	0.00	20.87
6	PH III+	Ericsson	4.55	Ericsson	3.78	Motorola	2.35	-	0.00	10.68
7	PH IV	Nokia	42.0	Nortel	30.0	Nortel	40.0	ITI/Alcatel	40.0	152.00
8	PH IV+	Ericsson	8.70	Ericsson	6.23	Motorola	5.06	-	0.00	19.99
9	PH IV++	Nokia	20.0	-	0.00	Nortel	2.60	ITI/Alcatel	20.0	48.60
		Ericsson	6.00			-	0.00			
10	PH IV+++	Ericsson	7.63	Ericsson	17.41	-	-	-	-	25.04
11	Phase IV.5	-	-	-	-	Nortel	27.05	-	-	50.05
		-	-	-	-	Motorola	23	-	-	
12	Phase V.1	Ericsson	50	Ericsson	55	ITI/Huawei	90	ITI/Alcatel	90.00	285.00
13	Phase V.2/USO	Ericsson	31.97	Ericsson	5.29	-	-	-	-	37.26
14	Phase VII	ZTE	61.4	ZTE	42.19	ZTE	40.12	ZTE	6.29	150.00
15	Phase VII +	ZTE	15	ZTE	31.69	ZTE	33.25			79.94
16	Ph VIII.4	ZTE		ZTE		Nokia		Nokia		

Table 9. Various Phases of BSNL CMTS Tender

Phase VIII.4 GSM Project

Circle	Tentative Plan for 3G (no. of Node Bs)	Tentative Plan for 4G (No. of e Node Bs)
AP	1282	1150
KTK	946	534
TN	1428	566
KRL	1083	662
CHTD	463	288
SZ Total	**5202**	**3,200**
Raj	1770	328
Har	639	232
HP	305	74
UP (W)	664	324
UP (E)	1449	350
UTL	223	122
PB	1224	362
J&K	340	108
NZ Total	**6614**	**1900**
A&N	80	30
NE-I	294	98
ASM	285	272
ODS	348	430
JHK	249	290
WB	962	200
NE-II	95	88
Kol TD	745	226
BR	429	266
EZ Total	**3487**	**1,900**
GUJ	1948	1068
MH	2979	1184
MP	1453	528
CHG	834	220
WZ Total	**7214**	**3000**
Grand Total	**22517**	**10000**

Table 10. Phase VIII.4 Tentative Node Schedule

4.4 SOME DEFINITIONS USED IN BSNL TENDERS

(i) "The Purchaser" means the Bharat Sanchar Nigam Limited, Statesman House, Barakhamba Road, New Delhi.

(ii) "The Bidder" means the individual or firm who participates in the tender and submits its bid.

(iii) "The Supplier" means the individual or firm supplying the goods and services under the contract.

(iv) "The existing vendor (s)" means vendors from whom GSM/UMTS based cellular mobile network equipment was purchased under previous contracts and with whom AMC contracts are subsisting.

(v) "The Goods" means all equipment, machinery, services and/or other materials which the Supplier is required to supply to the Purchaser under the contract.

(vi) "The Advance Purchase Order" means the intention of the Purchaser to place the Purchase order on the bidder.

(vii) "The Purchase Order" means the order placed by the purchaser on the Supplier signed by the Purchaser including all attachments and appendices thereto and all documents incorporated by reference therein. The purchase order shall be deemed as "Contract" appearing in the document.

(viii) "The Contract Price" means the price payable to the Supplier under the purchase order for the full and proper performance of its contractual obligations.

(ix) "Validation" is a process of testing the equipment as per the specifications including requirements for use in BSNL network. Validation is carried out in simulated field environment and includes stability, reliability and environmental tests.

(x) "Commissioning" means successful completion of all prescribed tests and integration of all the network elements including the fulfilment of all the obligation except those relating to Warranty and AMC.

(xi) "support", "capability", "provision" etc appearing in the bid document and in the GRs means that the support/capability/provision etc for the referred functionality shall be provided in the network element(s) together with the associated hardware, software licenses and all related databases for commercial exploitation by BSNL as part of the requirements under his tender.

4.5 STEPS IN TENDER FOR CMTS

Expression of Interest Route: In situations where BSNL proposes to induct new technology/equipment/new service and the specifications of the new technology/equipment/new service are not firmed up, BSNL may invite Expression of Interest (EOI) from the available vendors of that technology/equipment/new service.

↓

Based on the offers received from the bidders who choose to participate in the EOI, the bidders satisfying the terms of EOI will be short-listed. Before short listing the participants for handing over the tender documents, BSNL may freely interact with them; obtain clarifications and feedback on the delivery of similar equipment/services elsewhere.

↓

The short listed bidders will be given the tender document containing detailed technical, commercial and financial conditions.

↓

After evaluation by a designated committee, the contract shall be awarded with the approval of competent authority to the successful bidder(s) as per the terms and conditions stipulated in the EOI and the technical, commercial and financial bid.

4.6 CONCLUSION

Various phases of BSNL CMTS Tenders have been discussed.

5 BACKHAUL MEDIA FOR MOBILE RADIO NETWORK (OFC/ OFC SYSTEMS/ MINI LINK) AND RRH

5.1 LEARNING OBJECTIVES

After completion of this chapter participant will able to understand about:

- Importance of backhaul media in 3G
- Various type of Backhaul media
- Choice of backhauling
- Concept of Cloud RAN

5.2 INTRODUCTION

The physical part of a communications network between the central backbone and the individual local networks is known as backhaul. Mobile backhaul refers to the transport network that connects the core network and the RAN (Radio Access Network) of the mobile network. Recently, the introduction of small cells has given rise to the concept of front haul, which is a transport network that connects the macro cell to the small cells. Whilst mobile backhaul and front haul are different concept, the term mobile backhaul is generally used to encompass both concepts.

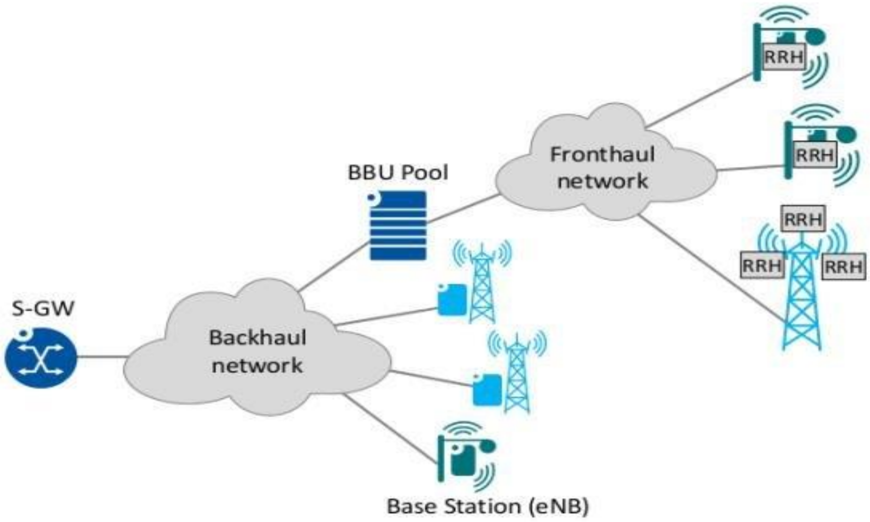


Figure 35: Backhaul Concept

Cell phones communicating with a single cell tower constitute a local subnetwork; the connection between the cell tower and the rest of the world begins with a backhaul link to the core of the internet service provider's network (via a point of presence). A backhaul may include wired, fiber optic and wireless components. Wireless sections may include using microwave bands and mesh and edge network topologies that may use a high-capacity wireless channel to get packets to the microwave or fiber links.

5.3 MOBILE BACKHAUL N/W

- Mobile backhaul is the transport network that connects the core network and the RAN/Cell Site.

- The connection between the cell tower and the rest of the world begins with a backhaul link to the core N/w.
- A backhaul may include wired, fiber optic and wireless components.
- Wireless sections may include using microwave bands and mesh and edge network topologies
- Interconnection b/n core network elements is done through backbone N/w.

5.3.1 FRONT HAUL VS BACKHAUL

- Split RAN architecture has reshaped the traditional definitions of front haul and backhaul.
- In its earliest incarnation, backhaul was simply described as the connection between Cell Site to BSC/RNC (In 2G/3G)
- Front haul became a necessary addition when a new link connected centralized BBU to individual RRH.
- Front haul is connection in RAN infrastructure between the Baseband Unit (BBU) and Remote Radio Head (RRH).
- Front haul originated with LTE networks when operators first moved their radios closer to the antennas.
- This new link was established to supplement to the backhaul connection between the BBU and central network core.

5.4 IMPORTANCE OF MOBILE BACKHAUL

Wireless and fixed-line backhaul infrastructure is an essential component of the mobile telecommunications network. Mobile networks are ubiquitous and support a mix of voice, video, text and data traffic originating from and terminating to mobile devices. All of this traffic must be conveyed between the mobile cellular base stations and the core network. The 3G and 4G Long-Term Evolution (LTE) strive for more network capacity, latency reduction, and the need to deliver an enhanced user experience. In the era of 5G, where a network will be densified and more stringent requirement will be imposed, mobile backhaul will become even more important.

5.5 MOBILE BACKBONE NETWORK

Mobile backbone network refers to the interconnection of core elements situated at separate geographic locations. As the requirement of bandwidth is large, typically, OFC is used in the backbone network. However, MW is also sometimes used in the backbone network, particularly in those areas where laying fibre is not a feasible option due to difficult terrain, time constraints or economic viability.

5.6 TECHNOLOGY CHOICES FOR MOBILE BACKHAUL

The most common network type in which backhaul is implemented is a mobile network. A backhaul of a mobile network, also referred to as mobile-backhaul connects a cell site towards the core network. The two main methods of mobile backhaul implementations are fiber-based backhaul and wireless point-to-point backhaul. Other methods, such as copper-based wire line, satellite communications and point-to-multipoint wireless technologies are being phased out as capacity and latency requirements become higher in 4G and 5G networks.

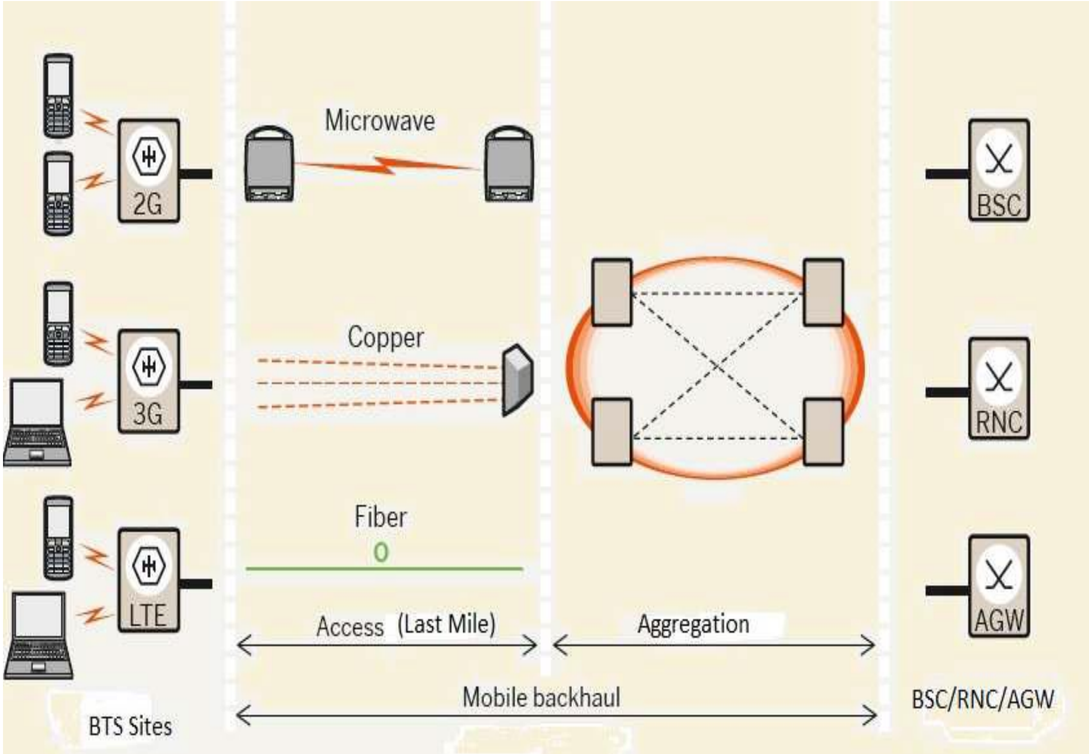


Figure 36: Mobile Backhaul Network Choices

The technological solutions used for backhaul, including both wireline and wireless solutions are given below:

5.6.1 COPPER-LINE

Copper-based backhaul was the primary backhaul technology for 2G/3G. At the heart of copper-based backhaul is the T1/E1 protocol, which supported 1.5 Mbps to 2 Mbps. This bandwidth can be boosted by using DSL over the copper pair and DSL is still an option for mobile backhaul for indoor small cells, in-building and public venue small cell networks.

5.6.2 FIBRE-OPTIC IN BACKHAUL MEDIA FOR MOBILE RADIO NETWORK (OFC/OFC SYSTEMS)

This technology is the mainstay wired backhaul in MNO networks and second overall only to microwave backhaul. Even though fibre has significant inherent bandwidth carrying capability, several additional techniques can be used to offset any bandwidth constraints and essentially rendering the fibre assets future-proof.

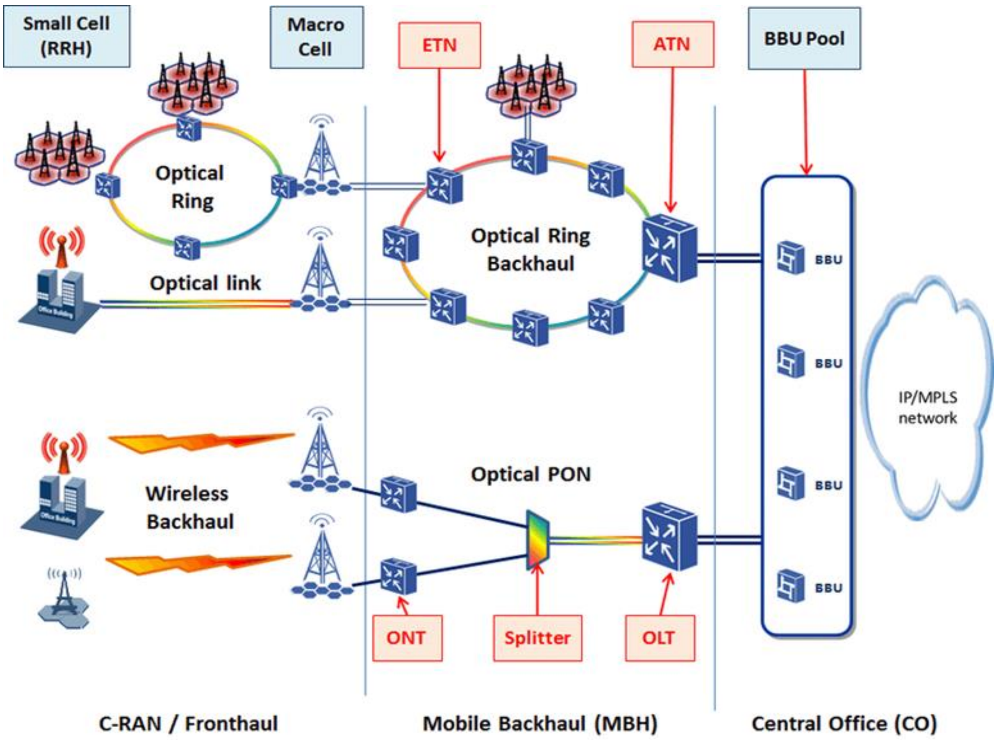


Figure 37: OFC Media and System Mobile Network Backhaul

These techniques include Wavelength Division Multiplexing (WDM) technology which enables multiple optical signals to be conveyed in parallel by carrying each signal on a different wavelength or colour of light. WDM can be divided into Coarse WDM (CDWM) or Dense WDM (DWDM). CWDM provides 8 channels using 8 wavelengths, while DWDM uses close channel spacing to deliver even more throughput per fibre. Modern systems can handle up to 160 signals, each with a bandwidth of 10 Gbps for a total theoretical capacity of 1.6 Tbps per fibre.

The traffic generated by LTE has accelerated the demand for Fiber to the Tower (FTTT) and has required Mobile Network Operators (MNOs) to upgrade many aspects of their backhaul networks to fibre-based Carrier Ethernet. The main limitations of fibre are the cost and logistics of deploying fibre (ducts etc.). Also it can take several months to provision a cell site with fibre optic backhaul. Fibre optic will remain as the main choice for backhaul.

5.6.3 WIRELESS BACKHAUL (MICROWAVE MINI-LINK)

Despite fibre being the preferred choice for 3G/4G/5G backhaul, microwave backhaul is the most used technology due to a combination of its capability and relative ease of deployment (i.e. no need for trenches/ducting) making it a low-cost option that can be deployed in a matter of days. Microwave backhaul solutions in the 7 GHz to 40 GHz bands, in addition to higher microwave bands such as V-band (60 GHz) and the E-band (70/80 GHz) can be relied. Backhaul links using the V-band or the E-band are well suited to supporting 5G due to their 10 Gbps to 25 Gbps data throughput capabilities.

Figure 38: Microwave Mini-Links for Mobile Communications

Microwave can be used in LOS or NLOS mode which makes it ideal to be used in a chain, mesh or ring topologies to enable resilience and/or reach.

5.6.4 LOS VS. NLOS

LOS backhaul has the advantage of using a highly directed beam with little fading or multi-path dispersion and enables efficient use of spectrum as multiple transceivers can be located within a few feet of each other and use the same frequency to transmit different data streams.

NLOS backhaul is much more "plug and play" and so take less time with less skilled labour to set up. NLOS backhaul OFDM technology (Orthogonal Frequency Division Multiplexing) to relay information back to a central base station. NLOS backhaul needs only to be within a range of the receiver unit with OFDM providing a level of tolerance to multi-path fading not possible with LOS

5.6.5 SATELLITE BACKHAUL

Satellite Backhaul is a niche solution and used in fringe areas (e.g. remote rural areas) and sometimes as an emergency/temporary measure (e.g. a disaster area. This backhaul is used in developing markets and as a complementary role in developed markets. The technology can deliver 150Mbps/10Mbps (downlink/.uplink). However, latency is a challenge as there a round trip delay of circa 500-600ms for a geostationary satellite. LEO (Low Earth Orbit) satellites have tried to address the latency issue (i.e. using a much lower orbit of 1500km versus 36000km and resulting in a one way trip of circa 50ms). However, LEO satellites are not geostationary and thus there is sometimes a need to route traffic via multiple satellites.

5.6.6 FREE SPACE OPTICS (FSO)

Free Space Optics (FSO) is a newer low-latency technology that offers speeds comparable to fibre optics that transmit voice, video and data with up to 1.5Gbps, and can be deployed as backhaul to expand mobile network footprint with building-to-building connectivity. The high bandwidth can be provided with a reception of light by deploying free space optics technology.

BSNL is likely to use free space optics, a new line-of-sight outdoor wireless technology, to overcome backhaul constraints in large arid areas of Rajasthan and Gujarat plains.

5.6.7 WIFI BACKHAUL

There is marginal use of this technology for macrocell backhaul. The unlicensed nature of the technology combined with the growing interference from increasing public and private WLANs plus poor transmission ranges severely limits its deployment.

5.7 CHALLENGES IN MOBILE BACKHAUL

There are a number of market trends that result in new challenges and requirements that must be met by the backhaul.

5.7.1 EVOLUTION OF LTE

Technical innovations occurring on LTE, which is known as LTE-Advanced Pro or 4.5G which enable enhancements such as improved peak bandwidth and greater energy efficiency for IoT connections. The peak bandwidth of 4.5G is around 1Gbps which is 8-10x higher than standard LTE, and will enable (inter alia) support of video traffic at 4K resolution to mobile devices.

5.7.2 EMERGENCE OF 5G

The 5G network will comprise both NR (New Radio) as well as a new 5G Core Network (5GC). The advent of NR offers a leap in bandwidth speeds in comparison to 3G and 4G via the utilisation of higher frequency spectrum. The higher frequencies enable wider channel bandwidths at the access but also result in smaller cell sizes. Both have implications for backhaul.

5.7.3 NETWORK SLICING

In 5G Network, one concept of "network slicing" is introduced whereby the physical network infrastructure can be partitioned into bespoke logical networks ("slices") in the RAN and 5G core which are targeted to the needs of a specific application or use case. Slicing will impact on the backhaul network.

5.7.4 SUBSCRIBER GROWTH

Backhaul strategy/evolution must cope with both an increase in subscriptions as well as a large number of those subscriptions being "high bandwidth" users.

5.7.5 MOBILE DATA TRAFFIC GROWTH

The increasing subscriber total plus increased access bandwidth usage of those subscribers results in mobile data traffic increasing at a rate.

5.7.6 STRINGENT LATENCY REQUIREMENTS

Both 5G mission-critical applications and increased video streaming will result in more stringent end-end latency requirements and impact on the backhaul latency budget.

If higher latency backhaul links are deployed (e.g. satellite links), then such backhaul would only carry 2G/3G and non-latency sensitive LTE services.

5.7.7 NETWORK DENSIFICATION:

The increased demand for mobile broadband results in the number of macrocell. The new macrocells include both 4G and 5G technologies. This results in extra traffic to backhaul as well as additional challenges due to the smaller cell size for 5G NR.

5.8 ALTERNATIVE ARCHITECTURES FOR MOBILE BACKHAUL OPTIMISATION

5.8.1 MULTI ACCESS EDGE COMPUTING

MEC (Multi-access edge computing) is where computing and intelligence capabilities that were mostly centralized in the core network are provided at the edge of the access network. MEC enables high bandwidth and ultra-low latency access to cloud computing/IT services at the edge to be accessed by applications developers and content providers.

MEC, while incurring a cost to implement core functions at the edge, can provide opportunities to optimise backhaul demand via caching and/or local breakout. Caching reduces the load on mobile backhaul and enhances the customer experience by storing frequently accessed contents in the edge network. Customers can access the contents at a lower latency (with less distance for signal to travel) and backhaul demand is reduced as there is no need to reach further to the external network to obtain the contents. Local breakout also enables the mobile backhaul to be optimised as the contents do not need to travel to the core network and then to the internet. The caveat with local breakout is that the transport network to connect the edge to the internet needs to be in place and therefore won’t optimise cost in certain scenarios.

5.8.2 CLOUD RAN

Cloud RAN is where some layers of radio access network are centralized to an edge site rather than at the cell site, which allows some (or all) of the processing capabilities to be focused at the edge site reducing the complexities at the cell site. This architecture is suitable in the small cell era, where only a little space and cost constraint is affordable at the cell site. While the architecture may not be suitable for traditional macrocell base stations as they would need to process significant load of signal transmitted from/received by various radio elements, heterogeneous networks with many small cells would benefit from this architecture.

As shown in the figure below, Cloud RAN in its two forms (low-level and high-level splits) significantly reduces complexities and capabilities at the cell site to be concentrated in the edge site. The low-level split is where only the physical layer is processed at the edge site while all the electronics are concentrated in the edge site. This architecture allows easy installation and very low complexity at the cell site but comes at a higher fronthaul cost as baseband signals would need to be transferred. On the other hand, high-level split brings relatively less fronthaul cost but comes with more complexity at the cell site than low-level split.

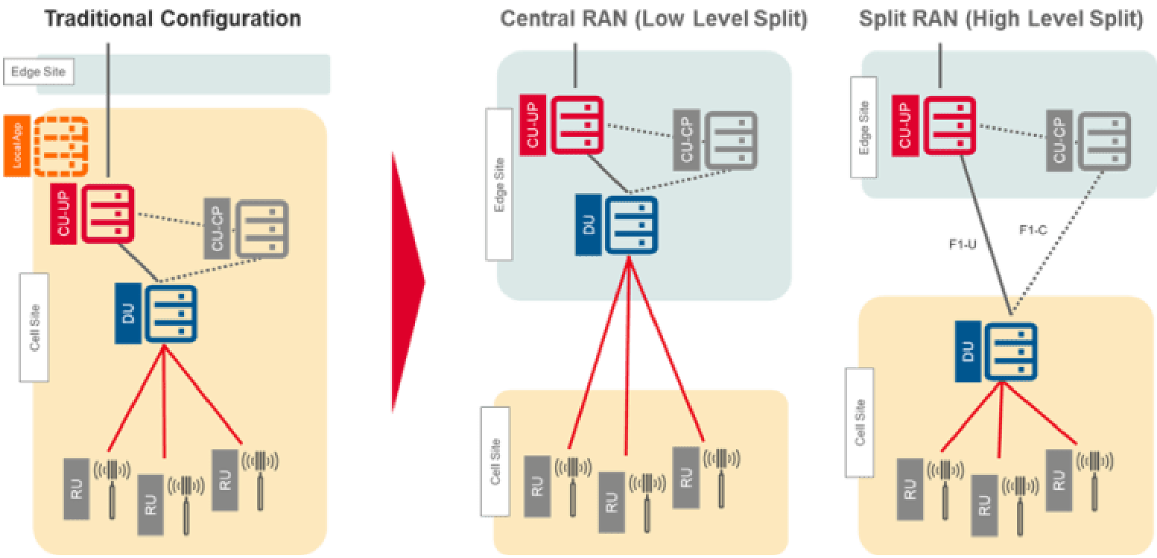


Figure 39: Cloud RAN Architecture

5.8.3 RRH

A remote radio head (RRH), also called a remote radio unit (RRU) in wireless networks, is a remote radio transceiver that connects to radio base station unit via electrical or wireless interface.

The RRH is termed "Remote" as it is usually installed on a mast-top, or tower-top location that is physically some distance away from the base station hardware which is often mounted in an indoor rack-mounted location. In wireless system technologies such as GSM, CDMA, UMTS, LTE this Radio equipment is remote to the BTS/NodeB/eNodeB, and is also called Remote Radio Head.

This equipment will be used to extend the coverage of a BTS/NodeB/eNodeB like rural areas or tunnels. They are generally connected to the BTS/NodeB/eNodeB via a fibre optic cable using Common Public Radio Interface protocols.

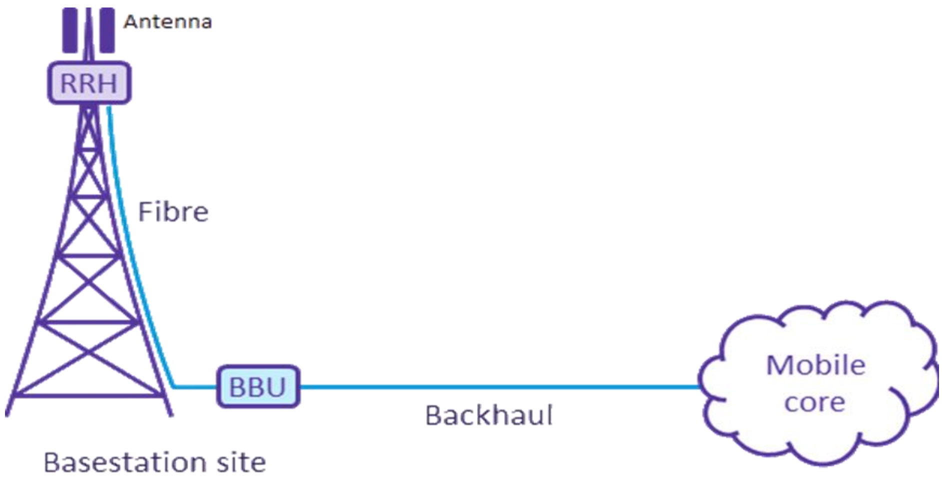


Figure 40: RRH

Using Wireless (Microwave, Millimetre Wave, MMW, Free Space Optics, and FSO) links instead of fibre allows the Remote Radio Head (RRH) to be connected without need for fibre optics. By avoiding the needs for digging, trenches, leased circuits from telcos, dark fibre or way-leaves for disrupting busy city streets, 4G/LTE networks can be realised very quickly with installation taking hours rather than days, weeks or months.

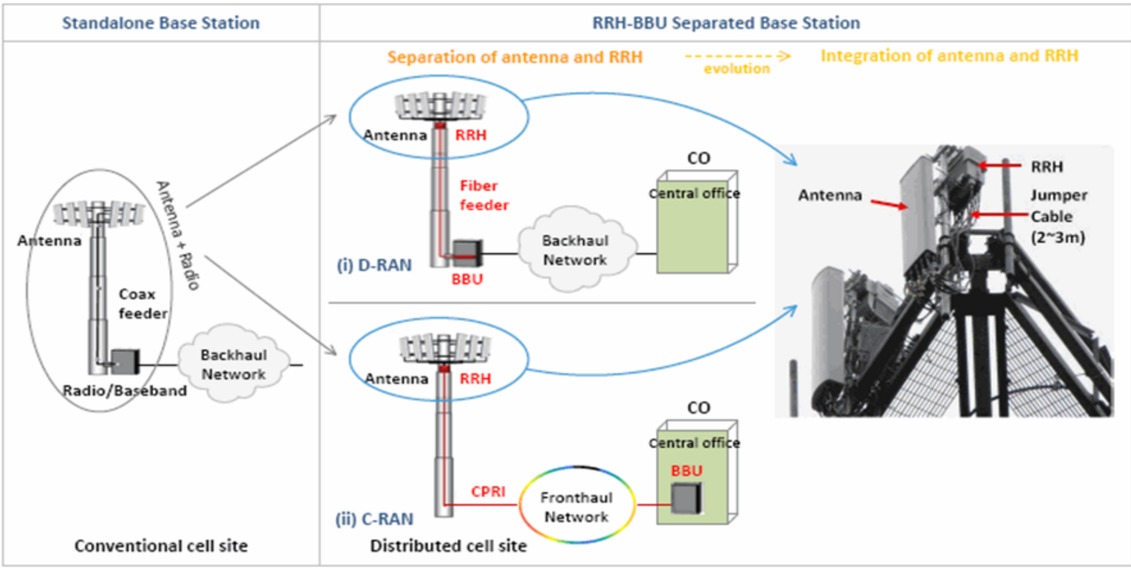


Figure 41: Backhaul for RRH

5.8.4 IMPORTANCE OF RRH

RRHs have become one of the most important subsystems of today's new distributed base stations. The RRH contains the base station's RF circuitry plus analog-to-digital/digital-to-analog converters and up/down converters. RRHs also have operation and management processing capabilities and a standardized optical interface to connect to the rest of the base station. This will be increasingly true as LTE and WiMAX are deployed. Remote radio heads make MIMO operation easier; they increase a base station's efficiency and facilitate easier physical location for gap coverage problems. RRHs will use the latest RF component technology including Gallium nitride (GaN) RF power devices and envelope tracking technology within the RRH RF power amplifier (RFPA).

5.8.5 RRH PROTECTION IN FIBER TO THE ANTENNA SYSTEMS

Fourth generation (4G) and beyond infrastructure deployments will include the implementation of Fiber to the Antenna (FTTA) architecture. FTTA architecture has enabled lower power requirements, distributed antenna sites, and a reduced base station footprint than conventional tower sites. The use of FTTA will promote the separation of power and signal components from the base station and their relocation to the top of the tower mast in a Remote Radio Head (RRH).

According to the Telcordia industry standard that establishes generic requirements for Fiber to the Antenna (FTTA) protection GR-3177,the RRH shifts the entire high-frequency and power electronic segments from the base station to a location adjacent to the antenna. The RRH will be served by optical fiber and DC power for the optical-to-electronic conversion at the RRH.

RRHs located on cell towers will require Surge Protective Devices (SPDs) to protect the system from lightning strikes and induced power surges. There is also a change in electrical overstress exposure due to the relocation of the equipment from the base station to the top of the mast.

5.8.6 PROTECTION FROM LIGHTNING DAMAGE

RRHs can be installed in a low-profile arrangement along a rooftop, or can involve a much higher tower arrangement. When installed at the highest point on a structure (whether a building or a dedicated cell tower), they will be more vulnerable to receiving a direct lightning strike and higher induced lightning levels, compared with those installed in a lower profile manner below the upper edges of the building.

As noted in GR-3177, while surges can be induced into the RRH wiring for lightning striking the nearby rooftop or even the base station closure, the worst case will occur when a direct strike occurs to the antenna or its supporting structure. Designing the electrical protection to handle this situation will provide protection for less damaging scenarios it can also be use in optical fiber communication but different type.

5.9 CONCLUSION

In order to have best of Network and throughput from it backhaul is of at most importance. Introduction of cloud RAN has open the path for low latency network and path for future radio technologies.

6 KPI REPORTS FOR 2G/3G/4G

6.1 LEARNING OBJECTIVES

After completing this chapter participants will able to understand:

- Key Performance Indicators (KPIs) of 2G/3G/4G
- Quality of Service (QoS).
- Reports of KPIs
- QoS parameters related to Network Accessibility, Service Accessibility, and Network Retain ability.

6.2 INTRODUCTION

Key Performance Indicators are a set of quantifiable measures used in GSM, UMTS, HSPA, and LTE networks to gauge or compare performance in terms of meeting mobile network's strategic and operational goals. KPIs vary between management, marketing, operations and network engineering people depending on their priorities, perspectives or performance criteria sometimes referred to as "Key Success Indicators (KSI)".

6.3 KPI OF GSM

In GSM all the events being occurred over air interface are triggering different counters in the Base Station Controller (BSC). The KPIs are derived with the help of these counters using different formulations. RF Optimizer makes frequent use of statistical data for routine optimization activities. This raw data, which is actually based on counters, makes optimization tasks quite cumbersome as counters are in thousands. So, to make the tasks simpler, counters are appended into formulae, whereas, each formula reflects a specific performance indicator. All major performance indicators are categorized as Key Performance Indicators (KPIs). The KPIs are available in report form through OMC.

Following 2G network KPI optimizations are covered in this chapter:

- SDCCH congestion Rate
- SDCCH drop Rate
- TCH congestion/Blocking Rate
- Call Setup Success Rate
- TCH (call) drop Rate
- Handover Success Rate
- Paging Success Rate
- RACH Success Rate
- Data KPI improvement

6.3.1 SDCCH CONGESTION RATE

During Location Update and set up of MO and MT calls, MS usually seizes SDCCH to exchange signalling. SMS is also sent/delivered through SDCCH channel in idle mode. When BSC receives SDCCH request from MS, it checks SDCCH resource. If all SDCCHs are occupied at that moment, SDCCH congestion takes place. Its day average value should be ≤ 1%.

Causes and solutions:
(a) Large traffic volume exceeding network capacity
Solution: Increase cell capacity by adding more TRXs.

(b) Too many location update at LAC boundaries
Solution: (i) Adjust LAC selection and/or modify LAC boundaries
(ii) Adjust CRH (Cell Reselection Hysteresis)
(iii) Adjust parameter setting of periodic location update timer (T3212)

(c) Too much SMS traffic
Solution: (i) Implement dynamic SDCCH allocation mode
(ii) Increase SDCCH channels

(d) Hardware fault in TRX or transmission system (Abis link etc.)
Solution: (i) Replace the faulty hardware
(ii) Check and repair the transmission system

(e) Unreasonable setting of system parameters and RACH parameters
Solution:
(i) Increase RACH access threshold appropriately to cope with interference
(ii) Reduce Max Retrans appropriately

6.3.2 SDCCH DROP RATE:

When MS is already on SDCCH and in-between communication with Base station SDCCH channel got disconnected abruptly then SDCCH Drop has occurred.

Process for Optimization:
Identify the Bad performing Cells for SDCCH Drop Rate. Then follow the below mentioned Process after Analyzing detailed report

a) The Main Reasons for High SDCCH Drop Rate are improper Parameters Configuration and Bad RF & Environmental factors.
b) First Audit for any parameters related discrepancies and define as per standard parameters set.
c) Check for Neighbour Relations and correct if it is not proper.
d) Low Coverage: Through Drive Test Find out the low coverage patched and try to improve the coverage.
e) Interference: Check for interference from repeaters, Intra-Network interference due to aggressive reuse or improper Frequency, Inter-Network can also be the case. Find out the actual cause and rectify it.
f) Antenna System: High VSWR due to feeders, improper antenna configuration (Ex. Sector cable Swap)
g) Check for Hardware Issue and rectify if you found any.
h) After the activity check the subsequent days report and repeat the procedure for pin pointing the actual cause.

6.4 TCH CONGESTION/BLOCKING RATE

If during call attempt MS is not getting a TCH as all the available TCH in the cell are already occupied, TCH congestion/blocking occurs. Its day average value should be ≤ 2%.

Process for Optimization

- Check TRX/Hardware Fault in the affected cell

- Check carried Traffic (Erlang) from BH Report and increase no. of TRX in the cell (If possible). No. of TCH required according to traffic can be analyzed from Erlang-B table (please see the table)
- Implement Half Rate/AMR-Half Rate if already maximum no. of TRX is equipped.

Explore possibilities of sharing the traffic of affected cell with neighbouring cell by:

- Antenna azimuth/tilt/height adjustment of affected/ neighbouring cells.
- HO margin adjustment for making logical slope to neighbouring cells.
- Directed Retry/Traffic handover may be enabled.
- In very exceptional cases power of affected cell may be reduced.
- Additional sector may be installed in the affected BTS.
- Dual band may be implemented in the affected BTS to increase no. of TRX.
- Last option: Introduction of new BTS in the affected area

Erlang B Traffic Table

Maximum Offered Load Versus B and N
B is in %

N/B	0.01	0.05	0.1	0.5	1.0	2	5	10	15	20	30	40
1	.0001	.0005	.0010	.0050	.0101	.0204	.0526	.1111	.1765	.2500	.4286	.6667
2	.0142	.0321	.0458	.1054	.1526	.2235	.3813	.5954	.7962	1.000	1.449	2.000
3	.0868	.1517	.1938	.3490	.4555	.6022	.8994	1.271	1.603	1.930	2.633	3.480
4	.2347	.3624	.4393	.7012	.8694	1.092	1.525	2.045	2.501	2.945	3.891	5.021
5	.4520	.6486	.7621	1.132	1.361	1.657	2.219	2.881	3.454	4.010	5.189	6.596
6	.7282	.9957	1.146	1.622	1.909	2.276	2.960	3.758	4.445	5.109	6.514	8.191
7	1.054	1.392	1.579	2.158	2.501	2.935	3.738	4.666	5.461	6.230	7.856	9.800
8	1.422	1.830	2.051	2.730	3.128	3.627	4.543	5.597	6.498	7.369	9.213	11.42
9	1.826	2.302	2.558	3.333	3.783	4.345	5.370	6.546	7.551	8.522	10.58	13.05
10	2.260	2.803	3.092	3.961	4.461	5.084	6.216	7.511	8.616	9.685	11.95	14.68
11	2.722	3.329	3.651	4.610	5.160	5.842	7.076	8.487	9.691	10.86	13.33	16.31
12	3.207	3.878	4.231	5.279	5.876	6.615	7.950	9.474	10.78	12.04	14.72	17.95
13	3.713	4.447	4.831	5.964	6.607	7.402	8.835	10.47	11.87	13.22	16.11	19.60
14	4.239	5.032	5.446	6.663	7.352	8.200	9.730	11.47	12.97	14.41	17.50	21.24
15	4.781	5.634	6.077	7.376	8.108	9.010	10.63	12.48	14.07	15.61	18.90	22.89
16	5.339	6.250	6.722	8.100	8.875	9.828	11.54	13.50	15.18	16.81	20.30	24.54
17	5.911	6.878	7.378	8.834	9.652	10.66	12.46	14.52	16.29	18.01	21.70	26.19
18	6.496	7.519	8.046	9.578	10.44	11.49	13.39	15.55	17.41	19.22	23.10	27.84
19	7.093	8.170	8.724	10.33	11.23	12.33	14.32	16.58	18.53	20.42	24.51	29.50
20	7.701	8.831	9.412	11.09	12.03	13.18	15.25	17.61	19.65	21.64	25.92	31.15
21	8.319	9.501	10.11	11.86	12.84	14.04	16.19	18.65	20.77	22.85	27.33	32.81
22	8.946	10.18	10.81	12.64	13.65	14.90	17.13	19.69	21.90	24.06	28.74	34.46
23	9.583	10.87	11.52	13.42	14.47	15.76	18.08	20.74	23.03	25.28	30.15	36.12
24	10.23	11.56	12.24	14.20	15.30	16.63	19.03	21.78	24.16	26.50	31.56	37.78
25	10.88	12.26	12.97	15.00	16.13	17.51	19.99	22.83	25.30	27.72	32.97	39.44
26	11.54	12.97	13.70	15.80	16.96	18.38	20.94	23.89	26.43	28.94	34.39	41.10
27	12.21	13.69	14.44	16.60	17.80	19.27	21.90	24.94	27.57	30.16	35.80	42.76
28	12.88	14.41	15.18	17.41	18.64	20.15	22.87	26.00	28.71	31.39	37.21	44.41
29	13.56	15.13	15.93	18.22	19.49	21.04	23.83	27.05	29.85	32.61	38.63	46.07
30	14.25	15.86	16.68	19.03	20.34	21.93	24.80	28.11	31.00	33.84	40.05	47.74
31	14.94	16.60	17.44	19.85	21.19	22.83	25.77	29.17	32.14	35.07	41.46	49.40
32	15.63	17.34	18.21	20.68	22.05	23.73	26.75	30.24	33.28	36.30	42.88	51.06
33	16.34	18.09	18.97	21.51	22.91	24.63	27.72	31.30	34.43	37.52	44.30	52.72
34	17.04	18.84	19.74	22.34	23.77	25.53	28.70	32.37	35.58	38.75	45.72	54.38
35	17.75	19.59	20.52	23.17	24.64	26.44	29.68	33.43	36.72	39.99	47.14	56.04
36	18.47	20.35	21.30	24.01	25.51	27.34	30.66	34.50	37.87	41.22	48.56	57.70
37	19.19	21.11	22.08	24.85	26.38	28.25	31.64	35.57	39.02	42.45	49.98	59.37

Table 11. Erlang B Table

6.4.1 CALL SETUP SUCCESS RATE (CSSR)

CSSR indicates the probability of successful calls initiated by MS. It is an important KPI for evaluating the network performance. If CSSR is too low, the subscribers are not likely to make calls successfully. Its value should be ≥95%

CSSR value depends on

I. SDCCH Assignment success Rate
II. SDCCH Drop Rate
III. TCH Assignment Success Rate

Process of optimisation

Find out the causes of a low CSSR.(Check whether a low CSSR is caused by SDCCH/Immediate Assignment Success Rate problems, SDCCH Drop Rate problems, or TCH Assignment Success Rate problems.) and accordingly following actions may be taken

a) Minimise SDCCH Congestion (Refer SDCCH Congestion in the same chapter)
b) Minimise SCDDH Drop (Refer SDCCH Drop in the same chapter)
c) Minimise TCH Congestion (Refer TCH Congestion in the same chapter)
d) Check Hardware/Transmission Faults and Feeder Cable Swap (if any)

e) Check value of parameters like RXLEV_ACCESS_MIN/RACH Min Access Level/Tx-integer etc.

6.4.2 CALL DROP RATE

Call drops are identified through SACCH messages. A Radio Link Failure counter (RLT) value is broadcast on the BCH. The counter value may vary from network to network. At the establishment of a dedicated channel, the counter is set to the broadcast value (which will be the maximum allowable for the connection). The mobile decrements the counter by 1 for every FER (unrecoverable block of data) detected on the SACCH and increases the counter by 2 for every data block that is correctly received (up to the initial maximum
value). If this counter reaches zero, a radio link failure is declared by the mobile and it returns back to the idle mode.
If the counter reaches zero when the mobile is on a SDCCH then it is an SDCCH Drop. If it happens on a TCH, it is a TCH drop.

Sometimes an attempted handover, which may in itself have been an attempt to prevent a drop, can result in a dropped call.

When the quality drops, a mobile is usually commanded to perform a handover. Sometimes however, when it attempts to handover, it finds that the target cell is not suitable. When this happens it jumps back to the old cell and sends a Handover Failure message to the old cell. At this stage, if the handover was attempted at the survival threshold, the call may get dropped anyway. If on the other hand the thresholds were somewhat higher, the network can attempt another handover. Call Drop Rate should be ≤ 2%.

Causes of call drop

a) Blind spot, low coverage level.
b) Unavoidable interference can be the inter network interference, interference from repeaters, or intra network interference resulting from aggressive frequency reuse.
c) Poor transmission quality and unstable transmission links over the Abis interface end other interfaces.
d) Faulty hardware/high VSWR/ Feeder Cable swap
e) Unreasonable settings of handover parameters/during inter BSC/MSC handover.
f) If pre-emption is used in MSC then lower priority MS will face call drop.
g) Unreasonable setting of radio parameters.

Process of optimisation

a) Check radio parameters. Adjust unreasonable settings of radio parameters.
b) Proper frequency plan viz. achieve minimum interference level by proper BCCH planning, HSN, MAIO planning.
c) Minimizing coverage holes by physical optimization (Orientation, Height, E.Tilt, M.Tilt).
d) Setting Radio link timeout parameter as per inter site distance viz. for rural sites RLT can be of higher value.
e) Similar for Rural site where uplink quality is poor, Rxlev Access min, Rach Access min parameter can be set appropriately. Proper balance should be maintained for this parameter else path imbalance will result and TCH drop will increase.
f) Minimize Abis and other interface fluctuation – Link stability plays very vital role.
g) Check and remove BTS/BSC hardware fault and Cable swap/high VSWR (if any).
h) During HO to neighbour cells should be having free TCH resources else call drop may increase. For this proper half rate thresholds should be defined as per traffic pattern, decongestion of these cells by capacity argument.

i) Proper Neighbour definition should be maintained – some handovers cannot be performed and thus call drops.

6.4.3 HANDOVER SUCCESS RATE (HOSR)

Handovers are meant for maintaining call continuity when subscriber crosses over from one cell to another cell. KPI to be monitored for handover performance in GSM is “Handover Success Rate”.

Handover Process: The overall handover process is implemented in the MS, BSS & MSC.

- Measurement of radio subsystem downlink performance and signal strengths received from surrounding cells, is made in the MS.
- These measurements are sent to the BSS for assessment.
- The BSS measures the uplink performance for the MS being served and also assesses the signal strength of interference on its idle traffic channels.
- Initial assessment of the measurements in conjunction with defined thresholds and handover strategy may be performed in the BSS. Assessment requiring measurement results from other BSS or other information resident in the MSC, may be perform. In the MSC.
- The MS assists the handover decision process by performing certain measurements.
- When the MS is engaged in a speech conversation, a portion of the TDMA frame is idle while the rest of the frame is used for uplink (BTS receive) and downlink (BTS transmit) timeslots.
- During the idle time period of the frame, the MS changes radio channel frequency and monitors and measures the signal level of the six best neighbour cells.
- Measurements which feed the handover decision algorithm are made at both ends of the radio link.

Process of optimisation

a) Identify the Bad performing Cells for HOSR
b) Take the detailed report showing cause & target cell
c) Check whether HO parameters are defined correctly.
d) BCCH & BSIC confusion i.e. check whether same BCCH and BSIC combination is repeated in nearby cells.
e) Minimise TCH Congestion as TCH congestion in target cell results HO fail.
f) Unnecessary Handovers – more number of handovers, higher risk of facing quality problem and even in call drop
g) Missing neighbour – Best server is not in there in neighbour list
h) Feeder cable swap
i) One way neighbour handover
j) If neighbour is defined through external cells (between cells in different OMC servers e.g. 2G-3G HO/HO b/w cells of different vendors) - need to define correct CGI, BCCH, BSIC etc. in external cells.

6.4.4 PAGING SUCCESS RATE

Paging Success rate is the percentage of valid page responses received by the system.
Paging Channel Congestion should be ≤ 1%.

Process of optimisation

a) Removal of non existing Cell site database created in BSCs
b) Correct LAC dimensioning; split LA if paging discard is due to big LA.
c) Define correct channel configuration for CCCH. Avoid combining SDCCH in the BCH+CCCH timeslot.

d) Remove SDCCH congestion in network as page response is sent to network through SDCCH.
e) Eliminate Abis /A interface congestion/error.
f) Correcting the various Paging/Location Update timers/parameters in MSC/BSC/Cell.
g) Poor Paging Success rate is also observed due to poor RF environment (Site outage/ Poor Signal Level etc.).
h) Use correct paging strategy according to network size and topology.

6.4.5 RACH SUCCESS RATE

Random Access Channel (RACH) is used by the MS on the "uplink" to request for allocation of an SDCCH. This request from the MS on the uplink could either be as a page response (MS being paged by the BSS in response to an incoming call) or due to user trying to access the network to establish a call. For all services there will CH REQ (Channel Request) from MS and in the response of CH REQ if MS will get the IMM ASS CMD (Signalling Ch) Access to system is successful. Nature of this Access REQ is random so it is call Random Access Channel Request.

Process of optimisation

a) Identify the Bad performing Cells for RACH Success Rate
b) Take detailed report and analyze for no of failure of Request and failures.
c) The main reasons for bad RACH success rate could be access from very distant place with very low coverage; Parameters Configuration discrepancies.
d) First Check for Parameters Configuration discrepancies and correct as per standard parameter set.
e) **The main parameters to be verified are**:
    - "MS MAX Retrans" allows the MS to retransmit again for AGCH by not incrementing the RACH access failure counter. It can set depending upon Traffic and Clutter.
    - "Tx-Interger" will reduce the RACH collision and can improve RACH success rate.
    - "T3122" waiting time for next network access.
    - "RACH Min.Access Level (dbm)" very important parameter for low coverage rural areas.
    - "CCCH conf" & "BS_AG_BLKS_RES" check properly defined or not? Because if you have overload with AGCH "IMM ASS" can't be send in the response of CH REQ.
f) Check for Hardware Issues (Ex. BTS sensitivity has very crucial role to play here)
g) Check for Uplink Interference and quality.
i) Check for UL-DL imbalance and correct if any problem.

6.5 DATA KPI IMPROVEMENT

6.5.1 TBF SUCCESS RATE

Temporary Block Flow (TBF) is a physical connection used by the two Radio Resource entities to support the unidirectional transfer of PDUs on packet data physical channels. The TBF is allocated radio resource on one or more PDCHs and comprises a number of RLC/MAC blocks carrying one or more LLC PDU. TBF Success Rate is when during a data session, TBFs are successfully established on UL and DL.

Process of optimisation

a) Identify the Bad performing Cells for TBF Success Rate.

b) Identify the bifurcation of Poor TBF Success Rate: whether UL or DL is poor or it is poor in both directions.
c) Take the detailed report showing (Ex. Total TBF Requests, Total TBF Success, Failure reasons)
d) Identify the failure reasons after analyzing detailed report and follow the below mentioned process.
Failure is mainly due to TBF Congestion or MS No response.

6.5.2 TBF CONGESTION:

i. Check the Static and Dynamic PDCH definition from BSC Configuration data) If you find Zero Static or Dynamic PDCH, define the same.
ii. If PDCH definition is sufficient as per the guidelines, then check whether the TBF requests are high. If requests are high, then we need to define more PDCHs in the cell. But before defining more PDCHs, check whether the Voice Utilization is not high and there is no TCH Congestion in the cell.
iii. Check Hardware/TRX alarms; Resolve if find any.
iv. Audit for any parameters related discrepancies and define as per standard parameters set.

MS No Response: RF and Environmental Factors:

i. Low Coverage Areas (Try to reduce low coverage patches with physical optimization; New sites)
ii. Interference/ Bad quality/ UL-DL Imbalance;
iii. Check the states for TRx on which PDCH is configured can be issue of TRx also; Change TRx if you found random behavior of TRx.

6.5.3 AVERAGE GPRS/EDGE RLC THROUGHPUT

Throughput is the amount of data uploaded/downloaded per unit of time.

Process of optimisation

a) Identify the Bad performing Cells for Poor GPRS/EDGE Throughput.
b) Identify the bifurcation of Poor Throughput: whether UL or DL is poor or it is poor in both directions.
c) Take the detailed report showing (Ex. Total TBF Requests, Coding Scheme Utilization)
d) Identify the cells after analyzing detailed report and follow the below mentioned process.
e) Take the configuration dump of the poor cells:
   I. Check The Static and Dynamic PDCH definition from BSC Configuration data)
   II. If you find Zero Static or Dynamic PDCH, define the same.
   III. If PDCH definition is sufficient as per the guidelines, then check whether the TBF requests are high. If requests are high, then we need to define more PDCHs in the cell. But before defining more PDCHs, check whether the Voice Utilization is not high and there is no TCH Congestion in the cell.
   IV. Check whether there are enough Idle TS defined at the site. If not, definition to be done.
f) Check whether it is due to poor radio conditions/interference; check C/I. Perform a drive test to analyze the cell in more detail.
g) Check Gb Congestion/Utilization at the BSC/PCU.
h) Check Hardware/TRX alarms; Resolve if find any.
i) Audit for any parameters related discrepancies and define as per standard parameters set.

6.5.4 DOWNLINK MULTI SLOT ASSIGNMENT SUCCESS RATE

User timeslot request based on traffic types and MS multi-timeslot capability and the actual timeslot allocated by the system which can also be termed as Downlink Multislot Assignment Success rate.

Process of optimisation

a) Identify the Bad performing Cells for Poor Poor DL Multislot Assignment.
b) Take the detailed report showing (Ex. Total TBF Requests, Failure in terms of TS requests)
c) Identify the cells after analyzing detailed report and follow the below mentioned process.
d) Take the configuration dump of the poor cells:
   I. Check The Static and Dynamic PDCH definition from BSC Configuration data)
   II. If you find Zero Static or Dynamic PDCH, define the same.
   III. If PDCH definition is sufficient as per the guidelines, then check whether the TBF requests are high. If requests are high, then we need to define more PDCHs in the cell. But before defining more PDCHs, check whether the Voice Utilization is not high and there is no TCH Congestion in the cell.
   IV. Check the multiplexing thresholds and upgrade/downgrade reports.
e) Check whether it is due to poor radio conditions/interference; check C/I. Perform a drive test to analyze the cell in more detail.
f) Check Gb Congestion/Utilization at the BSC/PCU.
g) Check Hardware/TRX alarms; Resolve if find any.
h) Audit for any parameters related discrepancies and define as per standard parameters set.

6.6 3G UMTS KPI

6.6.1 3G KPIS ARCHITECTURE

Figure 42: 3G KPI Structure

RAN KPI Class :

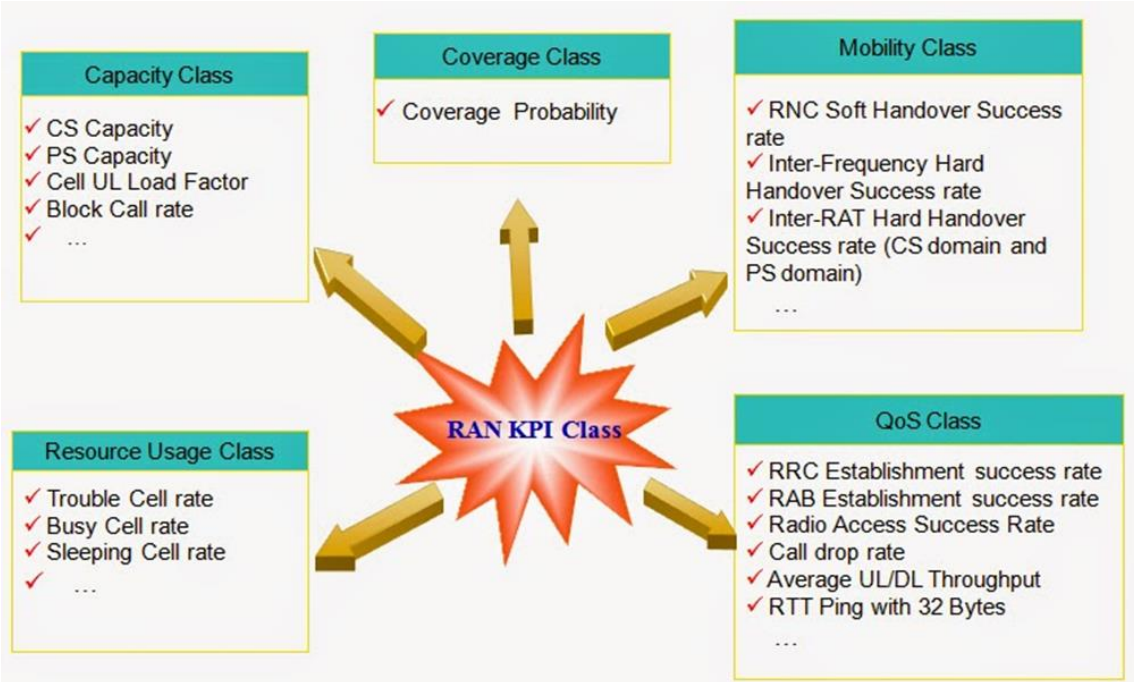


Figure 43: 3G KPI Class

6.7 4G LTE KPI

As specified in the 3GPP TS 32.451 document, there are several types of KPI parameters that are integral to any LTE network, depending on the target they measure:

- Accessibility
- Retainability
- Integrity
- Availability
- Mobility

Others can be added depending on the the network's need, such as:

- Utilization
- Traffic
- Latency

Accessibility

Accessibility is a measurement that allows operators to know information related to the mobile services accessibility for the subscriber. The measurement is performed through E-UTRAN's E-RAB service.

Retainability

Retainability measures how many times a service was interrupted or dropped during use, thus preventing the subscriber to benefit from it or making it difficult for the operator to charge for it. Therefore, a high retainability is very important from a business stand point.The measurement is performed through E-UTRAN's E-RAB service.

Integrity

Integrity measures the high or low quality of a service while the subscriber is using it.The measurement is performed through E-UTRAN's delivery of IP packets.

Availability

Availability measures a service's availability for the subscriber.The measurement is performed by determining the percentage of time that the service was available for the subscribers served by a specific cell. The measurement can also aggregate data from more cells or from the whole network.

Mobility

Mobility measures how many times a service was interrupted or dropped during a subscriber's handover or mobility from on cell to another.The measurement is performed in the E-UTRAN and will include Intra E-UTRAN and Inter RAT handovers.

KPIs for LTE RAN (Radio Access Network)

LTE KPI	INDICATORS
Accessibility KPI	• RRC setup success rate • ERAB setup success rate • Call Setup Success Rate Are used to measure properly of whether services requested by users can be accessed in given condition, also refers to the quality of being available when users needed. eg. user request to access the network, access the voice call, data call, ...
Retainability KPI	• Call drop rate • Service Call drop rate *Are used to measure how the network keep user's possession or able to hold and provide the services for the users*
Mobility KPI	• Intra-Frequency Handover Out Success Rate • Inter-Frequency Handover Out Success Rate • Inter-RAT Handover Out Success Rate (LTE to WCDMA) *Are used to measure the performance of network which can handle the movement of users and still retain the service for the user, such as handover,...*
Integrity KPI	• E-UTRAN IP Throughput • IP Throughput in DL • E-UTRAN IP Latency *Are used to measure the character or honesty of network to its user, such as what is the throughput, latency which users were served.*
Availability KPI	• E-UTRAN Cell Availability Partial cell availability (node restarts excluded) *Are used to measure how the network keep user's possession or able to hold and provide the services for the users*
Utilization KPI	• Mean Active Dedicated EPS Bearer Utilization *Are used to measure the utilization of network, whether the network capacity is reached its resource.*

Table 12. LTE KPI

6.8 TYPE OF REPORTS

- "Time consistent Busy hour" or "TCBH" means the one hour period starting at the same time each day for which the average traffic of the resource group concerned is greatest over the days under consideration and such Time Consistent Busy Hour shall be established on the basis of analysis of traffic data for a period of ninety days;
- Cell Bouncing Busy Hour (CBBH) means the one hour period in a day during which a cell in cellular mobile telephone network experiences the maximum traffic.
- Whole Day/Day Average Report means value of concerned indicator is calculated over whole day period or day average is taken.

6.9 SAMPLE TRAFFIC REPORTS

6.9.1 BSC PERFORMANCE REPORT

BSC	Call_setup_success_rate	RTCH_drop_rate	SDCCH_drop_rate	RTCH_assign_cong_rate	RTCH_HO_success_rate	RTCH_Erlang_total (Er)	SDCCH_cong_rate	GPRS_DL_TBF_estab_fail_rate	GPRS_UL_TBF_estab_fail_rate	GPRS_DL_LLC_Data MB	GPRS_UL_LLC_Data MB
BSC1	98.73%	0.98%	0.62%	0.19%	94.89%	24859.4	0.06%	3.14%	2.50%	32342.8	6012.6
BSC2	98.01%	1.02%	0.94%	0.62%	96.40%	7418.1	0.26%	3.41%	2.23%	11981.8	1894.1
BSC3	97.89%	0.99%	1.24%	0.29%	91.23%	8270.1	0.23%	3.21%	2.19%	9294.3	1478.0
BSC4	97.89%	1.06%	1.46%	0.19%	92.21%	8193.8	1.68%	3.09%	1.91%	10392.7	1648.3
BSC5	97.82%	1.23%	1.43%	0.27%	95.04%	3747.6	0.40%	2.67%	1.95%	4494.6	803.8
BSC6	97.30%	1.15%	0.94%	0.68%	69.49%	8457.3	0.62%	4.03%	2.59%	1652.2	348.3
BSC7	97.23%	1.57%	0.94%	1.20%	79.71%	11370.1	0.80%	6.98%	2.15%	14407.3	2285.1
BSC8	97.14%	2.25%	2.18%	0.23%	88.90%	723.2	1.13%	3.14%	2.43%	1969.5	275.6
BSC9	97.00%	2.62%	1.77%	0.39%	89.18%	1934.2	1.82%	11.77%	3.59%	1647.0	255.4
BSC10	96.91%	1.32%	1.08%	1.33%	92.75%	12804.6	0.79%	4.72%	2.52%	17990.4	3046.4
BSC11	94.85%	1.73%	1.58%	2.84%	91.28%	11042.4	0.72%	3.48%	1.56%	14746.4	2024.3
BSC12	94.78%	12.53%	1.86%	2.05%	88.51%	3082.5	1.79%	4.13%	2.22%	4138.4	663.6
BSC13	94.77%	0.56%	0.90%	0.63%	93.52%	8100.5	0.11%	3.27%	2.60%	7042.9	1216.7
BSC14	94.67%	1.07%	1.51%	1.05%	64.54%	7629.9	0.09%	4.17%	2.24%	7356.4	1333.8
BSC15	91.49%	1.91%	1.80%	4.16%	80.81%	15909.5	1.06%	3.46%	1.85%	19474.1	2834.1
BSC16	86.88%	1.21%	0.98%	16.49%	70.38%	1364.3	0.55%	3.85%	1.90%	1689.5	324.1

6.9.2 CELL/ TRX PERFORMANCE REPORT

Cell	CI	Number_Of_TRX	Number_Of_TCH	Call_setup_success_rate	RTCH_drop_rate	RTCH_assign_cong_rate	RTCH_assign_cong_rate_BH	RTCH_HO_success_rate	RTCH_Erlang_BH (Er)	RTCH_Erlang_total (Er)	SDCCH_cong_rate	GPRS_DL_TBF_estab_fail_rate	GPRS_UL_TBF_estab_fail_rate	GPRS_DL_LLC_Data MB	GPRS_UL_LLC_Data MB
Cell1	6517	4	27	99.46%	0.37%	0.00%	0.00%	97.57%	16.9	196.4	0.00%	1.73%	1.18%	295.8	35.7
Cell2	6518	4	27	99.15%	0.42%	0.00%	0.00%	91.77%	28	358.1	0.00%	2.94%	2.07%	443.5	66.3
Cell3	6519	4	27	98.33%	0.79%	0.00%	0.00%	95.31%	18.7	225.2	0.00%	2.35%	1.47%	469.7	75.5
Cell4	61267	2	13	97.96%	3.41%	0.25%	0.19%	Nerr	8.6	102.5	0.00%	2.29%	0.38%	236.7	20.1
Cell6	61269	2	13	36.56%	1.45%	62.88%	87.37%	Nerr	9.9	151.3	17.55%	2.58%	0.26%	375.1	40.4
Cell7	6657	3	20	92.69%	1.84%	1.39%	1.99%	85.03%	16.3	214.8	0.60%	1.37%	1.27%	56.2	13.3
Cell8	6658	4	27	99.35%	0.36%	0.00%	0.00%	98.77%	2.4	19.2	0.00%	0.82%	0.50%	101.1	18.5
Cell9	6659	3	20	98.46%	0.81%	0.12%	0.90%	98.08%	7.6	95.2	0.00%	2.97%	0.81%	39.2	5.9
Cell10	6617	4	27	99.37%	0.92%	0.03%	0.39%	97.09%	37.8	457	0.01%	2.84%	2.10%	399.8	73.6
Cell11	6618	4	27	99.30%	0.73%	0.00%	0.00%	98.47%	8.8	71.4	0.00%	2.30%	2.78%	42.8	34.0
Cell12	6619	4	27	99.29%	0.97%	0.00%	0.00%	98.29%	18.8	228.9	0.00%	2.13%	0.89%	433.8	73.1
Cell13	6997	4	29	97.14%	1.54%	1.47%	4.47%	90.38%	6.7	76.7	0.00%	2.43%	2.34%	49.0	9.4
Cell14	6998	4	29	99.28%	1.72%	0.00%	0.00%	98.58%	2	21.1	0.00%	11.26%	4.08%	3.7	1.2
Cell15	6999	4	29	97.73%	1.75%	0.03%	0.00%	97.71%	4	52.1	0.00%	3.11%	1.88%	64.2	11.8
Cell16	6527	4	26	98.88%	1.06%	0.01%	0.08%	89.30%	34.9	346.8	0.00%	4.35%	3.84%	181.2	33.2
Cell17	6528	4	27	99.02%	0.80%	0.00%	0.00%	96.71%	24.8	325.6	0.00%	2.82%	1.96%	407.0	102.8
Cell18	6529	4	27	99.34%	0.29%	0.00%	0.00%	97.35%	31.6	393.6	0.00%	2.61%	1.56%	599.9	98.9
Cell19	6587	4	28	97.60%	0.55%	1.14%	2.17%	93.61%	18.7	254.1	0.00%	1.93%	1.08%	342.5	89.4
Cell20	6588	4	28	99.45%	0.53%	0.00%	0.00%	98.15%	17.5	222.2	0.00%	1.51%	0.90%	294.4	73.8
Cell21	6589	4	28	99.55%	0.18%	0.00%	0.00%	98.76%	32	398.7	0.06%	2.52%	1.32%	328.1	97.6
Cell22	6677	4	28	98.84%	1.24%	0.00%	0.00%	97.48%	16.3	197.4	0.00%	2.42%	1.01%	277.4	32.5
Cell23	6678	4	28	99.21%	0.75%	0.00%	0.00%	97.72%	22.9	258	0.00%	2.93%	0.84%	464.9	71.2
Cell24	6679	4	28	99.09%	1.19%	0.00%	0.00%	95.66%	20.4	254.6	0.00%	0.72%	0.57%	581.1	52.1
Cell25	6537	4	27	98.94%	0.49%	0.00%	0.00%	97.20%	22.1	283.9	0.00%	1.31%	1.15%	486.0	58.0
Cell26	6538	4	27	99.43%	0.44%	0.02%	0.00%	98.27%	18.8	232.4	0.00%	1.72%	1.35%	319.9	48.2
Cell27	6539	4	26	96.76%	0.52%	2.79%	18.01%	77.28%	50.8	662.6	0.00%	2.98%	1.47%	405.4	76.8
Cell28	6547	4	27	96.38%	1.01%	0.00%	0.00%	92.52%	20.9	272.5	0.01%	4.27%	3.07%	255.7	69.0
Cell29	6548	4	27	98.90%	1.30%	0.00%	0.00%	86.85%	27.6	358	0.00%	3.72%	7.64%	283.1	55.2
Cell30	6549	4	26	99.21%	0.36%	0.13%	0.25%	94.37%	41.1	487	0.04%	4.64%	2.66%	292.2	61.3
Cell31	6597	4	26	92.40%	3.76%	0.01%	0.00%	95.05%	11.7	157	0.00%	11.50%	3.03%	34.1	6.0
Cell32	6598	2	12	94.18%	2.54%	0.17%	0.00%	98.55%	6.7	74.5	0.00%	5.72%	2.17%	37.3	7.2

TRX	ALLOC_SDCCH_CARR	ALLOC_TCH_CARR	BUSY_TCH_CARR_MEAN	BUSY_TCH_MAX	DL_BER_TRX	UL_BER_TRX
Cell 1/TRX1	52946	3951	0.67	5	5.36	3.88
Cell 1/TRX2	7534	1220	0.15	5	5.95	5.97
Cell 1/TRX3	6	1456	0.18	6	4.55	5.64
Cell 1/TRX4	0	7073	1.12	8	4.52	5.56
Cell 2/TRX1	0	2399	0.77	8	1.84	3.66
Cell 2TRX2	0	2334	0.74	8	1.92	4.38
Cell 3/TRX1	58350	3595	0.95	5	3.03	1.87
Cell 3TRX2	13346	16531	3.39	14	4.17	4.3
Cell 3/TRX3	93	22312	4.52	16	3.25	4.06
Cell 3/TRX4	0	18161	3.52	16	2.73	3.17
Cell 4/TRX1	0	14122	2.46	14	1.59	5.01
Cell 4TRX2	0	15560	2.53	14	1.45	4.45
Cell 5/TRX1	77402	4001	0.88	5	4.43	3.56
Cell 5/TRX2	40662	13110	2.32	12	6.01	9.03
Cell 5/TRX3	45556	14013	2.34	12	5.96	8.62
Cell 5/TRX4	0	13001	2.59	15	3.35	5.96
Cell 6/TRX1	0	10772	3.32	15	6.17	6.77
Cell 6TRX2	0	11567	3.44	15	6.86	6.75

6.10 CONCLUSION

KPIs are important as they calibrate the network to a specific level. With KPIs standerization of network can be done

7 MOBILE SALES MANAGEMENT (BCCS, FRANCHISE MANAGEMENT, SALES CHANNEL MANAGEMENT) AND SANCHARSOFT

7.1 LEARNING OBJECTIVE

After completion of this chapter participants will understand:

- Billing process in CMTS
- Billing System Components
- Difference between Mobile Billing and Land line Billing
- Role of CSC/CSR
- BSNL Sales Structure
- Sancharsoft

7.2 BASIC FEATURES OF MOBILE BILLING NETWORK

- The GSM Cellular network includes a state of art billing and customer care system supporting several customer friendly features. The Network is identified as local access in the entire licensed service area as against the SDCA based local area. The components of the Mobile Billing have different elements like airtime charges, roaming charges, messaging charges, and value added service charges apart from PSTN charges for inter network traffic.
- There are other differences like the concept of a prepaid and post paid. It is envisaged that the volumes in case of prepaid services will be more than the post-paid services. Further there would be a dealer and distributor network in place, which would be a significant activity in terms of interaction with the billing system.
- While considering the design, structure and organizational framework, there is a need to have a system that incorporates efficient practices. It is very important to incorporate the responsibilities attached to the activities of commercial and financial nature at appropriate levels.

7.3 MOBILE NETWORK HARDWARE

- The Mobile network consists of zonal Billing and Customer Care System (BCCS) catering to more than one licensed service area. The BCCS will have CSR (Customer Service Representative) terminals that will be stationed in different locations across the circle. A CSR terminal can also be networked through a Local Area Network to enable a number of persons to key in data and work in the system. These terminals have capabilities to interact with the BCCS in respect of provisioning, billing, collections and trouble ticketing.
- While CSR terminals can provide varied functions, access to these functions is controlled through defining the roles of each terminal and also depending on level of staff and officers manning such terminals. Normal functions such as data feeding, creation of account, trouble ticketing and generation of duplicate bill shall only be available at front-end Basic Level CSRs. All other functions such as service provisioning, activation, billing etc. shall be handled at terminals designated as High Level CSRs.

7.4 MOBILE BILLING AND CUSTOMER CARE COMPARED TO BASIC SERVICES

The activities will be dependent on the nature of system design and operations. This essentially consists of a centralized Billing and Customer Care System (BCCS) through which are linked a number of CSR terminals located all over the circle and across different circles in a zone. These terminals have the facility to enable multifarious activities like provisioning, creation of customer information, billing, interacting with billing system, collections, reports, trouble ticketing, querying on various aspects. Unlike basic services, various commercial, billing and accounting functions are integrated in a single system using shared common database of customers, service subscriptions etc. This would enable overcoming the inherent coordination problems faced hitherto, by virtue of having easy access to the common database for various functional needs from the CSR terminals. This facilitates CMTS business units to have an organization and a system, which can be managed by a flat and a non-hierarchical set up.

7.5 BASIC CONCEPTS

- Network Access to BCCS from CSR.
- Network access from CSR terminals can be segmented to serve a particular part of the service area, a group of MSISDN (Mobile Subs) etc on the basis of the specific criteria. This feature would enable CSRs to be assigned to deal with specific geographical segments.
- CSR would have functional segmentation, assigning specific functions to particular CSR terminals. For example, a CSR could be assigned only for order entry and querying on bills.
- Regulated and buffered access for the channel partners, as and when so decided. (Channel partners are the Dealers and Distributors appointed for promoting CMTS).

7.6 ACTIVITIES AND RESPONSIBILITY CENTRES

- GSM Mobile network includes a state-of art Billing and Customer Care System (BCCS) supporting several customer friendly features. Apart from capturing the billing related data, the BCCS also integrates a data communications network with Customer Support Representative (CSR) terminals spread across the entire zone. CSR terminals are conceived to be the gateways for accessing the sophisticated facilities built into the BCCS for providing quick and complete customer care. Some of the salient features of the CSR are:
- On-line creation of Account and support for hierarchical account creation with parent-child relationship.
- On line creation, suspension, withdrawal of service including provisioning, addition, modification, suspension and withdrawal of a host of supplementary and value added services.
- Complaint management.
- Contract management

7.7 ROLE OF CUSTOMER SERVICE CENTERS (CSCS)

- CSCs of BSNL would provide excellent visibility for the mobile service.
- CSCs are to serve as direct sales outlets of BSNL but not to be predominant avenues for BSNL mobile products. There has to be synergy in operations with Channel partners.
- Service and product marketing, to a large extent, would be channel driven.
- Channel partners to provide first level customer care with well-defined multi-level escalation procedures.
- CSC locations to facilitate market intervention by BSNL and to regulate the conduct of the channel partners.
- CSC to play a vital role in the Brand building exercise and not primarily as sales outlet.

7.8 ROLE OF CSRS

Basic level CSR in CSCs shall address primary customer needs i.e. receipt of order forms and feeding them, handling customer queries for services, sale of prepaid cards, issuance of duplicate bills, trouble ticketing etc and handling other requests for facility provisioning and counseling on tariff plans. Higher-level CSR shall address in addition to basic functionalities, the service provisioning aspects, activation, billing etc and transactions with Channel partners.

7.8.1 CSR LOCATION

- Basic level CSR to be located in the CSCs. These CSRs shall be under control of an officer/official not below the rank of Group C.
- Higher level CSRs to be located at the SSA HQs. These terminals will handle responsible activities, which are elaborated subsequently. They will also provide support for the channel partners. The extent of deployment shall match the response time specified for the channel partners. These CSRs shall input the data received from channel partners in batch mode. These CSRs shall be under control of an officer not below the rank of Group B. An officer with suitable aptitude and credentials may be selected.

7.8.2 CSR FUNCTIONALITIES:

- Any terminal connected to BCCS through CSR can be designated to handle any type of Commercial, Billing & Accounting and Customer Care activities / functionalities. The functionalities will include commercial & customer care activities like receipt of application forms, feeding them, activation of accounts after verification of credit limits, activation of pre paid cards, handling of customers' queries and trouble ticketing on services and tariff and billing functionalities like printing of bills, issue of duplicate of bills, bill modifications / corrections wherever necessary, receipt and accounting of payments, watching of payments and taking follow up action wherever payments are not made, authorising disconnections for non payments and reconnections, follow up action for recovery of outstanding dues of disconnected lines and, preparation of accounting statements to a limited extent, customers' record updation regarding payments etc.
- Considering the accessibility to all types of functionalities from CSR terminals, access to information based on the level and role assigned to the user, would be restricted through suitable login and password.

7.9 CIRCLE (LICENSE AREA) LEVEL

The circle for CMTS Services would normally be the license area. In many cases, the area of CMTS circle would be different from that of basic services. Since CMTS Circle is identified as SBU (Strategic Business Unit) there will be a responsibility centre at the Circle Level which will get sub-ledger reports for all units generated by the system, giving information on monthly billings, collections, revenue per line, revenues from pre-paid cards, statements for revenue sharing with other service providers/carriers etc, collection efficiency, reduction of outstanding, clarification on billing and collection matters. Co ordination and control unit for mobile operations comprising GM (Mobile services), DGM (Finance) of CMTS, Marketing and Commercial officers shall form part of the same to review and handle all issues relating to billing and collection mechanism. This set up will also carry out revenue-tariff correlation analysis and propose tariff rebalancing / product repositioning / product repackaging proposals to Corporate office for consideration. Circles will also propose implementation schedule (i.e. dates of launching of alternative packages and their currency). Different tariff plans approved for various circles shall be implemented on dates and during periods as approved by corporate office.

7.10 BSNL SALES STRUCTURE AND CHANNELS

Initially BSNL did not have a well-defined exclusive sales structure. The concept of commercial officer, CSCs and Marketing agents was expanded by introduction of franchisees with the launch of BSNL mobile services in October 2002. Since then, a strong need was felt to strengthen sales channels in BSNL and also to create sales role specific job structure in BSNL. In October 2009, as part of Project Shikhar, a new sales setup has been designed. Consumer mobility and Consumer Fixed Access verticals have dedicated GM/DGM rank officers at Corporate as well as Circle level to plan, manage and effect retail sales. The following are sales channels of BSNL:

7.10.1 FRANCHISEES

BSNL has put in place Franchisee Sales & Distribution policy 2009.A comprehensive Sales & Distribution Policy is also being worked out. Franchisees are appointed through EOI route by respective SSAs. Salient features of this scheme are:

- Well defined geographical area for franchisee called as primary area
- Exclusive franchisee showroom as per design specified by BSNL
- Franchisees to appoint Feet on Street (FoS)
- Franchisee shop to open 0800h to 2200h
- Financial penalty for not meeting cut off performance score
- Franchisee can appoint any number of sub franchisees/retailers on nonexclusive basis.

Franchisees play a very important role in serving customers across the country and improve BSNL visibility. BSNL is yet to build the reach comparable to competitors. In order to motivate franchisees, time to time reward scheme are introduced.

7.10.2 DIRECT SELLING AGENTS (DSA'S):

Any 10th pass can become a DSA. Retired BSNL employees/spouses can also become DSAs. The objective is to sell BSNL services door to door extending ultimate convenience to BSNL customers. Any number of DSAs can be appointed by SSA Heads.

7.10.3 ANY OTHER RETAIL OUTLETS:

Any other outlets such as shopping malls, post offices etc. can also be appointed as DSA to sell BSNL services with the approval of concerned CGM. BSNL has also allowed to appoint Service Centre Agents (SCA) of Common Service Centres (CSC) of Department of Information Technology being setup in rural areas across the country as DSAs. DIT is setting up 1,12,000 CSCs and is expected to strengthen BSNL's reach.

7.10.4 EPIN FRANCHISEES:

BSNL has also appointed EPIN franchisees across the country. All recharge vouchers, sancharnet card, VCC card etc. have a secret PIN for use of respective service. These PINs are sold in bulk to appointed franchisees. Any Indian Registered company / Registered Cooperative Society / Registered NGO fulfilling prescribed criteria can become Circle level or All India level franchisee. For Circle level franchisees, the commission structure depends on the type of agreement i.e. exclusive or non-exclusive. All India franchisees are appointed on non-exclusive basis. These franchisees can sell these PINs through point of sales terminal or through PC connected to main server of franchisee.

7.10.5 BUSINESS ASSOCIATES (BA'S):

These are now handled by Enterprise Business/Business Development units. Their primary job is to sell Data services but they are allowed to sell complete range of BSNL services to act as single window Total telecom Solution provider to enterprise customers.

7.10.6 WEB SELF CARE (WSC):

Sales are possible through link provided on BSNL website www.bsnl.co.in . VCC card, Call Now, FLPP and mobile recharge vouchers can be purchased with the help of Internet banking account of certain banks such as ABN, AXIS, BoB, BoI, BoP, IDBI, PNB, SBI, UBI etc.

7.10.7 SALES TEAMS:

Heads of SSA have to appoint a suitable BSNL executive preferable CSC incharge to act as single window interface for the franchisees. Nodal officer is required to maintain inventory, stock register and reconcile revenue and sales made by franchisees. Minimum three months inventory has to be stocked by SSAs. In October 2008, BSNL decided to appoint sales staff in each SSA.Each circle has been asked to appoint 250-300 sales teams. Each team comprises of 4-6 Telephone mechanics, TOAs lead by JTO/SDE/Sr SDE rank officer. 4-6 such teams have to report to an officer of AGM rank who has to be allocated specific sales targets by SSA Head. Existing line staff accepting sales duty is being designated as Retailer Manager. Special teams are being appointed under Project Udaan and Project Vijay. Very lucrative reimbursement schemes have been put in place. For example under Project Vijay, travel & meal allowance varying from Rs 1300-Rs 2600 is allowed to sales team member depending on their quantum of work. Similarly for Udaan sales team leader & sales associates Rs 1400/- per month is allowed towards meal & travel expenses.

Sales software in CRM module of CDR project: As part of BSNL CDR/Convergent billing project under commissioning, a centralized CRM module having sales features is also being put in place for handling all BSNL service as a single window concept. Functions like lead generation, lead qualification, selling to a retail new/existing customer will be available.

7.11 SANCHARSOFT

Sancharsoft is a web application created for the management of SIM, Recharge Coupons & Top up Cards of Mobile Services of BSNL.

- It is an Inventory Management Package.
- Management Reports are hosted on intranet.bsnl.co.in.

7.11.1 SANCHARSOFT: TECHNICAL DETAILS

It is a web based package created on MS IIS platform using asp (MS Active server pages technology & Javascript). All the CSR clients can access to the web service and can login using their username & password. All Dealers, DSA's and Retailers can use the service via secure network when extended to them.

7.11.2 OBJECTIVE OF SANCHARSOFT

Sancharsoft is a tool for Management of

- CMTS Sales and Distribution Network.
- Franchises and Retailers performance Monitoring.
- DSA and BSNL Shoppe Performance Monitoring.

- Other Channel Partners like BPCL, Handset Vendors.
- Franchise and Retailers Database Management and Reporting.
- Payment of Commission.
- Reconciliation of Recharge Vouchers with revenue realized.
- Reconciliation of CTOPUP revenue realized v/s CTOPUP carried out.
- Monitoring of Inventory levels with Franchisee, Retailers and DSA/PCOs.

7.11.3 CAPABILITIES OF SANCHARSOFT

- Sales and Distribution.
- Auto Activation, deactivation and swapping of prepaid cards.
- Recharge voucher enabling, Damaged card blocking.
- Franchisee, Retailer and Other channels Performance Monitoring.

7.11.4 LIMITATION OF SANCHARSOFT

- Accounting- it is an inventory package to facilitate the invoice.
- Real time utilization of Infrastructure details like equipped capacity etc. Can't handle other products like Landline, Broadband.

7.11.5 THREE KEY MODULES OF SANCHARSOFT.

SIM Module

- (Activations, CAF-Customer Application Form) SIM Allotment upto POS (Point Of Sale) and Retailer Network.
- Invoice Generation.
- SIM Activation.
- CAF Monitoring, CAF Information Storage and retrieval.
- Dynamic Stock and Sale Report.

Recharge Module

- Opening Balance Coupon Loading (one time only during Change Over) • Ease of Distribution and Sales.
- Expiry / missing cards blocking.

C-TOP Module.

- CTOP UP Sales from nearest CSC.
- Cash receipt/revenue reports.
- Sales Reconciliation.
- Performance Monitoring.
- Balance and status of any CTOP number to Franchises / CSC / FMT / RMC. FMT-Franchisee Manager Team, RMC- Retailer Manager Coordinator)

7.11.6 BENEFITS OF SANCHARSOFT.

1. SIM Module
   - (Activations, CAF-Customer Application Form)
   - At a glance report of BSNL S&D (Sales and Distribution).
   - CAF and SIM Tracking.
   - Available cards stock with Retailers / Franchisees.
   - Commission and Retention bonus reports.
   - Direct activation by retailer possible.

- CAF submission due, Retailer Activation Report, CAF Collection from retailer by courier can be implemented.

2. Recharge Module.
- Ease of Sales and Distribution down the line to Franchisee and
- Retailers.
- Auto Voucher enabling, blocking etc.
- Franchisee / Retailers Target monitoring.
- Easier and Faster replacement of damaged cards.

3. C-TOP Module.
- Sales Report and Balance Report of Franchisee to FMT.
- Sales and Balance Report of Retailers to Franchisee.
- Overall performance of Franchisee including CTOP sales / Voucher sales.
- Easier Access to CTOP – i.e. Sales form CSC instead of SSA HQ.
- Direct SIM commission remittance to CTOP number – for Franchisee / Retailer.

7.11.7 SANCHARSOFT MENU

The various menus used for Prepaid, Recharge / Topup cards are:

- Home
- Prepaid
- Recharge
- Replacement
- Stock
- Re-printing
- Reports
- Query
- Dealer sales

7.11.8 SANCHARSOFT EXAMPLE WINDOW

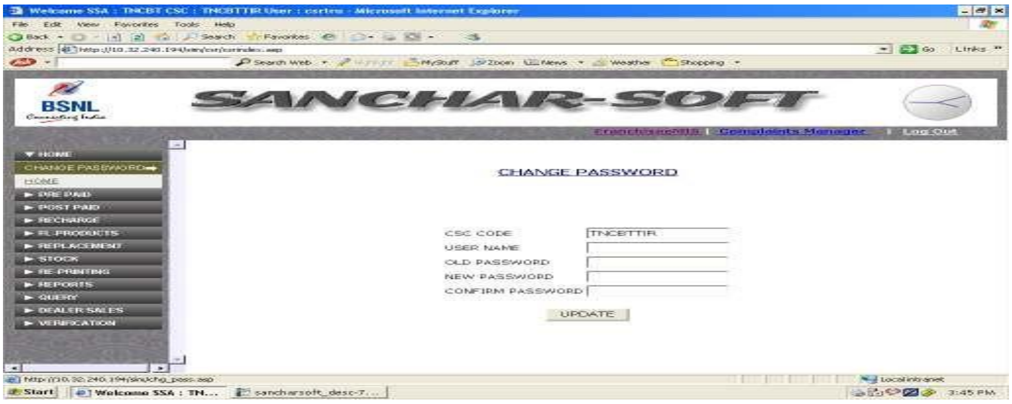


Figure 44: Sancharsoft

Prepaid Menu
- Normal
- Prepaid by choice
- Discount sale.

Recharge Menu
- Coupons
- CTOPUP Standard
- CTOPUP Flexi

- Delete Uploaded.
- Coupon Blocking
- Offline sales.

Replacement Menu

- SIM Cards
- Replacement – Recharge / Top-Up coupons
- Stock Menu
- Stock return
- Stock Diversion
- Stock indent
- Reprinting
- Prepaid
- Replacement
- CTOPUP recharge
- PCO/DSA invoice
- Stock return

Reports

- Daily statement
- Consolidated sales
- Stock

7.12 CONCLUSION

Billing and sanchsoft is important tool for Sales and Distribution.

8 3G MOBILE NETWORK

8.1 LEARNING OBJECTIVE

After completion of this chapter student will able to understand:

- The Universal Mobile Communication Services (UMTS) and its benefits over the 2G mobile Communication
- Technologies used in UMTS
- Wideband Code Division Multiple Access technology
- WCDMA Radio network system architecture.
- UMTS core network elements
- Various domains in 3G Core Network

8.2 INTRODUCTION

3G refers to the 3rd generation of mobile telephony (that is cellular) technology. The 3rd generations the name suggests, follow two earlier generations. The 1st generation (1G) began in the early80's with commercial development of advanced mobile phone service (AMPS) cellular networks. Early AMPS network used frequency division multiplex access (FDMA) to carry analogy voice over channels in the 800MHZ frequency band. The 2nd generation (2G) emerged in the 90's when mobile generators deployed two competing digital voice standards. In the North America, some operators adopted IS-95, which uses CDMA to multiplex up to 64 calls per channel in the 800MHZ band. Across the world, many operators adopted the global system for mobile communication (GSM) standard, which used the time division multiple accesses (TDMA) technique to multiplex up to 8 calls per channel in the 900MHZ and 1800MHZ spectrum bands.

The international telecommunication union (ITU) defined the 3rd generation (3G) of mobile telephony standards IMT-2000 to facilitate growth, increase bandwidth and support more diverse applications. Some of the limitations of 2Gsystems, it's only voice oriented, it has limited data capabilities, no worldwide (WW) roaming and incompatible system in different countries. Despite the extension of 2G system i.e. 2.5G such as GPRS and EDGE, which provides the enhanced facilities and much improved data rates, but there was still incompatibility issues and WW-roaming problems. Therefore, there was a need of a system that could provide more advanced services. Some of the features of the 3G systems are:

- Bit rates up to 2Mbps
- Variable bit rate to offer bandwidth on demand
- Multiplexing of services with different Qos requirements on a single connection
- Quality requirements from 10% frame error rate to 10-6 bit error rate.
- Co-existence with different systems and inter-system handovers for coverage enhancement sand loading balancing.
- Uplink and downlink asymmetry e.g. web browsing causes more loading to downlink than to uplink.
- High spectrum efficiency
- Co-existence of FDD (Frequency division duplex) and TDD (time division duplex) modes

8.3 3G STANDARDS AND WCDMA RELEASES

Universal Mobile Telecommunication System (UMTS) is the standard for European 3G based WCDMA systems which turned out to be the preferred solution for countries with 2G because of its high data capability. The 3rd Generation Partnership Project (3GPP) manages the UMTS and has assumed responsibility for the continued standardization of GSM since July 2000. If we recall the first commercial UMTS network was deployed in 2001 by NTT Do Como in Japan after since then other countries soon took the same step in deploying the network including Germany, UK, France etc. During the development of the UMTS specifications for the WCDMA systems within the3GPP, it went through a series of phases and continuous update for instance the first UMTS specification released which is known as the 3GPP *Release-99* which was functionally frozen in December 1999, which then implemented similar services with those of GSM phase 2+(GPRS/EDGE). However the 3G network might still offer additional services which are not available on the GSM platform e.g. video call. In the second phase brought about the3GPP *Release- 4* which would introduce mainly an all IP-Core Network which would allow for the separation of call signalling and control from all actual connections i.e. within the core network the flow of data will pass through a media gateway (MGW) which would in turn maintain the connection and perform other switching functions this approach was known as *Soft Switching*, however release-4 became frozen in march 2001because of newer releases to be introduced. After a while there was another release termed as the 3GPP *Release 5* which introduced the IP Multimedia Subsystem (IMS) which would unify and perform all IP based multiservice i.e. a combination of more than one service on a physical channel to a user e.g. voice & video or image. The introduction of HSDPA and wide band AMR services are evolution of the Air Interface in order to enhance the speed of the data rate, which was done by integrating the voice data on the dedicated channel and data on the downlink shared channel are all multiplexed and carried on the same carrier which allows for speed up to 14.Mbps.

However release 5 specifications were soon frozen in 2002, nevertheless subsequent releases within the specifications occur mainly with the transport technology; basically the changes are made to improve the flexibility and efficiency of the operating network.

UMTS is an International Mobile Telecommunications - 2000 (IMT-2000) 3G system. The other main IMT–2000 system proposed by the ITU is CDMA 2000.

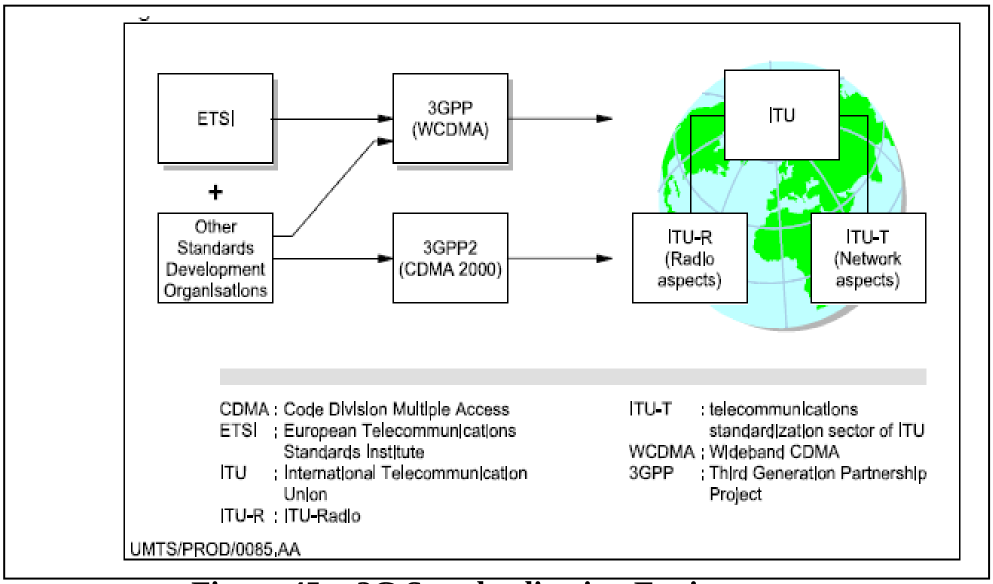


Figure 45: 3G Standardization Environment

8.4 Overview of UMTS release architectures

This section provides a general description of the current standard UMTS release architectures. UMTS architectures provide a smooth transition from second generation telecommunications systems by slowly phasing in new software and new network elements.

a) 3GPP currently defines standards for the following UMTS releases
b) 3GPP Release 99 (R99),
c) 3GPP Release 4 (Next Generation Network (NGN) architecture),
d) 3GPP Release 5 (all-IP core network).

Note : Release 2000 (R00) is split into "Release 4" and "Release 5".

<table>
<tr><th colspan="2" rowspan="2">3GPP Release</th><th colspan="2">Radio Access Networks (RANs)</th><th colspan="3">Core Network</th></tr>
<tr><th>BSS elements</th><th>UTRAN elements</th><th>CSCN elements</th><th>PSCN elements</th><th>common elements</th></tr>
<tr><td colspan="2">R99</td><td rowspan="3">BSC
BTS</td><td rowspan="3">RNC
Node B</td><td>MSC
GMSC
IWF</td><td rowspan="3">SGSN
GGSN
BG</td><td rowspan="2">HLR
VLR
AuC
EIR
SMS MSCs</td></tr>
<tr><td rowspan="2">R00</td><td>R4 (NGN architecture)</td><td rowspan="2">R99 elements
+
MSC server
GMSC server
MGW</td></tr>
<tr><td>R5 (All-IP core network)</td><td>R99 and R4 elements
+
HSS
IM subsystem</td></tr>
</table>

Figure 46: Summary of 3GPP network architectures

8.5 WCDMA RADIO ACCESS NETWORK

The main purpose of the WCDMA Radio Access Network is to provide a connection between the handset and the core network and to isolate all the radio issues from the core network. The advantage is one core network supporting multiple access technologies. The WCDMA Radio Access Network consists of two types of nodes:

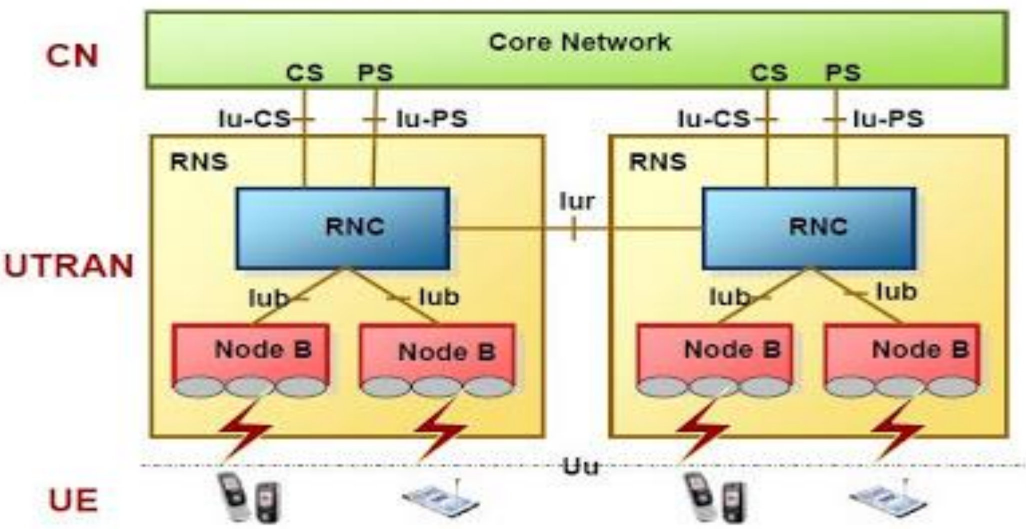


Figure 47: WCDMA Radio Access Network

8.6 RADIO BASE STATION (NODE B)

The Radio Base Station handles the radio transmission and reception to/from the handset over the radio interface (Uu). It is controlled from the Radio Network Controller via the Iub interface. One Radio Base Station can handle one or more cells.

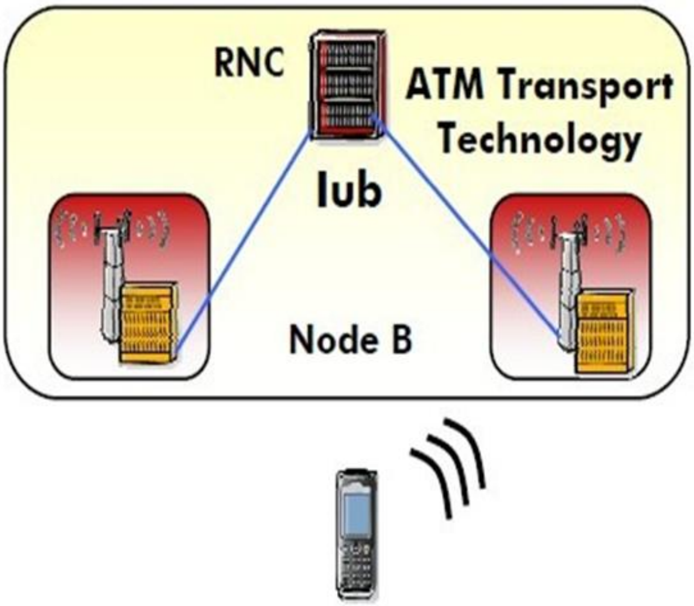


Figure 48: WCDMA Node B

8.6.1 FUNCTIONS OF NODE B:

- Radio transmission and reception handling
- Involved in the mobility management
- Involved in the power control
- Modulation / Demodulation
- Closed loop power control

8.7 RADIO NETWORK CONTROLLER (RNC)

The Radio Network Controller is the node that controls all WCDMA Radio Access Network functions. It connects the WCDMA Radio Access Network to the core network via the Iu interface. There are two distinct roles for the RNC, to serve and to control. The Serving RNC has overall control of the handset that is connected to WCDMA Radio Access Network. It controls the connection on the Iu interface for the handset and it terminates several protocols in the contact between the handset and the WCDMA Radio Access Network. The Controlling RNC has the overall control of a particular set of cells, and their associated base stations.

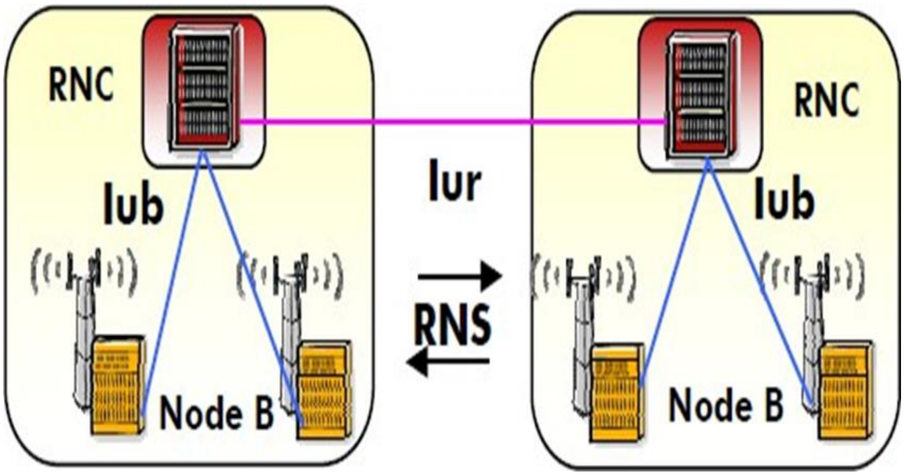


Figure 49: Radio Network Controller

Main Functions of this Intelligent part of UTRAN System includes;

- Radio resource management (code allocation, Power Control,
- congestion control, admission control)
- Call management for the users
- Connection to CS and PS Core Network
- Radio mobility management

When a handset must use resources in a cell not controlled by its Serving RNC, the Serving RNC must ask the Controlling RNC for those resources. This request is made via the Iur interface, which connects the RNCs with each other. In this case, the Controlling RNC is also said to be a Drift RNC for this particular handset. This kind of operation is primarily needed to be able to provide soft handover throughout the network.

8.8 RADIO ACCESS BEARERS

The main service offered by WCDMA RAN is the Radio Access Bearer (RAB). To establish a call connection between the handset and the base station a RAB is needed. Its characteristics are different depending on what kind of service/information to be transported. The RAB carries the subscriber data between the handset and the core network. It is composed of one or more Radio Access Bearers between the handset and the Serving RNC, and one Iu bearer between the Serving RNC and the core network. 3GPP has defined four different quality classes of Radio Access Bearers:

- Conversational (used for e.g. voice telephony) – low delay, strict ordering
- Streaming (used for e.g. watching a video clip) – moderate delay, strict ordering
- Interactive (used for e.g. web surfing) – moderate delay
- Background (used for e.g. file transfer) – no delay requirement

8.9 3G CORE NETWORK (CN)

The 3G UMTS core network architecture is a migration of that used for GSM with further elements overlaid to enable the additional functionality demanded by UMTS. The core network provides all the central processing and management for the system. The CN is similar to the network and switching subsystem (NSS) of the GSM architecture. The main function of the CN is to perform packet routing, connection of users, security, billing etc. The core network is the overall entity that interfaces to external networks including the public phone network and other cellular telecommunications networks.

The UMTS Core Network elements can be categorised into two domains depending on the type of traffic and functions they handle.

- Circuit switched elements: These elements are primarily based on the GSM network entities and carry data in a circuit switched manner, i.e. a permanent channel for the duration of the call.
- Packet switched elements: These network entities are designed to carry packet data. This enables much higher network usage as the capacity can be shared and data is carried as packets which are routed according to their destination.

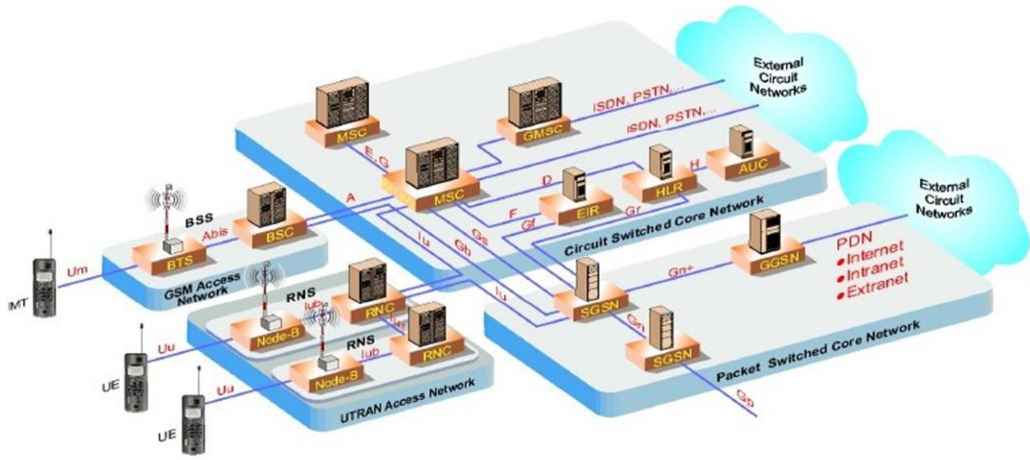


Figure 50: UMTS Core Network

8.10 CIRCUIT SWITCHED CORE NETWORK

The circuit switched elements of the UMTS core network architecture include the following network entities:

8.10.1 MOBILE SWITCHING CENTRE (MSC):

The MSC is the interface between the Radio Access Network (RAN) and fixed networks. It provides mobility management, call control and switching functions to enable circuit-switched services to and from mobile stations.

8.10.2 GATEWAY MSC (GMSC):

The GMSC interfaces with the fixed networks, handles subscriber location information from the HLR and performs routing functions to and from mobile stations. GMSC functionality can be contained in all or some of the MSCs of the network, depending on network configuration.

8.11 PACKET SWITCHED ELEMENTS

Packet Switched core network includes elements that support packet switching technology. Packet-switching technology routes packets of user data independently of one another. No dedicated circuit is established. Each packet can be sent along different circuits depending on the network resources available. The packet switched elements of the 3G UMTS core network architecture include the following network entities:

8.11.1 SERVING GPRS SUPPORT NODE (SGSN):

As the name implies, this entity was first developed when GPRS was introduced, and its use has been carried over into the UMTS network architecture. The SGSN provides a number of functions within the UMTS network architecture.

- **Mobility Management:** When a UE attaches to the Packet Switched domain of the UMTS Core Network, the SGSN generates MM information based on the mobile's current location.

- **Session Management:** The SGSN manages the data sessions providing the required quality of service and also managing what are termed the PDP (Packet data Protocol) contexts, i.e. the pipes over which the data is sent.

- **Interaction with other areas of the network:** The SGSN is able to manage its elements within the network only by communicating with other areas of the network, e.g. MSC and other circuit switched areas.

- **Billing:** The SGSN is also responsible billing. It achieves this by monitoring the flow of user data across the GPRS network. CDRs (Call Detail Records) are generated by the SGSN before being transferred to the charging entities (Charging Gateway Function, CGF).

8.11.2 GATEWAY GPRS SUPPORT NODE (GGSN):

Like the SGSN, this entity was also first introduced into the GPRS network. The Gateway GPRS Support Node (GGSN) is the central element within the UMTS packet switched network. It handles inter-working between the UMTS packet switched network and external packet switched networks, and can be considered as a very sophisticated router. In operation, when the GGSN receives data addressed to a specific user, it checks if the user is active and then forwards the data to the SGSN serving the particular UE.

8.11.3 BORDER GATEWAY (BG)

The BG provides connectivity, and interworking and roaming capabilities between two different PLMNs.

8.12 SHARED ELEMENTS

Some network elements, particularly those that are associated with registration are shared by both domains and operate in the same way that they did with GSM. The shared elements of the 3G UMTS core network architecture include the following network entities:

8.12.1 HOME LOCATION REGISTER (HLR)

This database contains all the administrative information about each subscriber along with their last known location. In this way, the UMTS network is able to route calls to the relevant RNC / Node B. When a user switches on their UE, it registers with the network and from this it is possible to determine which Node B it communicates with so that incoming calls can be routed appropriately. Even when the UE is not active (but switched on) it re-registers periodically to ensure that the network (HLR) is aware of its latest position with their current or last known location on the network.

8.12.2 VISITOR LOCATION REGISTER(VLR)

The VLR manages mobile subscribers in the home PLMN and those roaming in a foreign PLMN. The VLR exchanges information with the HLR.

8.12.3 EQUIPMENT IDENTITY REGISTER (EIR)

The EIR is the entity that decides whether a given UE equipment may be allowed onto the network. Each UE equipment has a number known as the International Mobile Equipment Identity. This number, as mentioned above, is installed in the equipment and is checked by the network during registration.

8.12.4 AUTHENTICATION CENTRE (AUC)

The AuC is a protected database that contains the secret key also contained in the user's USIM card.

8.12.5 EQUIPMENT IDENTITY REGISTER (EIR)

The EIR stores information on mobile equipment identities.

8.12.6 SMS MSCS

SMS MSCs enable the transfer of messages between the Short Message Service Center and the PLMN.

8.13 ENHANCEMENT IN UMTS ARCHITECTURE IN FUTURE RELEASES

The first enhancement was the bearer independent circuit switched core network in release 4. In this architecture, the mobile switching centre is split in two. The circuit switched media gateway (CS-MGW) handles the traffic functions of the MSC, but uses different transport protocols that we will see in the next section. It also includes a media conversion function, which allows it to communicate with networks that are using other types of transport protocol. The MSC server combines the signalling functions of the MSC with those of the VLR, and also controls the CS-MGW over a signalling interface that lies between them. A GMSC server is built in the same way.

The main network enhancement in release 5 is the IP multimedia subsystem (IMS). This is an extra network which interfaces with the packet switched domain, and which provides users with real time packet switched services that cannot be supplied using the packet switched domain alone. The home subscriber server (HSS) was also introduced in release5, and combines the functions of the HLR and the AuC. The third release5 enhancement (not shown in the figure) is an architectural feature known as IuFlex. In earlier releases, each radio network controller was connected to just one MSC and one SGSN. IuFlex introduces a more flexible architecture in which each RNC can be connected to multiple MSCs and multiple SGSNs.

The main release 6 enhancement is wireless local area network (WLAN) interworking. This allows users to access the network operator's packet switched services using a wireless LAN. The services are supplied either by the IMS, or by data servers that are controlled by the network operator and directly connected to a GGSN. The connection uses some extra core network components that are not shown in the figure, known as the WLAN access gateway (WAG) and packet data gateway (PDG).

8.14 CONCLUSION

WCDMA is very successful technology due to its robust radio network design. By virtue of WCDMA and frequency reuse the capacity and of WCDMA system is increased tremendously. But with the introduction of Data on mobile WCDMA has lost its shine as it deliveries very less data rates. Thus WCDMA has been migrated to newer technologies such as LTE and LTE Advance.

9 4G MOBILE NETWORK

9.1 LEARNING OBJECTIVES

After completion of this chapter participant will able to understand about:

- LTE Network Component
- 4G Core Network
- Elements of 4G Core
- Functionalities of 4G Core Network Elements

9.2 THE NEED FOR 4G – LTE- GROWTH OF MOBILE DATA

For many years, voice calls dominated the traffic in mobile telecommunication networks. The growth of mobile data was initially slow, but in the years leading up to 2010 its use started to increase dramatically. To illustrate this, Figure shows Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2016–2021 of the total traffic being handled by networks throughout the world, in exabytes (1million terabytes) per month. The figure covers the period from January 2016 to July 2021, during which time the amount of data traffic increased by a factor of over 100.. For example, Figure shows forecasts by Analysys Mason of the growth of mobile traffic in the period from 2011 to 2016. Note the difference in the vertical scales of the two diagrams. In part, this growth was driven by the increased availability of 3.5G communication technologies. More important, however, was the introduction of the Apple iPhone in 2007, followed by devices based on Google’s Android operating system from 2008. These smartphones were more attractive and user-friendly than their predecessors and were designed to support the creation of applications by third party developers. The result was an explosion in the number and use of mobile applications, which is reflected in the diagrams. As a contributory factor, network operators had previously tried to encourage the growth of mobile data by the introduction of flat rate charging schemes that permitted unlimited data downloads. That led to a situation where neither developers nor users were motivated to limit their data consumption. As a result of these issues, 2G and 3G networks started to become congested in the years around 2010, leading to a requirement to increase network capacity.

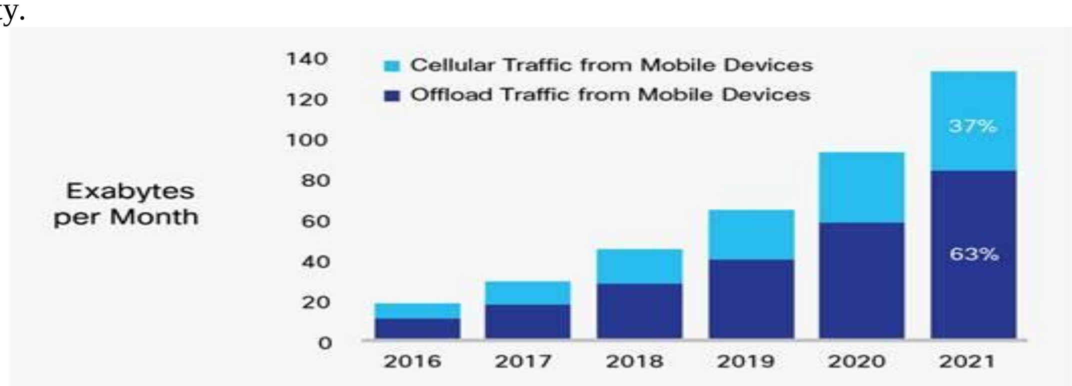


Figure 51: Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update, 2016–2021

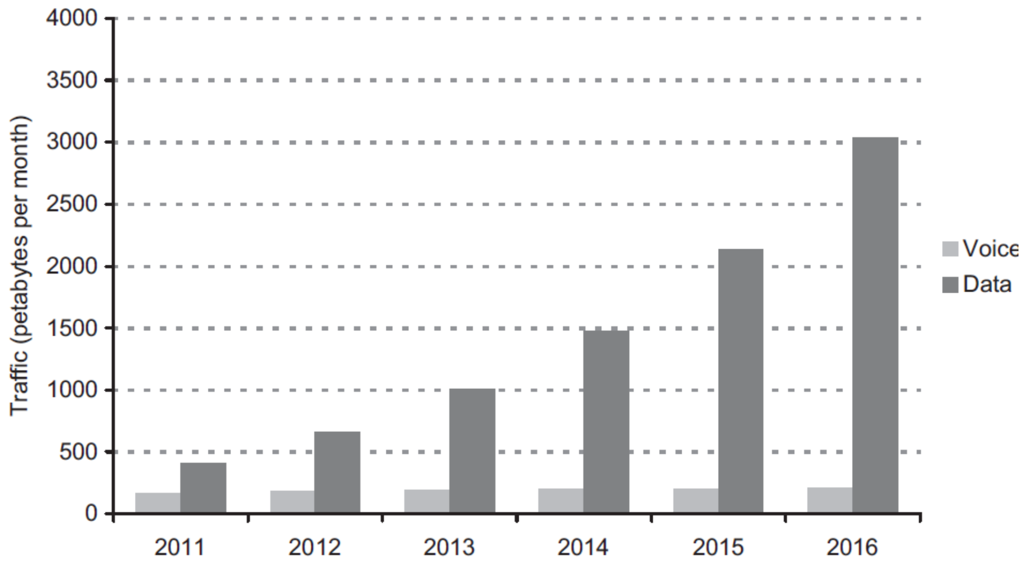


Figure 52: Forecasts of voice and data traffic in worldwide mobile telecommunication networks, in the period from 2011 to 2016. Data supplied by Analysys Mason.

In the next section, we review the limits on the capacity of a mobile communication system and show how such capacity growth can be achieved.

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 . We will write it in its simplest form, as follows:

C = B log2 (1 + SINR)

Here,

SINR is the 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 and interference.

B is the bandwidth of the communication system in Hz,

C is the channel capacity in bits per sec .

It is theoretically possible for a communication system to send data from a transmitter to a receiver without any errors at all, provided that the data rate is less than the channel capacity.

In a mobile communication system, 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 in Figure, using bandwidths of 5, 10 and 20 MHz. 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 log10 (SINR)

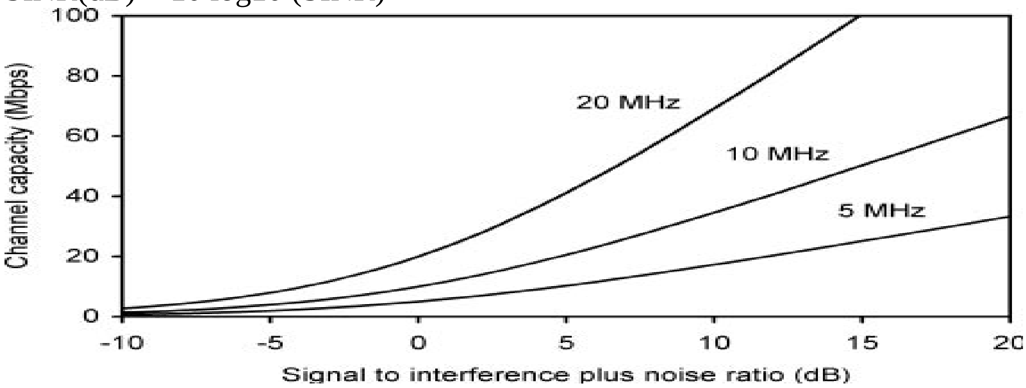


Figure 53: Shannon capacity of a communication system, in BW of 5, 10 and 20 MHz.

9.2.1 INCREASING THE SYSTEM CAPACITY

There are three main ways to increase the capacity of a mobile communication system, which we can understand by inspection of Equation and Figure. The first, and the most important, is the use of smaller cells. In a cellular network, the channel capacity is the maximum data rate that a single cell can handle. By building extra base stations and reducing the size of each cell, we can increase the capacity of a network, essentially by using many duplicate copies of Equation above.

The second technique is to increase the bandwidth. Radio spectrum is managed by the International Telecommunication Union (ITU) and by regional and national regulators, and the increasing use of mobile telecommunications has led to the increasing allocation of spectrum to 2G and 3G systems. However, there is only a finite amount of radio spectrum available and it is also required by applications as diverse as military communications and radio astronomy. There are therefore limits as to how far this process can go.

The third technique is to improve the communication technology that we are using. This brings several benefits: it lets us approach ever closer to the theoretical channel capacity, and it lets us exploit the higher SINR and greater bandwidth that are made available by the other changes above. This progressive improvement in communication technology has been an ongoing theme in the development of mobile telecommunications and is the main reason for the introduction of LTE.

9.2.2 ADDITIONAL MOTIVATIONS

Three other issues are driving the move to LTE. Firstly, a 2G or 3G operator has to maintain two core networks: the circuit switched domain for voice, and the packet switched domain for data. Provided that the network is not too congested, however, it is also possible to transport voice calls over packet switched networks using techniques such as voice over IP (VoIP). By doing this, operators can move everything to the packet switched domain, and can reduce both their capital and operational expenditure.

In a related issue, 3G networks introduce delays of the order of 100 milliseconds for data applications, in transferring data packets between network elements and across the air interface. This is barely acceptable for voice and causes great difficulties for more demanding applications such as real-time interactive games. Thus a second driver is the wish to reduce the end-to-end delay, or latency, in the network.

Thirdly, the specifications for UMTS and GSM have become increasingly complex over the years, due to the need to add new features to the system while maintaining backwards compatibility with earlier devices. A fresh start aids the task of the designers, by letting them improve the performance of the system without the need to support legacy devices.

9.3 FROM UMTS TO LTE , HIGH LEVEL ARCHITECTURE OF LTE

In 2004, 3GPP began a study into the long term evolution of UMTS. The aim was to keep 3GPP's mobile communication systems competitive over timescales of 10 years and beyond, by delivering the high data rates and low latencies that future users would require. Figure shows the resulting architecture and the way in which that architecture developed from that of UMTS.

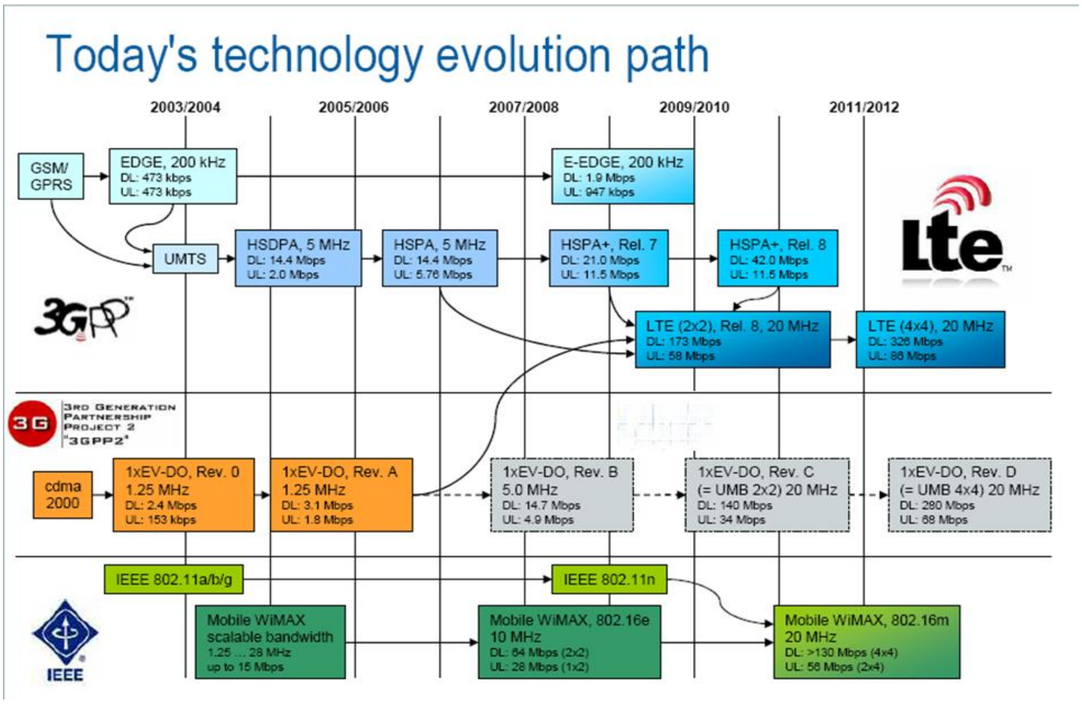


Figure 54: Technology Migration

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 communications 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 network, and long term evolution (LTE), which covered the radio access network, air interface and mobile. Officially, the whole system is known as the evolved packet system (EPS), while the acronym LTE refers only to the evolution of the air interface. Despite this official usage, LTE has become a colloquial name for the whole system, and is regularly used in this way by 3GPP.

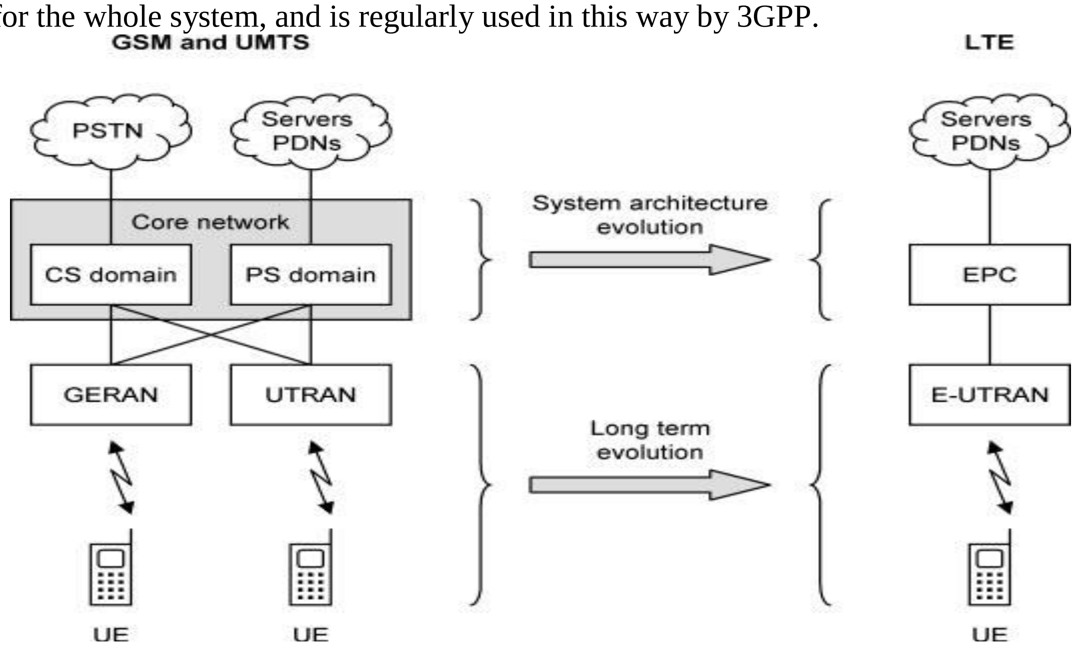


Figure 55: Evolution of the system architecture from GSM and UMTS to LTE.

9.3.1 LONG TERM EVOLUTION

The main output of the study into long-term evolution was a requirements specification for the air interface , in which the most important requirements were as follows.

LTE was required to deliver a peak data rate of 100 Mbps in the downlink and 50 Mbps in the uplink. This requirement was exceeded in the eventual system, which delivers peak data rates of 300 Mbps and 75 Mbps respectively.

For comparison, the peak data rate of WCDMA, in Release 6 of the 3GPP specifications, is 14 Mbps in the downlink and 5.7 Mbps in the uplink. It cannot be stressed too strongly, however, that these peak data rates can only be reached in idealized conditions, and are wholly unachievable in any realistic scenario.

A better measure is the spectral efficiency, which expresses the typical capacity of one cell per unit bandwidth. LTE was required to support a spectral efficiency three to four times greater than that of Release 6 WCDMA in the downlink and two to three times greater in the uplink. Latency is another important issue, particularly for time-critical applications such as voice and interactive games. There are two aspects to this.

Firstly, the requirements state that the time taken for data to travel between the mobile phone and the fixed network should be less than five milliseconds, provided that the air interface is uncongested. Secondly, that mobile phones can operate in two states: an active state in which they are communicating with the network and a low-power standby state. The requirements state that a phone should switch from standby to the active state, after an intervention from the user, in less than 100 milliseconds. There are also requirements on coverage and mobility. LTE is optimized for cell sizes up to 5 km, works with degraded performance up to 30 km and supports cell sizes of up to 100 km. It is also optimized for mobile speeds up to 15 km per hr, works with high performance up to 120 km per hr and supports speeds of up to 350 km per hr. Finally, LTE is designed to work with a variety of different bandwidths, which range from 1.4MHz up to a maximum of 20 MHz. The requirements specification ultimately led to a detailed design for the LTE air interface.

Feature	WCDMA	LTE
Multiple access scheme	WCDMA	OFDMA and SC-FDMA
Frequency re-use	100%	Flexible
Use of MIMO antennas	From Release 7	Yes
Bandwidth	5 MHz	1.4, 3, 5, 10, 15 or 20 MHz
Frame duration	10 ms	10 ms
Transmission time interval	2 or 10 ms	1 ms
Modes of operation	FDD and TDD	FDD and TDD
Uplink timing advance	Not required	Required
Transport channels	Dedicated and shared	Shared
Uplink power control	Fast	Slow

Table 13. Summarizes its key technical features, and compares them with those of WCDMA.

9.3.2 SYSTEM ARCHITECTURE EVOLUTION

The main output of the study into system architecture evolution was a requirements specification for the fixed network , in which the most important requirements were as follows.

The evolved packet core routes packets using the Internet Protocol (IP) and supports devices that are using IP version 4, IP version 6, or dual stack IP version 4/version 6. In addition, the EPC provides users with always-on connectivity to the outside world, by setting up a basic IP connection for a device when it switches on and maintaining that connection until it switches off. This is different from the behaviour of UMTS and GSM, in which the network only sets up an IP connection on request and tears that connection down when it is no longer required.

The EPC is designed as a data pipe that simply transports information to and from the user: it is not concerned with the information content or with the application. This is similar to the behaviour of the internet, which transports packets that originate from any application software, but is different from that of a traditional telecommunication system, in which the voice application is an integral part of the system. Because of this, voice applications do not form part of LTE: instead, voice calls are controlled by some external entity such as the IP multimedia subsystem (IMS). The EPC simply transports the voice packets in the same way as any other data stream.

Unlike the internet, the EPC contains mechanisms to specify and control the data rate, error rate and delay that a data stream will receive. There is no explicit requirement on the maximum time required for data to travel across the EPC, but the relevant specification suggests a user plane latency of 10 milliseconds for a non roaming mobile, increasing to 50 milliseconds in a typical roaming scenario . To calculate the total delay, we have to add the earlier figure for the delay across the air interface, giving a typical delay in a non roaming scenario of around 20 milliseconds.

The EPC is also required to support inter-system handovers between LTE and earlier 2G and 3G technologies. These cover not only UMTS and GSM, but also non 3GPP systems such as cdma2000 and WiMAX. Tables. summarize the key features of the radio access network and the evolved packet core, and compare them with the corresponding features of UMTS.

Feature	UMTS	LTE
Radio access network components	Node B, RNC	eNB
RRC protocol states	CELL_DCH, CELL_FACH, CELL_PCH, URA_PCH, RRC_IDLE	RRC_CONNECTED, RRC_IDLE
Handovers	Soft and hard	Hard
Neighbour lists	Always required	Not required

Table 14. Key features of the radio access networks of UMTS and LTE

Feature	UMTS	LTE
IP version support	IPv4 and IPv6	IPv4 and IPv6
USIM version support	Release 99 USIM onwards	Release 99 USIM onwards
Transport mechanisms	Circuit & packet switching	Packet switching
CS domain components	MSC server, MGW	n/a
PS domain components	SGSN, GGSN	MME, S-GW, P-GW
IP connectivity	After registration	During registration
Voice and SMS	Included	External

Table 15. Key features of the core networks of UMTS and LTE

9.4 FROM LTE TO LTE-ADVANCED

9.4.1 THE ITU REQUIREMENTS FOR 4G

The design of LTE took place at the same time as an initiative by the International Telecommunication Union. In the late 1990s, the ITU had helped to drive the development of 3G technologies by publishing a set of requirements for a 3G mobile communication system, under the name International Mobile Telecommunications (IMT) 2000. The 3G systems noted earlier are the main ones currently accepted by the ITU as meeting the requirements for IMT-2000.

The ITU launched a similar process in 2008, by publishing a set of requirements for a fourth generation (4G) communication system under the name IMT-Advanced [9–11]. According 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 40 MHz. We can see right away that these figures exceed the capabilities of LTE.

9.5 LTE NETWORK ARCHITECTURE

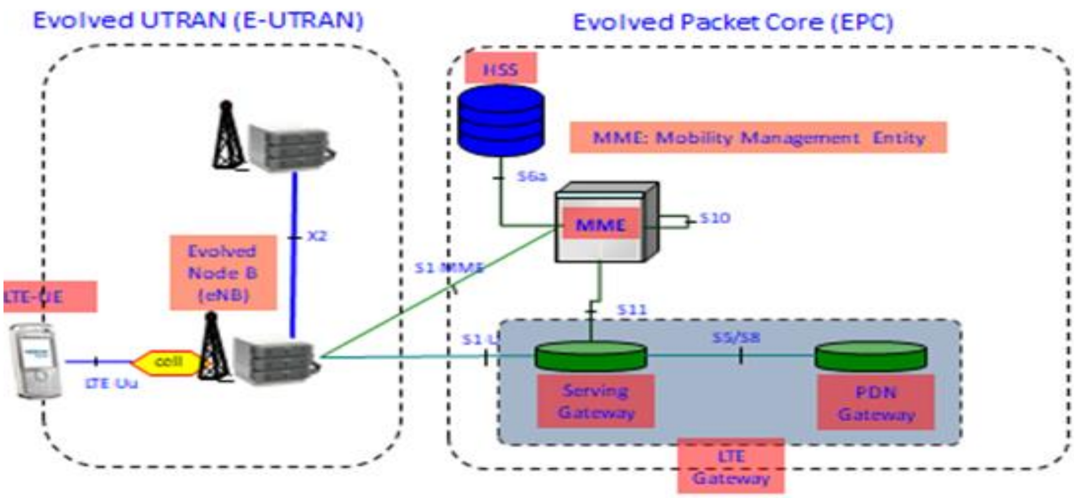


Figure 56: LTE Network Architecture

Main Functions of Evolved Node B (eNB)

- It is the only network element defined as part of EUTRAN.
- It replaces the old Node B / RNC combination from 3G.
- It terminates the complete radio interface including physical layer.
- It provides all radio management functions
- An eNB can handle several cells.
- To enable efficient inter-cell radio management for cells not attached to the same eNB, there is a inter-eNB interface X2 specified. It will allow to coordinate inter-eNB handovers without direct involvement of EPC during this process.

Mobility Management Entity (MME)

- It is a pure signaling entity inside the EPC.
- LTE uses tracking areas to track the position of idle UEs. The basic principle is identical to location or routing areas from 2G/3G.

- MME handles attaches and detaches to the LTE system, as well as tracking area updates
- Therefore it possesses an interface towards the HSS (home subscriber server) which stores the subscription relevant information and the currently assigned MME in its permanent data base.
- A second functionality of the MME is the signaling coordination to setup transport bearers (LTE bearers) through the EPC for a UE.
- MMEs can be interconnected via the S10 interface
- It generates and allocates temporary ids for UEs

Serving Gateway (SGW)

- The serving gateway is a network element that manages the user data path (bearers) within EPC.
- It therefore connects via the S1-U interface towards eNB and receives uplink packet data from here and transmits downlink packet data on it.
- Thus the serving gateway is some kind of distribution and packet data anchoring function within EPC.
- It relays the packet data within EPC via the S5/S8 interface to or from the PDN gateway.
- A serving gateway is controlled by one or more MMEs via S11 interface.
- At a given time, the UE is connected to the EPC via a single Serving-GW

Packet Data Network (PDN) Gateway

- The PDN gateway provides the connection between EPC and a number of external data networks.
- Thus it is comparable to GGSN in 2G/3G networks.
- A major functionality provided by a PDN gateway is the QoS coordination between the external PDN and EPC.
- Therefore the PDN gateway can be connected via S7 to a PCRF (Policy and Charging Rule Function).
- If a UE is connected simultaneously to several PDNs this may involved connections to more than one PDN-GW

9.6 VOICE OVER LTE (VOLTE)

Voice over LTE, or VoLTE is the standards definition for the delivery of services currently provided via Circuit Switch networks - mainly voice and SMS - over the Packet Switched only network of LTE, leveraging the core network IP Multimedia Sub-System (IMS). When mobile networks deploy LTE radio access technology, conformity to the VoLTE profile provides operators with assurance of interworking between their LTE network and the devices that connect to it, as well as providing for the expected user experience of voice Multi-Media Telephony service and SMS. In combination with Policy Control, IMS provides for the required QoS appropriate for voice service using LTE radio access technology, thereby providing the user experience of voice calls that subscribers expect. Moreover, VoLTE is designed to fully integrate with the existing user experience that is currently implemented with circuit switched voice devices, and therefore whether the call is a circuit switched call or a VoLTE call is transparent to the end user (including when moving in and out of LTE coverage) and is dependent only on which radio access technology to which the user is attached. At the same time, using new, wideband codecs can provide higher voice quality and enhance the user experience.

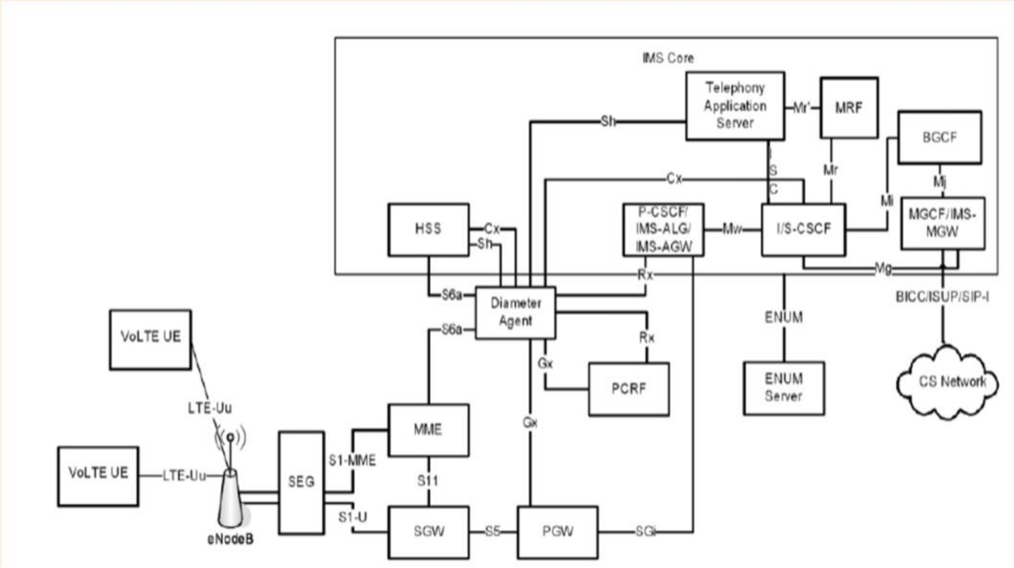


Figure 57: VoLTE Architecture

9.7 CONCLUSION

In this chapter we have studied about LTE Technologies. LTE along with VoLTE is perfect match for modern day voice and data.

10 CONCEPT OF SON

10.1 LEARNING OBJECTIVES

After completion of this chapter participant will able to understand about:

- Concept of SON
- SON Implementation
- Issues in SON implementation
- SON Data Creation
- Automatic handover in SON

10.2 INTRODUTION

Self Organising Network (SON) is a collection of procedures (or functions) for automatic configuration, optimization, diagnostication, and healing of cellular networks. It is considered to be a major necessity in future mobile networks and operations mainly due to possible savings in capital expenditure (CAPEX) and operational expenditure (OPEX) by introducing SON.

The drivers for SON are:

- The number and complexities of networks, nodes, elements and parameters
- Existence of multi-technology, multi-vendor and multi-layer operations within the network
- Traffic growth and capacity management
- Consistent quality and service availability
- The need for knowledge-based and interactive networks

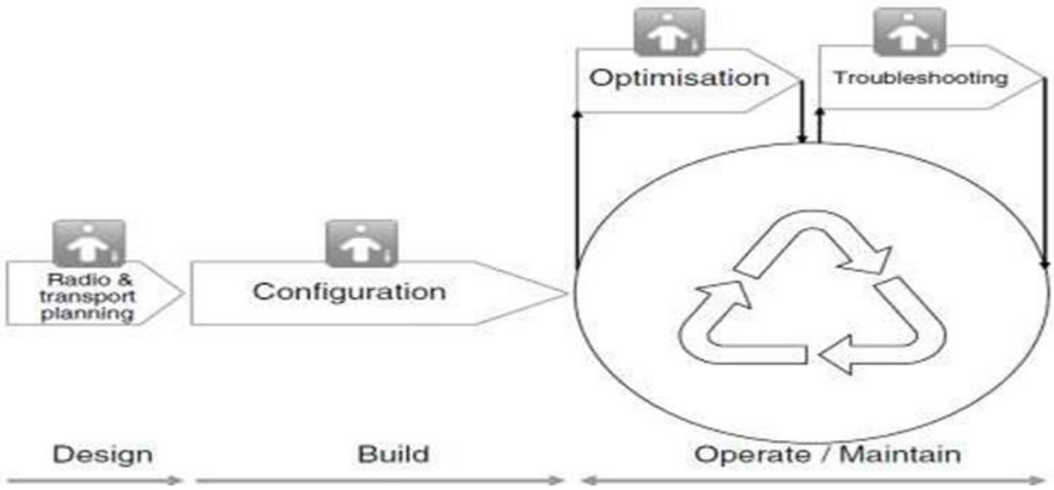


Figure 58: Network without SON Capability

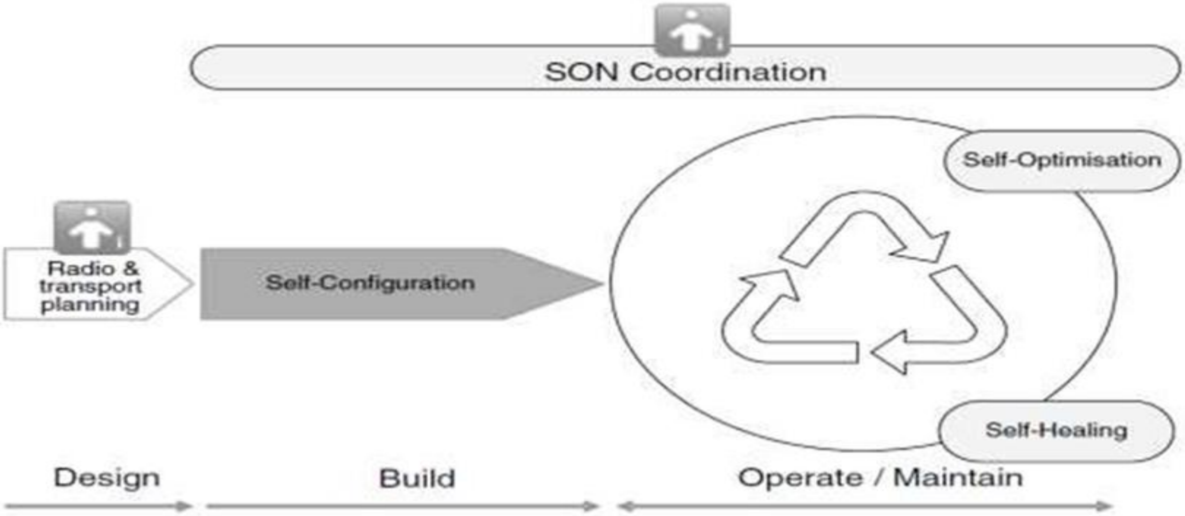


Figure 59: Network with SON Capability

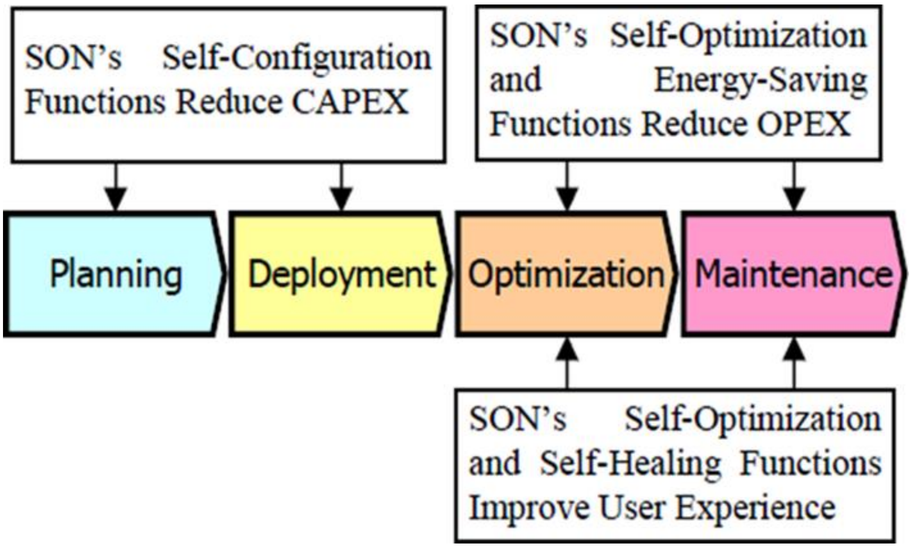


Figure 60: Benefits of SON

The main benefits of introducing SON functions in cellular networks are as follows.

- Reduced installation time and costs.
- Reduced OPEX due to reductions in manual efforts in connection with monitoring, optimizing, diagnosing, and healing of the network.
- Reduced CAPEX due to more optimized use of network elements and spectrum.
- Improved user experience.
- Improved network performance

10.3 SELF ORGANIZING NETWORKS (SON) CONCEPT

The SON functions are usually categorized into three main groups: Self-configuration, self-optimization, and self-healing. It should be noted that a given SON function can belong to more than one of these categories.

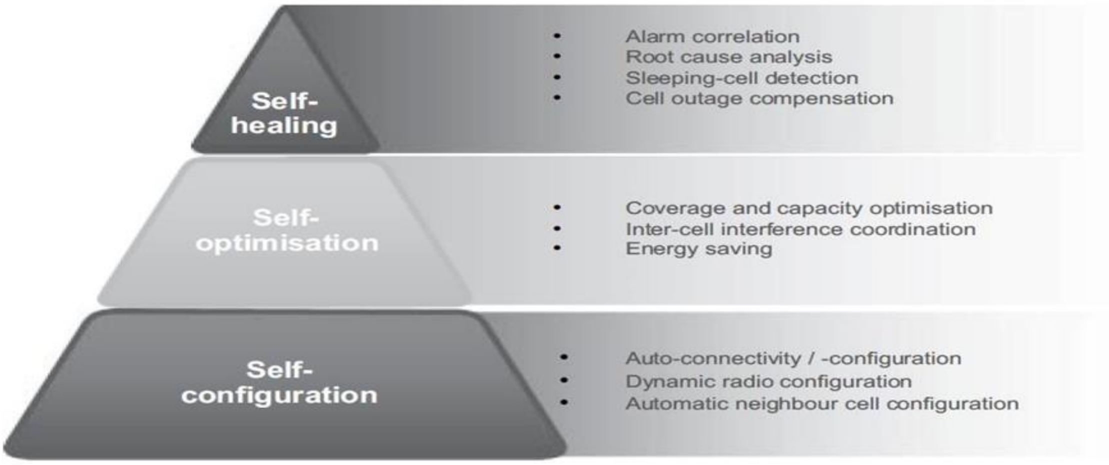


Figure 61: Functions of SON

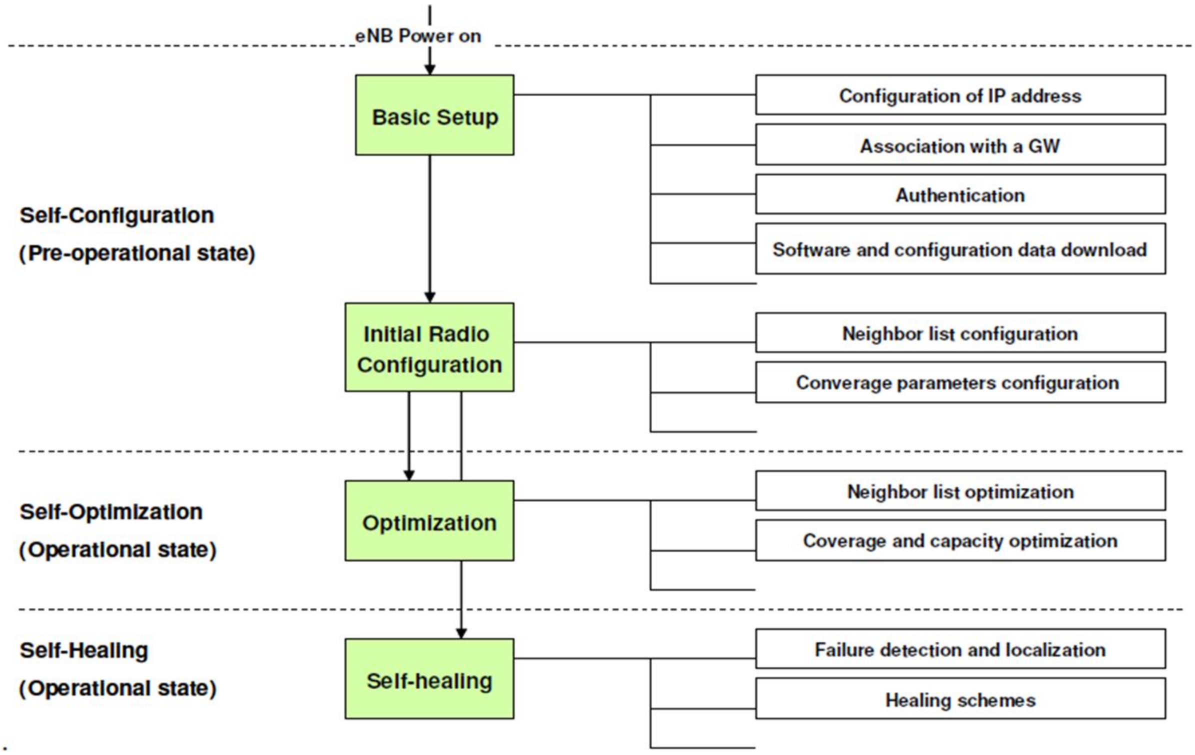


Figure 62: 3GPP SON FRAMEWORK

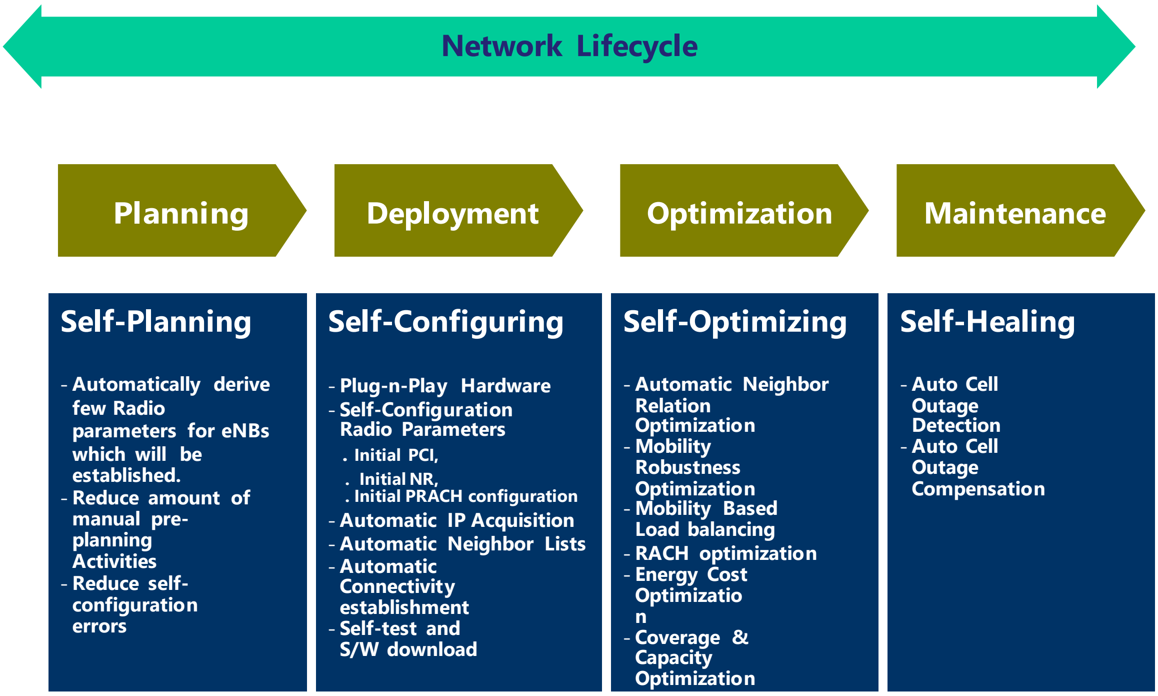


Figure 63: SON Technology

10.3.1 SELF CONFIGURATION

The Self-configuration SON is a collection of algorithms that aims at reducing the amount of human intervention in the overall installation process by providing “plug and play” functionality in network elements such as the E-UTRAN NodeBs (eNBs). This will result in faster network deployment and reduced costs for the operator in addition to a more integral inventory management system that is less prone to human errors. This process involves three key operations: set-up, authentication and radio configuration.

Self-configuration is a broad concept which involves several distinct functions that are covered through specific SON features, such as automatic software management, self test, Physical cell ID configuration (PCI), and automatic neighbor relations (ANR). The latter function is not only used during installation but is also an important part during normal operations.

The self-configuration should take care of all soft- configuration aspects of an eNB once it is commissioned and powered up for the first time. It should detect the transport link and establish a connection with the core network elements, download and upgrade to the latest software version, set up the initial configuration parameters including neighbor relations, perform a self-test, and finally set itself to operational mode. In order to achieve these goals, the eNB should be able to communicate with several different entities.

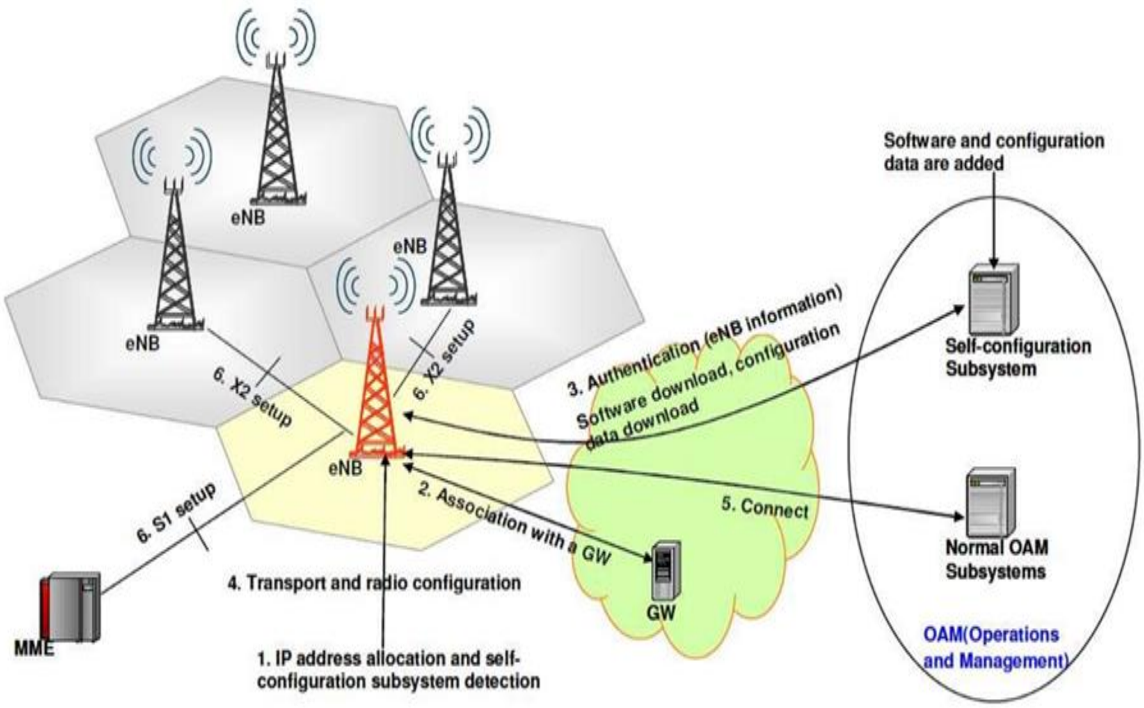


Figure 64: Self Configuration Procedure

The self-configuration actions will take place after the eNBs physically installed, plugged to the power line and to the transport link. When it is powered on, the eNB will boot and perform a self test, followed by a set of self-discovery functions, which include the detection of the transport type, tower-mounted amplifier (TMA), antenna, antenna cable length and auto-adjustment of the receiver-path.

After the self-detection function, the eNB will configure the physical transport link autonomously and establish a connection with the DHCP/DNS (dynamic host configuration protocol/domain name server) servers, which will then provide the IP addresses for the new node and those of the relevant network nodes, including serving gateway, mobility management entity (MME), and configuration server. After this, the eNB will be able to establish secure tunnels for operations administration and maintenance (OAM), S1, andX2linksandwillbereadytocommunicatewiththeconfiguration server in order to acquire new configuration parameters.

One of the OAM tunnels created will communicate the eNB with a dedicated management entity, which contains the software package that is required to be installed. The eNB will then download and install the corresponding version of the eNB software, together with the eNB configuration file. Such configuration file contains the preconfigured radio parameters that were previously planned. A finer parameter optimization will take place after the eNB is in operational state (self-optimization functions).

The self-configuration SON functions were among the first standardized by 3GPP (release 8) and have been more or less stable since then. From the roadmaps of different vendors it can be concluded that self-configuration SON is available and mature. These SON features will be extremely useful in the rollout phase to reduce the installation time compared with ordinary installation procedures, and also later when new eNBs are added to increase the network capacity. The actual decrease in OPEX is not easy to give since the corresponding installation without any (self) automatic features is difficult to foresee.

The self configuration procedures for LTE presents three automated processes: Self configuration of eNB, Automatic Neighbour Relations (ANR) and Automatic Configuration of Physical Cell ID (PCI).

10.3.2 SELF CONFIGURATION OF ENB

This is relevant to a new eNB trying to connect to the network. It is a case where the eNB is not yet in relation to the neighbour cells, but to the network management subsystem and the association of the new eNB with the serving gateway (S-GW). It is the basic set-up and initial radio configuration. The stepwise algorithm for self configuration of the eNB is outlined:

1. The eNB is plugged in/powered up.
2. It has established transport connectivity until the radio frequency trans- mission is turned on.
3. An IP address is allocated to it by the DHCP/DNS server.
4. The information about the self configuration subsystem of the Operation and Management (O & M) is given to the eNB.
5. A gateway is configured so that it connects to the network. Since a gateway has been connected on the other side to the internet, therefore, the eNB should be able to exchange IP packets with the other internet nodes.
6. The new eNB provides its own information to that self configuration subsys- tem so that it can get authenticated and identified.
7. Based on these, the necessary software and information for configuration (radio configuration) are downloaded.
8. After the download, the eNB is configured based on the transport and radio configuration downloaded.
9. It then connects to the Operation Administration Management (OAM) for any other management functions and data-ongoing connection.
10. The S1 and X2 interfaces are established.

10.3.3 AUTOMATIC NEIGHBOUR RELATIONS (ANR)

ANR is an automated way of adding/deleting neighbour cells. ANR relies on user equipment (UE) to detect unknown cells and report them to eNBs. Its operation can be summarized into: measurements, detection, reporting, decision (add/delete cell) and updating.

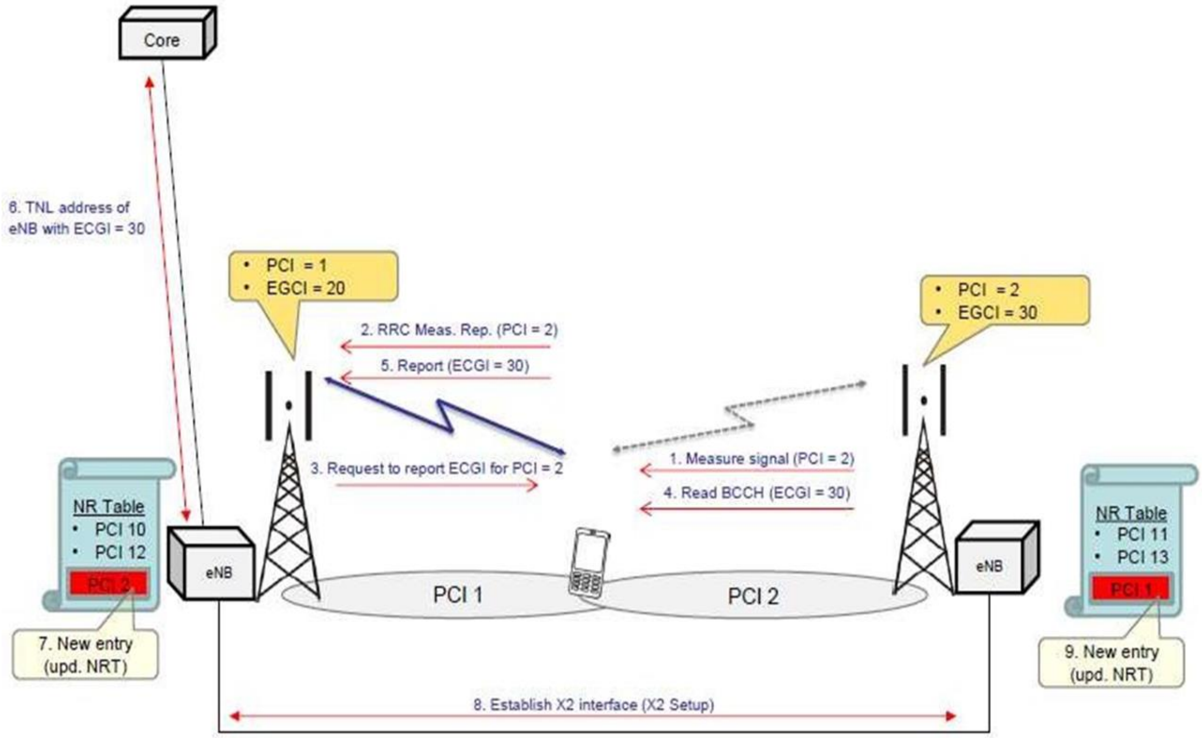


Figure 65: ANR with help of UE Measurement

The step-by-step ANR procedure is outlined:

1. During measurements, the UE detects PCI from an unknown cell.
2. The UE reports the unknown PCI to the serving eNB via Radio Resource Controller (RRC) reconfiguration message.
3. The serving eNB requests the UE to report the E-UTRAN Cell Global ID (ECGI) of the target eNB. The eNB is able to detect devices faster that way.
4. The UE reports ECGI by reading the broadcast channel (BCCH) channel.
5. Based on the ECGI, the serving eNB retrieves the IP address from the Mo- bility Management Entity (MME) to further set-up the X2 interface, since an initial X2 interface set-up would have happened during the target eNB’s self configuration.
6. Function is extended to inter-RAT and inter-frequency cases with suitable messaging.

10.3.4 ANR WITH OPERATION ADMINISTRATION & MANAGEMENT (OAM) SUPPORT

ANR with OAM support is a more centralized system of operation. The OAM is the management system of the network. ANR procedures with OAM support are outlined:

- The new eNB registers with OAM and downloads the neighbour information table which includes the PCI, ECGI and IP addresses of the neighbouring eNBs.
- The neighbours update their own tables with the new eNB information.
- The UE reports the unknown PCI to the serving eNB.
- The eNB sets-up the X2 interface using the neighbour information table formed previously.

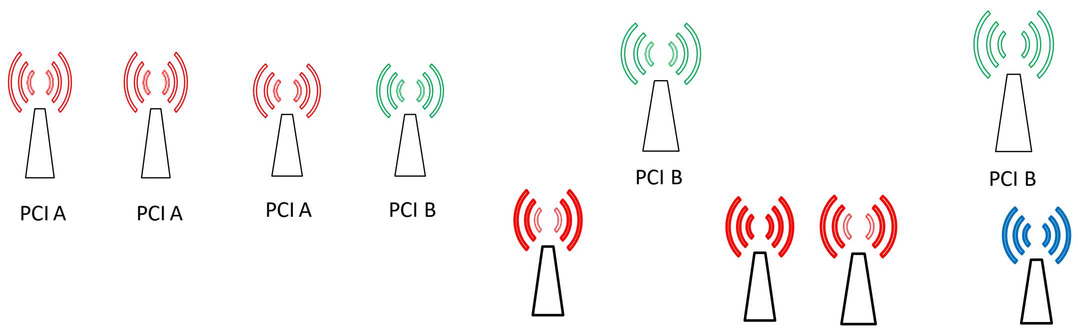
10.3.5 AUTOMATIC CONFIGURATION OF PHYSICAL CELL IDENTIFICATION (PCI).

The automatic configuration of physical cell ID (PCI) for eNBs in LTE was standardised in 3GPP release 8 as part of “eNB self configuration.” PCI is a locally defined identifier for eNBs with a restricted range (up to 504 values) and must be reused throughout the network. The PCI numbering of eNBs must locally be unique so that the UEs may be able to communicate and possible perform handovers. The goal of PCI configuration is to set the PCI of a newly introduced cell. The PCI is contained in the SCH (synchronization channel) for user equipment (UE) to synchronize with the cell on the downlink. When a new eNB is established, it needs to select PCIs for all the cells it supports. Since the PCI parameters have a restricted value range, the same value needs to be assigned to multiple cells throughout the network and must be configured collision free, that is, the configured PCI needs to be different from the values configured in all the neighbouring cells.

In today’s algorithms for automatic PCI assignments, conflicts may occur in the way they are allocated. Therefore, to achieve the aim of SON, work is currently being done to ensure automatic configuration of PCIs become a part of the standardized configuration.

PCI configuration must satisfy two rules:

- Collision Free: The PCI of one cell should not be the same as those of his neighbor cells.
- Confusion Free: The PCI of the neighbor cells should not be the same.



PCI A PCI A PCI B PCI C

Collision Based Collision Free Confusion Based Confusion Free

Figure 66: PCI Solution

10.3.6 SELF OPTIMIZATION

SON self-optimization functions are aiming at maintaining network quality and performance with a minimum of manual intervention from the operator. Self-optimization functions monitors and analyzes performance data and automatically triggers optimization action on affected network element(s) when necessary. This significantly reduces manual interventions and replaces them with automatic adjustments keeping the network optimized at all times. Self-optimizing SON functions make it possible to introduce new automatic processes that are too fast, and/or too complex to be implemented manually. This will improve the network performance by making the network more dynamic and adaptable to varying traffic conditions and improve the user experience.

Self configuration alone is not sufficient to guarantee effective management of the end-to-end network, the need for knowledge-based end-to-end monitoring is also very crucial. After configurations, automated processes/algorithms should be able to regularly compare the current system status parameters to the target parameters and execute corrective actions when required. This process ensures optimum performance at all times. This process is known as Self Optimization.

Some of the most important self-optimization SON use cases are:

(i) Physical cell ID(PCI);
(ii) Automatic neighbour relations(ANR);
(iii) Inter-cell Interference coordination(ICIC);
(iv) Mobility robustness optimization(MRO);
(v) Mobility load balancing optimization (MLB).

The two first use cases, PCI and ANR, may as well be categorized as self-configuration algorithms since they will be part of initial configuration procedures, but will also play an important part in normal operation and therefore may be viewed as being self optimization procedures.

10.3.7 PHYSICAL CELL ID CONFIGURATION (PCI)

The PCI automatic configuration was one of the first SON functions to be standardized by 3GPP. The self- configuration feature seems to be quite mature and all of the main vendors have this function implemented in their eNBs. Some vendors report tests with 100% handover success rate in networks where new eNB are introduced and the Automatic PCI Optimization are applied. The physical cell ID configuration is a SON function that should be implemented at eNB rollout.

10.3.8 AUTOMATIC NEIGHBOUR RELATIONS (ANR)

One of the more labour intense areas in existing radio technologies is the handling of neighbour relations for handover. A neighbour relation is information that a neighbour cell is a neighbour to an eNB. Each eNB holds a table of detected neighbour cells which are used in connection with handovers. Updating automatic neighbour relations (ANR) is a continuous activity that may be more intense during network expansion, but is still a time consuming task in mature networks. The task is multiplied with several layers of cells when having several networks to manage. With LTE, one more layer of cells is added; thus, optimization of neighbour relations may be more complex. Due to the size of the neighbouring relation tables in radio networks, it is a huge task to maintain the neighbour relations manually. Neighbour cell relations are therefore an obvious area for automation, and ANR is one of the most important features for SON. To explore its full potential, ANR must be supported between network equipment from different vendors. ANR was therefore one of the first SON functions to be standardized in 3GPP.

10.3.9 INTER-CELL INTERFERENCE COORDINATION (ICIC).

The main idea behind inter-cell interference coordination (ICIC) is to coordinate transmissions in different cells in such a way that the inter-cell interference and/or the effect of it is reduced. With the currently proposed solutions this is achieved by letting each cell omit using some of the spectrum resources (frequency/time slots/power) in order to reduce interference. Omitting to use spectrum resources implies that some capacity is lost, so the gains obtained by operating in an environment with less interference must more than compensate for this loss. The most important gain that can be achieved by ICIC is the ability to provide a more homogeneous service to users located in different regions of the network, especially by improving the cell-edge performance.

Mutual interference may occur between the cells in an LTE network. Interference unattended to leads to signal quality degradation. Inter-cell interference in LTE is coordinated based on the Physical Resource Block (PRB). It involves coordinating the utilization of the available PRBs in the associated cells by introducing restrictions and prioritization, leading to significantly improved Signal to Interference Ratio (SIR) and the associated throughput. This can be accomplished by adopting ICIC RRM (Radio Resource Management) mechanisms through signalling of Overload Indicator (OI), High Interference Indicator (HII), or downlink transmitter power indicator.

Multi-layer heterogeneous network layout including small cell base stations are considered to be the key to further enhancements of the spectral efficiency achieved in mobile communication networks. It has been recognized that inter-cell interference has become the limiting factor when trying to achieve not only high average user satisfaction, but also a high degree of satisfaction for as many users as possible.

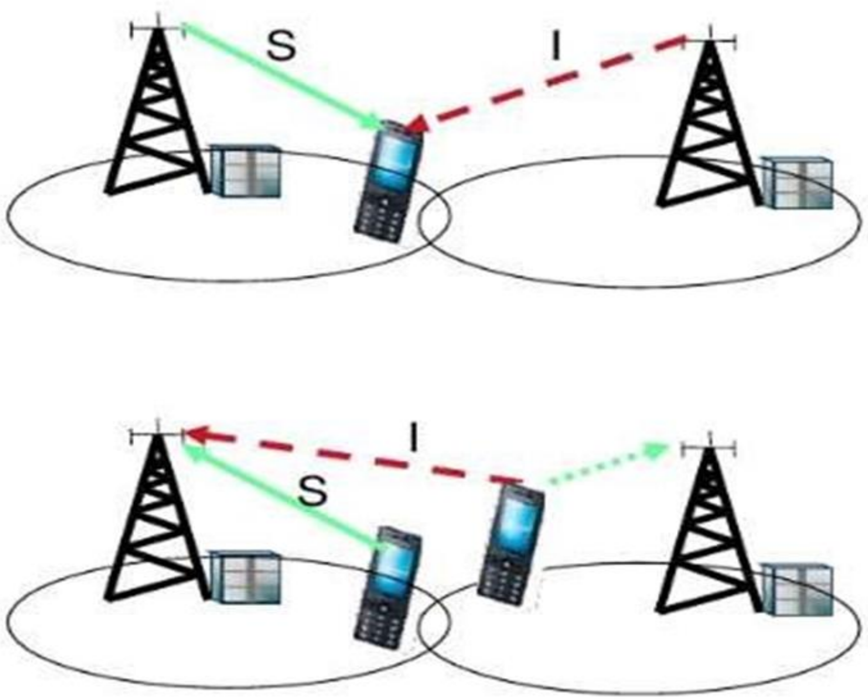


Figure 67: ICIC Use Case

The servicing operator for each cell carries out interference coordination, by configuring the ICIC associated parameters such as reporting thresholds/periods and prioritized resources. The ICIC SON algorithm is responsible for the automatic setting and updating of these parameters.

The ICIC SON algorithm work commenced in Release 9 but was not completed here. It is targeted at self configuration and self optimization of the control parameters of ICIC RRM strategies for uplink and downlink. To achieve interference coordination, the SON algorithm leverages on exchange of messages between eNBs in different cells through the X2 interface. The SON algorithm enables automatic configuration/adaptation with respect to cell topology, it requires little human intervention and leads to optimized capacity in terms of satisfied users.

10.3.10 MOBILITY ROBUSTNESS / HANDOVER OPTIMIZATION (MRO).

Handover coordination is very necessary in ensuring seamless mobility for user devices within a wireless network. In 2G/3G systems, setting handover parameters is a manual and time consuming task and sometimes too costly to update after initial deployment. Mobility Robustness Optimization (MRO) automates this process to dynamically improve handover operations within the network, provide enhanced end user experience and improved network capacity.

To achieve this aim, the question to be critically answered is "What triggers handover?" Therefore, 3GPP categorize handover failures into:

- Failures due to too late handover triggering
- Failures due to too early handover triggering
- Failures due to handover to a wrong cell

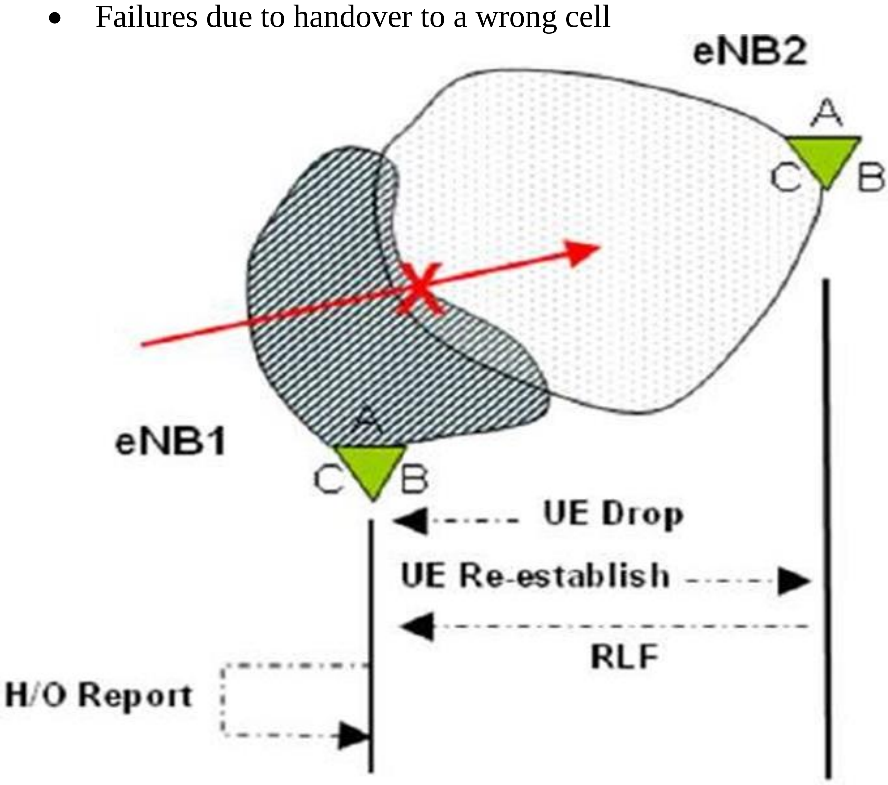


Figure 68: Too Late Handover

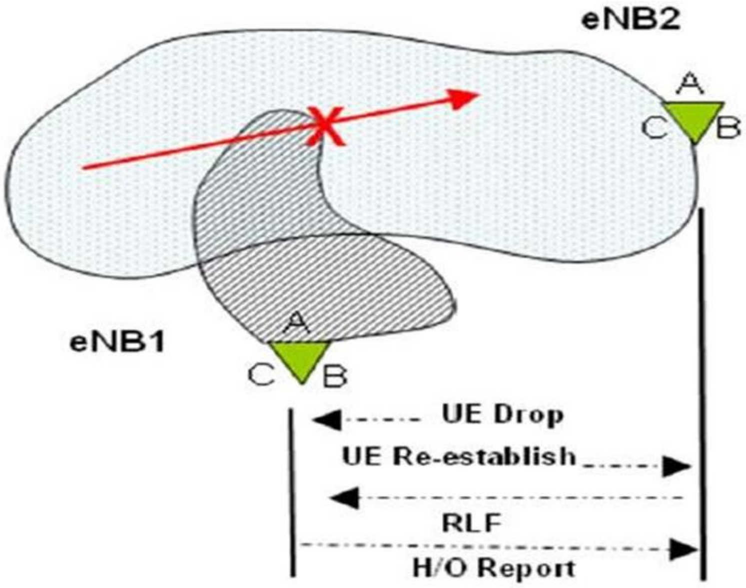


Figure 69: Too Early Handover

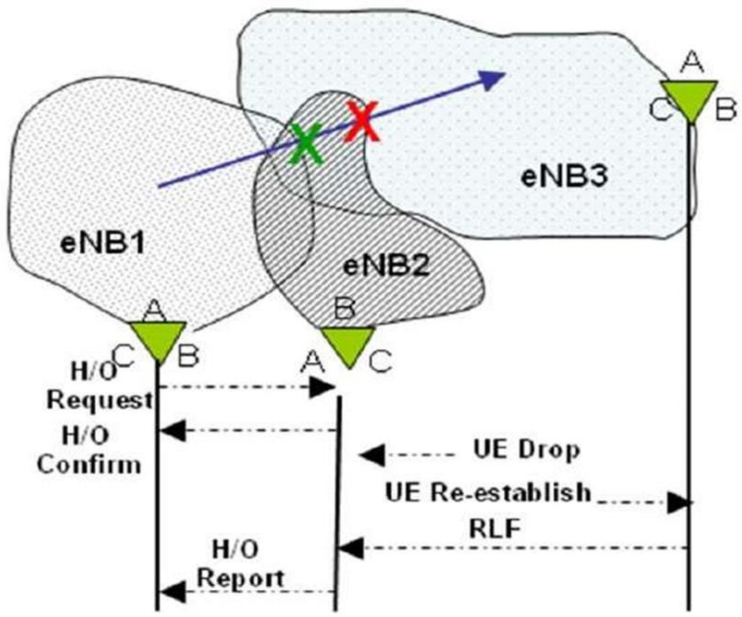


Figure 70: Wrong Handover

Also, unwanted handovers may occur subsequent to connection set-up, when cell-reselection parameters are not in agreement with the handover parameters.

Therefore, the MRO algorithm is aimed at detecting and minimizing these failures as well as reducing inefficient use of network resources caused by unnecessary handovers and also reducing handovers subsequent to connection set-up.

As specified by 3GPP, enabling MRO requires that:

a) The relevant mobility robustness parameters should be automatically configurable by the eNB SON entities;

b) OAM should be able to configure a valid range of values for these parameters; and

c) The eNB should pick a value from within this configured range, using vendor- specific algorithms for handover parameter optimization.

For efficient/effective MRO, there must be linkage to policies to ensure other parameters/QoE is not affected. This implies that all parameter modifications must align with other similar interacting SON algorithms (such as Load Balancing). Therefore, there is a need for communication between SON algorithms to resolve probable conflicts and ensure stability.

During roll-out of an LTE network, there will be areas having limited LTE coverage. Enabling handover from LTE to existing 2G/3G systems will therefore become an important feature. In this scenario, it will be very important to maintain a low drop rate for UEs moving from LTE to 2G/3G.

A SON MRO mechanism was introduced in release 10 for the purpose of detecting unnecessary inter-RAT handover. During the handover preparation the source RAT (LTE) requests optionally the target RAT (GSM/UMTS) to perform UE measurements of the source RAT. The measurements start following the successful handover, and the measurement duration is one of the parameters provided by the source RAT (max 100 seconds). The measurements stop if a new inter-RAT HO takes place during this time interval.

If during this period the UE measurements shows that the source RAT quality remains better than a configurable threshold, the target RAT will report to the source RAT that the handover could have been avoided. The source RAT may then take corrective action, for example, adjust the handover threshold or increase time-to-trigger setting for handovers to the concerned inter-RAT target cell.

MRO is very useful in the LTE network deployment process, reducing the need for extensive drive-testing. Since the LTE coverage often will be spotty in the beginning, inter- RAT MRO will also be very useful. For networks in operation MRO will ensure that the handover thresholds are optimal at all times and remove the need for manual task such as drive- testing, detailed system log, and post processing.

The benefits of MRO will be especially useful in HetNets, which are more dynamic where small cells appear and disappear. However, MRO solutions for HetNets are still not fully developed.

MRO is not critical for the operation of LTE networks today. The networks are usually stable macro networks with low to moderate traffic load, and most of the terminals are PC dongles and hence usually stationary when used. However, MRO will become more important as the penetra- tion of handheld terminals becomes larger, the traffic load increases and micro-, pico-, and femto-cells are introduced in the network. It will be beneficial to include MRO in LTE networks from the start but it will not be a critical function when the network is a stable macro network, but will offer reduced installation time and reduced OPEX costs. As the number of small cells in the network increase, MRO will be become more important and an MRO function capable of handling HetNet scenarios should be included.

10.3.11 MOBILITY LOAD BALANCING OPTIMIZATION (MLB)

The objective of mobility load balancing (MLB) is to intelligently spread user traffic across the system's radio resources in order to optimize system capacity while maintaining quality end-user experience and performance. Additionally, MLB can be used to shape the system load according to operator policy, or to empty lightly loaded cells which can then be turned off in order to save energy. The automation of this minimizes human intervention in the network management and optimization tasks.

Basic functionality of mobility load balancing was defined in Release 9. Release 10 added enhancements that addressed inter-RAT scenarios and inter-RAT information exchange.

Support for mobility load balancing consists of one or more of following functions:

(i) load reporting;
(ii) load balancing action based on handovers;
(iii) adapting handover and/or reselection configuration.

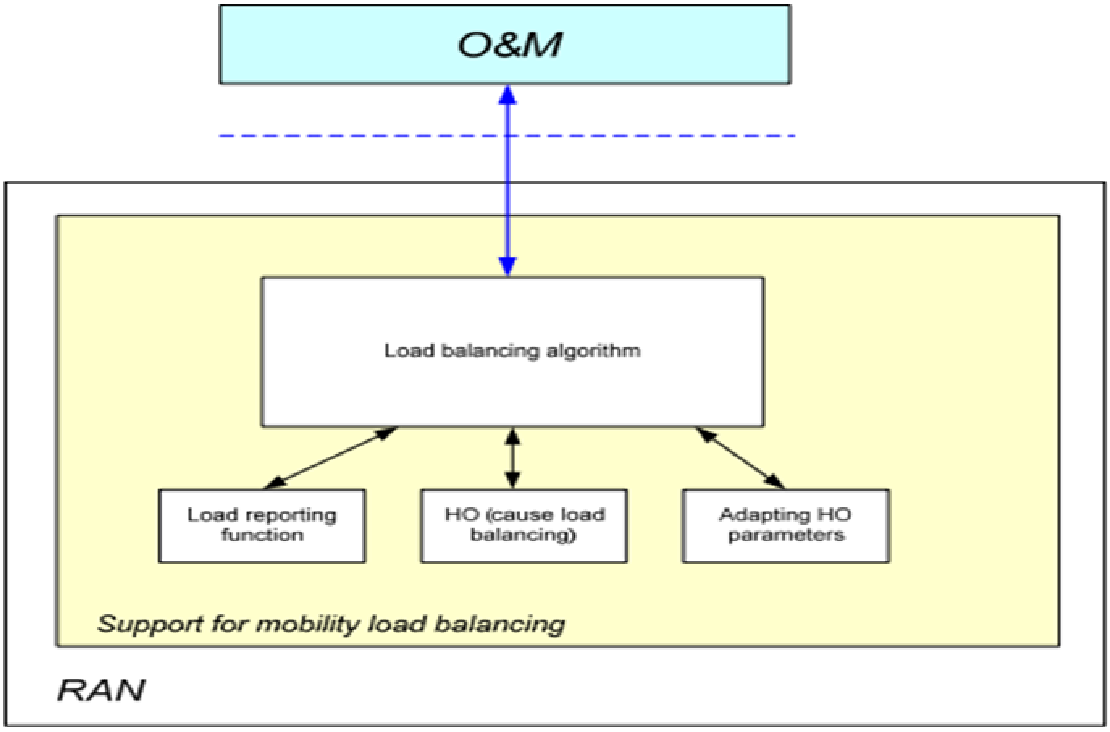


Figure 71: Mobility Load Balancing

Triggering of each of these functions is optional and depends on implementation. Current implementations of the MLB function are relatively simple. Moving load between cells are achieved by adjusting the handover thresholds and hence the position of the cell boundaries. As this can affect the handover performance, this must be coordinated with the MRO SON function. This can, for example, be achieved by letting the MRO function define an allowed interval for the handover threshold. The MLB function can then adjust the handover threshold within this interval.

One of the weaknesses of current MLB implementations is that the UEs that are moved from one cell to another do not usually constitute the optimal choice and can even cause problems in the target cell. For example, moving an UE that uses a lot of capacity can cause overloading in the target cell. This will lead to new MLB-based handovers and, if necessary precautions are not taken, even to ping-pong effects.

It should be notated that estimating what load an UE will represent in the new cell is not straightforward. The radio conditions in the new cell will be different from what it was in the original cell, hence the radio resources (i.e., the air time) required for a certain capacity will also be different. In the downlink the estimation can be done based on RSRP/RSRQ (reference signal received quality) reports from the UE. However, similar information is not available for uplink and extended information exchange between the eNBs is required.

MLB of idle mode UEs is more difficult than for active mode UEs. There is currently no way to know exactly on which cell an idle mode UE is camping. The only time the system becomes aware of the exact cell an UE is in, while in idle mode, is when the tracking area of the user changes and a tracking area update message is sent by the UE. Therefore, while parameters that control how and when a UE performs cell reselection (idle handover) are modi- fiable, there is no direct measurement mechanism for the system to determine when there are “too many” idle users. In current implementations the idle mode load balancing is usually done by adjusting the cell reselection parameters for the idle users based on the current active user condition.

The load balancing can be operated in different ways. One possibility is to only activate MLB when a cell becomes congested. Another possibility is to let MLB be a more continuous process trying to keep the load in different cells balanced at all times. In the latter case careful consideration should be given to the network signalling load. Currently, the rear eliminated knowledge on the advantages and disadvantages of operating MLB in different ways, and further studies and field trials should be performed. The way of operation should be configurable by the operator through the network management system.

To increase the effectiveness of the MLB function, especially in HetNet scenarios with many small cells, it will be necessary to develop more advanced algorithms. One potential improvement is to choose which UEs should be moved from one cell to another more carefully. The choice could be based on such parameters as capacity and QoS requirements, possibly including predicted values for these parameters based on historical information. The decision on what cells UEs should be moved to and from could also be performed more optimally, for example, based on current and historical statistical data on the load in different cells.

Basing the MLB related decisions on more information requires extended exchange of data between eNBs, which requires standardization of the necessary signalling support. Another area for improvement of MLB is its interworking with other SON functions, especially with MRO. In most cur-rent MLB implementations, MRO has priority and MLB has to adapt to the adjustments done by MRO. This significantly limits the MLB operation. For inter-RAT and inter-frequency handovers, MLB should probably have priority over MRO.

MLB also significantly overlap with the traffic steering and must be coordinated closely with this function.

In newly deployed LTE networks the traffic load will be modest and there will be little need for load balancing between LTE cells and between LTE and 2G/3G cells. As traffic increases, the usefulness of the MLB function also increases. It is therefore not necessary to include MLB in LTE deployments from the start. The usefulness of MLB increases as the network load increase and becomes important when the network develops in to a HetNet with many small cells.

10.3.12 COVERAGE AND CAPACITY OPTIMIZATION.

Coverage and Capacity Optimization (CCO) is a self optimization technique used in managing wireless networks according to coverage and capacity. CCO measures the health of the network and compares with performance target and policies as defined by individual operators. It has been identified by 3GPP as a crucial optimization area in which the SON algorithm determines the optimum antenna configuration and RF parameters (such as UL power control parameters) for the cells that serve a particular area and for a defined traffic situation, after the cells have been deployed.

For successful implementation of CCO SON algorithms, there is need to take into serious consideration, the difference between coverage optimization and capacity optimization. Coverage optimization involves identifying a “hole” in the network and then adjusting parameters of the neighbouring cells to cover the hole. However, in- creasing cell coverage affects spectral efficiency negatively due to declining signal power, which results in lesser capacity. It is therefore not possible to optimize cover- age and capacity at the same time, but a careful balance and management of the trade- offs between the two will achieve the optimization aim.

Adapting to network changes (such as addition/removal of eNBs and change in user distribution) manually is costly and time consuming. Hence, the CCO algorithms operate endlessly, gathering measurements and executing actions if needed. CCO is a slow process in which decisions are made based on long-run statistics.

Below is a list of functions the CCO algorithm is to perform as identified by 3GPP; but 3GPP does not specify how to perform these functions but are operator-defined:

- E-UTRAN coverage holes with 2G/3G coverage.
- E-UTRAN coverage holes without any other coverage.
- E-UTRAN coverage holes with isolated island coverage.
- E-UTRAN coverage holes with overlapping sectors.

10.3.13 RANDOM ACCESS CHANNEL (RACH) OPTIMIZATION.

RACH configuration within a network has major effects on the user experience and the general network performance. RACH configuration is a major determinant for call setup delays, hand-over delays and uplink synchronized state data resuming delays. Consequently, the RACH configuration significantly affects call setup success rate and hand-over success rate. This configuration is done in order to attain a desired balance in the allocation of radio resources between services and the random accesses while avoiding extreme interference and eventual degradation of system capacity. Low preamble detection probability and limited coverage also result from a poorly configured RACH. The automation of RACH configuration contributes to excellent performance with little/no human intervention; such that the algorithm monitors the current conditions (e.g. change in RACH load, uplink interference), and adjusts the relevant parameters as necessary. RACH parameter optimization provides the following benefits to the net- work:

- Short call setup delays resulting in high call setup rates

- Short data resuming delays from UL unsynchronized state
- Short handover delays resulting in high handover success rate

More generally, RACH optimization provides reduced connection time, higher throughput, and better cell coverage and system capacity. All the UE and eNB measurements are provided to the SON entity, which resides in the eNB. An eNB ex- changes information over the X2 interface with its neighbours for the purpose of RACH optimization. The PRACH Configuration is exchanged via the X2 setup and eNB configuration update procedures. An eNB may also need to communicate with the O&M in order to perform RACH optimization.

10.3.14 ENERGY SAVING

Mobile network operators are very keen on finding network energy saving solutions to minimize power consumption in telecommunication networks as much as possible. This will lead to reduced OPEX (since energy consumption is a major part of an operator's OPEX) and enable sustainable development on the long- run. Energy saving is very crucial today, especially with the increasing deployment of mobile radio network devices to cope with the growing user capacity.

OPEX due to energy consumption within a network can be significantly controlled by: a) the design of low-powered network elements; b) temporarily powering off un- used capacity; and c) working on the power amplifiers, since they consume majority of the available energy in a wireless network.

The normal practice is the use of modems to put the relevant network elements in stand-by mode. These modems have a separate management system. To achieve an automated system of saving energy, the network elements should be able to remotely default into stand-by mode using the minimum power possible when its capacity is not needed, and also switch-off stand-by mode remotely when needed, without affecting user experience.

The energy saving solutions in the E-UTRAN, which are being worked on by 3GPP, to be used as the basis for standardization and further works are: Inter-RAT energy savings; Intra-eNB energy savings; and Inter-eNB energy savings 3GPP has also stipulated the following conditions under which any energy saving solutions should operate, since energy savings should ideally not result in service degradation or network incompetence:

- User accessibility should be uncompromised when a cell switches to energy saving mode.
- Backward compatibility and the ability to provide energy savings for Rel-10
- Network deployment that serves several legacy UEs should be met.
- The solutions should not impact the physical layer.
- The solutions should not impact the UE power consumption negatively.

10.3.15 SELF-HEALING

Self-healing functionality was not initially defined a part of the 3GPP SON functionality, but it was taken into the SON standards in release 9 and 10, by 3GPP .

Self-healing is a collection of SON procedures which detects problems and solves or mitigates these to avoid user impact and to significantly reduce maintenance costs. Self healing involves automatic detection and localization of failures and the application of the necessary algorithms to restore system functionality. Self- healing is triggered by alarms generated by the faulty network elements. If it finds alarms that it might be able to correct or minimize the effects of, it gathers more necessary correlated information (e.g., measurements, testing results, and so forth), does deep analysis, and then trigger the appropriate actions.

The two major areas where the self-healing concept could be applied are as follows.

(1) Self-diagnosis: create a model to diagnose, learning from past experiences.

(2) Self-healing: automatically start the corrective actions to solve the problem.

Making use and analyzing data from the current optimization tools (alarm supervision system, OAM system, net- work consistency checks), optimizers can decide if network degradation occurs, which is the most likely cause, and then perform the needed corrections to solve the problem. The experience of optimizers in solving such problems in the past, and the access to a database of historic solved problems is very useful to improve the efficiency in finding solutions.

This whole optimization process could be enhanced in two steps as follows.

(i) Diagnosis model creation based on the experience of already solved problems, using a database with faults and their symptoms. Automatic troubleshooting action can be done without human intervention.

(ii) Self-test results from the periodic execution of consistency checks would help during the self diagnosis phase, to address better the healing process.

In the recommendation three different Self-healing SON functions are defined:

(i) cell outage,

(ii) self-recovery of network element (NE) software and

(iii) self-healing of board faults.

10.3.16 CELL OUTAGE.

This SON function has two basic components, namely, Cell Outage Detection (COD) and Cell Outage Compensation (COC) .

COD uses a collection of evidence and information to determine if a particular cell is not working correctly. The equipment usually detects faults in itself automatically. But in a situation where the detection system itself is faulty and has therefore failed to notify the OAM, such unidentified faults of the eNBs are referred to as sleeping cells. Cell Outage Detection and Compensation automatically handles these eNB failures by combining several individual mechanisms to determine if an outage has occurred, and then compensating for the failures after soft recovery techniques fail to restore normal service. The automated detection mechanism ensures the operator knows about the fault before the end user. The SON compensation system temporarily mitigates the problem.

10.4 SON ARCHITECTURE

The SON architecture defines the location of SON within the network. When implemented at a high level in the network (OAM), it is called Network Management System (NMS); while implementation at lower levels (network elements) like the eNBs is called Element Management System (EMS). For self-configuration techniques of SON, a self configuration subsystem is created in the OAM which handles the self configuration process. For self optimization, the subsystem can be created in the OAM or the eNB or both.

Therefore, depending on the location of SON algorithms, SON architecture may be described as being centralized, distributed or hybrid (a combination of centralized and distributed).

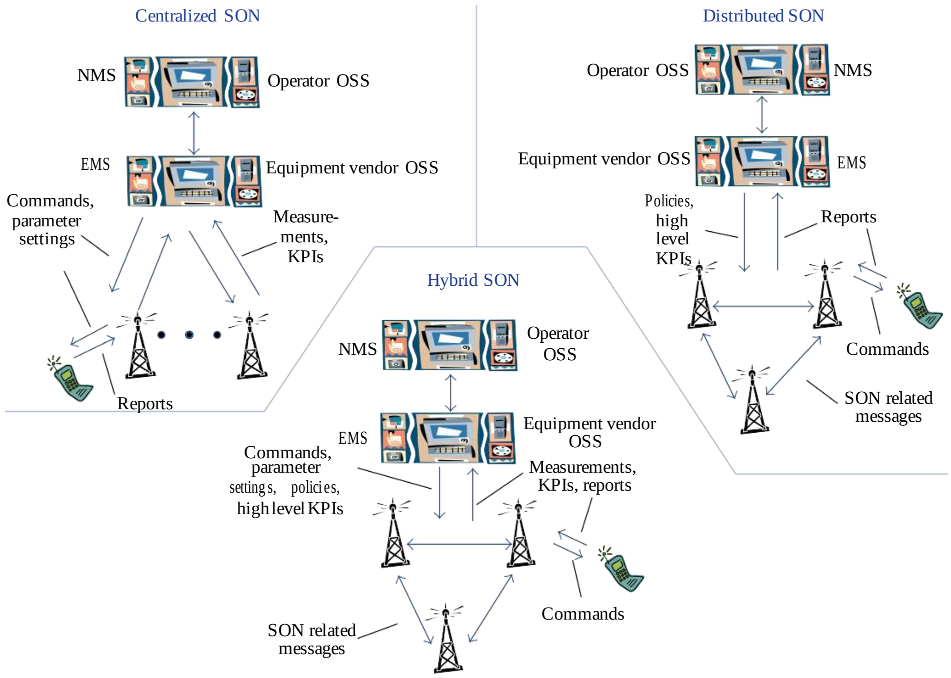


Figure 72: SON Architecture

10.4.1 CENTRALIZED SON

In a centralized SON architecture, the algorithms are executed at the network management level. Commands, requests and parameter settings data flow from the network management level to the network elements, while measurement data and reports flow in the opposite direction.

This is an example of the Network Management System (NMS) where the algorithms are created and executed in the OAM . In this type of SON architecture, the algorithms are present in just a few locations thereby making it simple and easy to implement.

The main benefit of this approach is that the SON algorithms can take information from all parts of the network into consideration. This means that it is possible to jointly optimize parameters of all centralized SON functions such that the network becomes more globally optimized, at least for slowly varying network characteristics. Also, centralized solutions can be more robust against network instabilities caused by the simultaneous operation of SON functions having conflicting goals. Since the control of all SON functions is done centrally, they can easily be coordinated. Another advantage is that multivendor and third party SON solutions are possible, since functionality can be added at the network management level and not in the network elements where vendor specific solutions are usually required.

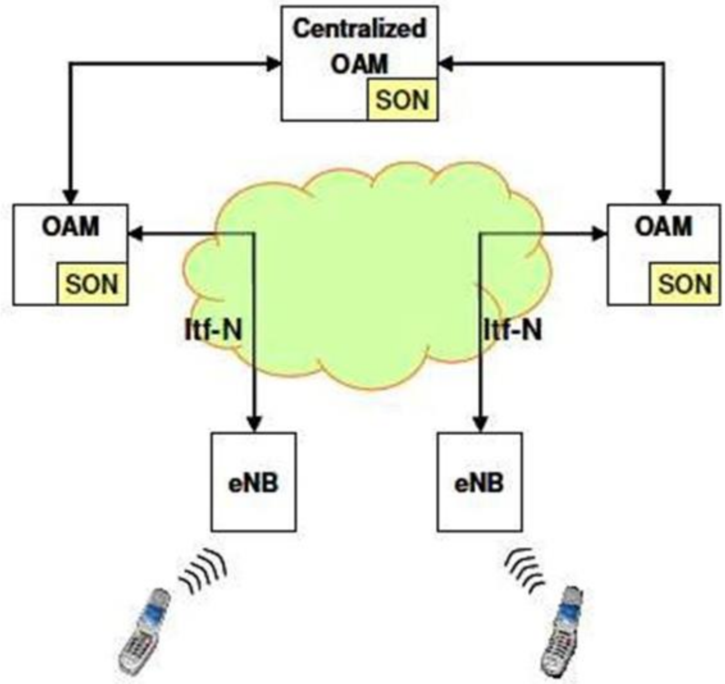


Figure 73: Centralized SON Architecture

The main drawbacks of the centralized SON architecture are longer response times, increased backbone traffic, and that it represents a single point of failure. The longer response time limits how fast the network can adapt to changes and can even cause network instabilities. The backbone traffic increase since measurement data have to be sent from the network elements to the network management system and instructions must be sent in the opposite direction. This traffic will increase as more cells are added to the network. If there are many pico- and femto-cells this traffic will be very significant. Also, the centralized processing power needed will be large.

10.4.2 DISTRIBUTED SON

In a distributed SON architecture, the SON algorithms are run in the network nodes and the nodes exchange SON related messages directly with each other. This architecture can make the SON functions much more dynamic than centralized SON solutions, so that the network can adapt to changes much more quickly. It is also a solution that scales very well as the number of cells in the network increases.

The main drawbacks are that the sum of all the optimizations done at cell level do not necessarily result in optimum operation for the network as a whole and that it is more difficult to ensure that network instabilities do not occur. Another drawback is that the implementation of the SON algorithm in the network elements will be vendor specific, so third party solutions will be difficult. Even if the algorithms themselves are executed in the network elements, the network management system is usually able to control the behavior of the SON function, for example, by setting the optimization criteria, receiving periodic reports, and being able to turn it off if necessary.

An example of the EMS in which the algorithms are deployed and executed at the eNBs is distributed SON. Therefore the SON automated processes may be said to be present in many locations at the lower level of the architecture. Due to the magnitude of deployment to be carried out caused by a large number of eNBs, the distributed SON cannot support complex optimization algorithms.

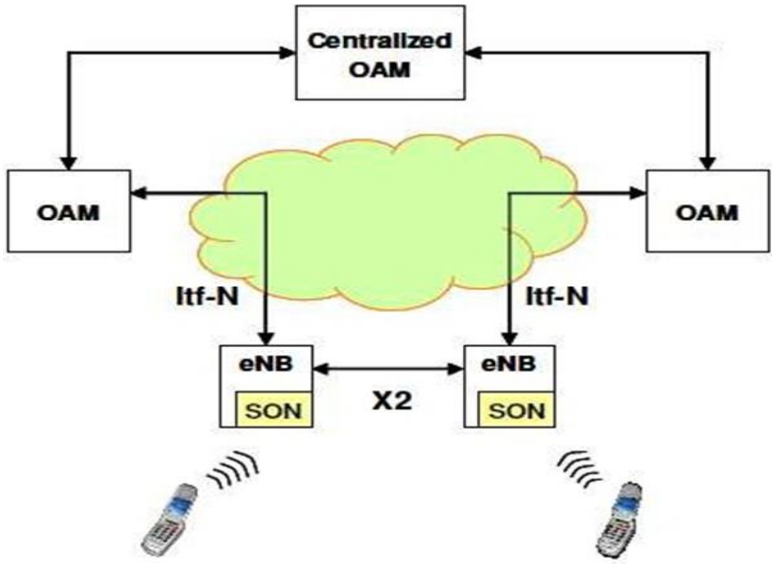


Figure 74: Distributed SON Architecture

In order to fully benefit from this architecture type, work is being done towards ex- tending the X2 interface (interface between the eNBs). However, distributed SON offers quick optimization/ deployment when concerned with one/two eNBs. An example of this is in ANR and load balancing optimizations.

10.4.3 HYBRID SON

An architecture in which the optimization algorithms are executed in both OAM and the eNBs is called Hybrid SON. Hybrid SON solution means that part of the SON algorithm is run on the network management level and part is run in the network elements. The solution represents an attempt to combine the advantages of centralized and distributed SON solutions: centralized coordination of SON functions and the ability to respond quickly to changes at the network element level.

The hybrid SON solves some of the problems posed by other architecture alternatives. The simpler optimization processes are executed at the eNBs while the complex ones are handled by the OAM; therefore, it supports various optimization algorithms and also supports optimization between different vendors. However, the hybrid SON is deployment intensive and requires several interface extensions.

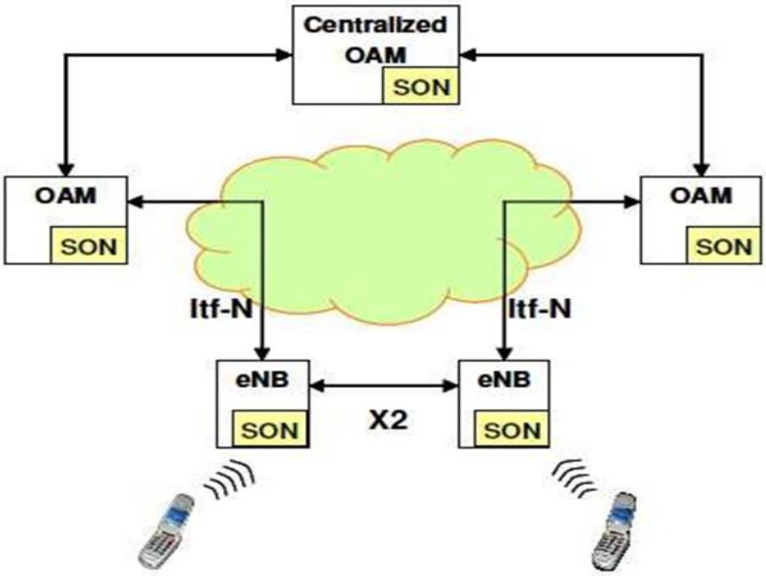


Figure 75: Hybrid SON Architecture

Unfortunately, the drawbacks of both centralized and distributed SON are also inherited. The SON related traffic in the backbone will be proportional to the number of network elements in the network, which means that it might not scale well. The same holds for the SON related processing required at the network management level. Also, since parts of the SON algorithms are running in the network elements and the interface between the centralized and distributed SON functions will be proprietary, third party solutions will be difficult.

It should be noted that the term "Hybrid SON" is not clearly defined and is used differently by different vendors. Some vendors classify their solutions as "hybrid" if the network management system can control the SON function by setting main parameters/policies, receiving reports and being able to turn it off if necessary.

10.5 3GPP SON EVOLUTION

Self Organizing Networks (SON) developed by 3GPP, using automation, ensures operational efficiency and next generation simplified network management for a mobile wireless network. The introduction of SON in LTE therefore brings about optimum performance within the network with very little human intervention.

3GPP standardization in line with SON features has been targeted at favouring multi- vendor network environments. Many works are on-going with- in 3GPP to define generic standard interfaces that will support exchange of common information to be utilized by the different SON algorithms developed by each vendor. The SON specifications are being developed over the existing 3GPP network management architecture defined over Releases 8, 9, 10 and beyond.

Release 8 marked the first LTE network standardization; therefore, the SON features here focused on processes involved with initial equipment installation and integration. Release 8 SON activities include:

- eNB Self Configuration: This involves Automatic Software Download and dynamic configuration of X2 and S1 interfaces.

- Automatic Neighbour Relation (ANR)
- Framework for PCI selection
- Support for Mobility Load Balancing

Release 9 marked enhancements on Release 8 LTE network; therefore, SON techniques in Release 9 focused on optimization operations of already deployed networks. Release 9 SON activities include:

- Automatic Radio Network Configuration Data Preparation
- Self optimization management
- Load Balancing Optimization
- Mobility Robustness/Handover optimization (MRO)
- Random Access Channel (RACH) Optimization
- Coverage and Capacity optimization (CCO)
- Inter-Cell Interference Coordination (ICIC)

Release 10 SON in LTE activities include enhancements to existing use cases and definition of new use cases as follows:

- Self optimization management continuation: CCO and RACH
- Self healing management: Cell Outage Detection and Compensation
- OAM aspects of Energy saving in Radio Networks
- LTE self optimizing networks enhancements
- Enhanced Inter-Cell Interference Coordination (eICIC)
- Minimization of Drive Testing

Release 11 SON activities include:

- UTRAN SON management: ANR
- LTE SON coordination management
- Inter-RAT Energy saving management
- Further self optimizing networks enhancements: MRO, support for Energy saving.

Release 12 SON activities include:

- Enhanced Network-Management-Centralized CCO
- Multi-vendor plug and play eNB connection to the network.
- The 3GPP SON standardization is a work in progress and is expected to cover all focus areas of wireless technology evolution, as it relates to network management, optimization and troubleshooting in multi-tech, multi-cell, multi-actor and heterogeneous networks.

10.6 CONCLUSION

Manual tuning of radio network is not possible as it involve lot parameter management and leads to false decision and poor network. SON is the best practice, but data inputted must be correct.

11 OMC-R REPORT AND TRAFFIC ANALYSIS

11.1 LEARNING OBJECTIVE

- What are main KPI's in GSM
- What are the thresholds for these KPIs
- How to maintain these KPI's
- Analysis of OMCR/traffic reports

11.2 KPI'S IN GSM

- TCH Congestion
- SDCCH Congestion
- Call Drop Rate
- Handover Success Rate
- Call Setup Success Rate
- Paging Success **Rate**

11.3 TCH CONGESTION

11.3.1 TCH CONGESTION: HOW TO CONTROL IT AND SHOULD BE<2%

- Analyze the requirement of no. of TRE as per Erlang-B table
- Increase TRE if traffic exceeds
- HR may be done
- Lowering of HR triggering thresholds.
- Directed retry/Traffic Handover may be enabled.
- Dual band (1800) may be introduced i.e. upto 8 TRE in the sector.

Erlang B Traffic Table

Maximum Offered Load Versus B and N

B is in %

N/B	0.01	0.05	0.1	0.5	1.0	2	5	10	15	20	30	40
1	.0001	.0005	.0010	.0050	.0101	.0204	.0526	.1111	.1765	.2500	.4286	.6667
2	.0142	.0321	.0458	.1054	.1526	.2235	.3813	.5954	.7962	1.000	1.449	2.000
3	.0868	.1517	.1938	.3490	.4555	.6022	.8994	1.271	1.603	1.930	2.633	3.480
4	.2347	.3624	.4393	.7012	.8694	1.092	1.525	2.045	2.501	2.945	3.891	5.021
5	.4520	.6486	.7621	1.132	1.361	1.657	2.219	2.881	3.454	4.010	5.189	6.596
6	.7282	.9957	1.146	1.622	1.909	2.276	2.960	3.758	4.445	5.109	6.514	8.191
7	1.054	1.392	1.579	2.158	2.501	2.935	3.738	4.666	5.461	6.230	7.856	9.800
8	1.422	1.830	2.051	2.730	3.128	3.627	4.543	5.597	6.498	7.369	9.213	11.42
9	1.826	2.302	2.558	3.333	3.783	4.345	5.370	6.546	7.551	8.522	10.58	13.05
10	2.260	2.803	3.092	3.961	4.461	5.084	6.216	7.511	8.616	9.685	11.95	14.68
11	2.722	3.329	3.651	4.610	5.160	5.842	7.076	8.487	9.691	10.86	13.33	16.31
12	3.207	3.878	4.231	5.279	5.876	6.615	7.950	9.474	10.78	12.04	14.72	17.95
13	3.713	4.447	4.831	5.964	6.607	7.402	8.835	10.47	11.87	13.22	16.11	19.60
14	4.239	5.032	5.446	6.663	7.352	8.200	9.730	11.47	12.97	14.41	17.50	21.24
15	4.781	5.634	6.077	7.376	8.108	9.010	10.63	12.48	14.07	15.61	18.90	22.89
16	5.339	6.250	6.722	8.100	8.875	9.828	11.54	13.50	15.18	16.81	20.30	24.54
17	5.911	6.878	7.378	8.834	9.652	10.66	12.46	14.52	16.29	18.01	21.70	26.19
18	6.496	7.519	8.046	9.578	10.44	11.49	13.39	15.55	17.41	19.22	23.10	27.84
19	7.093	8.170	8.724	10.33	11.23	12.33	14.32	16.58	18.53	20.42	24.51	29.50
20	7.701	8.831	9.412	11.09	12.03	13.18	15.25	17.61	19.65	21.64	25.92	31.15
21	8.319	9.501	10.11	11.86	12.84	14.04	16.19	18.65	20.77	22.85	27.33	32.81
22	8.946	10.18	10.81	12.64	13.65	14.90	17.13	19.69	21.90	24.06	28.74	34.46
23	9.583	10.87	11.52	13.42	14.47	15.76	18.08	20.74	23.03	25.28	30.15	36.12
24	10.23	11.56	12.24	14.20	15.30	16.63	19.03	21.78	24.16	26.50	31.56	37.78
25	10.88	12.26	12.97	15.00	16.13	17.51	19.99	22.83	25.30	27.72	32.97	39.44
26	11.54	12.97	13.70	15.80	16.96	18.38	20.94	23.89	26.43	28.94	34.39	41.10
27	12.21	13.69	14.44	16.60	17.80	19.27	21.90	24.94	27.57	30.16	35.80	42.76
28	12.88	14.41	15.18	17.41	18.64	20.15	22.87	26.00	28.71	31.39	37.21	44.41
29	13.56	15.13	15.93	18.22	19.49	21.04	23.83	27.05	29.85	32.61	38.63	46.07
30	14.25	15.86	16.68	19.03	20.34	21.93	24.80	28.11	31.00	33.84	40.05	47.74
31	14.94	16.60	17.44	19.85	21.19	22.83	25.77	29.17	32.14	35.07	41.46	49.40
32	15.63	17.34	18.21	20.68	22.05	23.73	26.75	30.24	33.28	36.30	42.88	51.06
33	16.34	18.09	18.97	21.51	22.91	24.63	27.72	31.30	34.43	37.52	44.30	52.72
34	17.04	18.84	19.74	22.34	23.77	25.53	28.70	32.37	35.58	38.75	45.72	54.38
35	17.75	19.59	20.52	23.17	24.64	26.44	29.68	33.43	36.72	39.99	47.14	56.04
36	18.47	20.35	21.30	24.01	25.51	27.34	30.66	34.50	37.87	41.22	48.56	57.70
37	19.19	21.11	22.08	24.85	26.38	28.25	31.64	35.57	39.02	42.45	49.98	59.37

Table 16. Erlang B Traiff Table

11.3.2 REPORT SHOWING TCH CONGESTION

	Number_Of_TCH	RTCH_available_nb_avg(GTCAVAN)(nb)	Call_setup_success_rate(GQSCSSR)(%)	RTCH_assign_cong_rate(GTCNACGR)(%)	RTCH_Erlang_BH(GTCTRE_BH)(Er)	RTCH_Erlang_total(GTCTRE)(Er)	RTCH_drop_rate(GQSTCCDR)(%)	RTCH_success(GTCAHSUN)(nb)	RTCH_HO_request(GTCHORQN)(nb)	RTCH_HO_success_rate(GTCHOSUR)(%)	SDCCH_cong_rate(GSDAHCGR)(%)	SDCCH_assign_request(GSDNARQN)(nb)
BAL-001_Bithali_3 (2013/61269)	13	6	68.58 %	30.85%	9.6	114.6	0.85%	7214	2881	39.95%	2.33%	16243
BAL-026D_Gaykhuri_2 (2008/6688)	28	6	41.81 %	57.16%	4.9	79.8	2.23%	5865	16147	19.63%	0.18%	14225
BAL-035E_Kukarra_USO_1 (2013/6867)	27	6	26.52 %	72.25%	4.9	74.5	6.23%	4782	7637	7.97%	9.70%	30698
BAL-035E_Kukarra_USO_3 (2013/6869)	26	6	24.06 %	75.06%	4.9	78.5	2.56%	5401	18071	5.85%	10.86%	46594
BAL-044F_JAM_3 (2008/6769)	13	6	67.66 %	31.41%	9.6	103.5	2.06%	7618	3494	49.60%	6.77%	18947
CHW-051D_Navegaon_JDO_V_2 (2010/7498)	12	6.2	62.44 %	35.68%	4.3	40.8	7.22%	3104	309	51.46%	6.08%	19931

Table 17. TCH congestion

- Antenna Adjustment in affected/ neighbor cell for traffic sharing
- HO margin Adjustment /Power adjustment (BS TX Power max)(in exceptional cases)
- Fourth sector may be introduced at the same BTS.
- Last option**:** Introduction of new BTS

11.4 SDCCH CONGESTION

- Defining Proper No of SDCCH Channels
- Optimize LAC boundary
- Check whether Boundary BTS==➔Define sufficient SDCCH Channels
- Dynamic SDCCH may be defined
- Check Hardware/Transmission Alarms
- Other reasons like low coverage areas/problem in TRX in which SDCCH is defined **etc.**

	Number_Of_TCH	RTCH_available_nb_avg(GTCAVAN)(nb)	Call_setup_success_rate(GQSCSSR)(%)	RTCH_assign_cong_rate(GTCNACGR)(%)	RTCH_Erlang_BH(GTCTRE_BH)(Er)	RTCH_Erlang_total(GTCTRE)(Er)	RTCH_drop_rate(GQSTCCDR)(%)	RTCH_success(GTCAHSUN)(nb)	RTCH_HO_request(GTCHORQN)(nb)	RTCH_HO_success_rate(GTCHOSUR)(%)	SDCCH_cong_rate(GSDAHCGR)(%)	SDCCH_assign_request(GSDNARQN)(nb)
BAL-035E_Kukarra_USO_1 (2013/6867)	27	6	26.52%	72.25%	4.9	74.5	6.23%	4782	7637	7.97%	9.70%	30698
BAL-035E_Kukarra_USO_3 (2013/6869)	26	6	24.06%	75.06%	4.9	78.5	2.56%	5401	18071	5.85%	10.86%	46594
BAL-085F_Mohgandhabera_V_2 (2013/61128)	13	8.5	46.78%	0.00%	0.5	3.4	4.75%	885	785	90.45%	9.04%	3129
BAL-085F_Mohgandhabera_V_3 (2013/61129)	13	9.5	73.42%	0.53%	2.7	13	6.12%	1519	828	83.94%	16.73%	11778
CHW-051D_Navegaon_JDO_V_1 (2010/7497)	20	8.5	94.74%	0.00%	3.9	15.1	7.12%	1109	116	93.97%	22.45%	15760
CHW-051D_Navegaon_JDO_V_3 (2010/7499)	13	2.9	95.86%	0.47%	3.3	14.7	9.71%	1153	126	89.68%	9.22%	6158

Table 18. SDCCH CONGESTION

11.5 CALL DROP: REASONS AND REMEDIES AND SHOULD BE<3%

- Cable swap
- Drop in A channel (Type 18 report for ALIL)
- Improper RF planning
- Wrong Hopping Parameters e.g. MAIO/HSN
- VSWR/RF cable fault
- Handover failure
- Poor signal strength/quality in UL/DL path
- External Interference
- Hardware faults e.g. in TRE, combiner etc
- Setting parameter like RLT, Rx lev. Access min., RACH Access min as per situation.
- Other reasons like fluctuation in Abis/Ater links.

	Number_Of_TCH	RTCH_available_nb_avg (GTCAVAN)(nb)	Call_setup_success_rate(GQSCSSR)(%)	RTCH_assign_cong_rate(GTCNACGR)(%)	RTCH_Erlang_BH (GTCTRE_BH) (Er)	RTCH_Erlang_total(GTCTRE)(Er)	RTCH_drop_rate(GQSTCCDR)(%)	RTCH_success(GTCAHSUN)(nb)	RTCH_HO_request(GTCHORQN)(nb)	RTCH_HO_success_rate(GTCHOSUR)(%)	SDCCH_cong_rate(GSDAHCGR)(%)	SDCCH_assign_request(GSDNARQN)(nb)
BAL-015C_Lamta_3 (2013/6779)	13	13	92.97%	0.00%	3.2	28	5.37%	2458	1498	52.87%	0.00%	9351
BAL-019C_Ukwa_1 (2013/6697)	27	28	82.78%	0.00%	25.4	303.4	9.40%	17895	3369	82.75%	0.09%	42549
BAL-032E_Birsula_USO_3 (2013/6899)	12	6	95.77%	1.95%	4.9	27.9	5.23%	1721	183	93.44%	0.00%	4788
BAL-035E_Kukarra_USO_1 (2013/6867)	27	6	26.52%	72.25%	4.9	74.5	6.23%	4782	7637	7.97%	9.70%	30698
BAL-036E_Newargaon_USO_1 (2013/6817)	13	1	95.36%	0.00%	0	0.1	33.33%	3	1	100.00%	0.00%	178

Table 19. Call Drop

HO success rate (Should be >95%):Reasons of HO fail

- Cable swap
- Congestion in target sector
- Missing neighbor/Too many neighbors
- Improper RF planning mainly same BCCH/BSIC
- Frequent Inter MSC/Inter BSC handovers
- Type 180 report may be used for sector wise handover analysis.

	Number_Of_TCH	RTCH_available_nb_avg(GTCAVAN)(nb)	Call_setup_success_rate(GQSCSSR)(%)	RTCH_assign_cong_rate(GTCNACGR)(%)	RTCH_Erlang_BH(GTCTRE_BH)(Er)	RTCH_Erlang_total(GTCTRE)(Er)	RTCH_drop_rate(GQSTCCDR)(%)	RTCH_success(GTCAHSUN)(nb)	RTCH_HO_request(GTCHORQN)(nb)	RTCH_HO_success_rate(GTCHOSUR)(%)	SDCCH_cong_rate(GSDAHCGR)(%)	SDCCH_assign_request(GSDNARQN)(nb)
BAL-001_Bithali_3 (2013/61269)	13	6	68.58%	30.85 %	9.6	114.6	0.85%	7214	2881	39.95 %	2.33%	16243
BAL-005B_Civillines_4 (2008/61297)	27	27	92.50%	5.83%	23.1	346.3	0.84%	26726	14207	74.57 %	0.00%	46065
BAL-015C_Lamta_3 (2013/6779)	13	13	92.97%	0.00%	3.2	28	5.37%	2458	1498	52.87 %	0.00%	9351
BAL-018C_TirodiV_2 (2013/6978)	28	13	99.31%	0.00%	3.4	28.5	0.92%	1522	392	58.16 %	0.00%	3884
BAL-021D_Bharveli_2 (2008/6558)	13	13	99.14%	0.00%	2	19.9	0.75%	2390	2408	57.43 %	0.00%	3954
BAL-025D_Mahketar_1 (2013/6647)	13	6	82.62%	12.43 %	4.1	35.2	4.82%	2386	309	46.28 %	0.72%	10640
BAL-026D_Gaykhuri_1 (2008/6687)	28	13	85.76%	13.71 %	23.1	380.7	0.32%	24919	17639	52.50 %	0.00%	37445

Table 20. Handover fail report

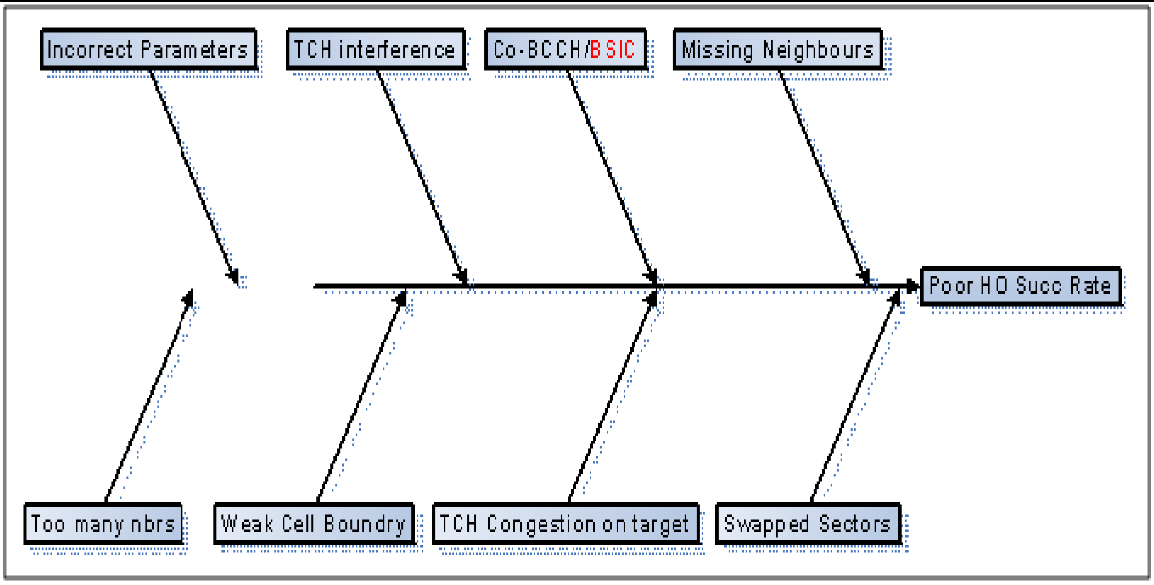


Figure 76: Fish bone diagram for the root cause analysis

11.6 CSSR: REASONS OF LOW CSSR

- TCH Congestion
- SDCCH Congestion/Drop
- Improper RF planning
- cable swap/VSWR
- Bad RF environment like poor Rxlev/Qual/TA
- Other reasons like HW faults, BER in Abis/Ater links

11/26/2013	Number_Of_TCH	RTCH_available_nb_avg(GTCAVAN)(nb)	Call_setup_success_rate(GQSCSSR)(%)	RTCH_assign_cong_rate(GTCNACGR)(%)	RTCH_Erlang_BH(GTCTRE_BH)(Er)	RTCH_Erlang_total(GTCTRE)(Er)	RTCH_drop_rate(GQSTCCDR)(%)	RTCH_success(GTCAHSUN)(nb)	RTCH_HO_request(GTCHORQN)(nb)	RTCH_HO_success_rate(GTCHOSUR)(%)	SDCCH_cong_rate(GSDAHCGR)(%)	SDCCH_assign_request(GSDNARQN)(nb)
BAL-001_Bithali_3 (2013/61269)	13	6	68.58%	30.85%	9.6	114.6	0.85%	7214	2881	39.95%	2.33%	16243
BAL-026D_Gaykhuri_2 (2008/6688)	28	6	41.81%	57.16%	4.9	79.8	2.23%	5865	16147	19.63%	0.18%	14225
BAL-033E_Chikhla_USO_1 (2013/61097)	13	12.7	69.19%	0.00%	1.2	9	1.74%	2235	2389	74.26%	0.00%	3051

Figure 77: REPORT SHOWING LOW CSSR

11.7 PAGING: HOW TO IMPROVE PAGE SUCCESS RATE

- Proper LAC dimension and distribution
- Separate Broadcast channel in place of Combined broadcast channel.
- Removal of dummy Cell site database created in Network
- Use of TMSI
- Minimize SDCCH cong/Cong in Abis interface/ BTS downtime etc

11.8 RX LEVEL IMPROVEMENT

- Recognizing potential areas (by Google earth/survey etc)
- Proper height/azimuth/tilt planning
- Direct TRE connection
- Reducing Overlap of sectors
- Plan of new BTS

11.9 INTERFERENCE REDUCTION TECHNIQUES: CO CHANNEL /ADJACENT CHANNEL

- Cell restriction (height/tilt adjustment)
- Power control (In UL/DL both path)
- Frequency hopping
- Proper Frequency planning (BCCH/BSIC/HSN/MAIO)
- DTX

11.10 CONCLUSION

Reports are very important to manage the network properly one should analyze the report to improve and monitor the network.

12 CNMS PORTAL AND MOBILE NOC

12.1 LEARNING OBJECTIVE

After completion of this chapter participant will able to understand:

- CNMC Portal
- CNMC Connectivity
- CNMC Use
- CNMC Menus and there need.
- Mobile NOC

12.2 CNMC

It is Centralized Network Monitoring Center of BSNL which is connected to all OMCRS across INDIA. It provides PAN INDIA BTS (Cell Wise) status, Voice and Data Traffic, KPI Parameters (2G/3G/4G). It also Provide External Alarms, Lock Site Details.

12.2.1 CNMC CONNECTIVITY

The CNMC works on website www.cnmc.bsnl.co.in and is connected as per below diagram

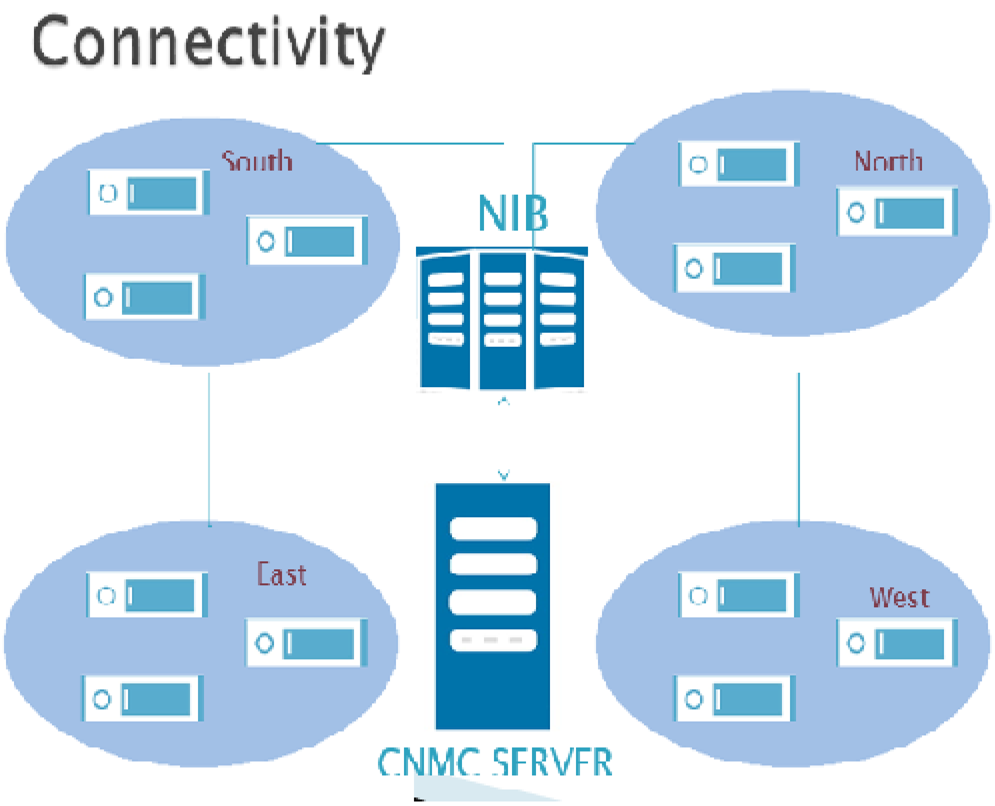


Figure 78: CNMC connectivity

12.2.2 CNMC ACCESS TECHNIQUES

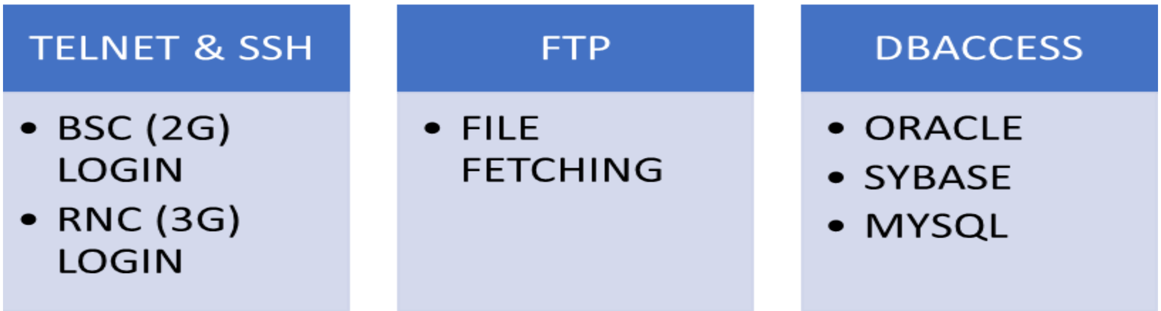


Figure 79: CNMC ACCESS TECHNIQUES

12.2.3 CNMC FUNCTIONS:

ALARMS

- REAL TIME STATUS OF BTS & SECTOR WISE ALL OVER INDIA
- Scripts runs continuously for every 15 minutes
- Drags Total down and Partial down alarms from all OMCRS over PAN INDIA

QoS

- The QoS reports are also generated on daily basis which are automated from 07:00 AM to 09:30 AM.
- The reports are fetched mostly from .csv/.txt files which are pulled from OMCR's of all the vendors and backed up at 06:30 PM every day.
- The QoS parameters for 2G and 4G are as below. WIP for 3G QoS.

Locked sites

- This module shows the locked sites from all pan India circles.
- These sites can be locked due to many reasons like owner issue, hardware failure issue etc. or maybe intentionally locked to get better overall availability .
- The circles need to comply with the reasons which need to be updated in the portal.
- This script runs only once for all vendors at midnight.

CGI reports

- Cell Global Identity (CGI) is a globally unique identifier for a Base Transceiver Station in mobile phone networks.
- Consists of Mobile Country Code (MCC), Mobile Network Code (MNC), Location Area Code (LAC) and Cell Identification (CI).
- It gives the above information for each sector/cell.
- We have approximately about 3.90L-4Lac cells.
- This information is fetched from the traffic reports once every month.

Many other useful parameters

- Revenue
- Gross Connection Growth
- MNP Ratio
- Voice Traffic
- Data Traffic

- Availability
- CDR
- CSSR
- Drive Test Conducted
- MTTR
- Halted Sites
- Low Traffic Sites
- 6th Month Collection Efficiency
- Increase in Daily IN revenue

The reports can be checked online. Some real time snapshots of CNMC at cnmc.bsnl.co.in are given below:-

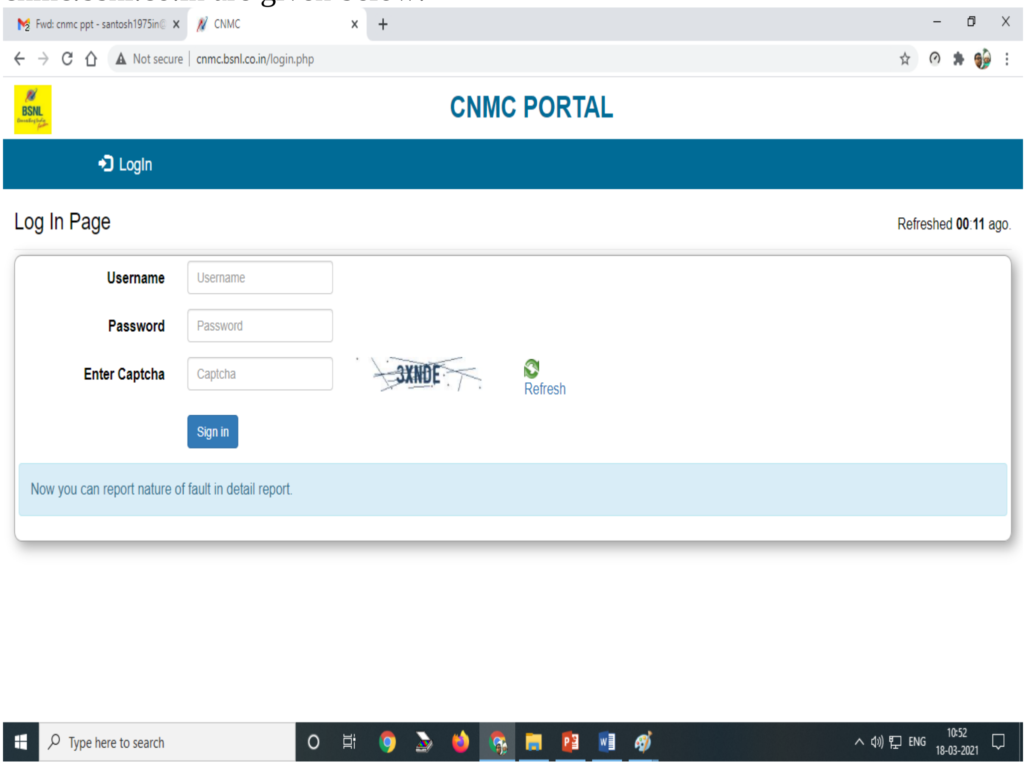


Figure 80: Time snapshots of CNMC

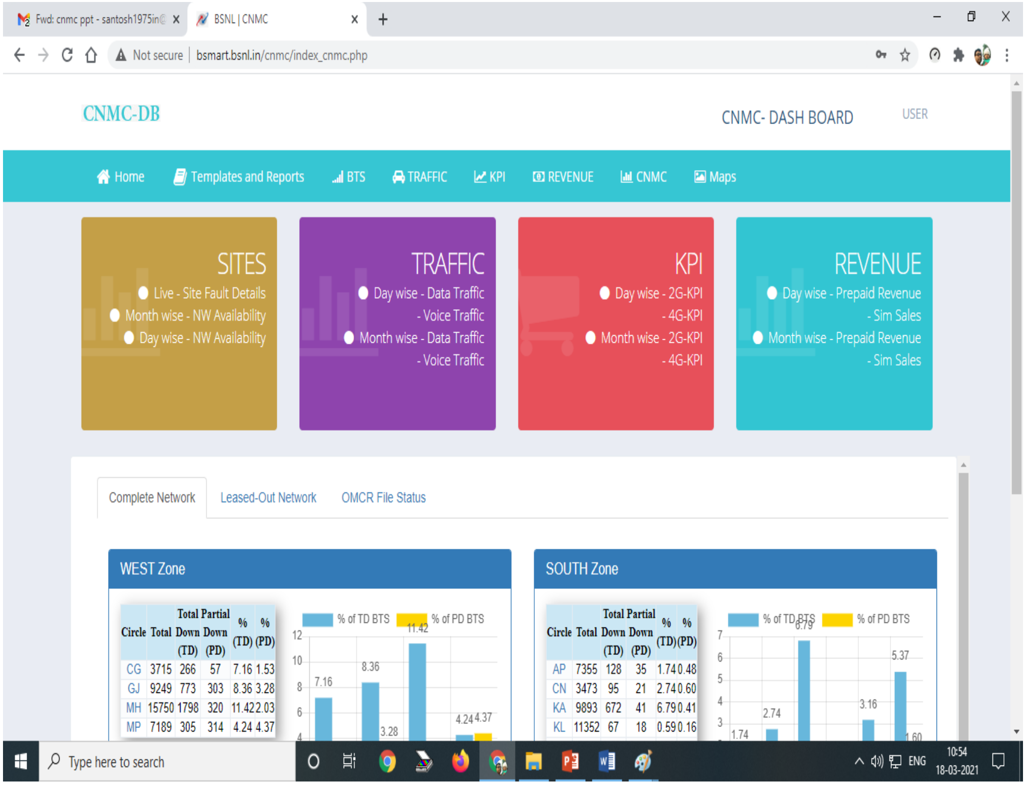


Figure 81: CNMC Portal

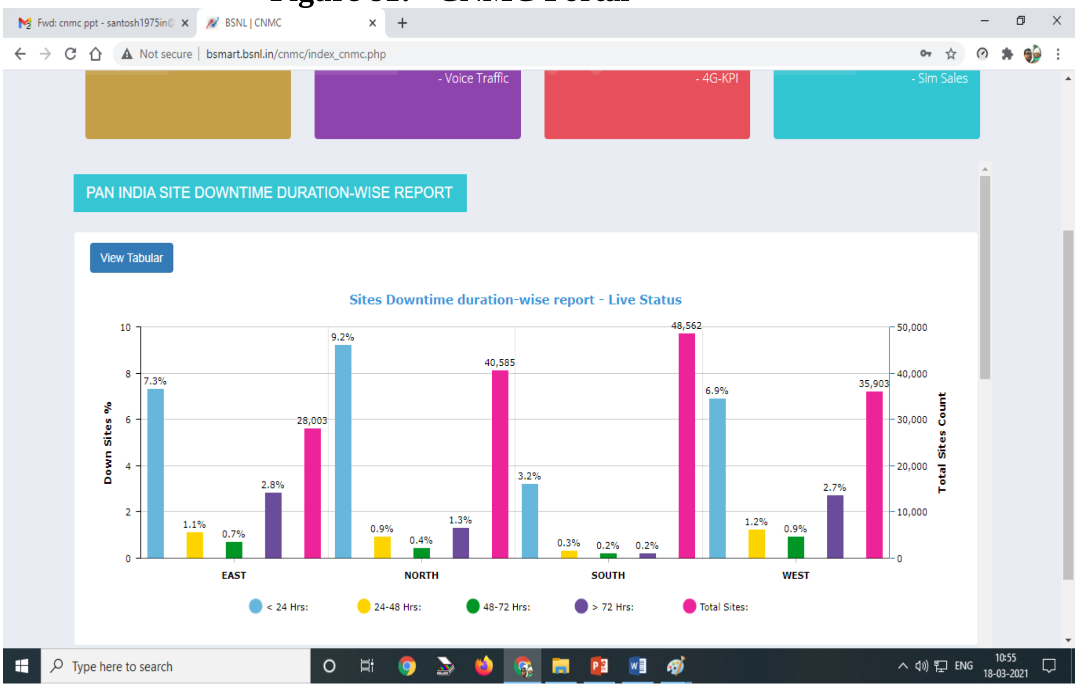


Figure 82: CNMC Portal

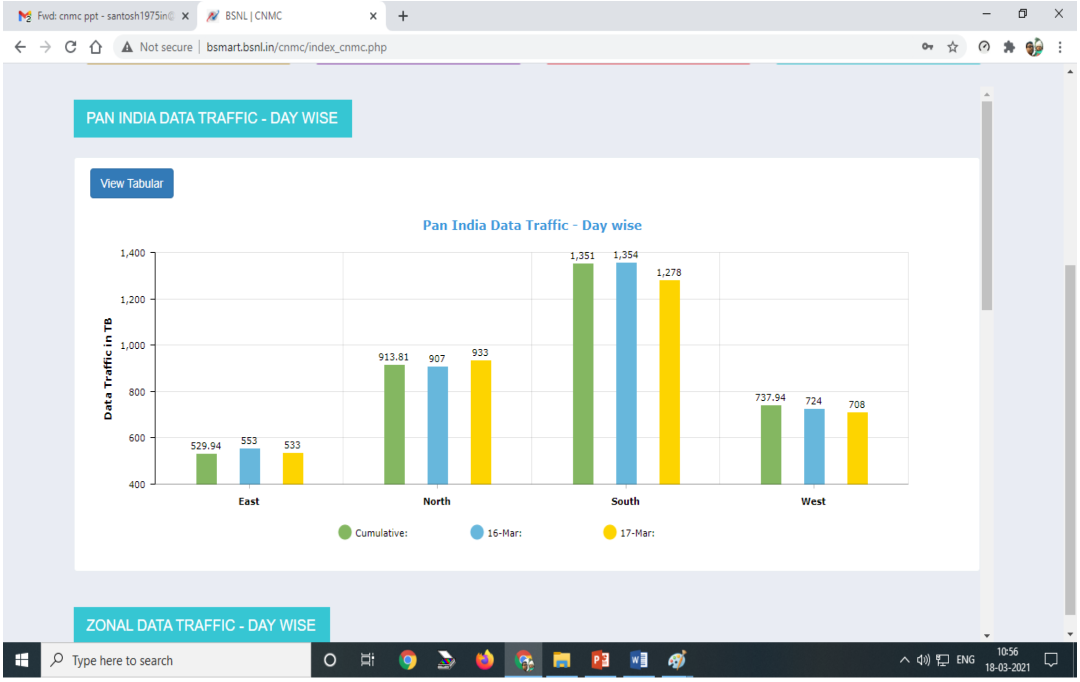


Figure 83: CNMC Portal

Figure 84: CNMC Portal

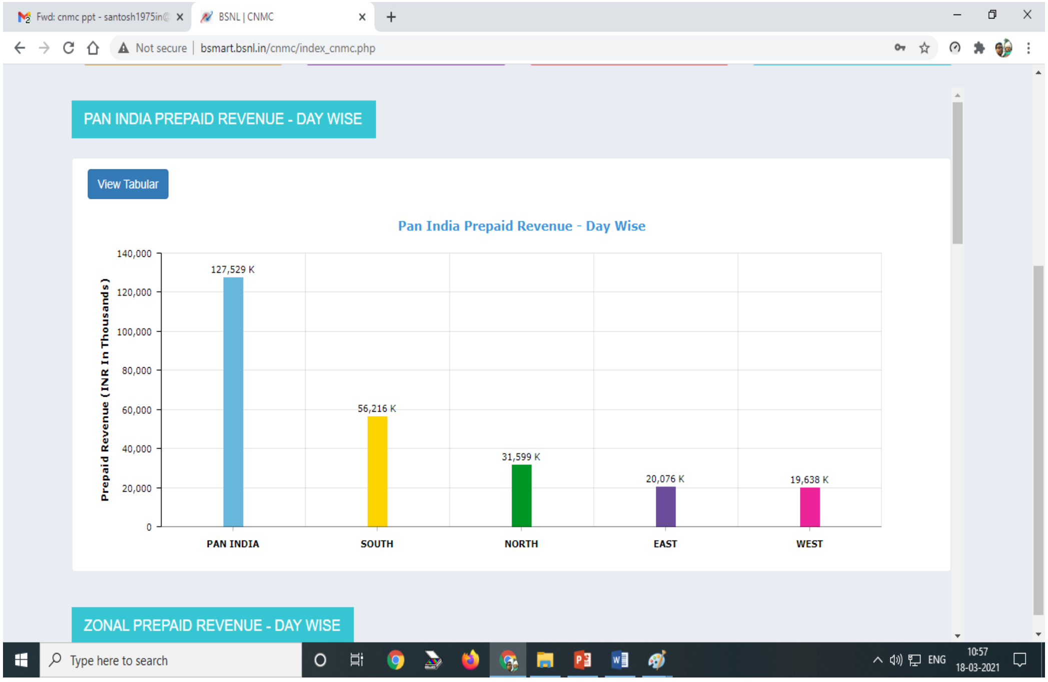


Figure 85: CNMC Portal

12.3 MOBILE NOC

Mobile network operation center is LIVE 24 hours, all days. More calls are made during day hours on a working day at a busy place in city centre whereas a much more urgent call could be made in an isolated highway stretch at 2am. A site outage at that time may cost someone a life. Hence, a mobile phone which is attached almost every waking hour to oneself, is the most important utility that is also a driver of business, a source of entertainment, could be a life saver and …… a means of communication too! And we need to make it work reliably 24 x 7.

12.3.1 FIVE OBJECTIVES OF 24X7 NOC

Establish a single establishment which has Visibility of all elements in the network and watching it ALL THE TIME

Knowledge of everything in the network and its surrounding that affacts the network Tools and Capability to analyse and distil the data to bring out what is important to act upon Expertise with confidence to advise the equipment in-charges on what is wrong and needs to be done to correct

Be a catalyst, bonding agent and an enabler among the mobile network maintenance fraternity

Thus, 24x7NoC shall in essence be a true mirror of everything in our network, an agile expert to improve the network and a supporting hand for all those who want to improve it.

12.3.2 MOBILE NOC FUNCTIONS

- Work Structure of NOC Pune
- Report preparation By NOC
- KPI PORTAL DEVELOPMENT

a) Work Structure of NOC Pune

Work Structure of NOC Pune				
Sr No.	Task	Details	Frequency	STAFF INVOLVED
1	Network monitoring	All NW	24*7	JTO & JE
2	Telephonic Support to field teams	All NW	24*7	JTO & JE
3	Bulk Failure monitoring	All NW	24*7	JTO & JE
4	Sites Creation /Deletion	All NW	as per request	JTO & JE
5	Partial Down Reset	All NW	Daily	JTO & JE
6	Addition deletion of TRX RSL	All NW	as per request	JTO & JE
7	RF Parameter Modification	As per Request/Mails From SSA	as per request	JTO & JE
8	Bulk RF changes	LAC , RAC,BCCH, BSIC, MAIO QAM , HR,FR,OSC,MCPA changes , External cells modification, Handover definitions, Automatic Frequency planning, Harmonisation etc.	As per request from RF Pune ,RF Mumbai, RF teams of SSA and NOC ,PUNE	JTO & JE

Table 21. Work Structure of NOC Pune

Work Structure of NOC Pune				
Sr No.	Task	Details	Frequency	STAFF INVOLVED
10	CNMC /CMTS portal Data addition/deletion/modification	All NW	Daily	JTO & JE
12	Deletion/Creation/Modification/ Shifting of sites in OMCR	Abis Shifting, BSC shifting	as per request	JTO & JE
13	Monitoring of Extension of external alarms	All NW	as per request	JTO & JE
14	Telephonic follow up from all ssa field teams	for updating outage reasons on CMTS portal	Daily	JTO & JE
		Bulk Failures, WTR Failures		JTO & JE
		EB Disconnection IP failures		JTO & JE
15	Site Name/IP changes	All NW	as per request	JTO & JE
16	KPI monitoring , analysis and modification, post modification analysis. Dump check .	All NW	Regular	JTO & JE

Table 22. Work Structure of NOC Pune

b) Report preparation By NOC

SR. NO	REPORT NAME	MEDIA OF COMMUNICATION	TIMING
1	WTR MAJOR FAULTS	WHATSUP TO NOC TEAM	DAILY MORNING 08:45 AM
2	MH_SITE_FAILURE AT 09:00 HRS	WHATSUP TO NOC TEAM/PGM SIR	DAILY MORNING 09:00 AM
3	SSA WISE AVAILABILITY	WHATSUP TO NOC TEAM/PGM SIR	DAILY MORNING 09:00 AM
4	AVAILABILTY SNAPSHOT DATED	WHATSUP TO NOC TEAM/PGM SIR	DAILY MORNING 10:00 AM
5	MH_SITE_FAILURE AT 18:00 HRS	WHATSUP TO NOC TEAM/PGM SIR	DAILY EVENING 06:00 PM
6	PARTAIL DOWN MORE THAN 15 DAYS	WHATSUP TO PUNE & NAGPUR OPERATION GROUP	DAILY BEFORE 10:00 AM
7	LEASE IN SITE FAILURE DUE TO BSNL REASONS MORE THAN 15 DAYS	WHATSUP TO PUNE & NAGPUR OPERATION GROUP	DAILY BEFORE 10:00 AM
8	LEASE OUT SITE FAILURE MORE THAN 24 HRS	WHATSUP TO PUNE & NAGPUR OPERATION GROUP	DAILY BEFORE 10:00 AM
9	HARDWARE FAULT MORE THAN 7 DAYS	WHATSUP TO PUNE & NAGPUR OPERATION GROUP	DAILY BEFORE 10:00 AM
10	MW FAULTS MORE THAN 15 DAYS	WHATSUP TO PUNE & NAGPUR OPERATION GROUP	DAILY BEFORE 10:00 AM
11	TRAFFIC REPORT	WHATSUP TO NOC TEAM/PUNE & NAGPUR MOBILE OPERATIN,GSMNOC GROUP & PGM SIR	DAILY BEFORE 12:00 AM
12	SITE FAILURE MORE THAN 7/30/90/180 DAYS WITH RCA	WHATS UP TO PUNE & NAGPUR MOBILE OPERATION MAIL TO ALL SSA & ALL HIGHER OFFICERS	DAILY BEFORE 12:00 AM
13	MISSING REASONS FOR OUTAGES OF THE MONTH	WHATS UP TO PUNE & NAGPUR MOBILE OPERATION	DAILY
14	SSAWISE PARTIAL DOWN REPORT	WHATS UP TO PUNE & NAGPUR MOBILE OPERATION	DAILY
15	2G RESET & 3G PARTIAL RESET PUNE ZONE	MAIL TO ALL SSA & ALL HIGHER OFFICERS	DAILLY
16	SSA WISE AVAILABILITY AT 17 HRS, AND DETAILED REASONS FOR SSA AVAILABILITY BELOW 85 %	WHATSUP TO NOC TEAM/PGM SIR	DAILY BEFORE 17:00 PM
17	IP QOS WEEKLY	MAIL TO ALL SSA & ALL HIGHER OFFICERS	WEEKLY
18	TRAI REPORT PREPARATION	MAIL TO ALL SSA & ALL HIGHER OFFICERS	MONTHLY
19	IP AVAILABILITY	MAIL TO ALL SSA & ALL HIGHER OFFICERS	MONTHLY
20	SITE WISE AVAILABILITY	MAIL TO ALL SSA & ALL HIGHER OFFICERS	MONTHLY
21	OUTAGE ANALYSIS REPORT	MAIL TO ALL SSA & ALL HIGHER OFFICERS	MONTHLY
22	ALL KPI GOOGLE SPREAD SHEET UPDATE	GOOGLE SPREAD SHEET	2ND TUESDAY EVERY MONTH

Table 23. Report by NOC

c) KPI PORTAL DEVELOPMENT

- Equipment of three venders are deployed in MH Circle , viz Alcatel/ Nokia/ ZTE.
- No NMS is available in BSNL Network
- There was No single entity was available with us which will provide a integrated reports of all Venders.
- Hence in 2018 NOC has started in-house development of centralized server which provides reports of all three venders on single platform.
- Over the period of two years the portal has become more mature and different reports are available on portal in very professional manner.
- No CAPEX is done on this project as we have used the server which was scraped.
- As development is continuous process we work on this server on daily basis as per requirement is placed by Management.

12.4 FEATURES OF KPI SERVER

- Server development is entirely in House
- Firewall is used for security purpose.

- Reports are available Daily , TCBH and BBH
- Reports are available cell wise / Site wise / BSC wise/ RNC and SSA wise
- 10 Mbps lease line is made available for seamless online availability
- Can be accessed via Mobile/ Laptop

A) LOGIN PAGE	
1. PORTAL LINK :	http://117.205.2.4/BSSKPI/index.php
2. USERNAME :	10 digit Mobile Number (eg:-9403685066)
3. DEFAULT PASSWORD	bsnl123

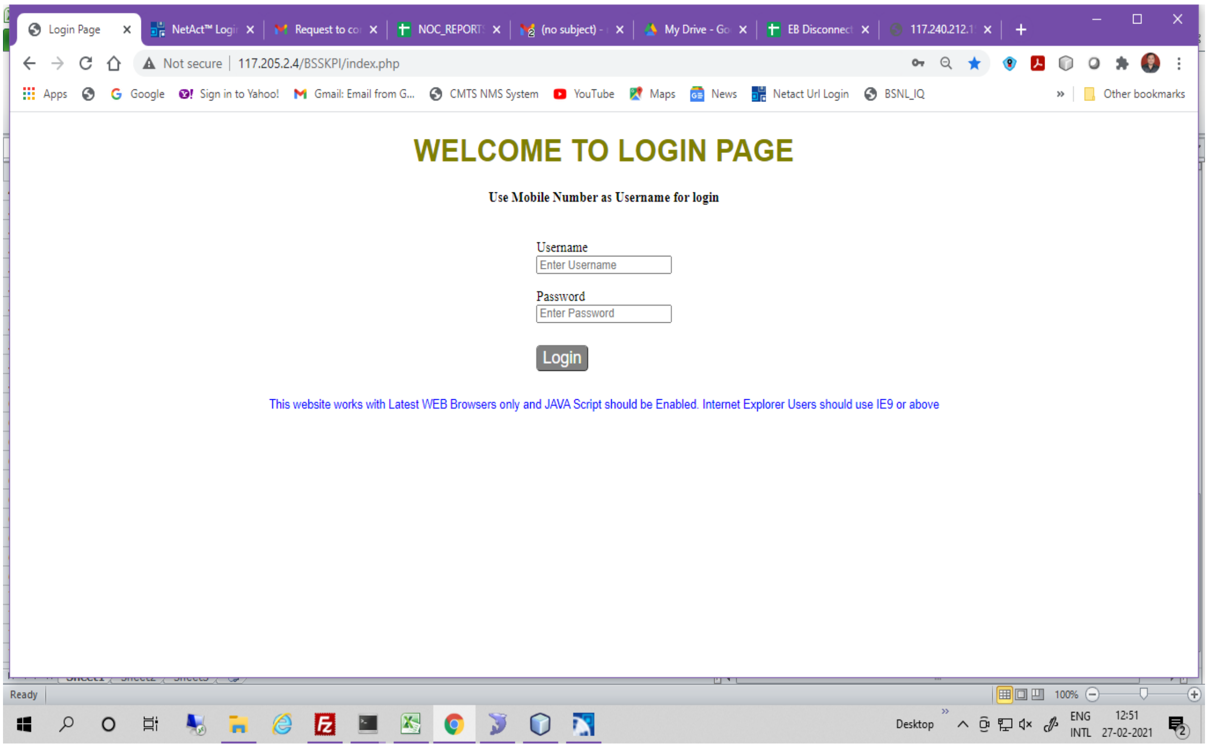


Figure 86: KPI Server

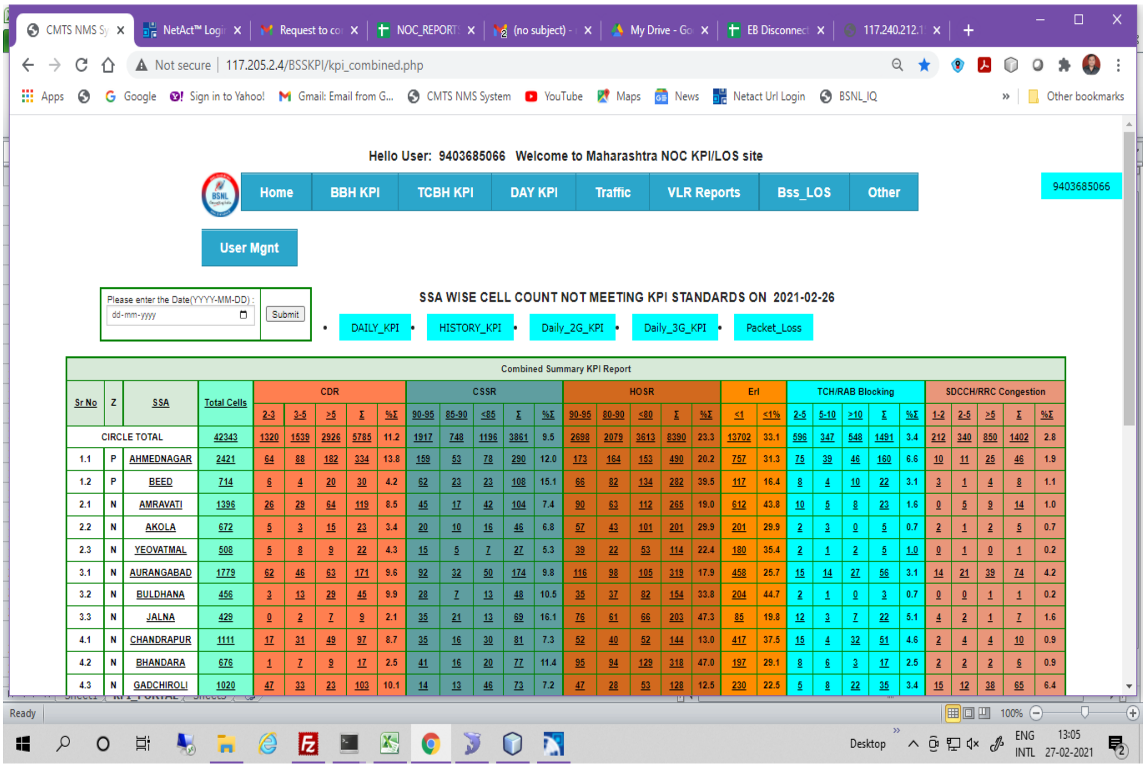


Figure 87: Home Page KPI portal

a) This is containing all sub Tab and also the summaries SSA wise report of KPI meeting for Last Day. The report contains cell wise BBH KPI, TCBH KPI and DAY KPI.

b) The DAILY_KPI - gives yesterday KPI meeting summary for the whole Network (2G/3G).

The HISTORY_KPI - gives summary of cells counts meeting KPI parameter for last 10 days out of 15 days for 2G/3G network.

Traffic –
It gives whole network traffic for last day as well as historical traffic data.
Live All Maharashtra BSC/RNC status.

VLR Report - It will display the Daily MSC VLR , PLMN VLR , roaming VLR, In-roam VLR, International Roam/In-roam VLR .

BSS_LOS:- Live Site failure report / bulk failure status.

g) Other - Different reports like Sleeping cells/ cell master/ping test etc.

12.5 CONCLUSION

CNMC and Mobile NOC are very important to manage the network properly

13 QOS AND QOE OF MOBILE NETWORK

13.1 LEARNING OBJECTIVE

After completion of this chapter participant will able to understand:

- QoS and QoE Definitions
- Concept of QoE
- QoS and QoE in LTE
- QoS and QoE service prospective

13.2 QOS AND QOE IN MOBILE BROADBAND NETWORK

13.2.1 DEFINITION OF QUALITY OF SERVICE

ITU-T Rec. E.800 defines quality of service as:

“Totality of characteristics of a telecommunications service that bear on its ability to satisfy stated and implied needs of the user of the service.”

ETSI defines QoS from the network perspective as:

“Quality of Service (QoS): the ability to segment traffic or differentiate between traffic types in order for the network to treat certain traffic differently from others”, and in the ISO definition, quality is defined as “the totality of characteristics of an entity that bear on its ability to satisfy stated and implied needs” (ISO 8402).

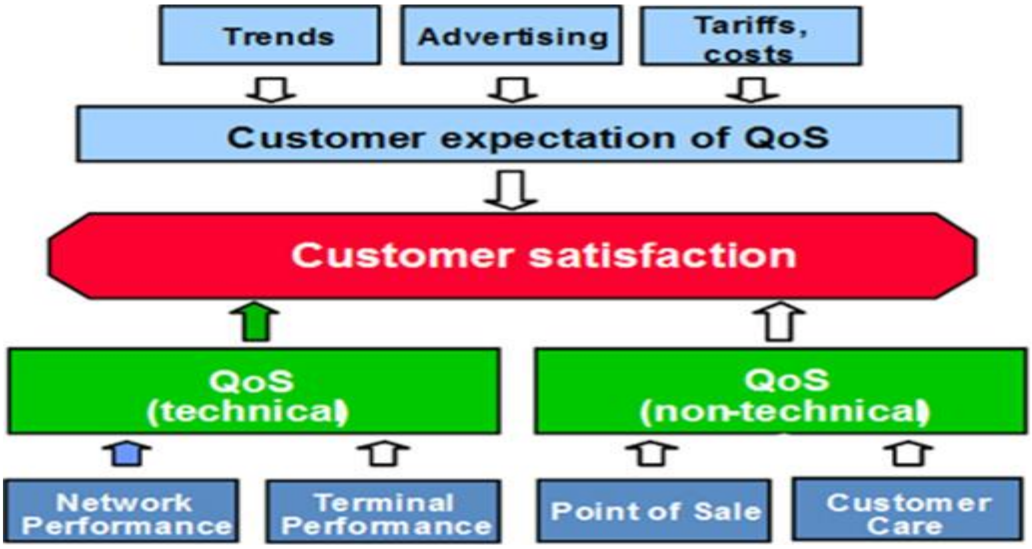


Figure 88: QoS technical and non-technical point of view, and customer satisfaction

Source: ITU-T Supplement 9 to Rec. Series E.800 (12/2013)

13.3 QOS TERMINOLOGY

General QoS terminology, as defined in ITU-T E.800, includes the following:

- **QoS requirements of user/customer (QoSR):** A statement of QoS requirements by a customer/user or segment/s of customer/user population with unique performance requirements or needs.
- **QoS offered/planned by service provider (QoSO):** A statement of the level of quality planned and therefore offered to the customer by the service provider.

- **QoS delivered/achieved by service provider (QoSD):** A statement of the level of QoS achieved or delivered to the customer. These parameters should be the same as specified for the offered QoS so that the two can be compared to determine what was actually achieved in order to assess the level of performance obtained.
- **QoS experienced/perceived by customer/user (QoSE):** A statement expressing the level of quality that customers/users believe they have experienced. Perceived QoS is assessed by customer surveys and from a customer's own comments on levels of service.
- **Characteristic:** A property which helps to differentiate between the individuals of a given population.
- **Criterion:** Collections of characteristics or a single characteristic, as appropriate, to describe benefit to a user of a product or a service.
- **Parameter:** A quantifiable characteristic of a service with specified scope and boundaries.
- **Objective (quantitative) parameters:** Parameters that are measurable (with instruments or observations) and a performance value assigned quantitatively may be classified as objective parameters.
- **Subjective (qualitative) parameters:** Parameters that can be expressed using human judgment and understanding may be classified as subjective or qualitative parameters.
- **Measure:** A unit by which a parameter may be expressed.
- **Metric (also called Indicator):** Value calculated from observed attribute/s of a measure.
- **Service:** A set of functions offered to a user by an organization. Item: Any part, device, subsystem, functional unit, equipment or system that can be individually considered.
- **User:** A person or entity external to the network, which utilizes connections through the network for communication.
- **Customer:** A user who is responsible for payment for the services.
- **Network performance:** The ability of a network or network portion to provide the functions related to communications between users.
- **Network provider:** An organization that owns a telecommunications network for the purpose of transporting bearers of telecommunication services.
- **Service provider:** An organization that provides services to users and customers.

13.4 DEFINITION OF QUALITY OF EXPERIENCE

According to ITU-T Recommendation P.10/G.100, quality of experience (QoE) was initially defined as "the overall acceptability of an application or service, as perceived subjectively by the end-user."

Quality of experience (QoE) is the degree of delight or annoyance of the user of an application or service.

The same ITU-T recommendation defined two new terms:

1. QoE influencing factors: This includes the type and characteristics of the application or service, context of use, the user expectations with respect to the application or service and their fulfillment, the user cultural background, socio-economic issues,

psychological profiles, emotional state of the user, and other factors whose number will likely expand with further research.

2. QoE assessment: This is the process of measuring or estimating the QoE for a set of users of an application or a service with a dedicated procedure, and considering the influencing factors (possibly controlled, measured, or simply collected and reported). The output of the process may be a scalar value, multi-dimensional representation of the results, and/or verbal descriptors. All assessments of QoE should be accompanied by the description of the influencing factors that are included. The assessment of QoE can be described as comprehensive when it includes many of the specific factors, for example a majority of the known factors. Therefore, a limited QoE assessment would include only one or a small number of factors.

QoE includes complete end-to-end system effects (end-user equipment, as well as network and service infrastructure). Overall acceptability may be influenced by user expectations and the context.

- QoE takes into account additional parameters:
- User expectations;
- User context (e.g. Personal mood, environment, work/home/outside, etc.);
- Potential discrepancy between the service offered and individual user awareness of the service and additional features (if any) for that service.

One may conclude that

"QoE is different from QoS as it is based on customer perception of the given service. QoE includes the complete end-to-end system elements (client, terminal, network, services infrastructure, etc.) and may be influenced by user expectations and context. In principle, QoE is measured subjectively by the end-user and may differ from one user to another."

But we will try to quantify the QoE of some application as per user prospective for some of the mostly used services.

The most used measure for QoE is the mean opinion score (MOS). Initially, the MOS scale referred to voice service only (ITU-T P.800), but is now used for other services such as video (e.g. Internet Protocol Television (IPTV). MOS is expressed as a single number in the range from 1 to 5, where the value of 1 corresponds to the lowest quality experienced by the end-user and 5 is the highest quality experienced

Mean Opinion Score	**Quality**
5	Excellent
4	Good
3	Fair
2	Poor
1	Bad

Table 24. Mean opinion score

The relationship between quality of service, quality of experience, and network performance

QoE is different from QoS and network performance as it has a subjective feature in its definition. QoE depends on the end-user perception in addition to features of services that may result in quite different ways of specifying the value. It is clear, however, that QoE is impacted by QoS and network performance.

Network performance applies to network provider planning, development, operations, and maintenance. As illustrated in Figure below total network performance is the detailed technical part of the QoS offered. As indicated in ITU-T Rec. G. 1000, it contributes to QoS as experienced by the user. The functions of a service depend on the performance of the network elements and the performance of user terminal equipment.

QoS is always end-to-end, i.e. user-to-user or user-to-content. Therefore, QoS measurements are also carried out end-to-end. End-to-end QoS depends on the contributions made by the components as described in Figure, including user, user equipment, access network, IP transport, core network, and the rest of the path end-to-end (e.g. through the Internet). QoE has a broader scope as it is impacted by QoS as well as by user expectations and context.

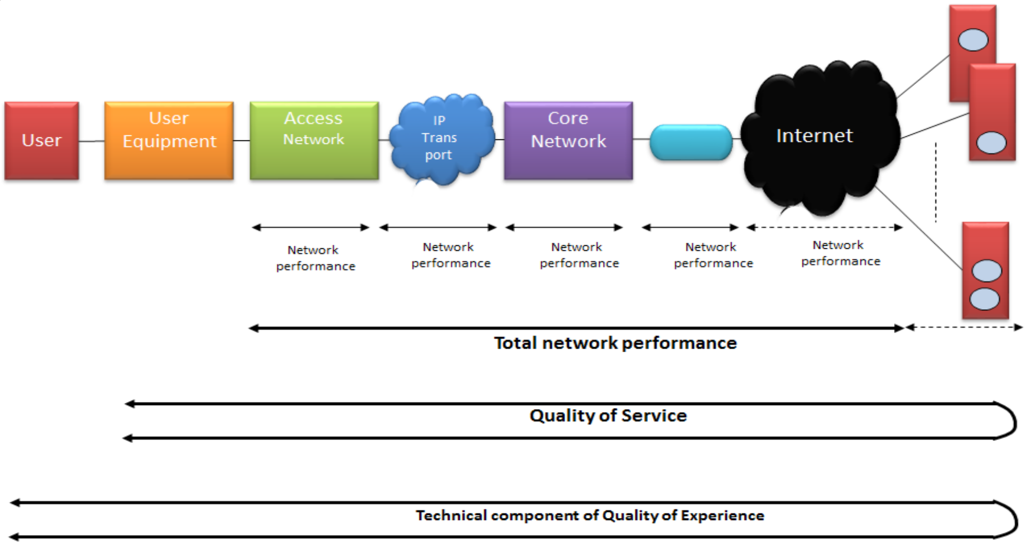


Figure 89: Network performance, QoS and QoE

Source: ITU

To provide QoS support for a given service, QoS criteria and parameters are required. ITU-T Rec. G.1000 defines these terms, which provide the general QoS framework. Seven QoS criteria are specified:

- Speed (refers to all service functions);
- Accuracy (e.g. Speech quality, call success ratio, bill correctness, etc.);
- Availability (e.g. Coverage, service availability, etc.);
- Reliability (e.g. Dropped call ratio, number of billing complaints, etc.);
- Security (e.g. Fraud prevention);
- Simplicity (e.g. Ease of software updates, ease of contract termination, etc.); and
- Flexibility (e.g. Ease of change in contract, availability of different billing methods such as online billing, etc.).
- The seven service quality criteria are mapped on a set of service functions by using a given matrix, as illustrated in Table 2 where the example provided is a matrix for mobile telephony service. Such mapping is also referred to as a performance model in ITU-T E.802. It is one of the three possible models for identification of user QoS criteria that is needed before defining QoS parameters (one must specify criteria used for definition of QoS parameters).

		Service quality criteria						
		Speed 1	Accuracy 2	Availability 3	Reliability 4	Security 5	Simplicity 6	Flexibility 7
Service function								
Service management	Sales & pre-contract activities 1	Processing time						
Service management	Provision 2	Supply time		Coverage				
Service management	Alteration 3	Response time						Ease of change in contract
Service management	Service support 4	Response time		Availability of call centre			Professionalism of help line	
Service management	Repair 5	Processing time						
Service management	Cessation 6	Call set-up time					Ease of contract cessation procedure	
Connection quality	Connection establishment 7	Call set-up time		Service availability				
Connection quality	Information transfer 8	One-way delay			Dropped call ratio within a specific time period			
Connection quality	Connection release 9	Release time						
Billing 10		Billing frequency			Number of billing complaints within period	Fraud protection/ prevention		Availability of different billing methods (e.g. online billing)
Network/Service management by customer 11							Ease of software updates	

Table 25. Performance model for a mobile telephony service with matrix of mapping service quality criteria and service functions (Source: ITU-T E.802.)

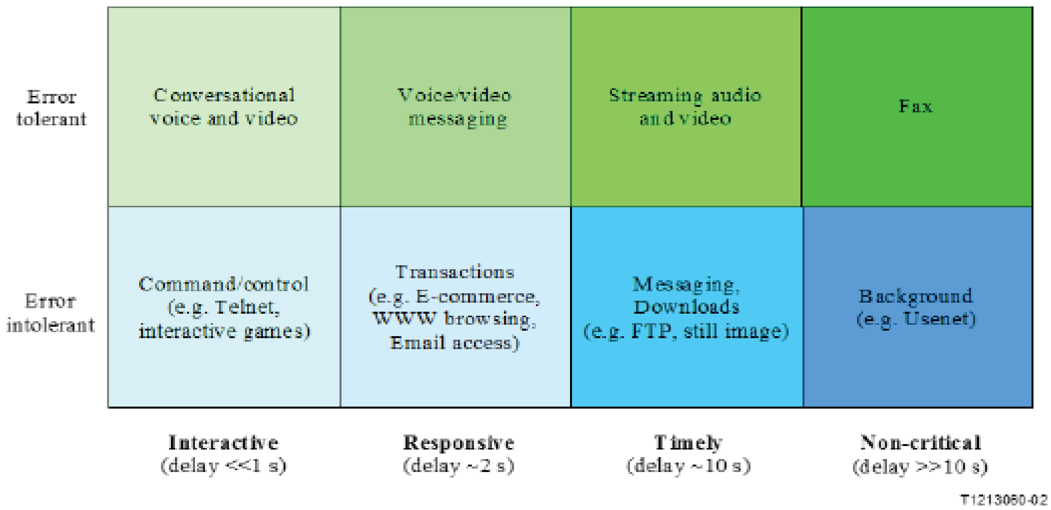


Figure 90: Model for user-centric QoS categories

13.5 QUALITY OF SERVICE (QOS) IN LTE

LTE Quality of Service (QoS) has become an important part of network planning & design when deploying 4G/LTE broadband wireless for data & voice services. There are subscribers who use LTE services for critical operations (e.g. voice calls, bank transactions, hospital operations), and there are subscribers who just want to enjoy premium Internet & applications experiences. LTE was designed to meet these increased data and application demands with reliable connections and low cost of deployment. A best case scenario would feature a highly-Flexible QoS framework that is built to withstand future challenges. Advanced LTE QoS priorities for certain customers or services during congestion. In LTE Broadband Network QoS is implemented between CPE and PDN Gateway and is applied to a set of bearers. 'Bearer' is basically a virtual concept and is a set of network configuration to provide special treatment to set of traffic e.g. VoIP packets are prioritized by network compared to web browser tra_c. In LTE, QoS is applied on Radio bearer, S1 bearer and S5/S8 bearer, collectively called as EPS bearer as shown in figure below:

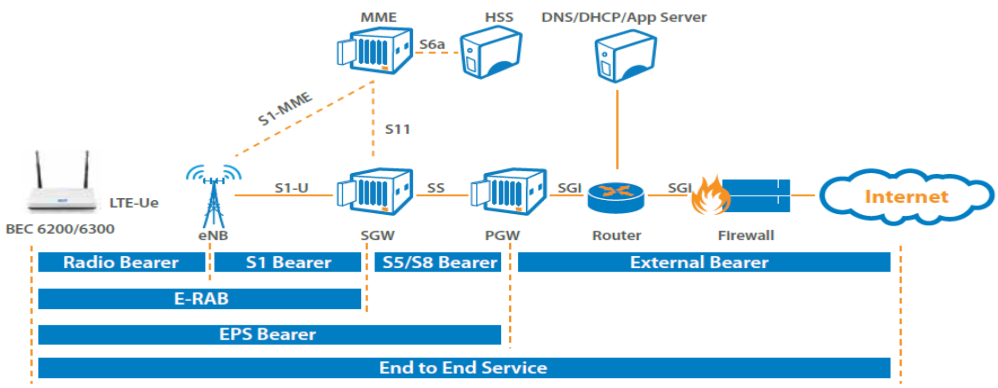


Figure 91: LTE End to End Bearer Setup

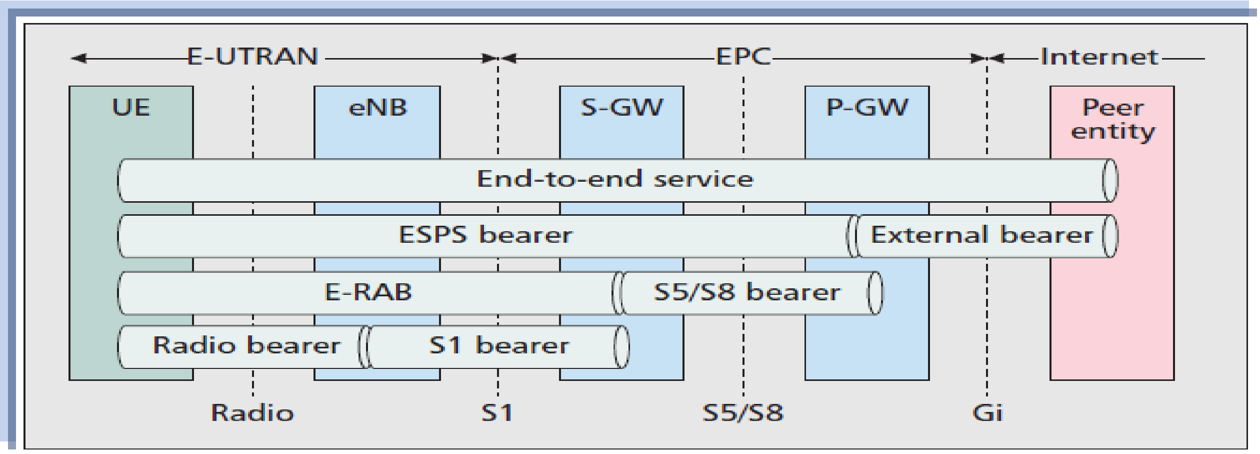


Figure 92: LTE Bearers Setup

13.5.1 UNDERSTANDING DEFAULT & DEDICATED BEARER

To best implement the concept of Qos in a LTE network, we must understand the bearer types and properties associated with each bearer. Two types of Bearer exist :-

- Dedicated bearer
- Default bearer.

Default bearer is established when a CPE is initially attached to LTE network while dedicated bearer is always established when there is need to provide QoS to specific service (like VoIP, video etc).

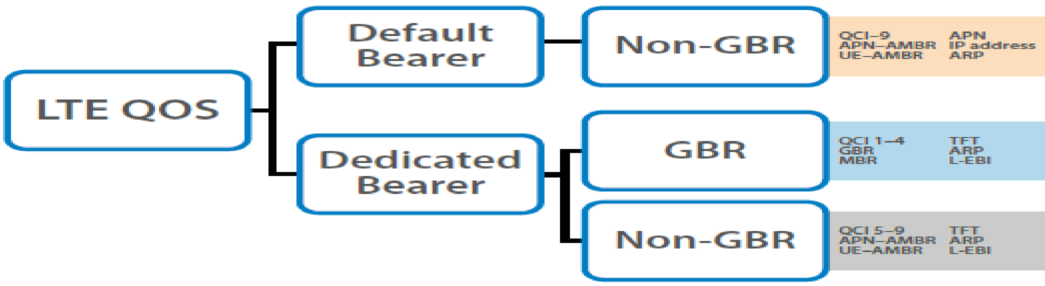


Figure 93: Types of QoS of LTE Bearer

Bearer in fixed broadband network is similar to a virtual traffic management concept. Bearer pre-determines how the user end data is treated when it travels across the LTE network. Network might treat certain type of data in a prioritized or different way and other data normally. Some flow of data type might be provided guaranteed bit rate while other may assign lower transfer rate. In a simply explanation, LTE bearers are sets of network parameter that define data specific treatment.

One example of using bearers to provide tiered service packages – A premium subscriber will always get at least 5Mbps download speed on his LTE broadband service while for a basic package subscriber there is no guaranteed bit rate and his speed may be subject to traffic conditions.

13.5.2 DEFAULT BEARER IN LTE

When a LTE broadband CPE initiate a connection to the network for the first time it will assigned a default bearer depend on the service subscribed and remain connected until service is changed or terminated. For many carriers Default bearer is the best effort service which means speed and quality may vary depend on network usage and time of the day. Each default bearer comes with an IP address. Each LTE broadband subscriber can have additional default bearers as well. Each default bearer will have a separate IP address. QCI 5 to 9 (Non- GBR) can be assigned to default bearer.

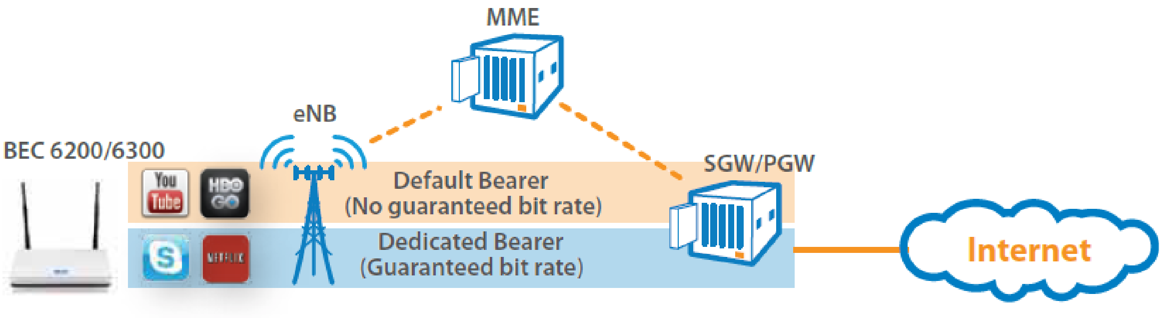


Figure 94: GBR /Non GBR in LTE in Default Bearer

13.5.3 DEDICATED BEARER IN LTE

In simple terms , dedicated bearers provide dedicated tunnel to one or more specific traffic (VoIP, Video) Dedicated bearers are the secondary bearers that are created on top of the existing default bearer. Dedicated bearer shares the IP address previously established by the default bearer therefore dedicated bearer does not require to occupy additional IP address.

Dedicated bearer are mostly used as GBR (Guaranteed Bit Rate) services although it can also can be a non-GBR service. On the other hand, Default bearer can only be non-GBR. Carrier or service providers that provide voice over LTE will find dedicated bearer useful to maintain high voice quality and to improve high QoS of voice service. Carriers or SP (Symbol Period) can use TFT (Traffic Flow Template) within dedicated bearer to assign special rule of treatment to specific data or services even SIP and VoIP can also be supported.

For services like VoLTE we need to provide better user experience and this is where Dedicated bearer would come handy. Dedicated bearer use TFT (Traffic Flow Template) to give special treatment to specific services.

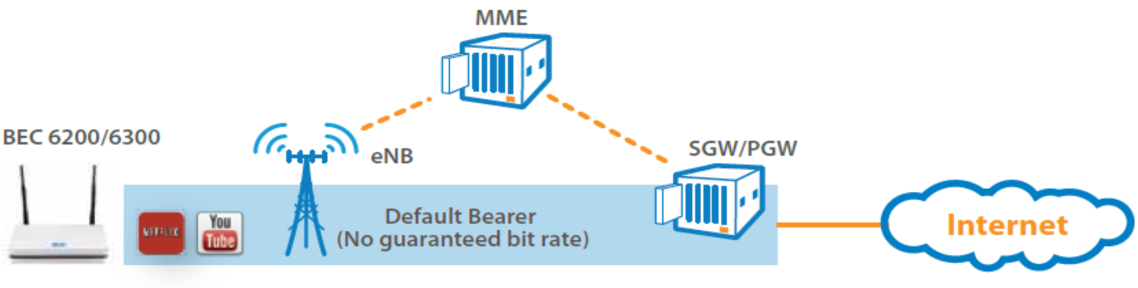


Figure 95: GBR /Non GBR in LTE in Dedicated Bearer

Dedicated bearer can be subdivided into Non-GBR and GBR types.

GBR - The minimum guaranteed bit rate per EPS bearer. GBRs are specified individually for uplink and downlink.

A value of a GBR QoS parameter is pre-determined and associated to the bearer. If the traffic carried by that GBR bearer conforms to the value of associated with the bearer, congestion-related packet losses will not occur on the services utilizing that GBR bearer. This can be initiated on the network end (e.g. the access base stations) during activation or admission control processes, and are executed when the bearer is established.

A GBR bearer typically is established “on demand” because it blocks transmission resources by reserving them in an admission control function.

An LTE fixed broadband carrier may leverage GBR bearers to implement "service blocking" rather than "downgrade service". For most carriers this is a preferred user experience, in which network carriers block a service request rather than enabling all services with degrades quality and performance.

This is relevant in scenarios in situations voice services will remained up while data and other traffics will be discontinued during an emergency or extreme heavy network loading.

Non-GBR – No minimum guaranteed bit rate per EPS bearer.

On the other hand Internet network service utilizing a non-GBR bearer is prone to congestion related packet losses. Non-GBR does not block any network specific traffic or transmission resources. A non-GBR is established in the default or dedicated bearer and however, can remain established for a long period of time.

Whether a service is realized based on GBR or non-GBR bearers, the policy of a carrier or service provider is depend on anticipated traffic load versus dimensioned capacity. Assuming sufficiently dimensioned capacity is available, any service, both real time and non-real time, can be realized based on non-GBR bearer.

Other parameter associated with all bearers - QoS class of identi_er (QCI) which de_nes IP level packets characteristics:

QCI	Type	Packet delay budget	Packet error loss rate	Example services
1	GBR	80 ms	10^{-2}	Conversational voice
2		130 ms	10^{-3}	Conversational video (live streaming)
3		30 ms	10^{-3}	Real-time gaming
4		280 ms	10^{-6}	Non-conversational video (buffered streaming)
5	Non-GBR	80 ms	10^{-6}	IMS signaling
6		280 ms	10^{-6}	Video (buffered streaming) TCP-based (e.g., web, -mail, chat, FTP, P2P file sharing, progressive video)
7		80 ms	10^{-3}	Voice, Video (live streaming) Interactive gaming
8		280 ms	10^{-6}	Video (buffered streaming) TCP-based (e.g., web, email, chat, FTP, P2P file sharing)

Table 26. QoS in 4G Services

13.6 QOS/QOE IN 5G NETWORK

3GPP specifications are the basis for creating interoperable 5G systems.

The 5G system is a complete mobile communications platform that delivers three key 5G service categories:

- Enhanced Mobile Broadband (eMBB)
- Massive Machine-Type Communications (mMTC)
- Ultra-Reliable Low Latency Communications (URLLC)
- The following are the expectations of the 5G QoS parameters:
- Speed/throughput of 10Gbps, and a target of 20Gbps
- End-to-end latency reduced to 1-10 milliseconds and 0.5 milliseconds on physical networks
- 100% network availability
- Reliability parameters expected to be 0.00001 in a 1 millisecond period, which are 0.01 in 4G
- Jitter reduced to 10-100 microseconds
- Bandwidth from 100Kbps for small sensor devices to several hundred megabits per second for industrial robot cameras

13.6.1 QOE IN 5G NETWORK

KPIs and QoS parameters are independent from radio and access technology, but the acceptance thresholds have to be adjusted to new services.

QoE is not directly depending of radio technology, but the expectation will increase with higher performance. Increasing expectation changes QoE but it happens for all technologies then.

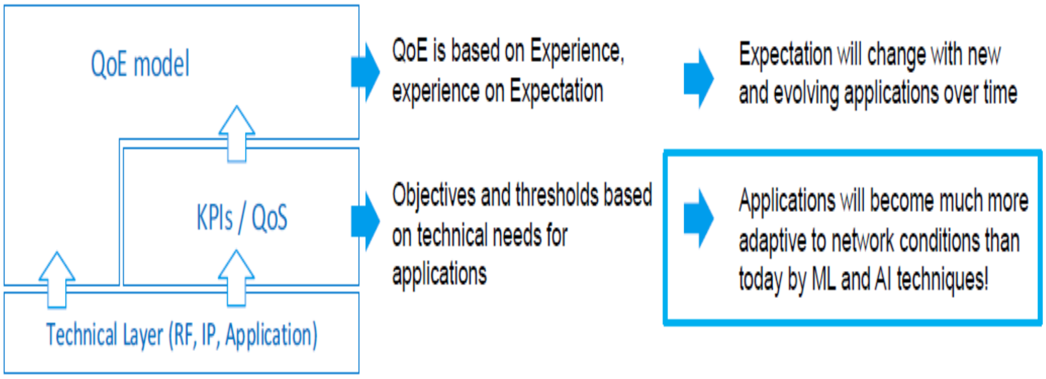


Figure 96: QoE/QoS in 5G

Source: Rohde and Schwarz

13.6.2 HOW TO MEASURE QOS AND QOE IN 5G?

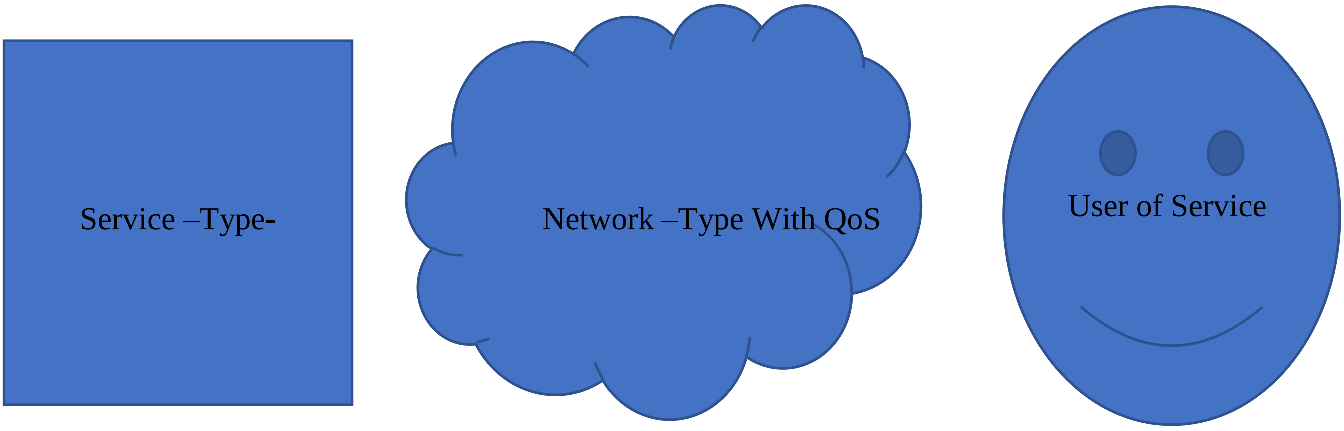
- QoE considers a user's expectation. QoS is more rational based on technical measurements Existing applications and uses cases (e.g. Web-Browsing, Video Streaming) are used in 5G too.
- KPIs and QoS parameters are the same as for 4G and below, they are widely independent from radio technology
- Quality usually reads as 'quality of media presentation' e.g. Speech-MOS or Video-MOS
- QoE models stay for a while too. Along with increasing expectation, QoE models have to be re-adjusted
- Evolving and new services (e.g.4K Video, Virtual Reality, Real-time Broadcasting, Real-time Gaming)
- Many existing KPIs and QoS parameters and concepts can be used (access time, failure ratio).
- New KPIs and QoS parameters are required for e.g. response times, seamless connectivity and similar.
- New QoE parameters for quality (e.g. 4K Video, 360°Video) are required.
- Quality will go beyond today's 'media presentation' concept and will include e.g. 'interactivity'

Service Type	QoS	QoE
eMBB (Enhanced Mobile Broadband)	• Speed/throughput of 10Gbps, and a target of 20Gbps	• No buffering at 4K Video • New QoE parameters for quality (e.g. 4K Video, 360°Video) are required as similar to Mean Opinion Score.
mMTC (massive	• 100% network availability	• Number of devices to be

Machine- Type Communication)	• Reliability parameters expected to be 0.00001 in a 1 millisecond period, which are 0.01 in 4G • Jitter reduced to 10-100 microseconds • Bandwidth from 100Kbps for small sensor devices to several hundred megabits per second for industrial robot cameras	supported by 5G Network i.e 1 million nodes per km2 • Always on network with IP (IPv6) Support). So that no user device should wait for address.
URLLC (Ultra Reliable Low Latency)	• End-to-end latency reduced to 1-10 milliseconds and 0.5 milliseconds on physical networks	• AI application support is to be experienced by user without delay.

13.7 CONCLUSION

The below diagram gives a conclusion to the QoS and QoE



Service **Defined by Operator, or by service provider**	**QoS** **What Network Promise to Deliver**	**QoE** **What User feels about the Service**