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University M'Hamed BOUGARA – Boumerdes

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MASTER

In **Telecommunication**
Option: **Telecommunications**

Title: LTE-Advanced Optimization and 5G Evolution

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Registration Number: 2020/2021

Dedication

I dedicate my dissertation work to my family and many friends. A special feeling of gratitude to my loving parents, whose words of encouragement and push for tenacity ring in my ears. Everyone who has never left my side and are very special.

I also would like to dedicate my work to my friends and Aquafamily who have supported me throughout the process. I will always appreciate all what they have done for me, especially my colleagues for helping me develop my technology skills and for all the time we passed together.

Finally special thanks to everyone who helped me from near or far, I wish you all the best and success in your life.

Acknowledgement

Thanks to Allah for providing me the great willing and strength to finish this work. I wish to express my sincere thanks and deep gratitude to my supervisor Pr. Mouloud CHALLAL for his support, assistance during the whole phases of my work. His assistance and encouragement have contributed essentially in finishing this work.

I owe special thanks to my co-supervisor Mr Bachir OULD BABA ALI (Deputy Director of Quality and Performance, Clients Perception Departments at ATM Mobilis) for his help, patience, understanding and encouragement. Also, special words of thanks with gratitude are devoted to all ATM Mobilis employees for their reception and treatment during the period of the Internship.

Finally, I would like to thank the staff of the Institute of Electrical and Electronic Engineering (IGEE, Ex. INELEC), Boumerdes University for their help and support given to this post-graduate study.

Abstract

The aim of this project is the optimization of LTE-Advanced Network which is a process based on network analysis, this includes the gathering of statistics and measurement results from the network management system.

To achieve this goal, we have used formulas of key performance indicator (KPI) counters, mechanism of traffic measurement counters, service drop rate, and common fault location methods. The obtained results from M2000 Huawei Software program. After applying the optimization procedure to each KPI such as Accessibility (RRC Connection Establishment Success Rate / e-RAB Establishment Success Rate), Retainability (Call Drop Rate), and Mobility (Handover Success Rate). The results indicate better performance and quality of service.

الهدف من هذا المشروع هو تحسين شبكة الجيل الرابع وهي عملية تعتمد على تحليل الشبكة، ويشمل ذلك جمع الإحصائيات ونتائج القياس من نظام إدارة الشبكة.

لتحقيق هذا الهدف، استخدمنا صيغًا لعدادات مؤشرات الأداء الرئيسية ، وآلية عدادات قياس حركة المرور، ومعدل إسقاط الخدمة، وطرق تحديد موقع الأعطال الشائعة . النتائج التي تم الحصول عليها من برنامج لشركة هواوي . بعد تطبيق إجراء التحسين على كل مؤشر أداء رئيسي مثل إمكانية الوصول (معدل نجاح إنشاء اتصال RRC / معدل نجاح إنشاء e-RAB) ، وقابلية الاحتفاظ (معدل انقطاع الاتصال) ، والتنقل (معدل نجاح التسليم). تشير النتائج إلى أداء أفضل وجودة الخدمة.

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List of Acronyms

1G: First Generation.
2G: Second Generation.
3G: Third Generation.
3GPP: Third Generation Partnership Project.
4G: Fourth Generation.
5G: Fifth Generation.
5GC: 5G Core.
5GS: 5G System.
AF: Application Function.
AMF: Access and Mobility Management Function.
AMPS: Advanced Mobile Phone System.
AUC: Authentication Center.
AUSF: Authentication Server Function.
BS: Base Station.
BSC: Base Station Controller.
BSS: Base Station Subsystem.
BTS: Base Transceiver Station.
CDMA: Code Division Multiple Access.
CDR: Call Drop Rate.
CN: Core Network.
DL: Downlink.
EDGE: Enhanced Data Rates for Global Evolution.
EIR: Equipment Identity Register.
eNB: Evolved Node Base Station.
EPC: Evolved Packet Core.
EPS: Evolved Packet Serving.
eRAN: evolved Radio Access Network.
ETSI: European Telecommunications Standards Institute.
E-RAB: EPS Radio Access Bearer.
E-UTRAN: Evolved Radio Access Network.
FDM: Frequency Division Multiplexing.
FDMA: Frequency Division Multiple Access.
FM: Frequency Modulation.
GGSN: Gateway GPRS Support Node.
gNB: Next Generation Node Base Station.
GPRS: General Packet Radio System.
GSM: Global System for Mobile communications.
HLR: Home Location Register.
HO: Handover.
HSPA: High Speed Packet Access.
HSS: Home Subscriber Server.

IMT: International Mobile Telecommunications.
KPI: Key Performance Indicators.
LTE: Long Term Evolution.
ME: Mobile Equipment.
MIMO: Multiple Input Multiple Output.
MISO: Multiple Input Single Output.
MME: Mobility Management Entity.
mMTC: Massive Machine-Type Communication.
MS : Mobile Station.
MSC: Mobile Services Switching Center.
NEF: Network Exposure Function.
ng-eNB: Next Generation Evolved Node Base Station.
Node B: Node Base Station.
NR: New Radio.
NRF: NR Repository Function.
NSS: Network Switching Subsystem.
OFDM: Orthogonal Frequency Division Multiplexing.
OFDMA: Orthogonal Frequency Division Multiple Access.
OMC: operations and maintenance center.
OSS: Operation Support Subsystem.
PCF: Policy Control Function.
PCRF: Policy Control and Charging Rules Function.
PDN: Packet Data Network Gateway.
RA: Random Access.
RAN: Radio Access Network.
RNC: Radio Network Controller.
RRC: Radio Resource Control.
SC-FDMA: Single Carrier - Frequency Division Multiple Access.
SGSN: Serving GPRS Support Node.
S-GW: Serving Gateway.
SIM: Subscriber Identity Module.
SIMO: Single Input Multiple Output.
SISO: Single Input Single Output.
SMF: Session Management Function.
TDMA: Time Division Multiple Access.
TNL: Transport Layer.
UDM: Unified Data Management.
UL: Uplink.
UMTS: Universal Mobile Telecommunications System.
UE: User Equipment.
UPF: User Plane Function.
uRLLC: Ultra-reliable low-latency Communication.
VLR: Visitor Location Register.
W-CDMA: Wideband CDMA.
xMBB: Extreme Mobile BroadBand.

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Introduction

Mobile Communication is the use of technology that allows us to communicate with others in different locations without the use of any physical connection. Mobile communication makes our life easier, and it saves time and effort by using cellular networks evolutions.

Cellular networks are high-speed, high-capacity voice and data communication networks with enhanced multimedia and seamless roaming capabilities for supporting cellular devices. With the increase in popularity of cellular devices, these networks are used for more than just entertainment and phone calls. They have become the primary means of communication for finance-sensitive business transactions, lifesaving emergencies. Today these networks have become the lifeline of communications [1].

Future mobile communications focus on everything Wireless in one Device along with Ubiquitous Communication among People and Devices. 5G network will provide high data rate, low latency, high reliability, energy saving, cost reduction, higher system capacity and massive device connectivity [2]. The aim of this project is the optimization of LTE-Advanced Network which is a process based on network analysis and an overview about different mobile networks and this project is structured as follows: 1st Chapter contains the evolution of cellular networks from 1G till 4G. Then 2nd Chapter explains 5G mobile networks NR expectations and challenges. Finally, 3rd Chapter where we are going to study the optimization of LTE-Advanced using Key Performance Indicators.

CHAPTER I

Evolution of Cellular Networks

I.1 Introduction:

Cellular mobile networks have been evolving for many years. The initial networks are referred to as "First Generation". These have now been replaced with "Second Generation" and "Third Generation" networks. Then 4G or "Fourth Generation". It is only now that "Fifth Generation" systems are being deployed [3].

This chapter presents an overview of Cellular Network Evolution from the 1G to the 4G mentioning their architectures, access methods and technologies used in this evolution.

I.2 First Generation Mobile Systems:

The 1G (First Generation) mobile systems were not digital. Based on an analogue technology known as Advanced Mobile Phone System (AMPS), which used Frequency Division Multiple Access (FDMA), 1G network offered a channel capacity of 30 KHz and a speed of 2.4 Kbps. 1G network only allowed voice calls to be made. These analogue systems were all proprietary based FM (Frequency Modulation) systems and therefore they all lacked security [3].

•Frequency: 150MHz / 900MHz.
•Bandwidth: Analog telecommunication (30 KHz).
•Technology: Analog cellular.
•Throughput (data rate): 2.4kbps.

I.3 Second Generation Mobile Systems:

2G (Second Generation) systems utilize digital multiple access technology, such as TDMA (Time Division Multiple Access). It allows several users to share the same frequency channel by dividing the signal into different time slots.
The most successful of all 2G technologies is GSM (Global System for Mobile communications). It was initially developed by ETSI (European Telecommunications Standards Institute) for Europe and designed to operate in the 900 MHz and 1800 MHz frequency bands [3].

•Frequency: 1800 MHz - 900 MHz.
•Bandwidth: 25 MHz.
•Technology: Digital cellular, GSM.
•Throughput (data rate): 64kbps.

I.3.1 GSM Architecture:

A GSM network comprises many functional units. These functions and interfaces are explained in this chapter. The GSM network can be broadly divided into:

- The Mobile Station (MS).
- The Base Station Subsystem (BSS).
- The Network Switching Subsystem (NSS).
- The Operation Support Subsystem (OSS).

Figure I.1 gives an example of the GSM Network Architecture.

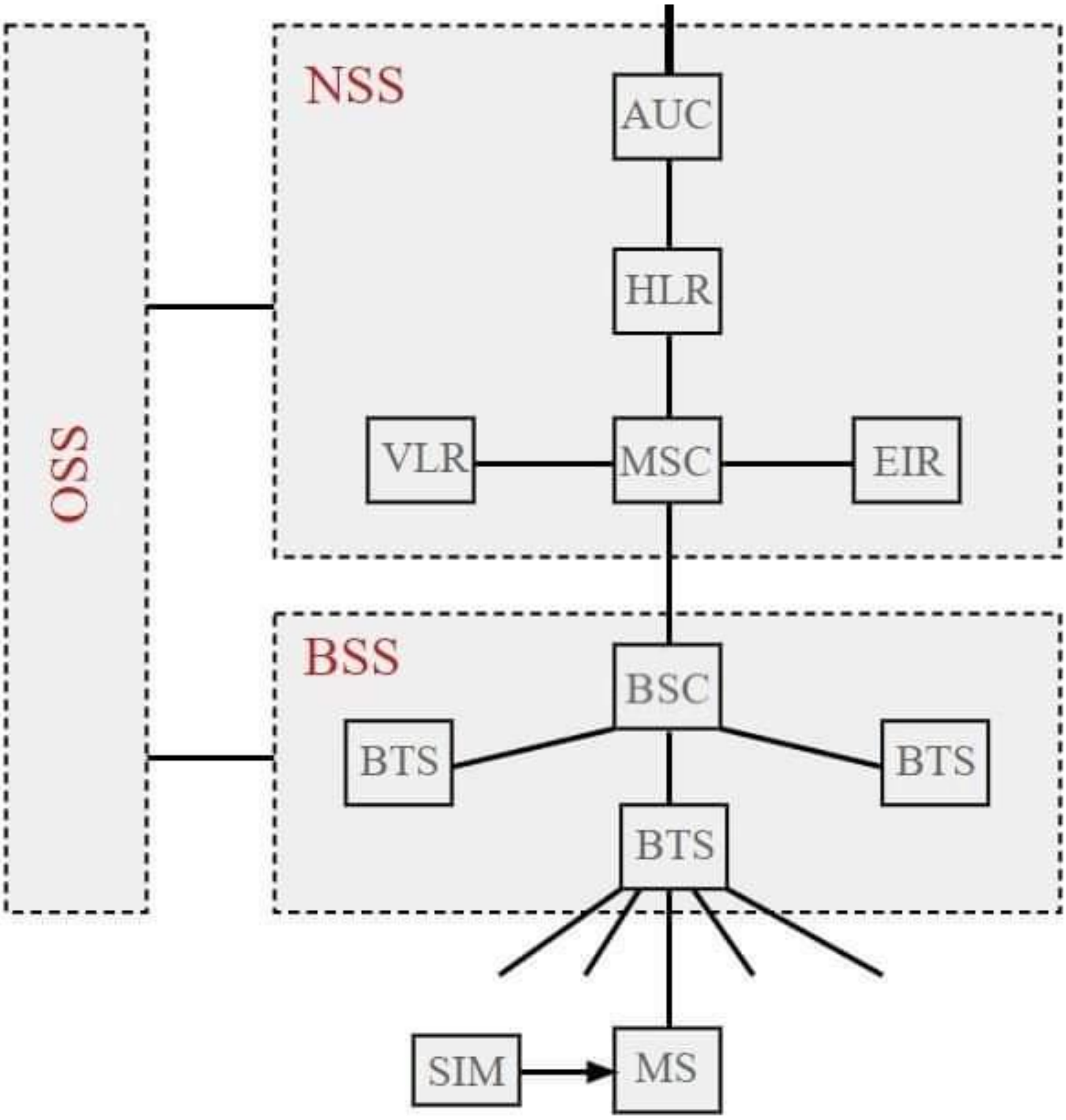

Figure I.1 GSM Network Architecture Diagram [4]

The Mobile Station (MS):

The Mobile Station consists of the mobile equipment (ME) and the subscriber identity module (SIM). As shown in Figure I.2 [4].

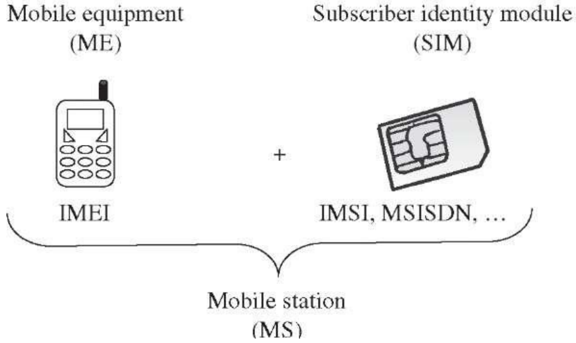

Figure I.2 Mobile Station Architecture Diagram

The Base Station Subsystem (BSS):

It is composed of two parts:

- The Base Transceiver Station **(BTS)** houses the radio transceivers that define a cell and handles the radio link protocols with the MS.
- The Base Station Controller **(BSC)** manages the radio resources for one or more BTSs. It handles radio channel setup, and handovers. The BSC is the connection between the mobile and the MSC [4].

The Network Switching Subsystem (NSS):

The major elements within the core network include:

- Mobile Services Switching Center **(MSC):** The central component of the Network Subsystem performs the switching of calls between the mobile and other fixed or mobile network users.
- Home Location Register **(HLR):** The HLR is a database used for storage and management of subscriptions.
- Visitor Location Register **(VLR):** The VLR is a database that contains temporary information about subscribers that is needed by the MSC in order to service visiting subscribers.
- Authentication Center **(AUC):** The Authentication Center is a protected database that stores a copy of the secret key stored in each subscriber's SIM card.
- Equipment Identity Register **(EIR):** The Equipment Identity Register (EIR) is a database that contains a list of all valid mobile equipment on the network [4].

The Operation Support Subsystem (OSS):

The operations and maintenance center (OMC) is connected to all equipment in the switching system and to the BSC. The implementation of OMC is called the operation and support system (OSS).

I.3.2 GPRS Systems:

Most 2G systems are being evolved. For example, GSM was extended with **GPRS** (General Packet Radio System) to support efficient packet data services, as well as increasing the data rates. As shown in Figure I.3 the diagram of GPRS network architecture [3].

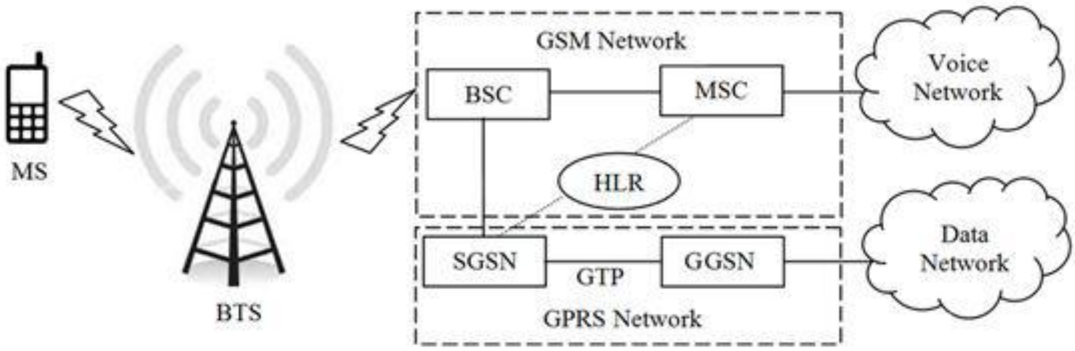

Figure I.3 GPRS Network Architecture Diagram

The deployment of GPRS requires the installation of new core network elements:

- The serving GPRS support node (**SGSN**) is the node controlling the BSC and serving the MS. It handles mobility, paging, and security and interfaces with the BSC.
- The gateway GPRS support node (**GGSN**) works with the packet data networks. Connected to the SGSN through an IP network, it contains routing information for GPRS users [4].

I.3.3 EDGE Systems:

GSM/GPRS systems also added **EDGE** (Enhanced Data Rates for Global Evolution) which uses a new modulation method (8PSK), three-bit of information can be transported by one symbol of modulation instead of one bit. This provided a significant advantage in being able to convey 3 bits per symbol, increasing the maximum data rate. Table I.1 compares between 2G releases [3].

	GPRS	EDGE
Modulation	GMSK	GMSK & 8-PSK
Symbol rate	270 ksym/s	270 ksym/s
Modulation bit rate	270kpbs	810kbps
Radio Data rate/time slot	22.8 kbps	69.2 kbps
User data rate/time slot	20kbps (CS-4)	59.2kbps (MCS-9)
User data rate(8 time slots)	160kbps	473.6kbps

Table I.1 Comparison between GPRS and EDGE

I.4 Third Generation Mobile Systems

Universal Mobile Telecommunications System (**UMTS**) is the third generation. **3G** (Third Generation) systems are defined by IMT2000 (International Mobile Telecommunications). The main 3G technology: **W-CDMA** (Wideband CDMA) was developed by the 3GPP (Third Generation Partnership Project). CDMA is a form of multiplexing, which allows numerous signals to occupy a single transmission channel, optimizing the use of available bandwidth [3].

•Frequency: 1.6 – 2.0 GHz.

•Bandwidth: 100MHz.

•Throughput (data rate): 2Mbps.

The diagram below in Figure I.4 represents UMTS Network Architecture.

Node B: Node Base Station.

RNC: Radio Network Controller.

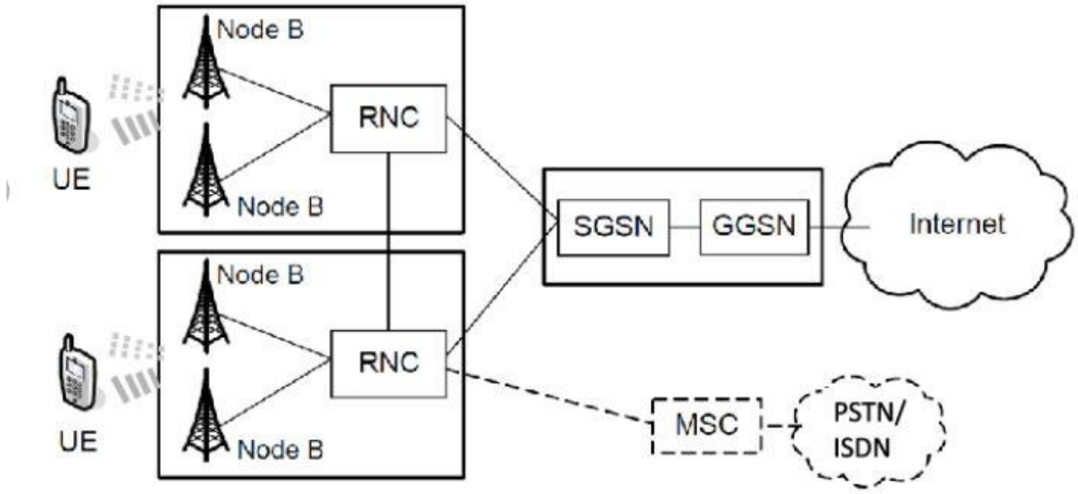

Figure I.4 UMTS Network Architecture Diagram [5]

The development of GSM, GPRS, EDGE, UMTS, HSPA and LTE is in stages known as 3GPP releases. Hardware vendors and software developers use these releases as part of their development roadmap. Figure I.5 illustrates the main 3GPP Releases that enhance the radio interface [3].

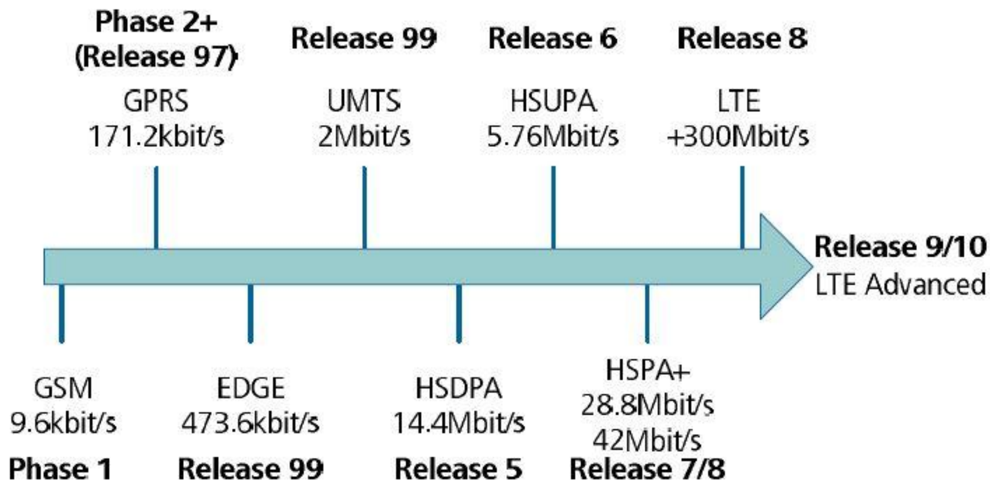

Figure I.5 Cellular Networks Releases [3]

I.5 Fourth Generation Mobile Systems:

LTE stands for Long Term Evolution**.** Its basis stands in the GSM/EDGE and UMTS/HSPA network technologies, with changes in terms of an increased capacity and higher speed by simplifying the core network. The main goal of LTE is to provide a high data rate, low latency and packet optimized radio access technology supporting flexible bandwidth deployments. The architecture of the LTE network can be seen in Figure I.6 [6].

EPC: Evolved Packet Core.
E-UTRAN: Evolved Radio Access Network.

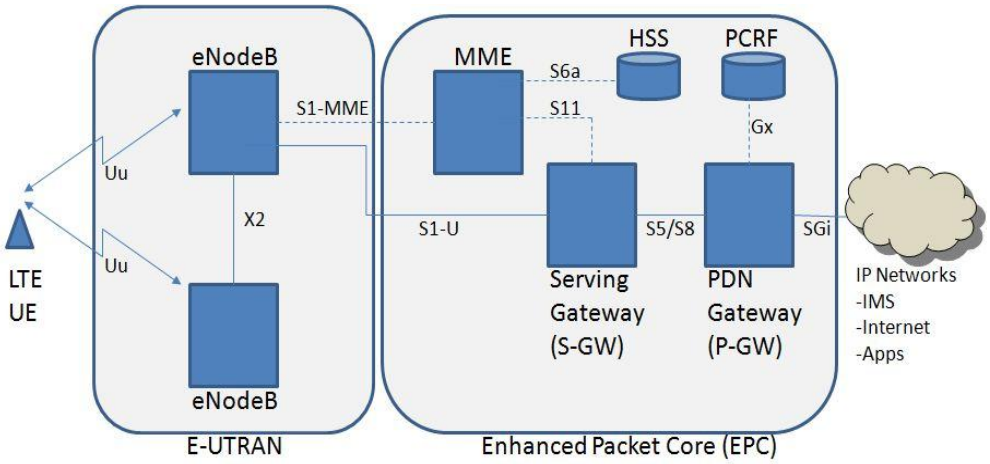

Figure I.6 LTE Network Architecture Diagram [6]

Mobility Management Entity (**MME)** controls the high-level operation of the mobile by means of signalling messages.

Home Subscriber Server **(HSS)** is a central database that contains information about all the network operator's subscribers.

Packet Data Network Gateway **(PDN)** The PDN gateway has the same role as the GPRS support node (GGSN) and the serving GPRS support node (SGSN).

The serving gateway (**S-GW)** acts as a router, and forwards data between the base station and the PDN gateway.

The Policy Control and Charging Rules Function (**PCRF**) is responsible for policy control decision-making [6].

Figure I.7 summarizes 2G, 3G and 4G Architectures in one diagram.

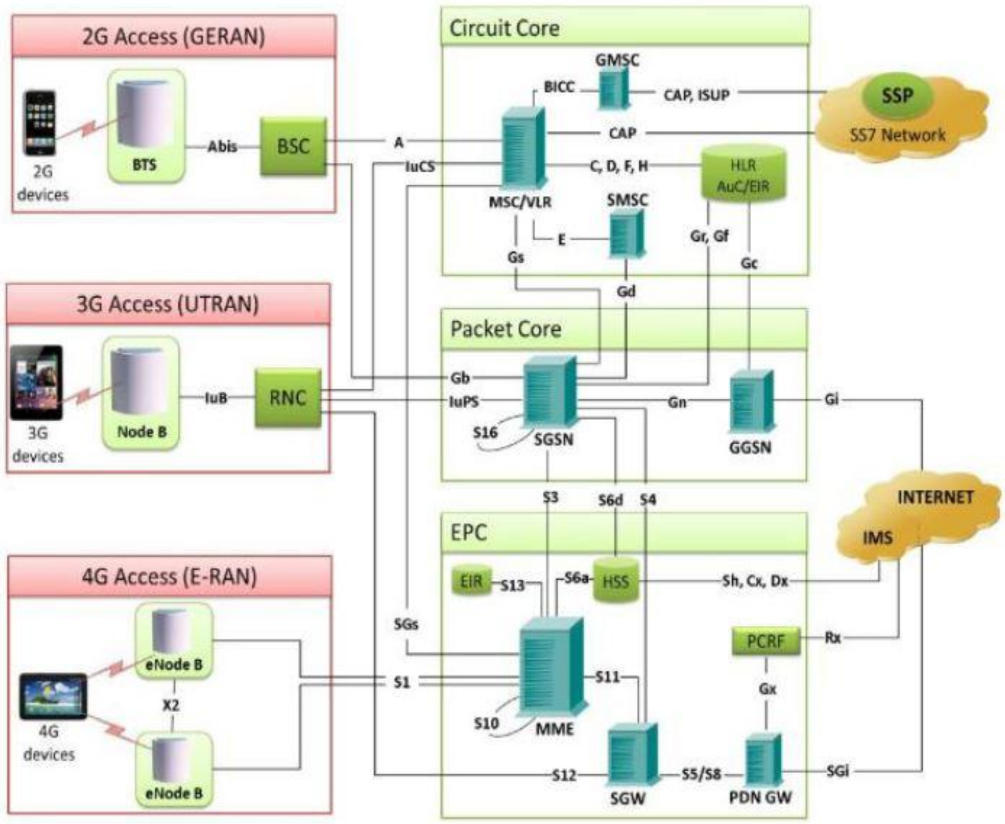

Figure I.7 2G/3G/4G Architectures [7]

I.6 Radio Interface Techniques:

In wireless cellular systems, mobiles have to share a common medium for transmission. There are various categories of assignment, the main four include: **FDMA** (Frequency Division Multiple Access), **TDMA** (Time Division Multiple Access), **CDMA** (Code Division Multiple Access) and **OFDMA** (Orthogonal Frequency Division Multiple Access) [3].

I.6.1 Frequency Division Multiple Access:

In order to accommodate various devices on the same wireless network, FDMA divides the available spectrum into sub-bands or channels. The concept of FDMA is illustrated in Figure I.8. Using this technique a dedicated channel can be allocated to a user, whilst other users occupy other channels, i.e. frequencies [3].

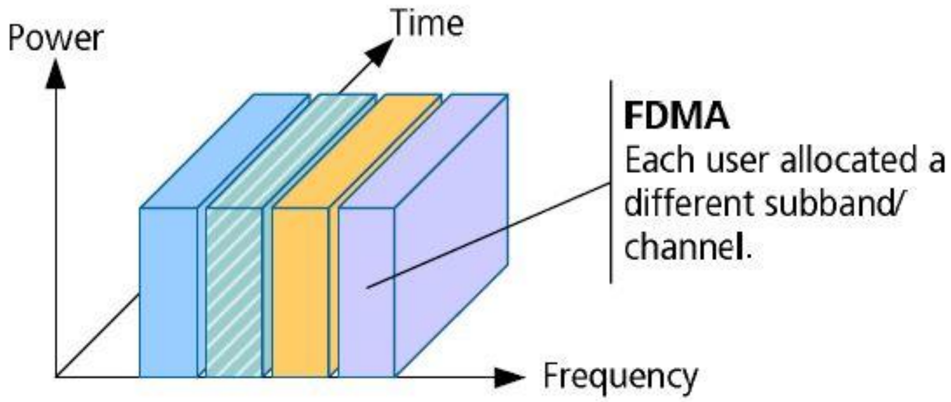

Figure I.8 Frequency Division Multiple Access [3]

I.6.2 Time Division Multiple Access:

In TDMA systems the channel bandwidth is shared in the time domain. Figure I.9 illustrates the concept of TDMA. It shows how each device is allocated a time on the channel, known as a “timeslot”. These are then grouped into a TDMA frame. The number of timeslots in a TDMA frame is dependent on the system, for example GSM utilizes 8 timeslots [3].

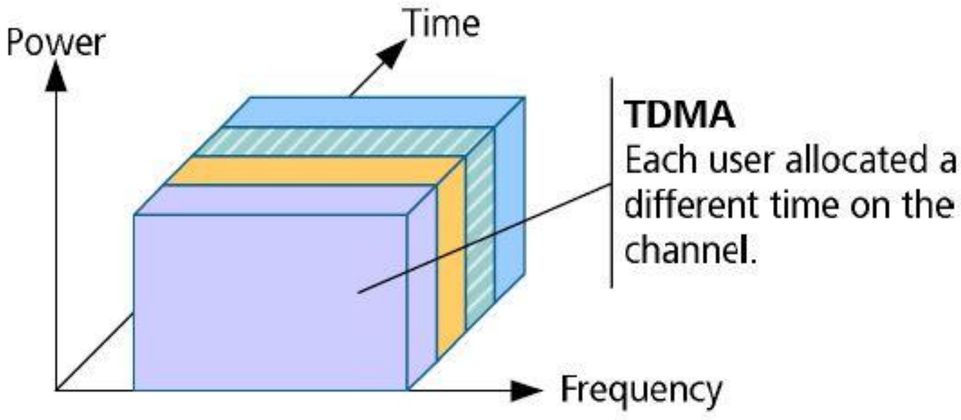

Figure I.9 Time Division Multiple Access [3]

I.6.3 Code Division Multiple Access:

The concept of CDMA is slightly different to that of FDMA and TDMA. Instead of sharing resources in the time or frequency domain, the devices are able to use the system at the same time and using the same frequency/bandwidth. This is possible due to the fact that each transmission is separated using a unique code. Figure I.10 illustrates the basic concept of CDMA [3].

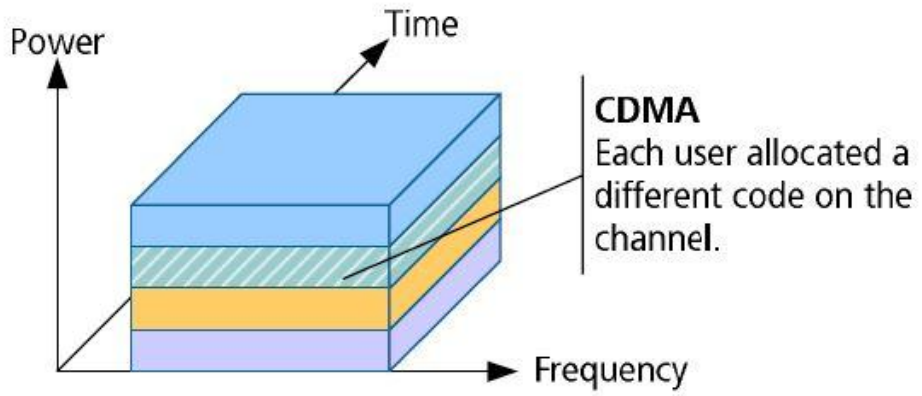

Figure I.10 Code Division Multiple Access [3]

I.6.4 Orthogonal Frequency Division Multiple Access:

OFDMA (Orthogonal Frequency Division Multiple Access) is the latest addition to cellular systems. It provides a multiple access technique based on OFDM (Orthogonal Frequency Division Multiplexing). Figure I.11 illustrates the basic view of OFDMA. It can be seen that the bandwidth is broken down into smaller units known as “subcarriers”. These are grouped together and allocated as a resource to a device. It can also be seen that a device can be allocated different resources in both the time and frequency domain [3].

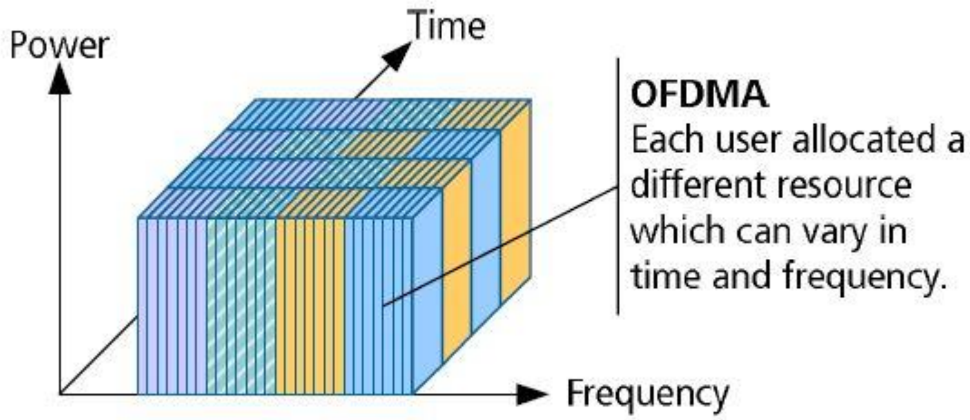

Figure I.11 Orthogonal Frequency Division Multiple Access [3]

I.7 LTE Evolution:

Releases 8 and 9 form the foundation of LTE, providing a highly capable mobile-broadband standard. However, to meet new requirements and expectations, the releases, as shown in Figure I.12 following the basic ones provide additional enhancements and features in different areas.

Release 10 marks the start of the LTE evolution. One of the main targets of LTE release 10 was to ensure that the LTE radio-access technology would be fully compliant with the IMT Advanced requirements, thus the name LTE-Advanced is often used for LTE release 10 and later [8].

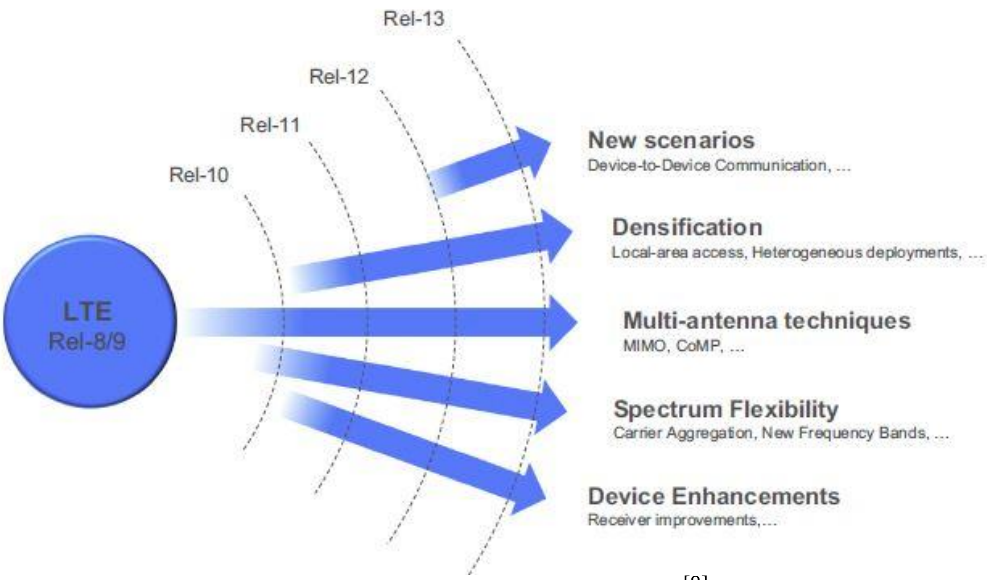

Figure I.12 LTE Releases [8]

I.8 Principles of OFDM:

The LTE air interface utilizes two different multiple access techniques both based on OFDM (Orthogonal Frequency Division Multiplexing):
OFDMA (Orthogonal Frequency Division Multiple Access) used on the downlink, **SC-FDMA** (Single Carrier - Frequency Division Multiple Access) used on the uplink [3]. As follows from Figure I.13 distinguishes between the two methods.

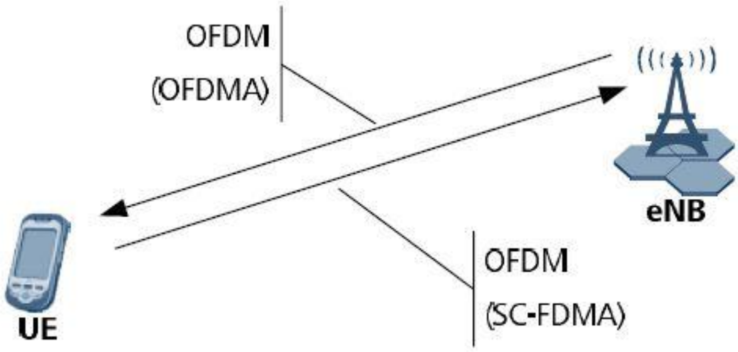

Figure I.13 Use of OFDM in LTE [3]

OFDM is based on **FDM** (Frequency Division Multiplexing) and is a method whereby multiple frequencies are used to simultaneously transmit information. Figure I.14 illustrates an example of FDM with four subcarriers. These can be used to carry different information and to ensure that each subcarrier does not interfere with the adjacent subcarrier, a guard band is utilized [3].

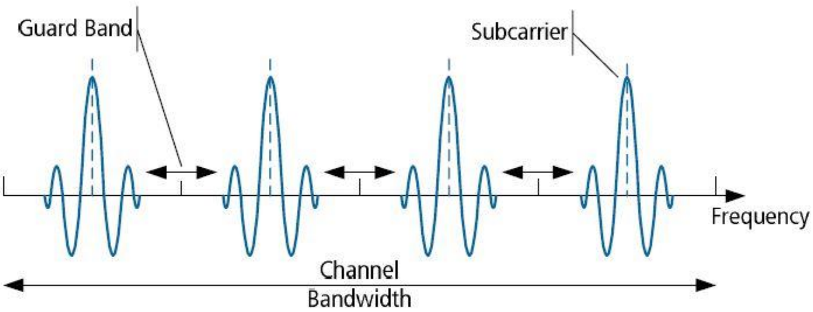

Figure I.14 FDM Carriers [3]

OFDM follows the same concept as FDM but it drastically increases spectral efficiency by reducing the spacing between the subcarriers. Figure I.15 illustrates how the subcarriers can overlap due to their orthogonality with the other subcarriers, i.e. the subcarriers are mathematically perpendicular to each other, when a subcarrier is at its maximum the two adjacent subcarriers are passing through zero. In addition, OFDM systems still employ guard bands. These are located at the upper and lower parts of the channel and reduce adjacent channel interference [3].

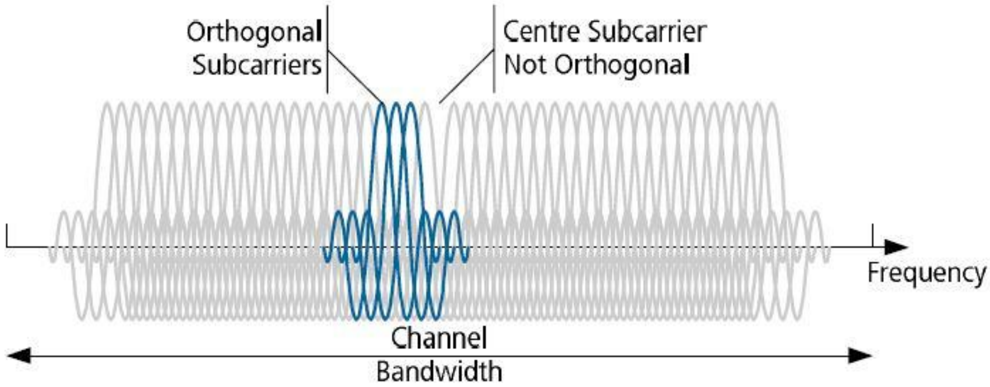

Figure I.15 OFDM Subcarriers [3]

I.8.1 Downlink Air Interface (OFDMA):

OFDMA is an extension of the OFDM technique to allow multiple user transmissions. OFDMA Symbol is the Time period occupied by the modulation symbols on all subcarriers. It transmits data in parallel across multiple subcarriers. The user multiplexing is in sub-carrier domain: user is allocated Resource Blocks. Bandwidths ranging from 1.4 MHz to 20 MHz [9].

I.8.2 Uplink Air Interface (SC-FDMA):

Single Carrier-FDMA is a recently developed single carrier multiple access technique which has a similar structure and performance to OFDMA. It transmits data in series employing multiple subcarriers. The user multiplexing in the frequency domain, a user is allocated different bandwidths. Bandwidths ranging from 1.4 MHz to 20 MHz.[9].

I.8.3 SC-FDMA and OFDMA Comparison:

The main reason SC-FDMA was specified for the uplink was because of its PA (Power Amplifier) characteristics. Typically, the SC-FDMA signal will operate with a 2-3dB lower PAPR (Peak-to-Average Power Ratio). This makes the system more efficient, thus increasing the battery life for mobile users. SC-FDMA is also better when it comes to larger cell coverage. It must be noted that OFDMA is better in a number of areas, such as Inter-symbol orthogonality and the ability to provide a more flexible frequency domain scheduling mechanism. This increases the system performance. In addition, OFDMA is more suitable for uplink MIMO operation and associated high date rate services [9].

Figure I.16 gives an example about OFDMA and SC-FDMA.

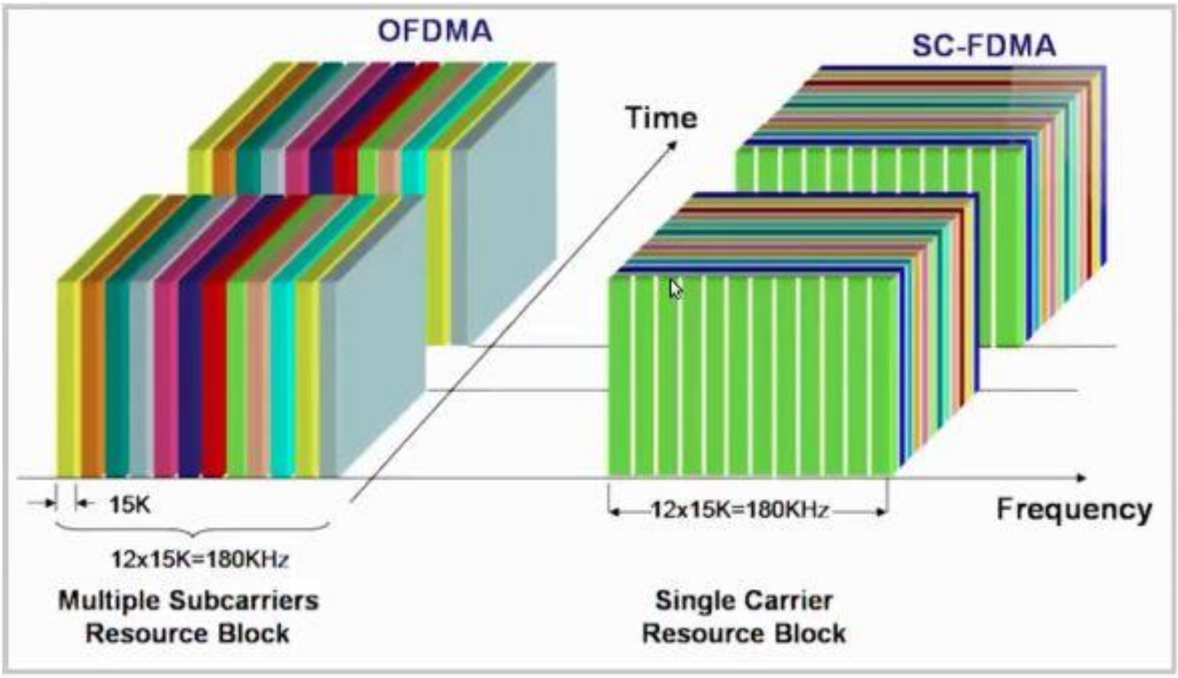

Figure I.16 OFDMA vs. SC-FDMA [9]

I.9 MIMO (Multiple Input Multiple Output):

I.9.1 MIMO Methods:

MIMO is the key technology of the LTE system, it relates to the use of multiple antennas at both the transmitter (Multiple Input) and receiver (Multiple Output) [10]. Figure I.17 shows an example of MIMO.

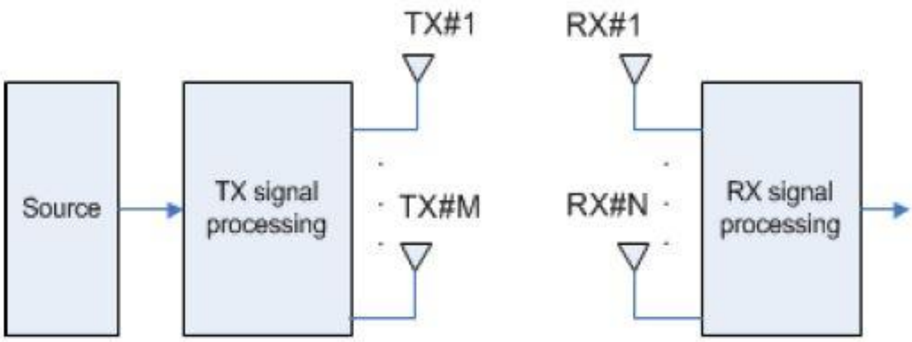

Figure I.17 Example of MIMO [10]

The terminology and methods used in MIMO can differ from system to system, however most fall into one of two categories:

SU-MIMO (Single User - MIMO) - this utilizes MIMO technology to improve the performance towards a single user.

MU-MIMO (Multi User - MIMO) - this enables multiple users to be served through the use of spatial multiplexing techniques [3].

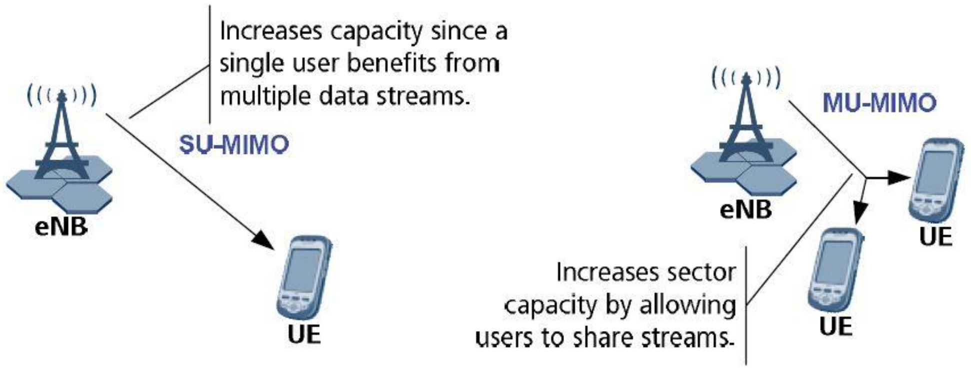

Figure I.18 SU-MIMO vs MU-MIMO [3]

I.9.2 Radio Channel Access Mode:

SISO (Single input single output): is the basic radio channel access mode, it is the default method in radio communication system at the beginning.

MISO (Diversity transmitting mode): multiple input single output, in other words, it means two or multi-transmitter but one receiver. Because the same information transmitted by a different antenna.

SIMO (Diversity receiving mode): is opposition with MISO, SIMO means single input multiple output, namely two or more receivers but one transmitter, usually refers to the receive diversity.

MIMO (Multiple input multiple output) two or more receivers and two or more transmitters. This model is not only the simple sum of SIMO and MISO. For MIMO system, the number of multiple receivers must be at least equal to transmit data stream [11].

Figure I.19 resume the access modes.

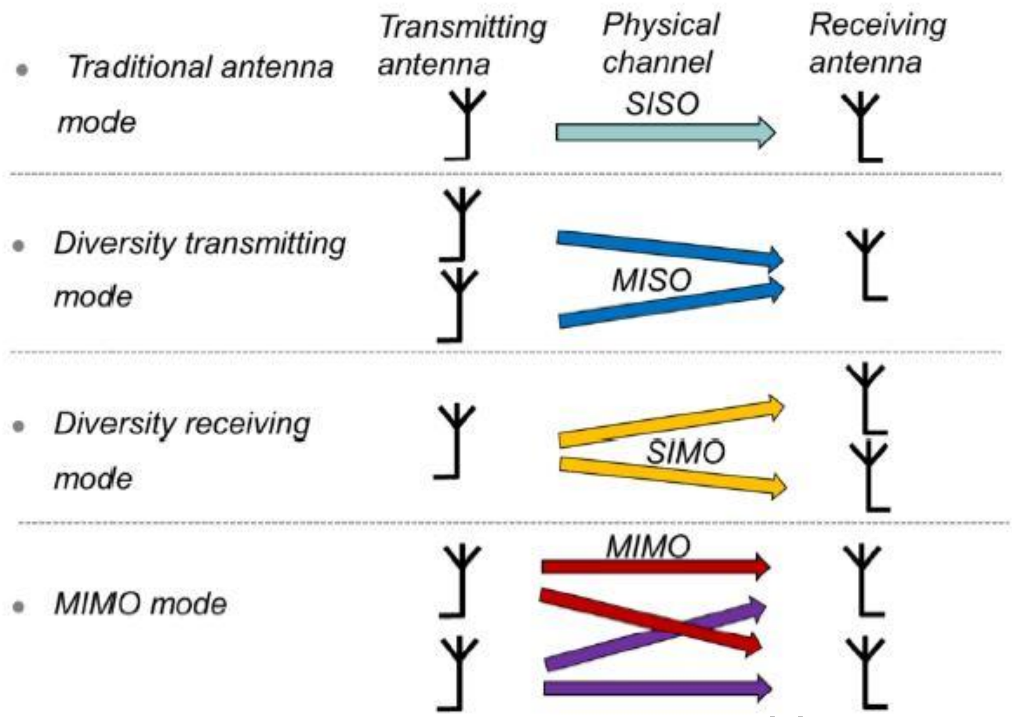

Figure I.19 Radio Channel Access Mode [11]

I.10 Summary:

Mobile networks have evolved rapidly as analogue voice gave way to digital voice, and now include data services and streaming digital video. Table I.2 compares all the generations of mobile systems seen in this chapter.

	1G	2G	3G	4G
Period	1980 – 1990	1990 – 2000	2000 – 2010	2010 – (2020)
Bandwidth	150/900MHz	900MHz	100MHz	100MHz
Frequency	Analog signal (30 KHz)	1.8GHz (digital)	1.6 – 2.0 GHz	2 – 8 GHz
Data rate	2kbps	64kbps	144kbps – 2Mbps	100Mbps – 1Gbps
Characteristic	First wireless communicatio n	Digital	Digital broadband, increased speed	High speed, all IP
Technology	Analog cellular	Digital cellular (GSM)	CDMA, UMTS, EDGE	LTE, WiFi

Table I.2 Comparison between generation mobile systems

CHAPTER II

Fifth Generation Evolution

II.1 Introduction:

5G (5th generation wireless systems) is the next major phase of mobile telecommunications standards. The scope of 5G will ultimately range from mobile broadband services to next-generation automobiles and connected devices.

The initial 5G New Radio (NR) specification was completed in June 2018 and published in the 3GPP Release 15 specification. Now, a variety of industry players, including network equipment vendors, network operators, semiconductor vendors, and device manufacturers, are developing new products that implement the new standard.

In this chapter, an overview about the expectations and the challenges, also the combinations and deployment options of the fifth-generation wireless communications in many economic sectors and vertical industries will lead to a large and wide diversity of communication characteristics imposing different requirements on mobile and wireless communication systems, as shown in the diagram (Figure II.1) below e.g. in terms of cost, energy dissipation, data rate, mobility, latency and reliability [12].

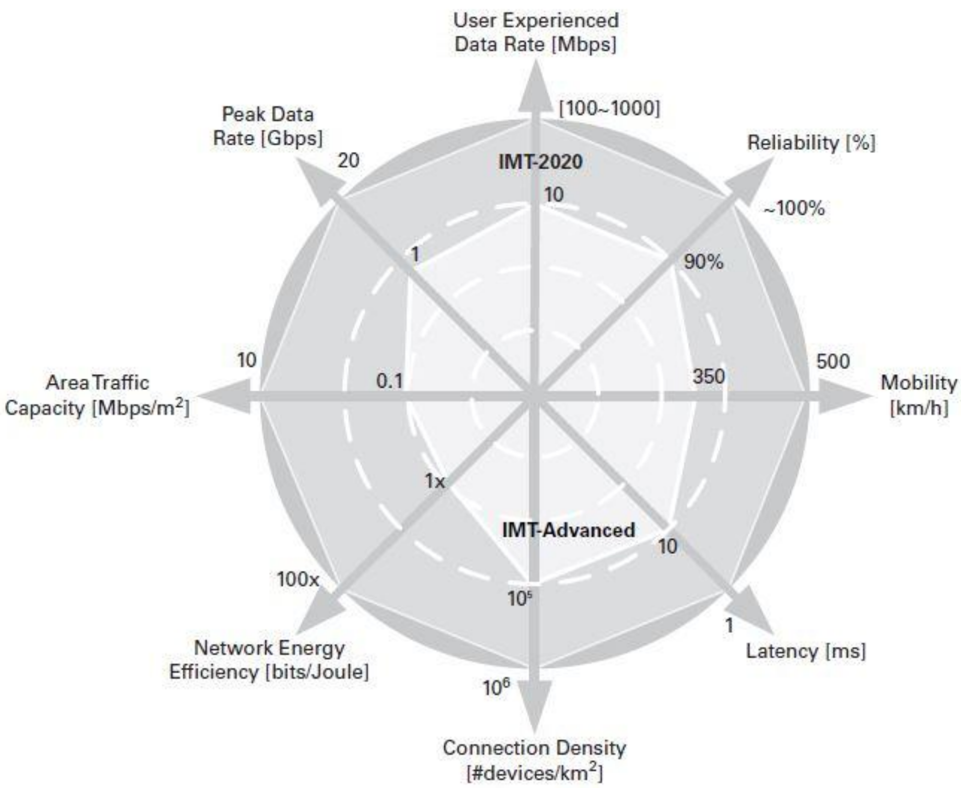

Figure II.1 Spider diagram for IMT-2020[12]

• Peak data rate [Gbps]: The maximum achievable user/device data rate.
• User experienced data rate [Mbps or Gbps]: The achievable user/device data rate across the coverage area.
• Radio Latency [ms]: The time needed for a data packet to travel from the source to the destination.
• Mobility [km/h]: The maximum supported vehicular speed at which a nominal QoS can be achieved.
• Connection density [#devices/km2]: The total number of connected devices per area.
• Energy efficiency [bits/Joule]: The bits transmitted to/received from users, per unit of energy consumption of the RAN.
• Reliability [%]: The percentage of successful transmissions completed within a certain time period.
• Area traffic capacity [Mbps/m2]: The total traffic throughput served per geographic area [12].

Table II.1 compares 5G with the previous mobile generations.

Marketing Name	ITU Name	3GPP Name	RAN Name	Core Name	System Name
3G	IMT-2000	UMTS	UTRAN	UMTS Core	UMTS System
4G	IMT-Advanced	LTE-Advanced	E-UTRAN	Evolved Packet Core (EPC)	Evolved Packet System (EPS)
5G	IMT-2020	5G	New Radio (NR)	5G Core (5GC)	5G System (5GS)

Table II.1 3G/4G/5G Naming

II.2 5G system concept:

The proposed 5G system concept generalizes key characteristics of the use cases and aligns the requirements, and combines technology components into three generic 5G communication services:

• Extreme Mobile Broadband (**xMBB**) provides both extreme high data-rate and low latency communications, and extreme coverage. xMBB provides a more uniform experience over the coverage area and graceful performance degradation as the number of users increases.

• Massive Machine-Type Communication (**mMTC**) provides wireless connectivity for tens of billions of network-enabled devices, scalable connectivity for an increasing number of devices, efficient transmission of small payloads; wide area coverage and deep penetration are prioritized over data rates.

• Ultra-reliable low-latency Communication (**uRLLC**) provides communication links for network services with extreme requirements on availability, latency and reliability.

Figure II.2 summarizes 5G communication services [12].

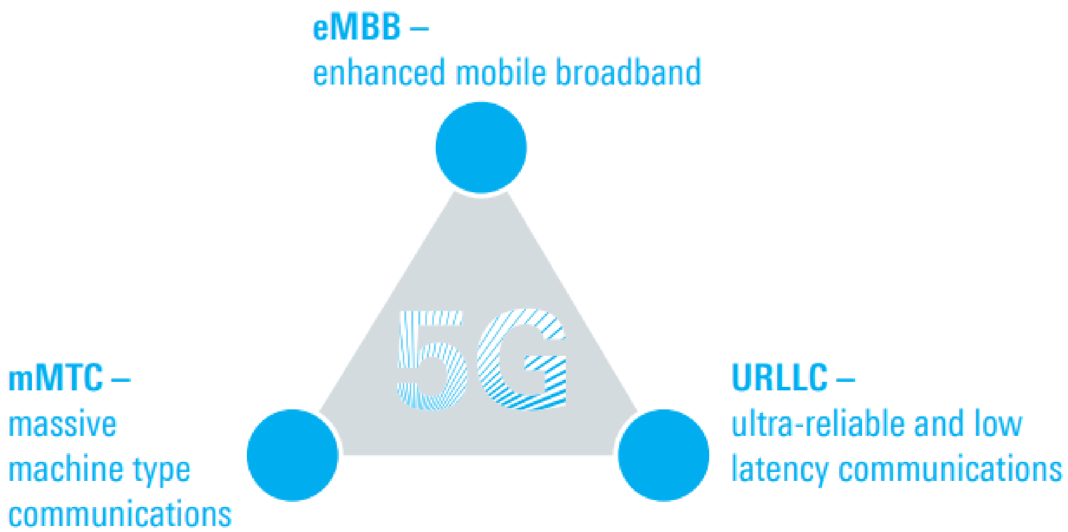

Figure II.2 5G use-cases classification [12]

II.3 Spectrum for 5G:

There is a considerable interest globally to make the spectrum available for 5G deployments. The spectrum of interest can be divided into bands at low, medium, and high frequencies:

- Low-frequency bands correspond to existing LTE bands below 2 GHz.
- Medium-frequency bands are in the range 3_6 GHz.
- High-frequency bands are in the mm-Wave range above 24 GHz.

The Microwave and Millimeter Wave (mmWave) frequency range is new for IMT deployment Frequency bands within the scope of the present Release 15 work in 3GPP are for this reason divided into two frequency ranges:

• Frequency range 1 (FR1) includes all existing and new bands below 6 GHz.
• Frequency range 2 (FR2) includes new bands in the range 24.25_52.6 GHz [13].

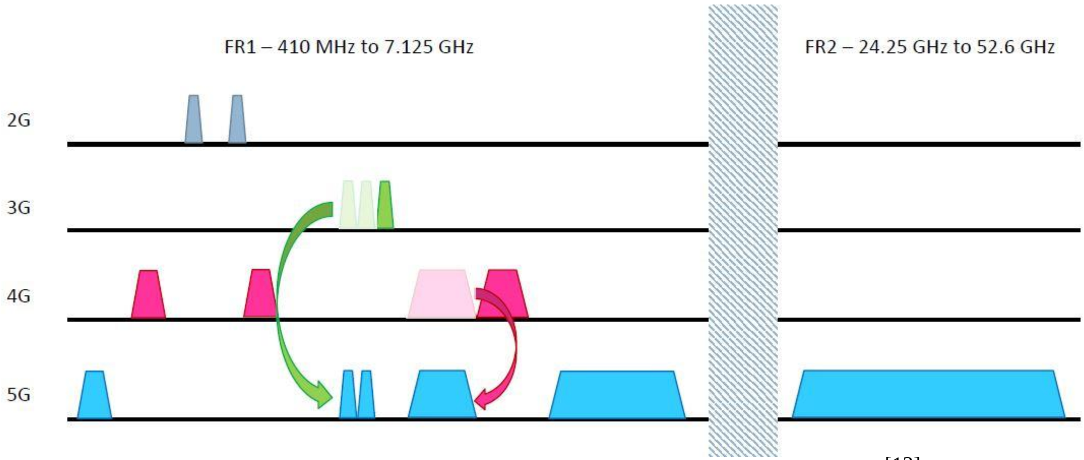

Figure II.3 Typical Operator Spectrum 2G, 3G, 4G, 5G [13]

II.4 Radio-Interface Architecture:

In parallel to the work on the NR (New Radio) radio-access technology in 3GPP, the overall system architectures of both the Radio-Access Network (RAN) and the Core Network (CN) were revisited, including the split of functionality between the two networks.
The RAN is responsible for all radio-related functionality of the overall network including, for example, scheduling, radio-resource handling, retransmission protocols, coding, and various multi-antenna schemes.
The 5G core network is responsible for functions not related to the radio access but needed for providing a complete network. This includes, for example, authentication, charging functionality, and the setup of end-to-end connections. Handling these functions separately, instead of integrating them into the RAN, is beneficial as it allows for several radio-access technologies to be served by the same core network [14].

II.4.1 5G Core Network:

The 5G core network builds upon the EPC with three new areas of enhancement compared to EPC: service-based architecture, support for network slicing, and control-plane/user-plane split. The 5G core can be illustrated as shown in Figure II.4.

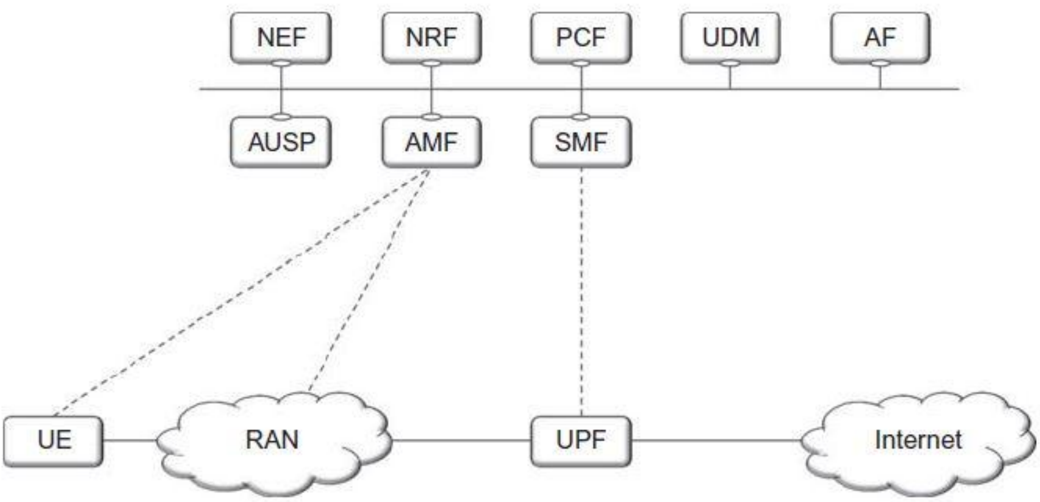

Figure II.4 High-level core network architecture [14]

The user-plane function consists of the User Plane Function (**UPF**) which is a gateway between the **RAN** and external networks such as the Internet. Its responsibilities include packet routing and forwarding, packet inspection, quality-of service handling, packet filtering and traffic measurements.
The control-plane functions consist of several parts. The Session Management Function (**SMF**) handles, among other functions, IP address allocation for the device, control of policy enforcement, and general session-management functions. The Access and Mobility Management Function (**AMF**) is in charge of control signalling between the core network and the device, security for user data, idle-state mobility, and authentication.
In addition, the core network can also handle other types of functions, for example, the Policy Control Function (**PCF**) responsible for policy rules, the Unified Data Management (**UDM**) responsible for authentication credentials and access authorization, the Network Exposure Function (**NEF**), the NR Repository Function (**NRF**), the Authentication Server Function (**AUSF**) handing authentication functionality, and the Application Function (**AF**) [14].

Table II.2 compares between 4G and 5G architecture functions.

EPC NE function		Corresponding NGC NF
MME	Mobility management	AMF
	User authentication	AUSF
	Session management	SMF
PDN-GW	Session management	
	User plane data forwarding	UPF
SGW	User plane data forwarding	
PCRF	QoS policy and charging rules	PCF
HSS	User profile database	UDM

Table II.2 comparison between 4G and 5G architecture functions [15]

The description above focused on the new 5G core network, developed in parallel to the NR radio access and capable of handling both NR and LTE radio accesses. However, to allow for an early introduction of NR in existing networks, it is also possible to connect NR to EPC, the LTE core network. This is illustrated as "option 3" in Figure II.5 and is also known as "non-standalone operation" as LTE is used for control-plane functionality such as initial access, paging, and mobility.
The nodes denoted eNB and gNB will be discussed in more detail in the next section; for the time being eNB and gNB can be thought of as base stations for LTE and NR, respectively [14].

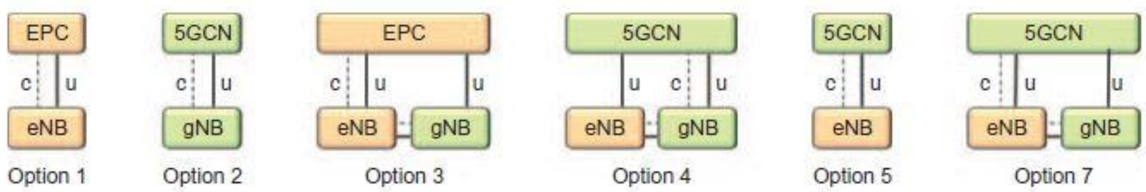

Figure II.5 Different combinations of core networks [14]

In option 3, the EPC core network is connected to the eNB. All control-plane functions are handled by LTE, and NR is used only for the user-plane data. The gNB is connected to the eNB and user-plane data from the EPC can be forwarded from the eNB to the gNB. There are also variants of this: option 3a and option 3x. In option 3a, the user-plane parts of both the eNB and gNB are directly connected to the EPC. In option 3x, only the gNB user plane is connected to the EPC and user-plane data to the eNB are routed via the gNB.
For standalone operation, the gNB is connected directly to the 5G core as shown in option 2. Both user-plane and control-plane functions are handled by the gNB. Options 4, 5, and 7 show various possibilities for connecting an LTE eNB to the 5GCN. Whilst 3GPP has defined a number of options, most implementations base their NSA deployment on Option 3/3a/3x. Options 3, 3a and 3x (Non-Standalone) allow NR deployments reusing EPC with the support of LTE eNB. With these options, the LTE eNB is connected to the EPC with Non-standalone NR. The NR user plane connection to the EPC goes via the LTE eNB(Option 3) or directly (Option 3A). In Option 3x, the solid line shown between LTE-eNB and gNB is used for user plane data transmission terminated at the gNB. These options are shown in Figure II.6 [14].

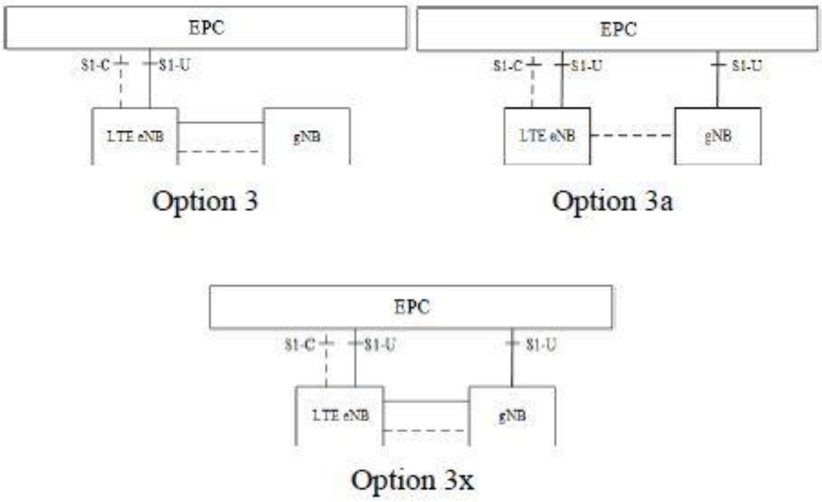

Figure II.6 5G System architecture, Option 3, 3a and 3x [13]

Figure II.7 depicts the simplified standalone and non standalone architectures

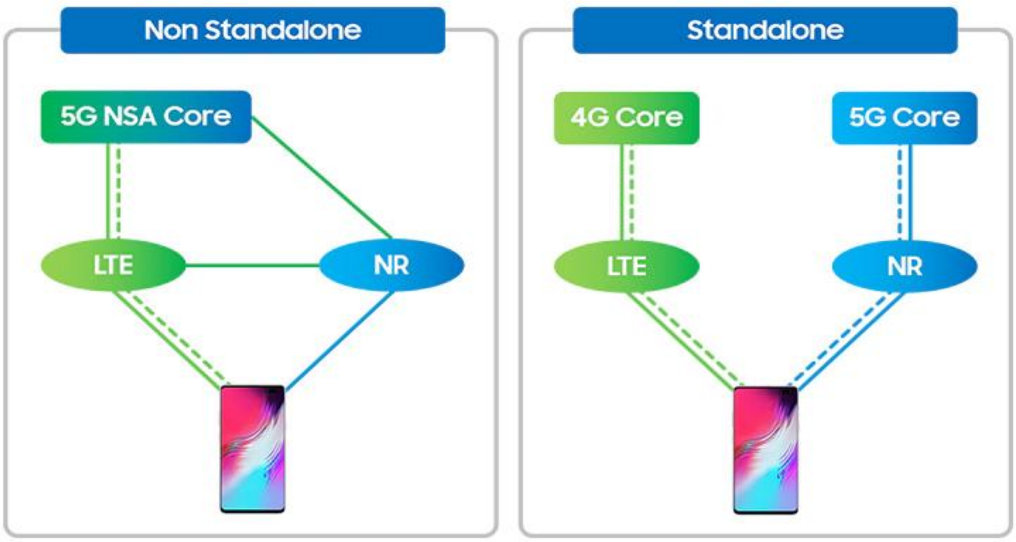

Figure II.7 5G Architecture (Simplified) [15]

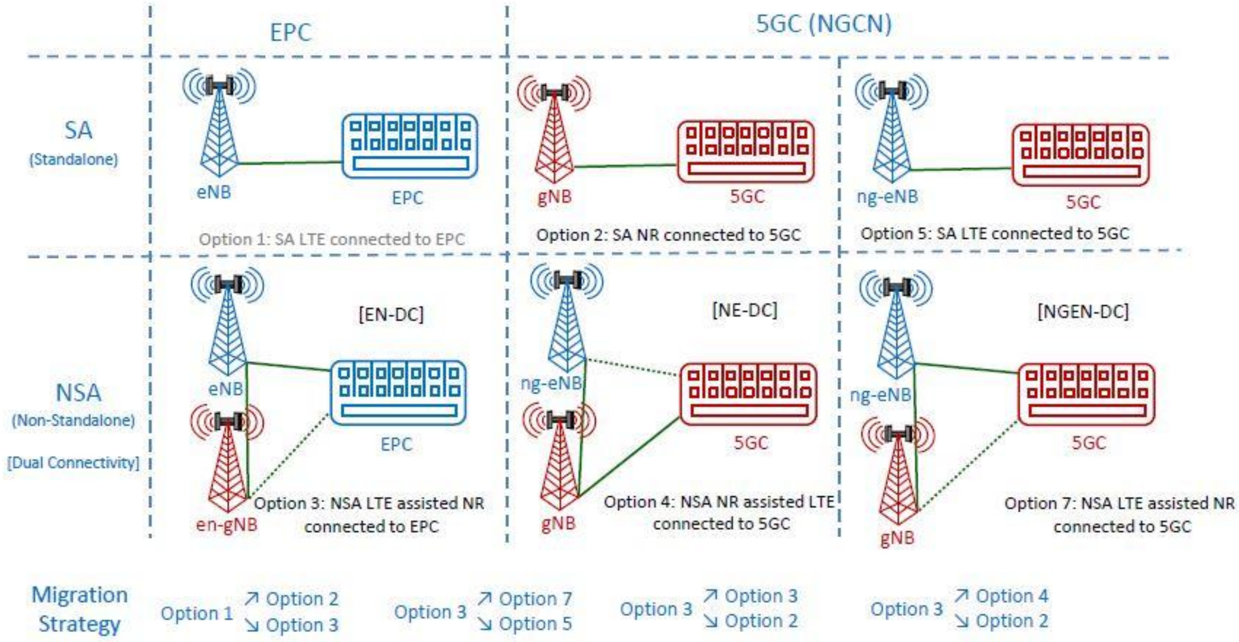

Figure II.8 5G Deployment Options and Migration Strategy [16]

Consequently, five deployment options are available for 5G as depicted in Figure II.8 Red colour denotes gNB and 5GC.

II.4.2 Radio Access Network:

The radio-access network can have two types of nodes connected to the 5G core network:

- A **gNB**, serving NR devices using the NR user-plane and control-plane Protocols.
- An **ng-eNB**, serving LTE devices using the LTE user-plane and control-plane Protocols.

A radio-access network consisting of both ng-eNBs for LTE radio access and gNBs for NR radio access is known as an NG-RAN, as shown in Figure II.9, although the term RAN will be used in the following for simplicity. Furthermore, it will be assumed that the RAN is connected to the 5G core and hence 5G terminology, such as gNB, will be used. In other words, the description will assume a 5G core network and an NR-based RAN as shown in option 2. However, as already mentioned, the first version of NR operates in non-standalone mode where NR is connected to the EPC using option 3 [14].

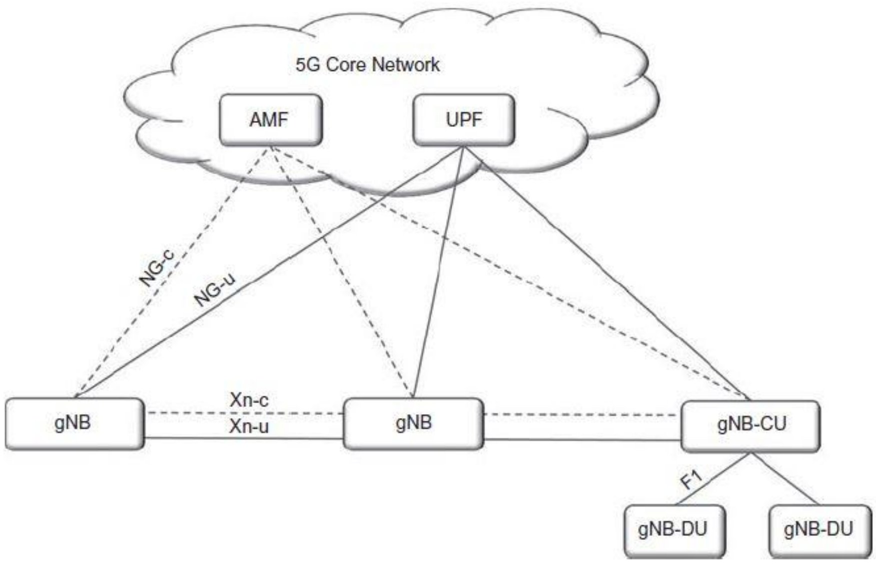

Figure II.9 Radio-access network interfaces [14]

II.5 Massive MIMO:

It is well known that, in classical MIMO, multiple antennas at both ends exploit wireless channel diversity to provide more reliable high-speed connections. Massive MIMO (also known as Large-Scale Antenna Systems) makes a bold development from current practice using a very large number of service antennas. Figure II.10 shows the speed improvement of wireless networks over the years starting from single-input-single-output (SISO) systems, single user (SU) and multiple users (MU) MIMO networks. MU-MIMO systems already provide significant advantages over earlier systems. Figure II.10 represents wireless networks evolutions using MIMO technologies [17].

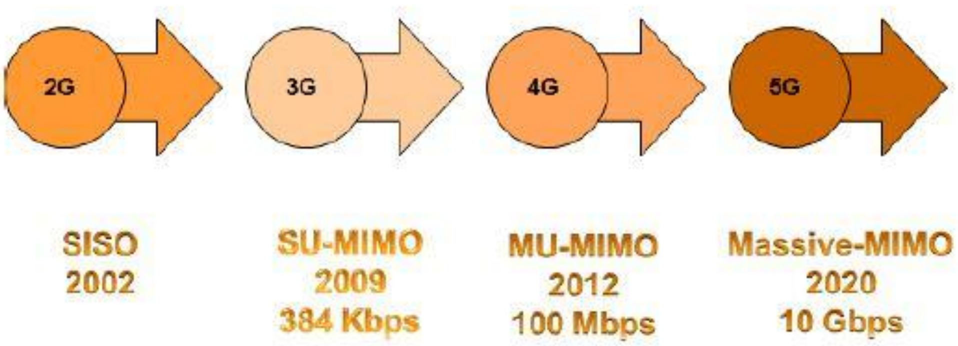

Figure II.10 Evolving speed of wireless networks [17]

II.5.1 MIMO systems

Conventional MIMO systems are composed of randomly distributed multiple antenna BSs, where each BS is serving a certain number of users. All BSs are working with the same access methods, diversity techniques, and type of transmission. Figure II.11 shows the uplink and the downlink of a massive MIMO single cell-system, the BS is composed of a few hundred service antennas serving a few hundred users each, usually with only one antenna [17].

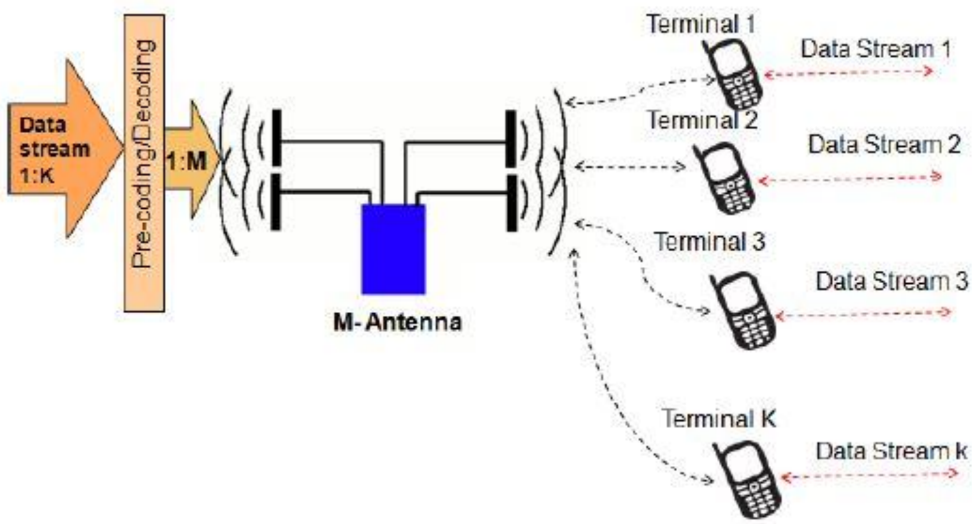

Figure II.11 Uplink and downlink operation of a MIMO link [17]

The steps of the uplink operation are as follows:

1. Encoding is employed to prepare data for transmission.
2. Pilot sequences and uplink data sequences are transmitted at the same time and over the same frequencies from each user to the BS.

3. The BS receives the sum of data streams from all the users and estimates the channel.
4. Decoding and detection operations produce individual data streams by utilizing the estimated CSI.

The steps of the downlink process are as follows:
1. Beamforming: Data streams are transmitted from the BSs to only the intended users by means of beamforming, where the different data streams may occupy the same frequencies at the same time.
2. Precoding: The previous operation is carried out knowing the frequency response of the propagation channels between each of its elements and each user and precoding the signals accordingly [17].

II.5.2 Challenges of Massive MIMO:

Massive MIMO technology can significantly improve the system capacity, but there are still many challenges to be overcome while deploying the actual networks. These challenges are coupled mainly to three key aspects of deploying 5G: network coverage, user experience and network capability [18].
The key technologies of Massive MIMO at the aspects of 5G network development and application are summarized in the following table:

Network development	Major challenges	Key technologies of Massive MIMO
Network coverage	• Coverage in various scenarios, such as high-rise buildings • Managing various types of interference	• Accurate and intelligent SSB configuration • Interference mitigation technologies
User experience	• User experience improvement in poor-performing scenarios such as cell edge and high mobility.	• Precise beamforming and intra-cell and inter-cell interference control • Configuration of reference signals and demodulation signals to make feedback information more timely and accurate.
Network capability	• Support accessing more users and more services. • Better user and service differentiation and value creation	• SDMA of control channels and service channels increases the capacity. • Differentiated QoS management and intelligent resource allocation, providing accurate user-level service capability

Table II.3 Summary of features/challenges/key technical points [18]

II.6 Summary:

5G is a system with, more capable air interface. It has been designed with an extended capacity to enable next-generation user experiences while it uses a different architecture combination, deployments options and migrations strategies.

CHAPTER III

LTE-ADVANCED Optimization

III.1 Introduction:

With the initial target of downlink peak data rate reaching above 100 Mbit/s, the next-generation Long Term Evolution (LTE) system is developed to meet the increasing demands on higher data rate due to fast expansion of multimedia applications. For a new wireless system like the LTE, a set of Key Performance Indicators (KPIs) are defined for the evaluation of system performance, in particular the performance of the evolved Radio Access Network (eRAN) [19].

In this chapter, some counters are necessary for the KPI calculation are also described in detail, also mechanism of traffic measurement counters, service drop rate, and common fault location methods. The KPIs are classified into categories based on the measurement targets: Accessibility (RRC Connection Establishment Success Rate / e-RAB Establishment Success Rate), Retainability (Call Drop Rate), and Mobility (Handover Success Rate). All the measurement results are exported from M2000"software program of Huawei". All of these methods are well explained in the Appendix added at the end of the chapter.

III.2 Accessibility:

In the LTE system, if the UE wants to access the network for a purpose such as service request, location update, or paging, the UE must first perform RA.

After the RA procedure, the control-plane connection between the UE and MME is established. The control-plane connection includes the RRC signalling connection and S1 connection. The RRC signalling connection is the signalling connection over the Uu interface between the UE and eNodeB; S1 connection is the signalling connection between the eNodeB and MME. After the control-plane connection is established, if the connection request is a service setup request, the MME triggers the eNodeB to set up an e-RAB. The eNodeB uses radio bearer management to set up, modify, or release e-RABs.

Access failures are classified into random access (RA) failure, RRC connection setup failure, authentication failure, and e-RAB setup failure [20].

III.2.1 Random Access Procedures:

An RA procedure occurs in one of the following five scenarios:

1- During the initial RRC connection establishment when the UE mode changes from RRC_IDLE to RRC_CONNECTED.

2- Upon a radio link failure.

3- During a handover.

4- When there is a need for random access in RRC_CONNECTED mode on arrival of downlink (DL) data. For example, after loss of uplink (UL) synchronization.

5- When there is a need for random access in RRC_CONNECTED mode on arrival of UL data. For example, after loss of UL synchronization [20].

III.2.2 RRC

III.2.2.1 Counters Related to RRC Connection Setup Requests:

These counters measure the number of RRC connection setup requests of each cell in an eNodeB. The RRC Connection Request message is the first RRC signalling message sent by the UE to eNodeB, requesting setup of an RRC connection [20].

Counter ID	Counter Name	Description
1526726657	L.RRC.ConnReq.Msg	Number of RRC Connection Request messages received from the UE in a cell, including the number of retransmitted messages
1526726658	L.RRC.ConnReq.Att	Number of RRC Connection Request messages received from the UE in a cell, excluding the number of retransmitted messages
1526728217	L.RRC.ConnReq.Att.Emc	Number of RRC Connection Request messages received from the UE for the emergency cause in a cell
1526728218	L.RRC.ConnReq.Att.HighPri	Number of RRC Connection Request messages received from the UE for the highPriorityAccess cause in a cell
1526728219	L.RRC.ConnReq.Att.Mt	Number of RRC Connection Request messages received from the UE for the mt-Access cause in a cell
1526728220	L.RRC.ConnReq.Att.MoSig	Number of RRC Connection Request messages received from the UE for the mo-Signalling cause in a cell
1526728221	L.RRC.ConnReq.Att.MoData	Number of RRC Connection Request messages received from the UE for the mo-Data cause in a cell

Table III.1 Connection Setup Requests [20]

III.2.2.2 Counters Related to RRC Connection Setup Attempts:

These counters measure the number of RRC connection setup attempts, which is the number of RRC Connection Setup messages the eNodeB sends in response to the RRC Connection Request message. The RRC Connection Setup message is the RRC signalling message sent by the eNodeB to UE containing the RRC connection setup result and configuration information [20].

Counter ID	Counter Name	Description
1526728216	L.RRC.ConnSetup	Number of RRC Connection Setup messages sent to the UE in a cell

Table III.2 RRC Connection Setup Attempts [20]

III.2.2.3 Counters Related to RRC Connection Setup Success:

These counters measure the number of RRC connection setup successes, which is the number of RRC Connection Setup Complete messages. The RRC Connection Setup Complete message is the RRC signalling message sent by the UE containing NAS signalling information and PLMN selection information [20].

Counter ID	Counter Name	Description
1526726659	L.RRC.ConnReq.Succ	Number of RRC Connection Setup Complete messages received from the UE in a cell
1526728222	L.RRC.ConnReq.Succ.Emc	Number of RRC Connection Setup Complete messages received from the UE for the emergency cause in a cell
1526728223	L.RRC.ConnReq.Succ.HighPri	Number of RRC Connection Setup Complete messages received from the UE for the highPriorityAccess cause in a cell
1526728224	L.RRC.ConnReq.Succ.Mt	Number of RRC Connection Setup Complete messages received from the UE for the mt-Access cause in a cell
1526728225	L.RRC.ConnReq.Succ.MoSig	Number of RRC Connection Setup Complete messages received from the UE for the mo-Signalling cause in a cell
1526728226	L.RRC.ConnReq.Succ.MoData	Number of RRC Connection Setup Complete messages received from the UE for the mo-Data cause in a cell

Table III.3 RRC Connection Setup Success [20]

Table III.1, 2, 3 and 4 containing the counters of RRC Connection Setup.

Methods of Performance Measurement:

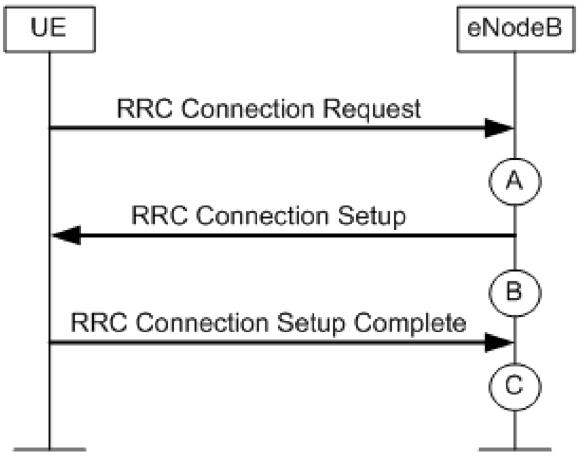

Figure III.1 RRC Measurement points[19]

Figure III.1 represents Measurement points: [Point A] When the cell receives the RRC Connection Request message, the counter L.RRC.ConnReq.Att increases by 1. [Point B] When the cell receives the RRC Connection Request message and delivers the RRC Connection Setup message to the UE, the counter L.RRC.ConnSetup increases by 1. [Point C] When the cell receives the RRC Connection Setup Complete message, the counter L.RRC.ConnReq.Succ increases by 1 [19].

Calculation of the RRC Setup Success Rate

RRCSetupSuccessRate= (L.RRC.ConnReq.Succ)/(L.RRC.ConnReq.Att)*100%.....(III.1) [19]

Target is >98% which is the acceptable value from equation (III.1).

III.2.2.4 Counters Related to RRC Connection Setup Failure:

These counters measure the number of RRC connection setup failures due to various cause values and the total number of RRC connection setup failures. The RRC Connection Reject message is the RRC signaling message sent by the eNodeB, informing the UE that the current access procedure is rejected [19].

Counter ID	Counter Name	Description	Original Release
1526727083	L.RRC.SetupFail.ResFail	Number of RRC connection setup failures due to resource allocation failures	Earlier than V100R003C00
1526727084	L.RRC.SetupFail.NoReply	Number of RRC connection setup failures due to no responses from the UE	Earlier than V100R003C00
1526728269	L.RRC.SetupFail.Rej	Number of RRC Connection Reject messages sent to the UE in a cell	V100R003C00

Table III.4 RRC Connection Setup Failure [19]

III.2.3 e-RAB

III.2.3.1 Counter related to e-RAB Setup Attempts:

This counter measures the total number of e-RAB setup attempts. If a UE wants to request a service from the radio network, the UE initiates the e-RAB setup procedure in the form of UE context setup procedure or e-RAB setup procedure [20].

Counter ID	Counter Name	Description
1526727545	L.E-RAB.AttEst	Total number of attempts by UEs to initiate E-RAB setup procedures

Table III.5 e-RAB Setup Attempts [20]

III.2.3.2 Counter related to e-RAB Setup Success:

This counter measures the total number of e-RAB setup successes. If a UE wants to request a service from the radio network, the UE initiates the e-RAB setup procedure in the form of UE context setup procedure or e-RAB setup procedure [20].

Counter ID	Counter Name	Description
1526727544	L.E-RAB.SuccEst	Total number of successful E-RAB setups initiated by UEs

Table III.6 e-RAB Setup Success [20]

Methods of Performance Measurement:

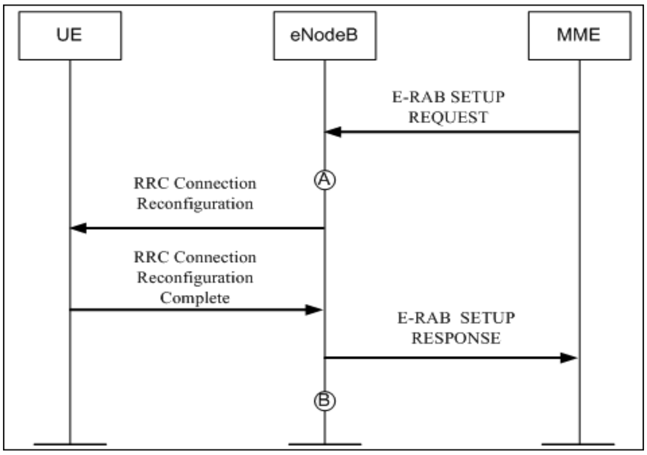

Figure III.2 Performance measurement points for e-RAB setup [19]

Figure III.2 represents measurement points: [Point A] when the eNodeB receives the INITIAL CONTEXT SETUP REQUEST or E-RAB SETUP REQUEST message from the MME, the number of e-RAB setup attempts increases by 1. If the message requires the setup of multiple e-RABs. [Point B] When the eNodeB sends the INITIAL CONTEXT SETUP RESPONSE or E-RAB SETUP RESPONSE message from the MME, the number of successful e-RAB setups increments by 1.If the message requires the setup of multiple e-RABs [19].

Calculation of the e-RAB Setup Success Rate:

ErabSetupSuccessRate=(L.E-RAB.SuccEst)/(L.E-RAB.AttEst)*100%.......(III.2) [20]

Target is >98% which is the acceptable value from equation (III.2).

III.2.3.3 Counters Related to e-RAB Setup Failure:

These counters measure the number of e-RAB setup failures due to various cause values. An e-RAB is an access-stratum bearer for user data. The e-RAB setup success rate reflects the capability of the cell to provide e-RAB connections. Measurement of the e-RAB setup failures reflects the distribution of e-RAB setup failures due to various cause values [20].
Table III.5, 6, and 7 containing e-RAB connection setup.

Counter ID	Counter Name	Description	Original Release
1526726717	L.E-RAB.FailEst.NoReply	Number of E-RAB setup failures due to no responses from the UE in a cell	Earlier than V100R003C00
1526728276	L.E-RAB.FailEst.MME	Number of E-RAB setup failures due to faults in the EPC	V100R003C00
1526728277	L.E-RAB.FailEst.TNL	Number of E-RAB setup failures due to faults at the transport network layer	V100R003C00
1526728278	L.E-RAB.FailEst.RNL	Number of E-RAB setup failures due to faults at the radio network layer	V100R003C00
1526728279	L.E-RAB.FailEst.NoRadioRes	Number of E-RAB setup failures due to insufficient radio resources	V100R003C00
1526728280	L.E-RAB.FailEst.SecurModeFail	Number of E-RAB setup failures due to security mode configuration failures	V100R003C00

Table III.7 e-RAB Setup Failure [20]

III.2.4 Measurement data:

III.2.4.1 RRC measurement data:

Table III.8 represents data and statistics exported from M2000.

Date	eNodeB Name	Cell Name	LocalCell Id	Availability	RRC Setup Success Rate (Service)	RRC Setup Success Rate (Signaling)	RRCConnection_Attempt_service	RRCConnection_Success_signaling
2021-06-04	UL_Hlifaya_40652	406520	3	79%	97,4558	99,049	3223	1979
2021-06-04	UL_TABACOOP_23639	23639T	23	100%	99,0134	96,3054	16522	15666
2021-06-04	JL-RN_Ouargla_Ghardaia (GOR_5)_3060	30606M	1	100%	99,0506	95,2802	316	323
2021-06-04	UL_MERS_EL_HADJADJ_31736	31736T	23	100%	99,1476	97,375	16777	2708
2021-06-04	UL_El_garta_7729	07729R	21	100%	99,158	97,9508	1544	478

Table III.8 RRC measurement data

Symptom:

The symptoms of an RRC connection setup failure on the eNodeB are as follows: After sending the RRC_CONN_SETUP message, the eNodeB fails to receive the RRC_CONN_SETUP_CMP message.

Possible causes:

Soft Device hanging.
A mismatch between the hardware and their licenses.
Hardware issue (cards).
Transmission issue.
UL Interference.

Handling actions:

Reset the card or replace it.
Correct the mismatch.
PRB Expansions to add.
Traffic balancing between the site and their Neighbours.
Check the transmission path and correct it.

Observation:

In this case, we apply Reset of the card.
It is clear that after the Soft Reset of the card since 05/06/2021, the number of RRCConnection_Success_signaling as shown in Table III.9 was decreased providing an improvement on the RRC Setup Success Rate. So we have optimized the cell mentioned in the same table.

Date	eNodeB Name	Cell Name	Avaibility	RRC Setup Success Rate (Service)	RRC Setup Success Rate (Signaling)	RRCConnection_Attempt_service	RRCConnection_Success_signaling	LTE_RRC_Congestion_Rate	L.RRC.SetupFail.Rej.Other
2021-06-01	UL_Hlifaya_4	40652O	100	99,9323	99,8978	4430	1933	0	0
2021-06-02	UL_Hlifaya_4	40652O	100	99,8706	99,8534	3090	1724	0	0
2021-06-03	UL_Hlifaya_4	40652O	100	99,6019	99,8527	4270	1711	0	0
2021-06-04	UL_Hlifaya_4	40652O	79	97,4558	99,049	3223	1979	0	0
2021-06-05	UL_Hlifaya_4	40652O	100	100	99,6849	2556	1898	0	0
2021-06-06	UL_Hlifaya_4	40652O	100	99,9575	99,7224	2352	1796	0	0

Table III.9 RRC measurement data for unique cell

III.2.4.2 e-RAB Traffic measurement data:

Table III.10 represents e- RAB measurement data and statistics obtained from M2000.

Date	eNodeB Name	Cell Name	LocalCell Id	LTE_ERAB_Congestion_Rate	ERABSetup_Attempt	LTE_ERAB_Setup_Success_Rate(%)	E-RAB Setup Failure(times)	L.E-RAB.FailEst.NoRadioRes
2021-06-05	UL_In_Guezam_Ville_11678	11678M	1	46,1322	212110	53,8339	97923	97851
2021-06-04	UL_In_Guezam_Ville_11678	11678M	1	45,8918	203762	54,0783	93571	93510
2021-06-05	UL_In_Guezam_Ville_11678	11678S	22	44,894	40188	55,0637	18059	18042
2021-06-05	UL_In_Guezam_Ville_11678	11678N	2	44,6339	110145	55,3044	49230	49162
2021-06-04	UL_In_Guezam_Ville_11678	11678N	2	44,4344	116941	55,4699	52074	51962
2021-06-05	UL_In_Guezam_Ville_11678	11678O	3	43,481	151680	56,4478	66060	65952
2021-06-04	UL_In_Guezam_Ville_11678	11678R	21	43,4303	103718	56,4936	45124	45045
2021-06-04	UL_In_Guezam_Ville_11678	11678O	3	42,9714	152185	56,9301	65546	65396
2021-06-05	UL_In_Guezam_Ville_11678	11678T	23	42,1359	65545	57,7985	27661	27618
2021-06-04	UL_In_Guezam_Ville_11678	11678T	23	41,349	66773	58,5716	27663	27610
2021-06-04	UL_In_Guezam_Ville_11678	11678S	22	41,129	42746	58,8008	17611	17581
2021-06-05	UL_In_Guezam_Ville_11678	11678R	21	40,7513	109010	59,1973	44479	44423
2021-06-05	UL_EL_ALIA_7502	07502N	2	40,6935	179272	59,2312	73087	72952
2021-06-05	UL_EL_ALIA_7502	07502O	3	40,4456	159157	59,4897	64475	64372
2021-06-05	UL_EL_ALIA_7502	07502M	1	40,3973	224978	59,5569	90988	90885
2021-06-05	UL_EL_ALIA_7502	07502S	22	39,2774	54110	60,6653	21284	21253
2021-06-05	UL_EL_ALIA_7502	07502R	21	38,1547	66600	61,7297	25488	25411
2021-06-05	UL_EL_ALIA_7502	07502T	23	37,5807	70648	62,2565	26665	26550

Table III.10 e-RAB measurement data

Symptom:

The symptoms of an e-RAB connection setup failure on the eNodeB are as follows: After sending the e-RAB _CONN_SETUP message, the eNodeB fails to receive the e-RAB _CONN_SETUP_CMP message.

Possible causes:

Hardware issue (cards) PRBs.
Transmission issue.
Congestion issue (lack of resources).
Overshooting sites.

Handling actions:

Troubleshooting cards.
Traffic balancing between the site and their neighbours (Selection and Reselection Parameters).
Activate Features to offload the traffic.
Ask For New Frequency.
Ask for New sites.

Observation:

In this case, there is a problem on the Hardware side so we check PRB Utilization counter as shown in Table III.11.

Date	eNodeB Name	LocalCell Id	DL_PRB_Utilization(%)	UL_PRB_Utilization(%)	L.Traffic.User.Max	Cell Traffic Volume_DL(Gbit)	Cell Traffic Volume_UL(Gbit)
2021-06-04 00:00	UL_In_Guezam_Ville_11678	23	93,0551	43,5785	55	20,6615	4,3915
2021-06-04 00:00	UL_In_Guezam_Ville_11678	21	92,8607	51,0067	66	32,6026	7,3321
2021-06-04 20:00	UL_In_Guezam_Ville_11678	1	98,3897	45,6222	201	140,6988	13,8957
2021-06-04 22:00	UL_In_Guezam_Ville_11678	2	97,7045	35,7676	141	95,5701	9,0634
2021-06-04 23:00	UL_In_Guezam_Ville_11678	3	98,3451	48,3146	129	64,925	10,0653
2021-06-04 23:00	UL_In_Guezam_Ville_11678	22	91,9261	36,576	45	27,1854	3,4617
2021-06-05 00:00	UL_In_Guezam_Ville_11678	3	98,6369	46,764	132	73,1288	9,4527
2021-06-05 10:00	UL_In_Guezam_Ville_11678	23	92,044	39,7628	63	24,1379	2,3767
2021-06-05 14:00	UL_In_Guezam_Ville_11678	2	98,5363	40,5232	144	104,4836	9,6568
2021-06-05 14:00	UL_In_Guezam_Ville_11678	22	93,2112	41,0706	55	28,7545	2,2607
2021-06-05 19:00	UL_In_Guezam_Ville_11678	1	98,3582	36,8521	214	154,8308	11,5435
2021-06-05 23:00	UL_In_Guezam_Ville_11678	21	92,7324	54,0758	70	34,3734	7,5048

Table III.11 PRB Utilization

Figure III.3 represents e-RAB Success Rate vs. Congestion Rate during 20 days of the cell UL_In_Guezam_Ville.

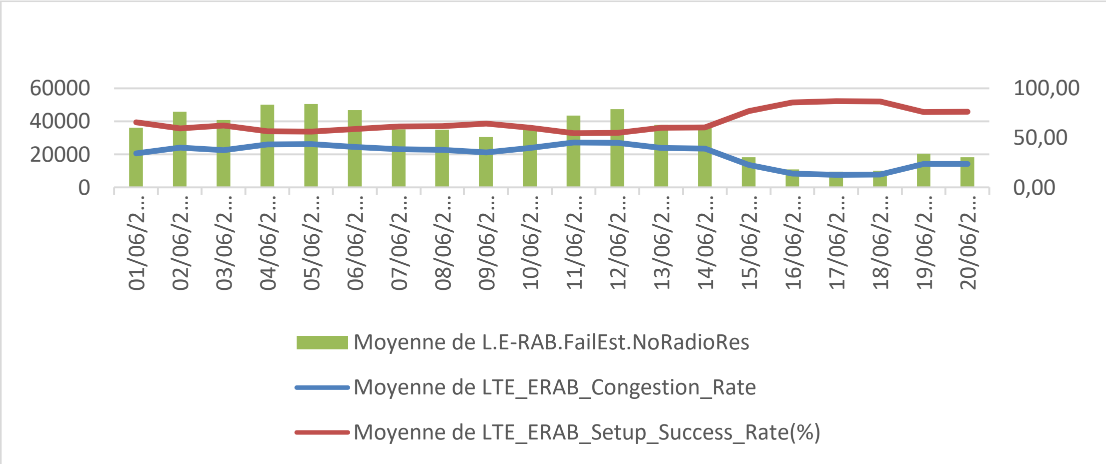

Figure III.3 e-RAB Success Rate

It is clear that the number of the congested resources was reduced by adding PRB Expansions with their licenses as shown in Figure III.3 on 14/06/2021 giving an improvement on the LTE ERAB Accessibility.

III.3 Retainability:

Retainability KPIs are used to evaluate the network capability to retain services requested by a user for the desired duration once the user is connected to the services. These counters can be calculated per cell or per cluster. Retainability KPIs are important in evaluating whether the system can maintain the service quality at a certain level [21].

III.3.1 Call Drop:

The Call Drop Rate (CDR) is defined as Abnormal ERAB release / All released ERAB.

III.3.1.1 Formulas of Call Drop Rate:

The Call Drop Rate is calculated as follows:

L.E-RAB.AbnormRel / (L.E-RAB.AbnormRel + L.E-RAB.NormRel) * 100%........(III.3) [21]

Target is <1.5%, which is the acceptable value from equation (III.3).

III.3.1.2 Abnormal Release Cause Counter:

Table III.12 lists the counters corresponding to the number of abnormal E-RAB releases for different causes [21].

Counter ID	Counter Name	Description	Unit
1526728282	L.E-RAB.AbnormRel.Radio	Number of abnormal E-RAB releases caused by radio-layer problems	Number
1526728283	L.E-RAB.AbnormRel.TNL	Number of abnormal E-RAB releases caused by transport-layer problems	Number
1526728284	L.E-RAB.AbnormRel.Cong	Number of abnormal E-RAB releases caused by network congestion	Number
1526728291	L.E-RAB.AbnormRel.HOFailure	Number of abnormal E-RAB releases caused by handover failures	Number
1526728292	L.E-RAB.AbnormRel.MME	Number of abnormal E-RAB releases caused by EPC problems	Number

Table III.12 Counters corresponding to the number of abnormal E-RAB releases [21]

Methods of Performance Measurement:

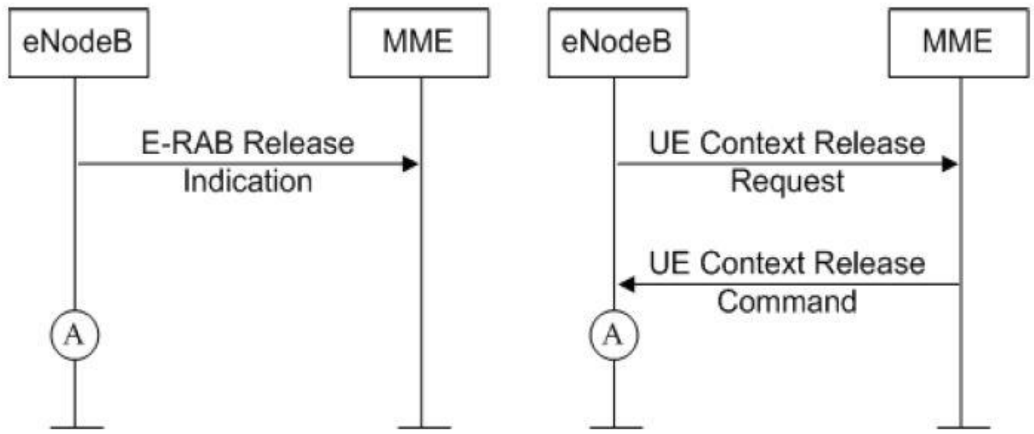

Figure III.4 Performance measurement points for abnormal ERAB [21]

As shown in Figure III.4, the abnormal ERAB release counter is incremented when the eNodeB sends an E-RAB Release Indication to the MME or receives a UE Context Release Command message from the MME and the release causes are not Normal Release, User Inactivity, Partial Handover, or Handover triggered. If the message contains several ERAB ID IEs, the counter will be incremented for each individual ERAB [21].

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III.3.2 CDR Traffic measurement data:

Service drops are monitored by means of traffic measurement on commercial networks. The service drop rate and the number of service drops are observed for determining a fault. The traffic measurement result exported from the M2000. Table III.13 and represents CDR measurement data and statistics obtained from M2000.

Date	eNodeB Name	Cell Name	Call Drop Rate (All)(%)	L.E-RAB.AbnormRel.eNBTot	L.E-RAB.AbnormRel.HOFailure	L.E-RAB.AbnormRel.MME.HOOut
2021-06-04	UL_05529	05529N	7,3582	2038	598	1136
2021-06-04	Champ de tir- M doukal_05	05561S	7,1231	790	0	18
2021-06-04	UL_Sidi_salemII_23704	23704N	5,8628	18202	13643	11539
2021-06-04	UL_3G_31171	31171O	4,8577	1329	5	28
2021-06-04	UL_OUED_JEMAA_48202	48202N	4,5806	2607	1	9
2021-06-04	UL_3G_31171	31171S	4,5685	1215	0	10
2021-06-04	UL_3G_31171	31171N	4,5567	1764	2	11

Table III.13 CDR measurement data (handover)

Symptom:

According to the definition of the traffic measurement counter on the eNodeB, if abnormal releases are counted into the L.E-RAB.AbnormRel.HOFailure counter, service drops are caused by handover failures.

Possible causes:

A service drop with the cause value being handover failure is caused by an abnormal release due to a failure in handover out of the serving cell.

Handling actions:

Use inter-specific-cell outgoing handover counters to determine the target cell with the largest service drop rate.

Optimize the handover relationship including handover parameters and neighbouring relationships and then check whether related counters are recovered.

Observation:

Both sites with yellow colour had an issue with same relation which is neighbours (New Site coming on air) has the same PCI (Physical Cell Identity) as the serving cell.

The proposed solution is to change this PCI and Delete/ Create.

Procedure:

To modify the EUTRAN Specified Physical Cell ID Cell configuration with the parameters as follows:

Downlink EARFCN:3000,Start Physical Cell ID:25,Specified Physical Cell ID Range:10,run the following command: MOD EUTRANSPEPCICELL: DlEarfcn=3000, StaPhyCellId=25, SpePhyCellIdRange=10.

Figure III.5 shows the procedure of optimization and the modification of PCI using Huawei Software.

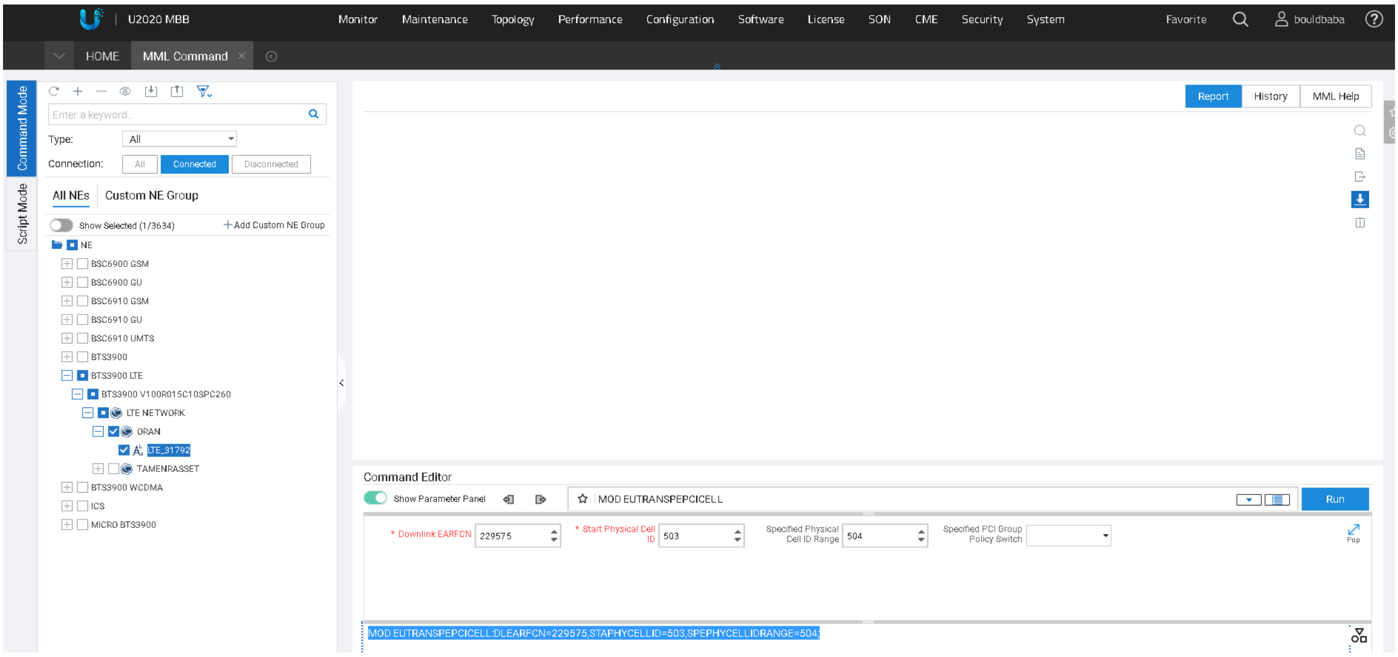

Figure III.5 PCI Commands

After applying the previous solution we notice that the CDR is decreasing to maintain our target which is less than 1.5% as shown in Table III.14. So the problem is solved and we have optimized those 2 cells.

Date	eNodeB Name	Cell Name	Call Drop Rate (All)(%)	Date	eNodeB Name	Cell Name	Call Drop Rate (All)(%)
2021-06-04	UL_05529	05529N	7,3582	2021-06-04	Sidi_salemII_23	23704N	5,8628
2021-06-05	UL_05529	05529N	9,6333	2021-06-05	Sidi_salemII_23	23704N	0,7872
2021-06-06	UL_05529	05529N	4,5768	2021-06-06	Sidi_salemII_23	23704N	0,6891
2021-06-07	UL_05529	05529N	0,3291	2021-06-07	Sidi_salemII_23	23704N	0,7175
2021-06-08	UL_05529	05529N	0,3151	2021-06-08	Sidi_salemII_23	23704N	0,7641
2021-06-09	UL_05529	05529N	0,2448	2021-06-09	Sidi_salemII_23	23704N	0,8162
2021-06-10	UL_05529	05529N	0,2802	2021-06-10	Sidi_salemII_23	23704N	0,4212
2021-06-11	UL_05529	05529N	0,18	2021-06-11	Sidi_salemII_23	23704N	0,0513

Table III.14 CDR measurement data

III.4 Mobility:

Mobility KPIs are used to evaluate the performance of E-UTRAN mobility, which is critical to the customer experience. Several categories of mobility KPIs are defined based on the following handover types: intra-frequency and inter-frequency [22].

The formula of Handover success rate is calculated as follows:

L.HHO.IntraeNB.IntraFreq.ExecSuccOut+L.HHO.IntereNB.IntraFreq.ExecSuccOut)/(L.HHO.IntraeNB.IntraFreq.ExecAttOut+L.HHO.IntereNB.IntraFreq.ExecAttOut) *100%..(III.4)[22]

Target is >98% which is the acceptable value from equation (III.4).

Table III.15 lists the counters corresponding to the number of Handover Preparation Failure releases for different causes.

Counter ID	Counter Name	Description	Unit
1526728282	L.HHO.Prep.FailOut.MME	Number of outgoing handover preparation failures due to faults in the EPC	Number
1526728283	L.HHO.Prep.FailOut.NoReply	Number of outgoing handover preparation failures due to no responses from the target cell	Number
1526728284	L.HHO.Prep.FailOut.PrepFailure	Number of outgoing handover preparation failures due to handover preparation failures at the target cell	Number
1526728291	L.HHO.Prep.FailOut.HOCancel	Number of outgoing handover failures due to handover cancellation messages sent by the source cell	Number

Table III.15 Handover Preparation Failure Counters [22]

III.4.1 Intra-frequency Handover Success Rate:

This KPI can be used to evaluate the intra-frequency Handover out success rate in a cell or a cluster. The intra-frequency handover (HO) includes both inter-eNodeB and intra-eNodeB scenarios. To illustrate the KPI calculation, we briefly discuss how the related counters (number of intra-frequency HO attempts and number of successful intra-frequency HO attempts) are collected.

Intra-eNodeB HO scenario is shown in Figure III.6. The HO attempt counter is collected at point B. When the eNodeB sends an RRCConnectionReconfiguration message to the UE, it decides to perform a handover. The eNodeB counts the number of attempts to perform intra-eNodeB intra-frequency HO in the source cell. The success HO counters are collected at point C. The eNodeB counts the number of successful intra-eNodeB intra-frequency HOs in the source cell when the eNodeB receives the RRCConnectionReconfigurationComplete message from the UE [19].

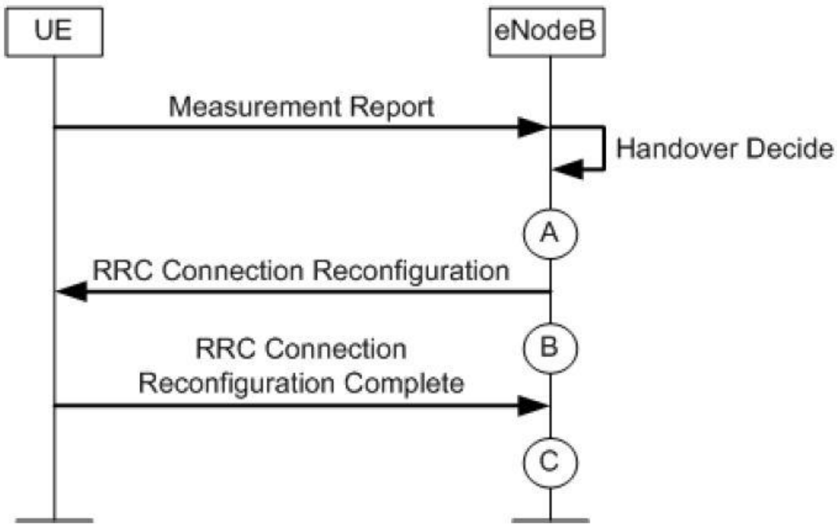

Figure III.6 Scenario for Intra-frequency Intra-eNB HO [19]

Two scenarios are available for the inter-eNodeB HO, as shown in FigureIII.7 and FigureIII.8. The HO attempts are collected at point B. When the Source-eNodeB (S-eNodeB) sends an RRC Connection Reconfiguration message to the UE, it decides to perform an inter-

eNodeB HO. In this KPI, the source and target cells of the handover are at the same frequency. The number of inter-eNodeB intra-frequency HO attempts is measured at the source cell.
The number of inter-eNodeB intra frequency success HOs is collected at point C as shown in Figure III.7 and Figure III.8. During a handover with the source and target cells at the same frequency, the number of successful inter-eNodeB intra-frequency HOs is measured in the source cell when the S-eNodeB receives a UE Context Release message from the Target-eNodeB (T-eNodeB) or a UE Context Release Command message from the MME, indicating that the UE access to the T-eNodeB is successful [19].

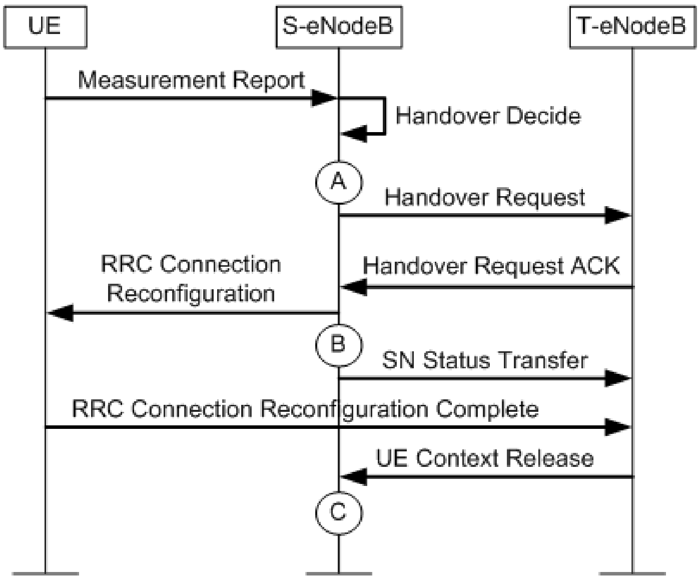

Figure III.7 Scenario A for intra-frequency inter-eNodeB HO [19]

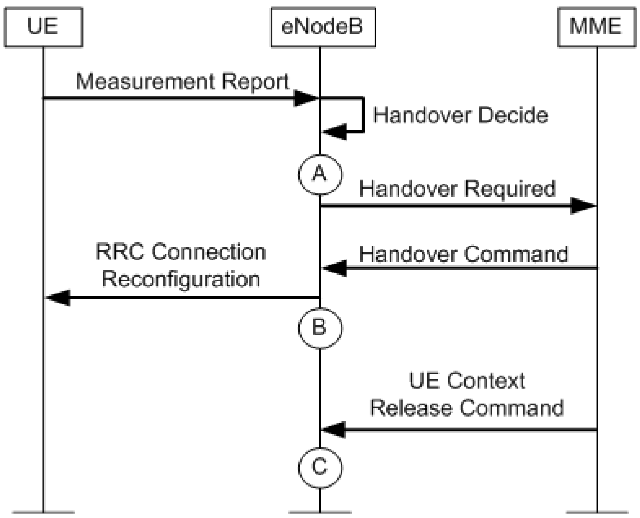

Figure III.8 Scenario B for intra-frequency inter-eNodeB HO [19]

III.4.2 Inter-frequency Handover Success Rate

Similar to Intra-frequency Handover Success Rate, the target eNodeB and source eNodeB are at different frequencies.
This KPI can be used to evaluate the inter-frequency handover success rate in a cell or a cluster. Note that the measurement points for the associated counters are the same as those for the intra-frequency HO scenario described before. The target LTE cell operates at a frequency different from that of the source LTE cell, which is the only difference.

As shown in Figure III.6, if the source and target cells at different frequencies are controlled by the same eNodeB, the eNodeB counts the number of intra-eNodeB inter-frequency HO attempts at point B and the successful intra-eNodeB inter-frequency HOs at point C in the source cell. As shown in Figure III.7, if the handover source and target cells are at different frequencies, the eNodeB counts the number of inter-eNodeB inter-frequency HO attempts at point B and the successful intra-eNodeB inter-frequency HOs at point C in the source cell [19].

III.4.3 Intra-frequency measurement data:

Table III.16 represents Intra-frequency measurement data and statistics exported from M2000.

Date	eNodeB Name	Cell Name	Integrity	Intra-frequency Handover Success Rate(%)	L.HHO.IntraFreq.NoData.ExecAttOut	L.HHO.IntraFreq.NoData.ExecSuccOut
2021-06-04	UL_Sidi_salemII_23704	23704N	100%	54,0919	10538	5602
2021-06-04	UL_Sidi_salemII_23704	23704O	100%	68,9411	2689	1901
2021-06-05	UL_Sidi_salemII_23704	23704O	100%	75,3004	2304	1818

Table III.16 Intra-frequency measurement data Ho exec

Symptom:

Low intra-frequency handover success rate.

Very low intra-frequency handover execution.

Possible causes:

Missing neighbour.

Mistake neighbour configuration/PCI conflict.

Incorrect handover event parameters.

EPC replies handover preparation failure.

Handling actions:

Check the neighbour/ANR configuration

Check EPC authentication & security configuration.

Check eNodeB alarm and basic configuration.

Observation:

In this case, the issue is caused by adding the new frequency of 2100MHz to the LTE, some parameters setting by relation was not correct.

Procedure:

The Parameter is IntraFreqHoA3Offset

Introduce margin to speed the Handover Execution.

Figure III.9 shows the procedure of optimization and the modification of Intra-frequency using Huawei Software.

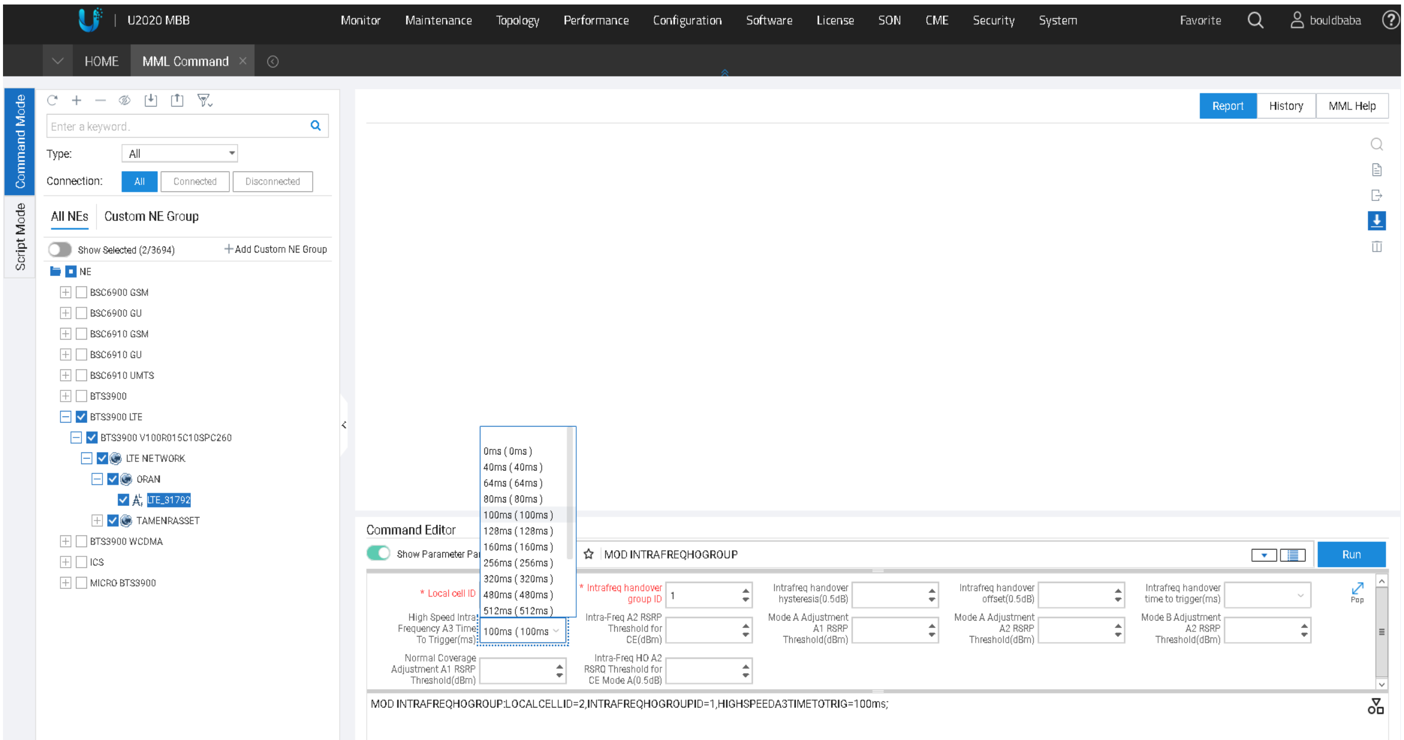

Figure III.9 Intra-frequency Commands

After an audit, the correction was done giving an improvement of HO success as shown in Table III.17 we notice that Intra-frequency Handover Success Rate is increasing on 10-06-2021 to maintain our target which is greater than 98%. So the problem is solved and we have optimized this cell.

Date	eNodeB Name	Cell Name	Intra-frequency Handover Success Rate(%)	L.HHO.IntraFreq.NoData.ExecAttOut	L.HHO.IntraFreq.NoData.ExecSuccOut
2021-06-04	UL_Sidi_sale	237040	68,9411	2689	1901
2021-06-05	UL_Sidi_sale	237040	75,3004	2304	1818
2021-06-06	UL_Sidi_sale	237040	74,7967	2328	1853
2021-06-07	UL_Sidi_sale	237040	76,2133	2424	2015
2021-06-08	UL_Sidi_sale	237040	74,6523	2186	1731
2021-06-09	UL_Sidi_sale	237040	77,566	2589	2096
2021-06-10	UL_Sidi_sale	237040	94,0904	2445	2345
2021-06-11	UL_Sidi_sale	237040	99,932	1853	1853

Table III.17 Intra-frequency measurement data Ho for unique cell

III.4.4 Inter-frequency measurement data:

Table III.18 represents Inter-frequency measurement data and statistics obtained from M2000.

Date	eNodeB Name	Cell Name	LocalCell Id	Integrity	Inter-frequency Handover Success Rate(%)
2021-06-04	UL_ARZEW_2_31695	31695N	2	100%	53,0303
2021-06-05	UL_BTLELIS_31115	31115N	2	100%	57,8171
2021-06-04	UL_31585	31585O	3	100%	58,2492
2021-06-04	UL_BTLELIS_31115	31115N	2	100%	59,3838
2021-06-05	UL_ARZEW_2_31695	31695N	2	100%	62,4309
2021-06-05	UL_AIN_EL_BEIDA_31718	31718R	21	100%	62,5
2021-06-05	UL_Belghaid_LPA_EXTENSI(	31764N	2	100%	66,6667
2021-06-05	UL_HAI_ISTIKLAL_BOUTLEL	31551N	2	100%	68,6275
2021-06-05	UL_Ras_Kalouche_26710	26710N	2	100%	68,75
2021-06-05	UL-HAI_ESSALAM_31670	31670O	3	100%	69,2308

Table III.18 Inter-frequency measurement data Ho Success Rate

Symptom:
Low inter-frequency Handover success rate.

Possible causes:
Missing neighbour.
Mistake neighbour configuration/PCI conflict.
Incorrect handover event parameters.
EPC replies handover preparation failure.

Handling actions:
Check the neighbour/ANR configuration.
Check EPC authentication & security configuration.
Check eNodeB alarm and basic configuration.

Observation:
In this case, the issue is caused by adding the new frequency of 2100MHz to the LTE, some parameters setting by relation was not correct.

Procedure:
The Parameter is InterFreqHoA3Offset
Introduce margin to speed the Handover Execution.

Figure III.10 shows the procedure of optimization and the modification of Inter-frequency using Huawei Software.

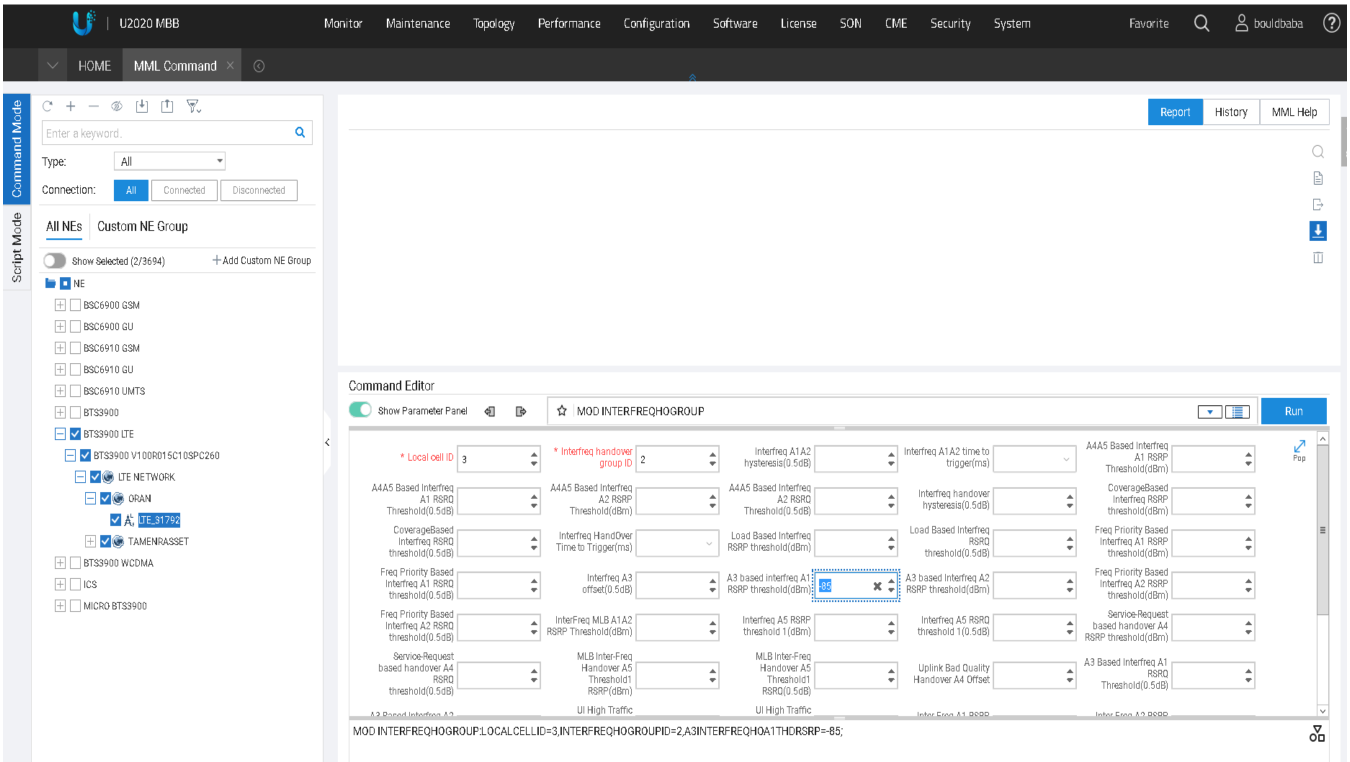

Figure III.10 Inter-frequency Commands

After an audit, the correction was done giving an improvement of HO success as shown in Table III.19 we notice that Inter-frequency Handover Success Rate is increasing on 06-06-2021 to maintain our target which is greater than 98%. So the problem is solved and we have optimized this cell.

Date	eNodeB Name	Cell Name	Integrity	Inter-frequency Handover Success Rate(%)
2021-06-04	UL-HAI_ESSALAM_31670	31670O	100%	100
2021-06-05	UL-HAI_ESSALAM_31670	31670O	100%	69,2308
2021-06-06	UL-HAI_ESSALAM_31670	31670O	100%	100
2021-06-07	UL-HAI_ESSALAM_31670	31670O	100%	92,8571
2021-06-08	UL-HAI_ESSALAM_31670	31670O	100%	100
2021-06-09	UL-HAI_ESSALAM_31670	31670O	100%	100
2021-06-10	UL-HAI_ESSALAM_31670	31670O	100%	100
2021-06-11	UL-HAI_ESSALAM_31670	31670O	100%	100

Table III.19 Inter-frequency measurement data Ho for unique cell

III.5 Summary:

The quality of network performance is mainly evaluated by KPI (Key Performance Indicator) . In this chapter, most of KPIs are attained by using Performance Measurement KPI, such as RRC Setup success Rate, HHO success rate…, these KPIs are coming from eNodeB performance statistic by using the Appendix of M2000 Huawei software program [23]. Table III.19 summarizes KPIs with the corresponding indicator used in this chapter.

KPI Classes	Indicators	Test Method
Accessibility	RRC Connection Establishment Success Rate	Stats.
	ERAB Establishment Success Rate	Stats.
Retainability	Call Drop Rate	Stats.
Mobility	Handover Success Rate (Intra-system)	Stats.

Table III.20 Summary of KPIs [23]

Conclusion

During this work, we have seen that mobile generations have been developed to guarantee a better performance and quality of service. Behind this evolution, there is a set of Key Performance Indicators that evaluate the performance of the LTE system. Some counters such as Accessibility (RRC Connection Establishment Success Rate / e-RAB Establishment Success Rate), Retainability (Call Drop Rate), and Mobility (Handover Success Rate) are necessary for the KPI calculation.

From all the obtained results, we can conclude that those KPIs, network analysis and measurements are necessary to ensure the performance and quality of service.

For future users, those KPIs should be updated according to the experiences of commercial network management and radio network optimization to make our life easier, to save time and effort.

References

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APPENDIX

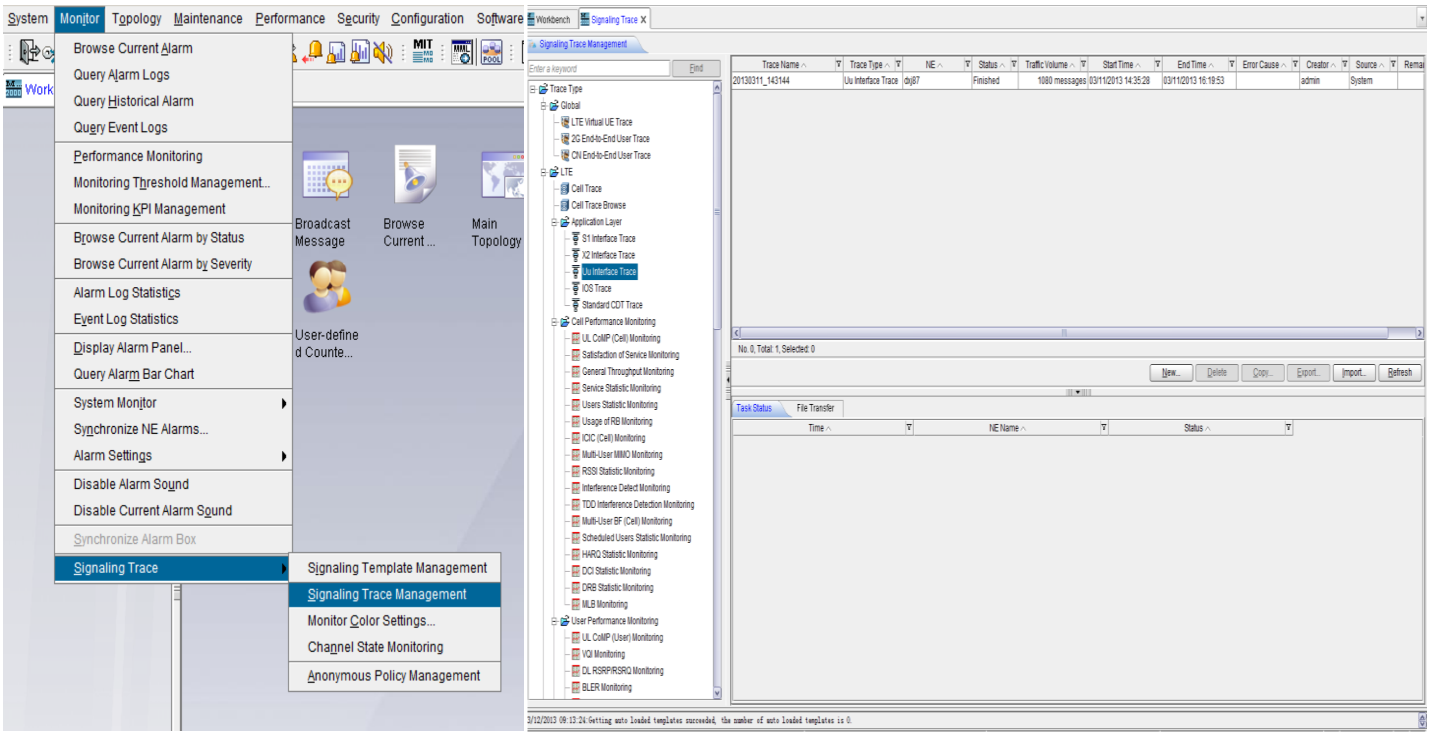
KPI Data collection from M2000

The M2000, as a centralized NE management unit, provides functions including

- operation configuration,
- Tracing and monitoring,
- Alarm query,
- KPI query management,
- Deployment and upgrade management.
- Functions mostly used in information collection include signalling tracing, performance monitoring, and KPI query.

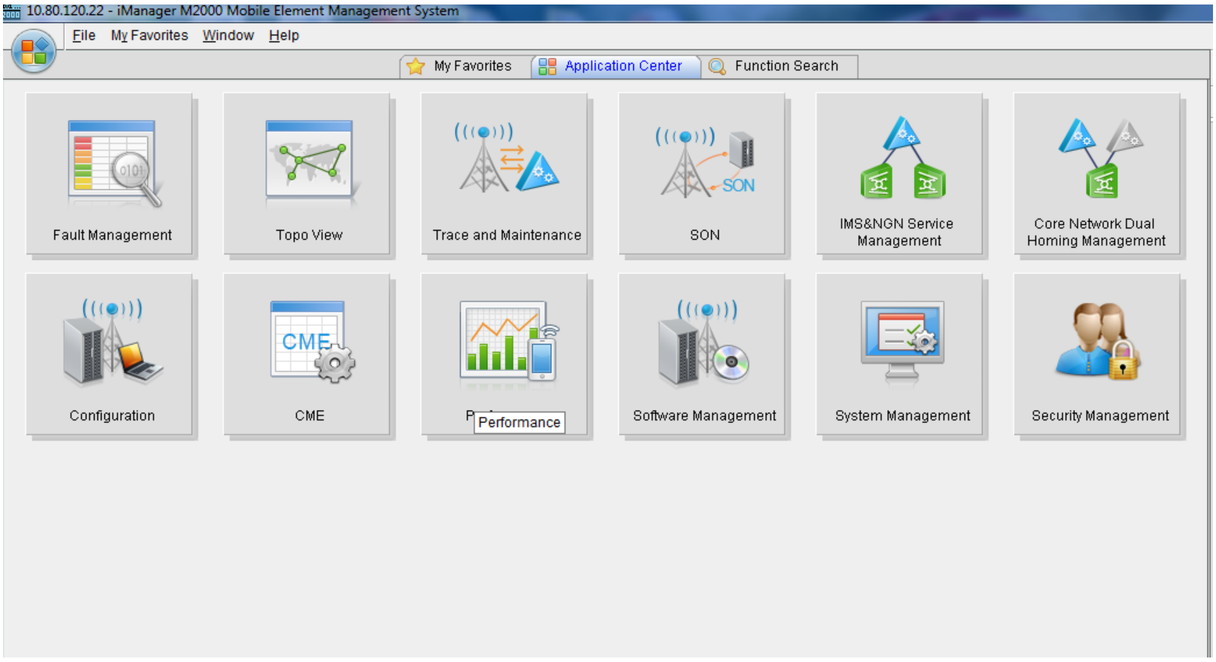
1. M2000 Interface:

Choose Monitor > Signalling Trace > Signalling Trace Management on the M2000 to open the signalling tracing or performance monitoring interface.

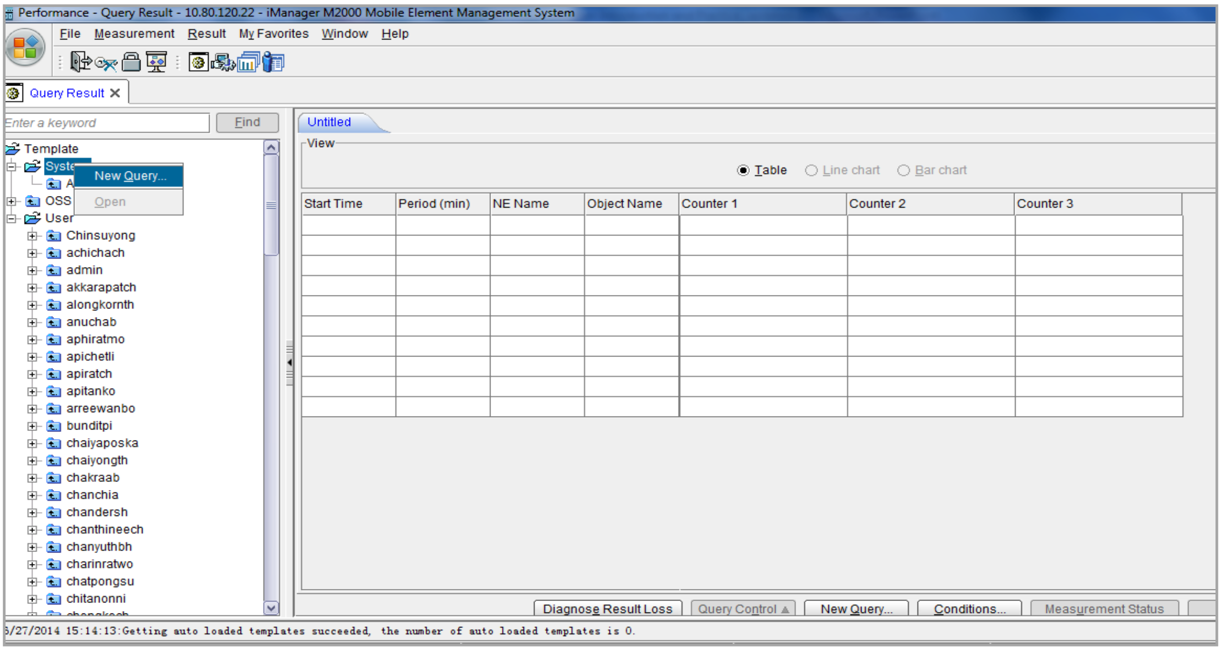


2. KPI Data Collection Selecting New Query:

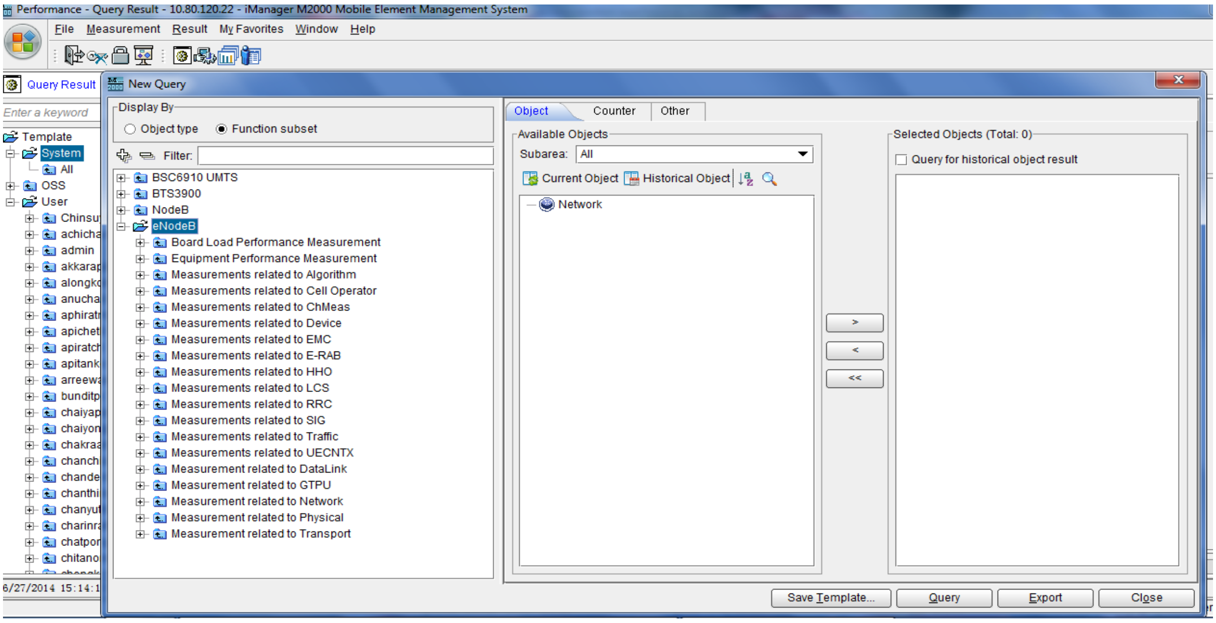
Choose the Performance tab.



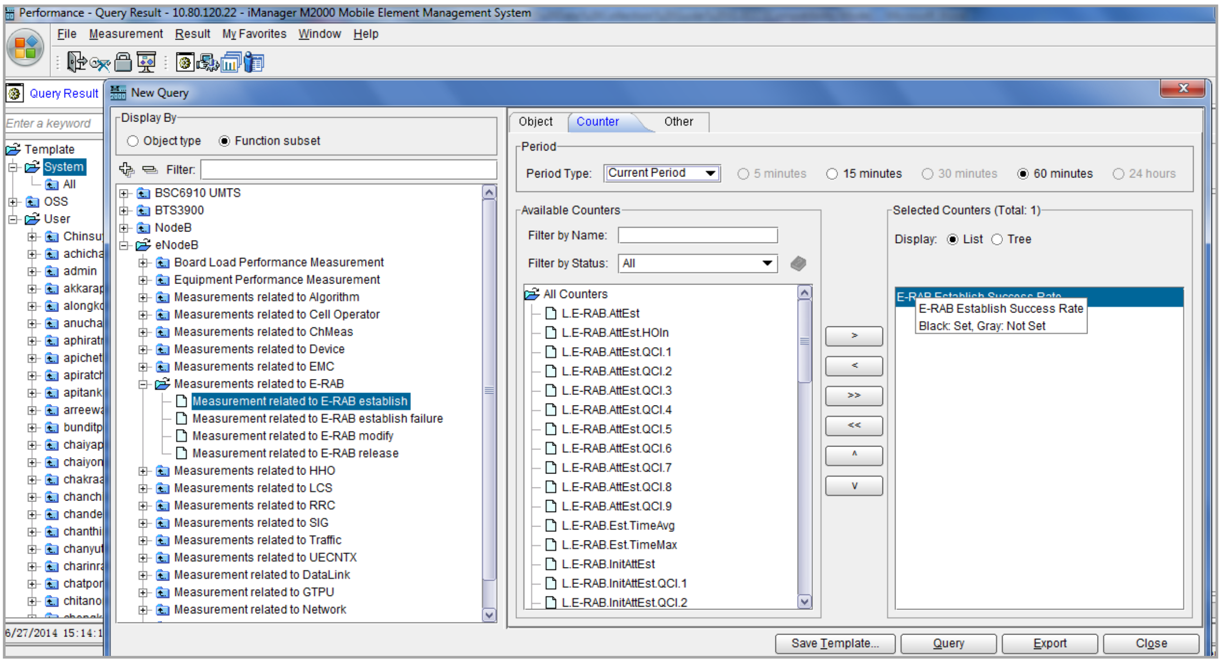
Choose the New query.



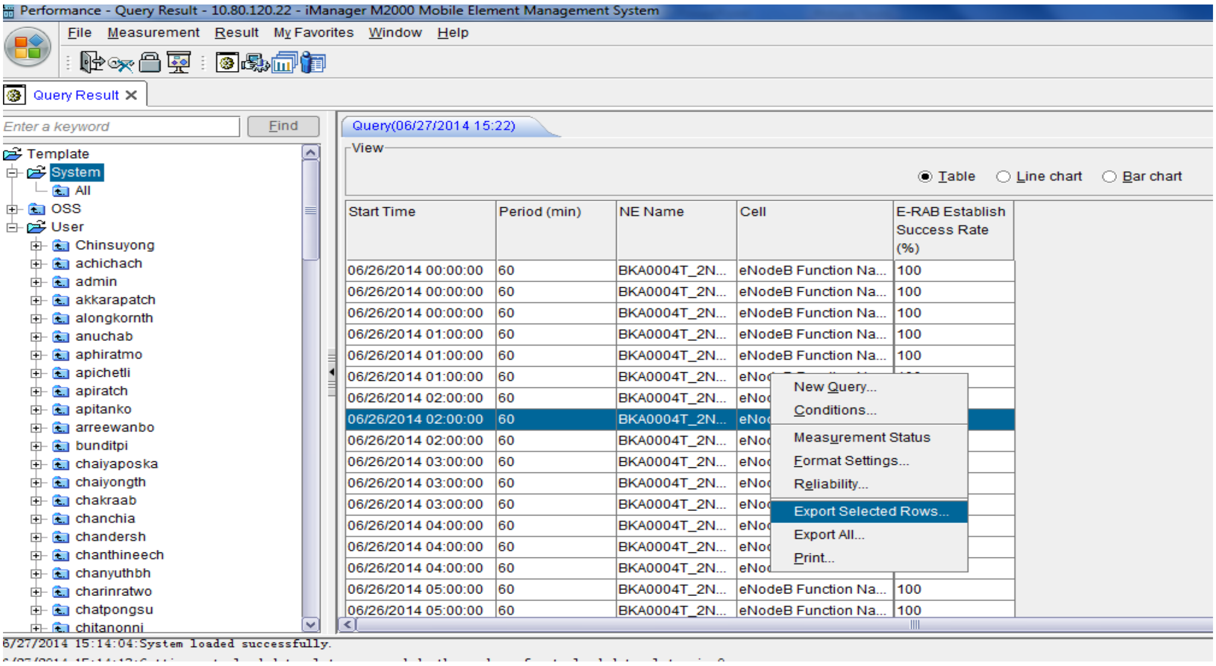
Select <eNodeB>to query desired counter and Period to fetch data.



After selecting press query for the output.

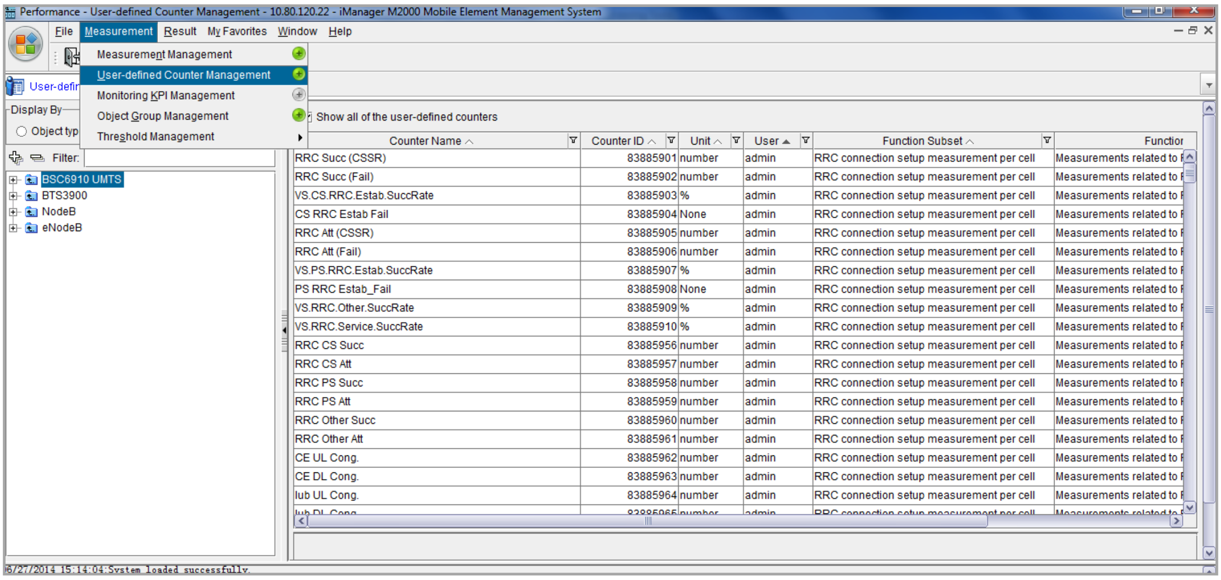


After successful query on the counter measurement, click on tab Save (bottom) to store in any local directory of the computer. The stored file will be in .CSV format which can open with Excel office application.

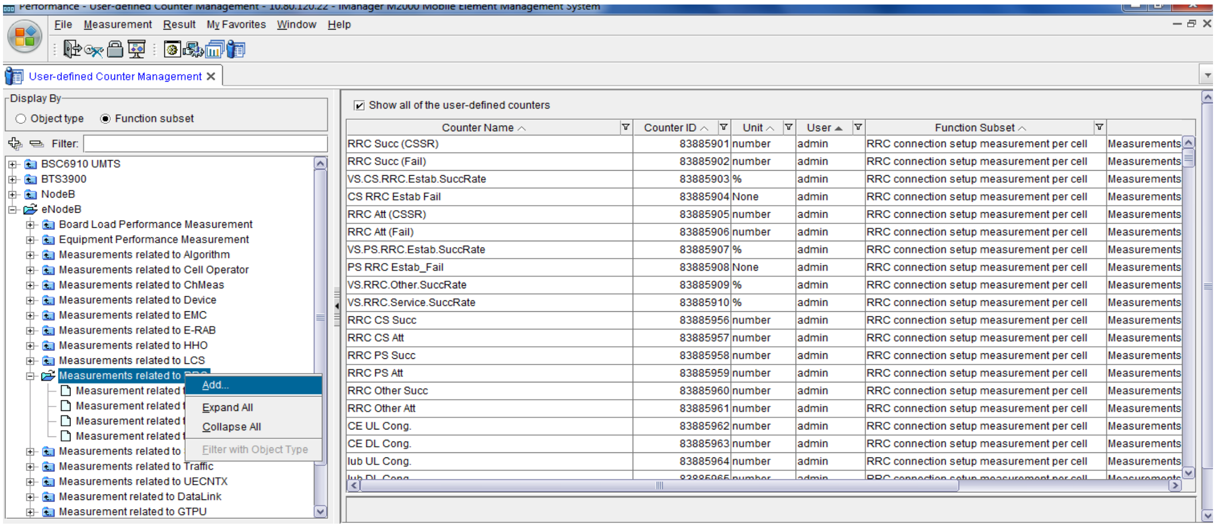


3. User Defined Counter Management:

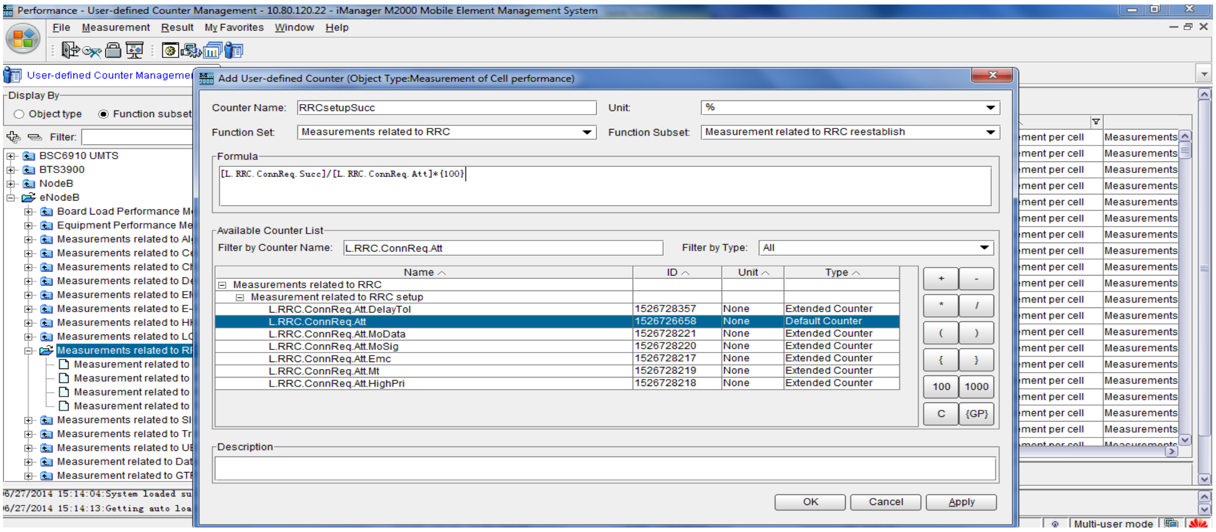
Select > User defined counter management under measurement Tab.



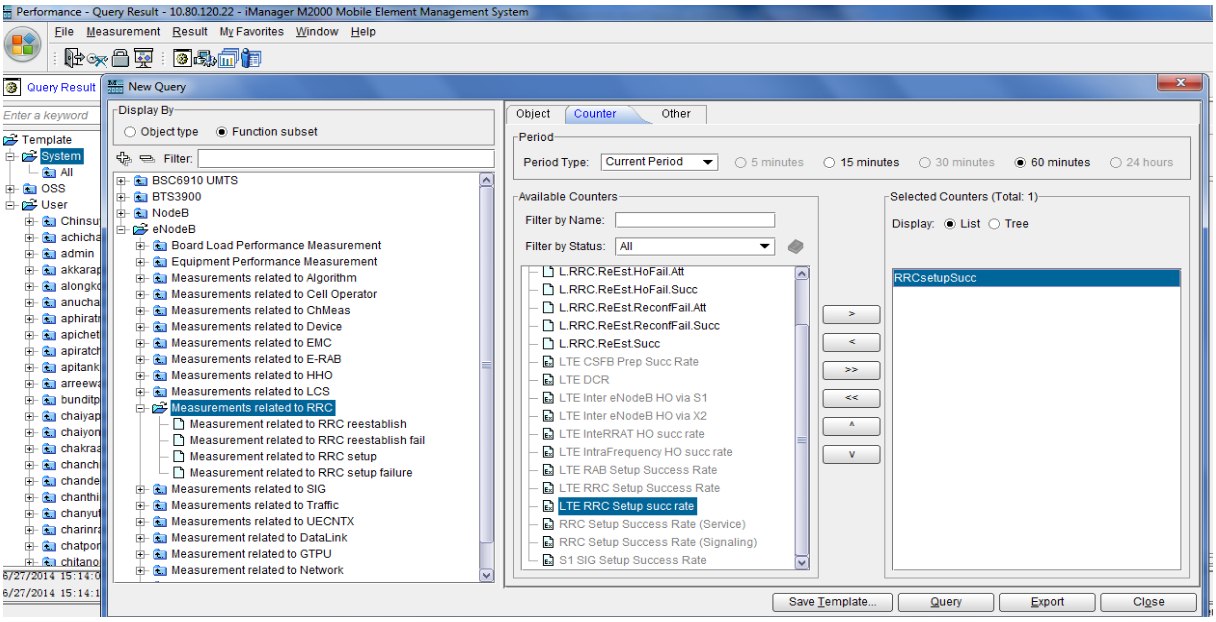
Select counter class depending on required KPI (example RRC Setup success rate) Right click and Add.



Select the name for the KPI in the counter name tab.
Select formula for the KPI in formula tab.
(Example [L.RRC.ConnReq.Succ]/[L.RRC.ConnReq.Att]*{100}) and Apply.

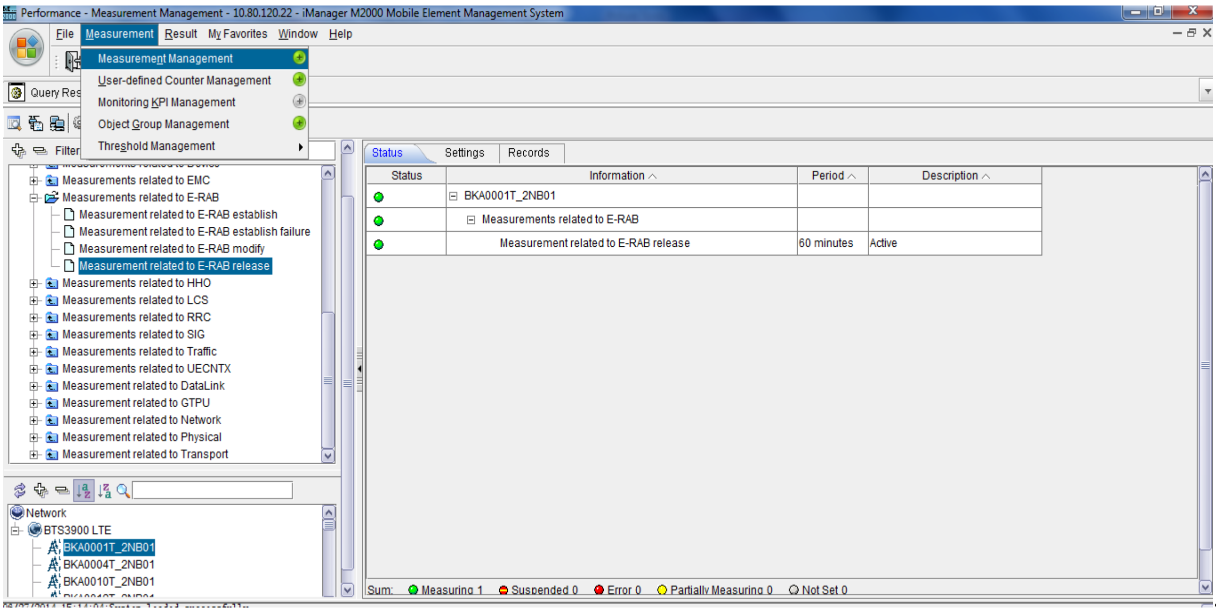


Next time when we query in RRC counter class we can find our user define KPI RRCSetupSucc .

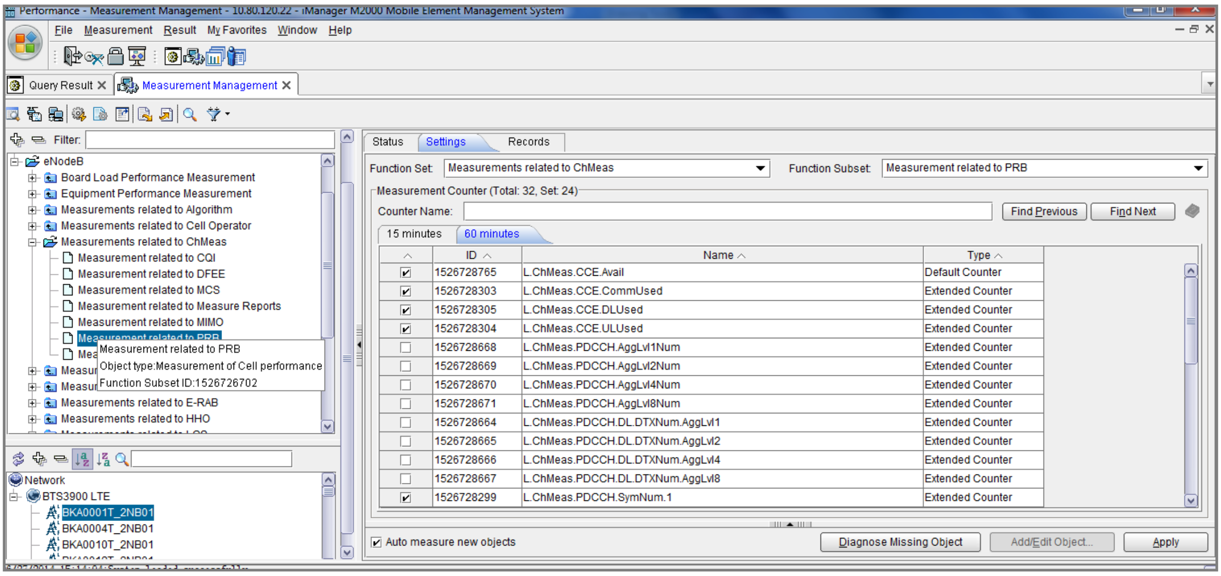


4. Measurement Management:

Select Measurement management under <Measurement> Tab.



Measurement management.



Measure Management is used to check whether the counters in the function subset to-be-queried NE are set for measurement during a correct period and whether the objects under the function subset can be measured.