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Cell planning and optimization for 4G and 5G mobile networks

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Dedecation

Thanks to God and his help, the preparation of my final studies project is completed

With love, respect and appreciation, I dedicate this work to:

To my mother ***Houria Hadji*** *and my father* ***Aissa****, who since I was very young have always done their best, It is thanks to you and for you that I wrote my dissertation.*

To my dear sisters ***Rahil hibatallah*** *and* ***Meriem elbatoul****.*
To my dear brothers ***Mohammed****and* ***Abderrahman Mahdi****.*
To my close friends, I can only say thank you very much for supporting and encouraging me throughout my work.

And to everyone I love in my life, To all those who have supported me, may they find here the expression of my Love and my deep Gratitude, Thank you all, Thank you for everything.

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List of Acronyms

1G First Generation

2G Second Generation

3G Third Generation

3GPP 3rd Generation Partnership Project

4G Fourth Generation

5G Fifth Generation

AVR Average

BCCH Broadcast Control Channel

BER Bit Error Rate

BH Busy Hour

BLER Block Error Rate

BS Bearer Services

BSC Base Station Controller

BSIC Base Station Identity Code

BSS Base Station Subsystem

BTS Base Transceiver Station

C/N Carrier to Noise ratio

C/I Carrier to Interference ratio

CS Circuit Switched

CCCH Common Control Channel

CDR Call Detail Record

COST European Cooperation in the field of Scientific and Technical research

CSSR Call Setup Success Rate

dbm Decibel

DL Downlink

Div Transmission diversity

DT Drive Tests

EDGE Enhanced Data Rates for GSM Evolution

EGPRS Enhanced General Packet Radio Service

E-NodeB Evolved NodeB

EPS Evolved Packet System

ERAB E-UTRAN Radio Access Bearer

FER Frame Error Rate

GPRS General Packet Radio Service

GPS Global Positioning System

GSM Global System for Mobile

HO Handover

IoT Internet of Things

ITU International Telecommunication Union

KPI Key Performance Indicator

LTE Long Term Evolution

MA Terminal Adapter

MS Terminal Station

MIMO Multi-Input Multiple-Output

MME Mobility Management Entity

MOS Mean Opinion Score

MT Mobile Technologies

PS Packet Switched

QoS Quality of Service

RAN Radio Access Network

RAT Radio Access Technology

RF Radio Frequency

RB Radio Block

RSRQ Reference Signal Received Quality

RSRP Reference Signal Received Power

RX Receive signal

SDCCH Stand Alone Dedicated Control Channel

SM Spatial multiplexing

SINR Signal to Interference & Noise Ratio

SQI Speech Quality Index

SSV Single Site Verification

TA Time Advance

TCH Traffic Channel

TEMS Test Mobile Systems

TRX Transceiver unit

TX Transmitter Signal

UE User Equipment

UL Uplink

UMTS Universal Mobile Telecommunications System

VAD Voice Activity Detection

VoIP Voice over IP

WCDMA Wideband Code Division Multiple Access

Introduction

The radio interface is the most important part of the mobile network, it is the access point of mobile phones for services. The access to the network is a very complicated task because it will be done through logical channels.

Most network operators try to enhance their existing radio networks by using monitoring tools and tasks. Among these important tasks, we can find planning and optimization. These two processes will be done simultaneously[17].

fourth generation (4G) communication systems.

In the first chapter, we conducted a study on network layout. In this chapter, several basic concepts related to the planning of a mobile network, of different generations, are introduced, making it possible to understand many of the tasks of a radio engineer during planning such as creating a link budget and calculating cell capacity[10].

The second chapter focuses on the various processes for improving the mobile network and key performance indicators (KPIs).

In the third chapter, we have described the TEMS investigation program it allows reading the log file acquired during the test drive in order to perform a deep analysis, improve the radio interface and address the various problems found.

In the last chapter, we presented our contribution to improving the performance of the Mobilis wireless access network at the level of the wilaya of M'sila (University Pole) by analyzing the KPIs collected, then identifying the causes of deterioration and proposing appropriate solutions.

Chapter I

Radio Network planning of different mobile generations

I.1 Introduction

RF Planning is the process of assigning frequencies, transmitter locations and parameters of a wireless communications system to provide sufficient coverage and capacity for the services required[14]. In this chapter, I will discuss the importance of radio network planning, and different method and phase of planning from the different generations of mobile network (2G, 3G, 4G, and 5G)

I.2 The importance of network planning:

The network planning process illustrated in the Figure 1.1 is an endless cycle is divided into five main phases, four of which are located before the network launch, and the last is located after the network launch.

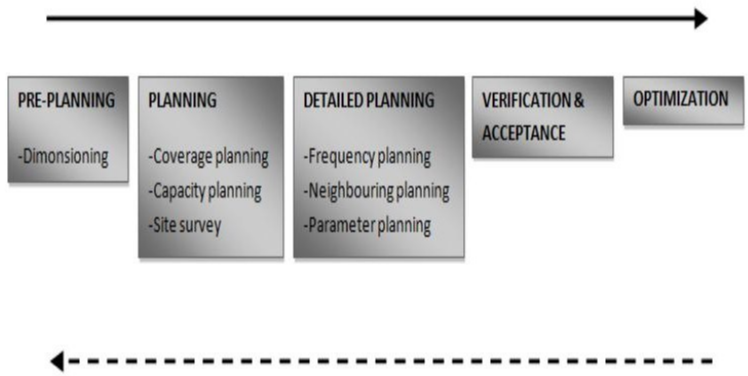


Figure I.1: Planning process steps

The cost of radio and network infrastructure must be kept to a minimum depending on radio coverage, cell size, frequency plans, and network topology. These factors include the characteristics of the environment to be covered (geographical and propagation characteristics), the characteristics of the subscribers to be served (density, user behavior), and a frequency band[11]

Therefore, depending on the area to be planned, network planning will have different goals:

1. Ensuring enough traffic capacity (serving a large number of customers) is the goal in metropolitan regions.

2. The goal is to provide the most comprehensive coverage (cell radius of around ten kilometers) in rural areas (low subscriber density areas) without requiring a large capacity.

Determining a cellular network's capacity and coverage is essential for an operator and is the process of network planning.

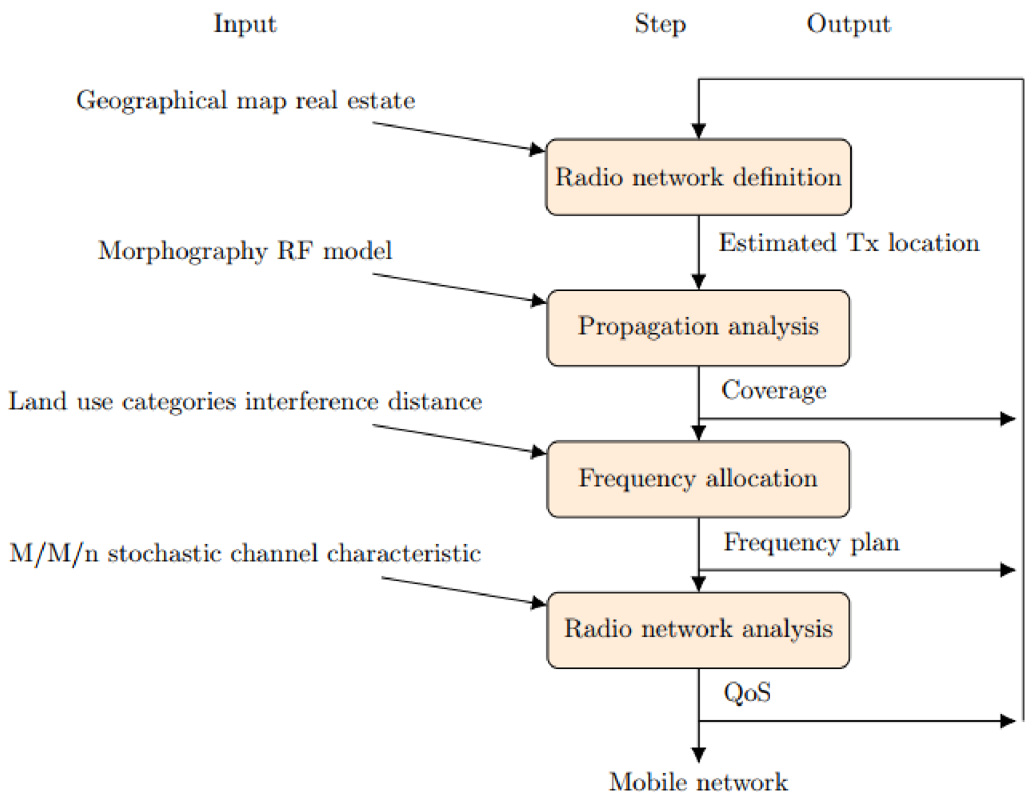


Figure I.2: Conventional approach to cellular network planning.

I.3 Mobile Network Planning in GSM and 3G:

The detailed planning of a mobile network can be divided into three subparts:

1. Coverage planning
2. Capacity planning
3. Frequency planning

I.3.1 Coverage planning

I.3.1.1 Coverage planning in GSM networks

A network's cellular coverage is mostly determined by human and natural factors, including subscriber behavior, terrain (rural, suburban, or urban), and propagation circumstances and geography[7]. Location probability serves as a gauge for a mobile network's coverage quality. To do this, it is necessary to forecast the region's radio propagation conditions as precisely as possible. Propagation models are useful to radio planners in two ways[1]. They have two options: they can either develop original propagation models tailored to specific regions of a cellular network, or they can make use of pre-existing standard models that are universally applicable. Using their own model will have the benefit of being more precise, but the construction process will take a very long time. While standard models are cost- and time-effective, their accuracy is restricted. Several general models (macro-cells or microcells) for urban, suburban, and rural areas are used to give an intermediate answer.

I.3.1.2 Coverage planning in GPRS & EDGE:

In order to enhance transmission quality, coverage planning is usually predicated on raising Carrier to Noise ratio (C/N) in both directions. For every type of network, a certain range of C/N values is provided for a given block error rate (BLER). The amount of error protection needs to be high in order to have a low necessary C/N[2].

It is necessary to compute a connecting budget in order to have a balanced coverage area. Comparisons between cell sizes for various mobile network generations are made possible by link budget calculations. A lot of factors need to be determined in order to calculate the liaison budget, including transmitter output power (MS/BS). Receiver performance for various coding systems (MS/BS); Diversity of antenna arrangements[9] .

I.3.1.3 Planning for coverage in WCDMA networks

The WCDMA and GSM coverage planning processes are essentially the same. Propagation models, however, need to be modified to take WCDMA technology into consideration. You can use either the Walfish–Ikegami or Okumara–Hata models to compute the R-cell range[19]. Following that, the site's 2.6R2 can be computed. However, more measurements and modifications have been performed to the WCDMA networks within the context of COST, the European Community's cooperative research program for scientific and technological research. The Okumara-Hata expanded model's validity is:

- Frequency f: 150–2000 MHz
- Distance R: 1–20 km
- UE height: 10–200 m

- MS height: 1–10 m

The correction factor c is given as follow:

$$\begin{aligned} 2\log^2\left(\frac{f}{28}\right) + 5.4 & \quad \text{For suburban areas} \\ 4.78\log(f) - 18.33\log_{10}(f) + 44.94 & \quad \text{For rural areas} \end{aligned} \tag{I.1}$$

In the context of WCDMA, the actual losses are obtained by adding this correction factor. Similar to this, the COST model—which is based on typical antenna sites and has a validity range—is applied to the Walfish-Ikegami model.

- Frequency f: 800–2000 MHz
- BS height hbs: 4–50 m
- UE height hms: 1–3 m
- Distance d: 0.02–5 km

I.3.2 Capacity planning:

I.3.2.1 GSM Network Capacity Planning:

When deploying a network, capacity planning is a crucial step since it establishes the quantity and capacities of base stations that are required. Capacity plans are created both in detail later on and for first estimates during the pre-planning phase. Coverage planning determines the number of base stations needed in a given area, while capacity planning determines the number of transceivers needed because it is directly related to the frequency reuse factor[8]. The number of base stations that can be deployed before the frequency can be reused is known as the frequency reuse factor. A frequency reuse example is presented in Figure 1.3. In all the uplink and downlink directions, a GSM 900 system can have a maximum of 125 frequencies. A channel is any of these frequencies. This indicates that 125 channels are accessible in both directions. The C/I ratio serves as the foundation for determining the minimum frequency reuse factor. The signal intensity starts to decline as soon as the C/I ratio drops, which lowers the frequency reuse factor[17]. The height of the antenna at the base station is another thing to consider. An excessively tall antenna will force the signal to travel farther, increasing the likelihood that it will cause interference. The number of base stations (completely utilized in terms of individual capacities) should be sufficient for the required network capacity, and this can be achieved by adjusting the average antenna height. Naturally, as was already mentioned, a significant component in this is the frequency reuse factor[5]. Capacity planning requires three key parameters: frequency consumption, average antenna height, and expected traffic.

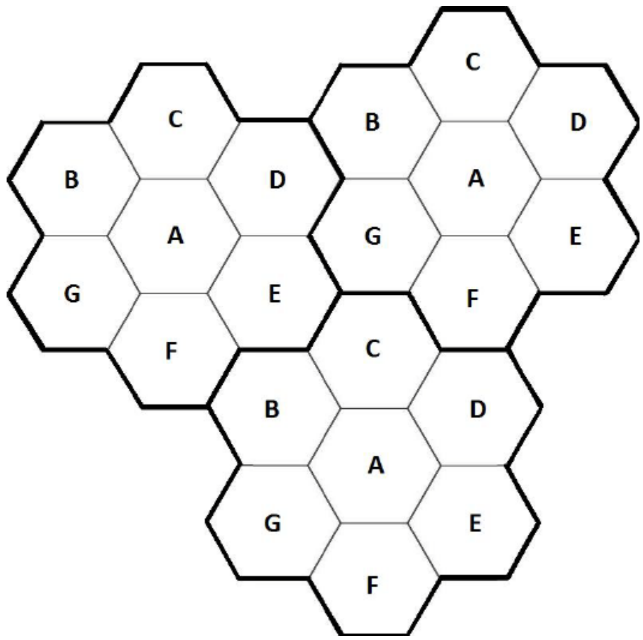


Figure I.3: Example of frequency reuse.

I.3.2.2 Capacity Planning of GPRS EDGE:

1. **GPRS :**

   The two components of GPRS network capacity planning are radio interface capacity planning and GB interface capacity planning. This section addresses the first. Voice, CS data, and PS data are the three types of traffic that flow across the GPRS network. When designing the radio interface's capacity, each of these needs to be considered. PS traffic is never given the same priority as CS traffic[1]. But some slots are reserved for PS traffic only because some PS services are delay-sensitive. The Erlang B tables, blocking, and C/I thresholds are the primary components of the CS traffic calculations, which are identical to those of the GSM radio interface. Assume the scenario depicted in Figure 1.2. Two TRXs are present in one cell. In an ideal world (one in which blocking is absent), 14 voice users could occupy the slots nonstop, resulting in 14 Erl of traffic. Six time slots remain, which might be used for data if there are only eight voice users. However, it should be mentioned that data can still be delivered over the gaps in the air interface since it is not affected by delays. The only data that needs constant time slot availability is delay-sensitive data[4]. There wouldn't be enough space for PS data when an old GSM network was converted to a GPRS network. Capacity problems in such situations could be effectively resolved by increasing the number of TRX and slots in the GPRS area (dedicated+default). Capacity planning in GPRS networks is greatly impacted by Quality of Service (QoS). A higher load would result in a lower call quality. The minimum QoS must be fulfilled for mission-critical applications, which implies that a load increase is only permitted up until the minimum QoS is attained. For a GPRS radio network to provide the appropriate degree of quality of service, frequency planning is therefore crucial[14].

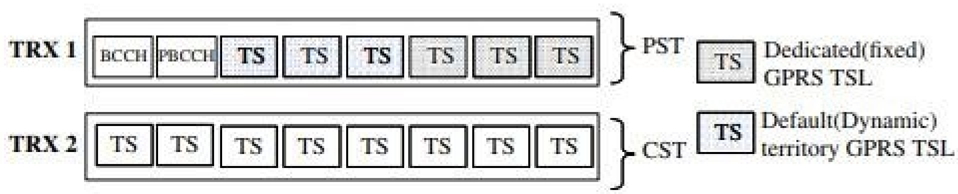


Figure I.4: GPRS timeslot allocation to CS and PS traffic.

2. **EDGE: :**

   By default, PS traffic may use the dedicated territory if CS traffic does not use it (i.e., CS traffic takes precedence over PS traffic for the default territory). The dedicated territory is especially for PS traffic, while the CSW territory is for CS traffic. Depending on load conditions, the amount of slots allotted to each of these territories can be dynamically altered[2].

I.3.2.3 Capacity Planning in WCDMA Networks:

Compared to GSM/EGPRS, capacity planning in WCDMA networks is significantly more difficult. Many factors, including as load, jamming, subscriber speed, traffic behavior, etc., influence coverage calculations.

Uplink: The air interface places restrictions on the WCDMA interference mechanism. As a result, cellular capacity—that is, the volume of traffic that a base station can support—and interference should be calculable by capacity planning. The radius and capacity of the cell are significantly impacted by the level of uplink interference. The overall amount of interference, including thermal noise power, in relation to thermal noise is shown by the interference margin (η).

$$\eta_u = \frac{E_b R N}{W N_0} \cdot (1+i) v_j \tag{I.2}$$

Where:
Eb/N0 = signal energy per bit/noise spectral density.
N = Total number of users/cell.
R = Bit rate. i = other cell-to-cell interference.
W = chip rate. v_j = User Activity Factor j

Downlink: All users share the power transmitted by the BS via a downlink connection[20]. The power communicated by the BS, EU locations, and interference all affect capacity. As a result, the power allocated to the common control channel (CCCH) and the power transmitted by the base station (BS) is required parameters for downlink computations. As a result, interference, EU locations, and the power broadcast by the BS all affect downlink capacity. This means that while each user in the uplink has their own amplifier to broadcast power, downlink computations are more complex than uplink directions. Coverage thus starts to depend on the user base. In DL, the factor (1 α) reduces the interference caused by the cell itself. This is because DL uses synchronized orthogonal pipe codes

$$\begin{aligned} \eta_{DL} &= [(1-\alpha_j)+i] \sum_{i=1}^{N} \text{load}_j \\ \text{load}_j &= \frac{1}{1+\left(\frac{W}{R_j} \Big/ \left(\frac{E_b}{N_0}\right)\right) \cdot \frac{1}{v}} \end{aligned} \tag{I.3}$$

The ITU vehicle subscriber for the macro cell is 0.6, and the ITU pedestrian subscriber for the micro cell is 0.9. Therefore, the orthogonality factor α_j is between 0.4 and 0.9. Because traffic in WCDMA might be asymmetric in both uplink and downlink directions, there is a possibility that both directions' loads will differ. But the DL load is more than the UL load. Additionally, there are differences in link performance in both directions (the EU has a higher noise figure than the BS)[13]. Only in the DL direction are soft transfer heads present. Each service's load factor needs to be computed independently. The overall cost then represents the sum of the various services provided in the cell area.

Flexible capacity works on the basis that a cell can be charged more when the surrounding cells discharge. The more users that can be admitted before the load (interference or transmitted power) of a cell reaches the load target, the less interference there is from all neighboring cells[12]. If the average load is low, there is additional capacity available in neighboring cells because this ability can be borrowed from neighboring cells. Due to a larger relative change for higher bit rates, the soft capability has a greater impact on real-time users at high bit rates. The soft capacity can be estimated based on the total interference to the BTS. Total interference includes interference from own cells as well as other cells. After applying the basic formula of Erlang B to this bigger pool of channels, the capacity obtained from Erlang is divided by 1 + i (the increase in power is also taken into account in UL) and distributed equally across surrounding (interfering) cells. From the expected load, the number of channels available in the resource pool (an average condition) can be calculated:

$$N_{\mathrm{UL}} = \left(\frac{\eta_{\mathrm{UL}}}{1+i}\right)\left(1+\frac{\left(\frac{W}{R}\right)}{\left(\frac{E_b}{N_0}\right)}\cdot\left(\frac{1}{v}\right)\right) \tag{I.4}$$

The soft blocking capacity (in Erlang) for RT services can be calculated using the Erlang B table and the equation:

$$\text{Soft capacity/cell} = \frac{\text{Erlang B}[N(1+i)\,\text{blocking \%}\,]}{(1+i)}\,[\text{Erl}] \tag{I.5}$$

The soft capacity of the DL is calculated using a similar method:

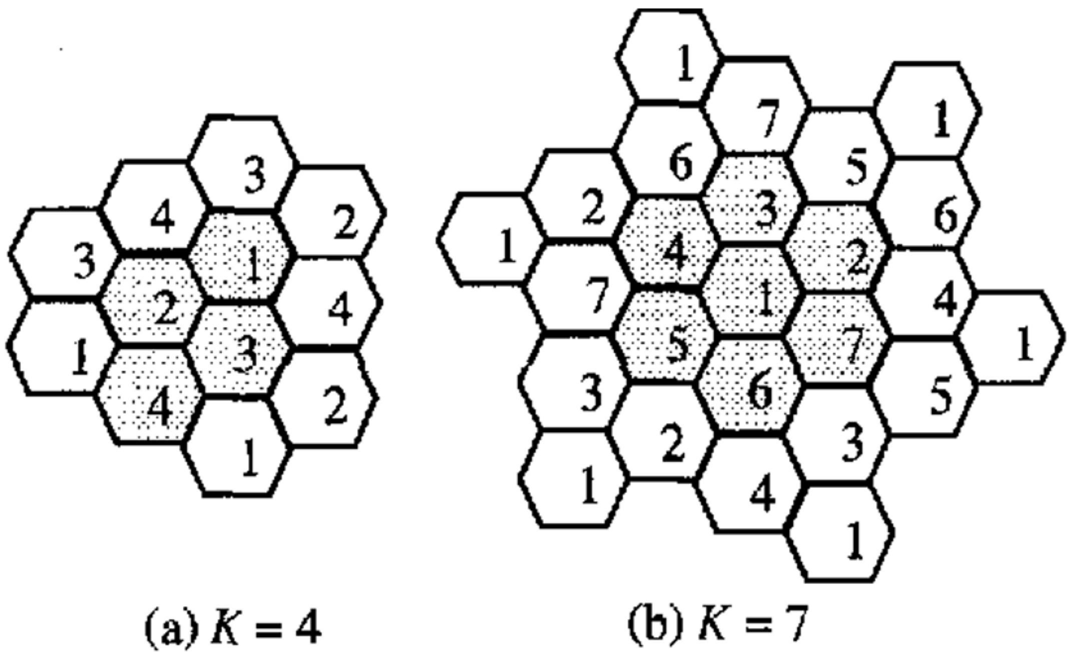


Figure I.5: Reuse schemes for 4- and 7-cell frequencies.

I.3.3 Frequency planning;

Frequency planning is actually an implementation of capacity planning. Frequency planning together with capacity planning tries to maximize the information flow (voice or data) over the radio interface and simultaneously to maximize the efficiency of the radio network infrastructure[10]. In cellular radio system planning the same frequencies is reused as often as possible in order to maximize capacity and thus minimize the radio network investments. The target is to have the maximum number of transceivers (a transmitter and receiver pair) at each base station without reducing radio quality; it has already been explained that frequency planning (together with capacity planning) begins with the specification of the required frequency channels (transceivers) at each base station. This work is related to the frequency reuse factor and was covered in detail in the capacity planning discussion

I.3.3.1 Frequency hopping:

Frequency hopping improves C/I and frequency reuse factor and thus increases the capacity of the radio network. The final improvement in frequency hopping capacity depends on the number of channels and frequency bandwidth[18]. The implementation of frequency hopping also has a significant effect on frequency planning, which is also highly dependent on the frequency hopping scheme. Baseband and synthesized frequency hopping schemes are generally used, for example, in GSM mobile networks and the limitation or sufficiency of frequency bands, as well as system limitations, have a significant impact on the choice of these frequency hopping systems for different purposes.

Figure I.6: frequency hopping in GSM.

I.4 Planning in LTE and 5G:

I.4.1 Coverage Planning in LTE(4G):

Coverage planning involves evaluating the budgets of DL and UL radio links. The maximum path loss is calculated based on the service rate defined by the airframe edge user who the SINR needed level to the receiver[16]. The minimum of maximum path losses in UL and DL directions is converted to a cell radius, using a propagation model appropriate to the deployment area. The radio link budget is the most important element of the coverage planning exercise[9]. The link budget includes key parameters such as antenna height, antenna gains, path loss, transmitted power, receiver sensitivity. The UL and DL that gives to provide a specific throughput to the cell edge user the calculation of the LTE link budget is similar to that of other cellular technologies. The maximum permissible attenuation of the radio wave passing through the air interface excludes congestion data.

I.4.2 Capacity Planning in LTE(4G):

Capacity sizing allows us to find the maximum capacity Supported by a cell. Its purpose is to determine the number of sites needed User traffic for a given area. The capacity is limited by the number of eNodeBs installed in the network, it depends on several factors such as the type of zone, the service, the number of subscribers[6]. To calculate the capacity in downlink and uplink, the following parameters must be used: LTE can provide very high speeds for uplink and downlink, as with any broadband communication system, due to the increased spectral efficiency and available bandwidth[3]. The spectral efficiency depends on the type of MIMO antenna, i.e. desired bit rate and bandwidth. It is represented by the following formula:

$$\eta_{BW} = \frac{\text{Débit}_{Req}}{B_w} \tag{I.6}$$

Number of subscribers supported by a cell:

$$\begin{aligned} N^{U_P}_{\text{subscriber/cell}} &= C_{\text{cell}}/\text{Throughput}^{U_P}_{\text{BH}} \\ N^{D_i}_{\text{subscriber/cell}} &= C_{\text{cell}}/\text{Throughput}^{D_i}_{\text{BH}} \end{aligned} \tag{I.7}$$

Cell: cell capacity
N subscriber/Cell UP, and N subscriber/Cell DL: Number of subscribers per cell for uplink and downlink.
Throughput BH, DL Throughput: the flow at the peak time of the load in the upward and downward direction.
Number of eNodeBs required: In this part we will calculate the number of subscribers per site according to the number of subscribers per cell by taking three cells per site in both links (uplink and down).

$$\begin{aligned} N^{U_P}_{\text{subscriber/Site}} &= N^{U_P}_{\text{subscriber/cell}} \times 3 \\ N^{D_i}_{\text{subscriber/Site}} &= N^{D_i}_{\text{subscriber/cell}} \times 3 \end{aligned} \tag{I.8}$$

For the calculation of the total number of sites:

$$\begin{aligned} N^{U_P}_{\text{subscriber/Site}} &= \min < N^{U_P}_{\text{subscriber/Site}}, N^{D_i}_{\text{subscriber/Site}} > \\ N^{eNodeB}_{\text{Capacity}} &= N_{\text{Total subscriber}}/N_{\text{subscriber/site}} \end{aligned} \tag{I.9}$$

Subscriber NTotal: is the total number of subscribers in the deployment area.
eNodeB NCapacity: is the number of eNodeB required to satisfy the capacity constraint.

Final number of eNodeB required

We will determine the final number of eNodeBs, but for this we must consider
The minimum number of eNodeB required to establish the requested coverage is marked as Ncouverture
The minimum number of eNodeB required to meet capacity requirements
NCapcity of eNodeB. In this case, ask for the number of sites that meet the coverage constraint The capacity is given by the following expression:

$$N^{\text{eNode}} = \min < N^{\text{eNodeB}}_{\text{Capacity}}, N_{\text{coverage}} > \tag{I.10}$$

I.4.3 Planning in 5G:

The 5G radio networks have introduced major changes in terms of service requirements and bandwidth allocation compared to cellular networks to date and hence, they have made the fundamental radio planning problem even more complex. The 5G networks introduce really different elements from the previous generations, mainly due to virtualization and service-based architecture. Among other things, they are designed for considerably higher data rates, very large numbers of connected Internet of Things (IoT) devices and low latency while providing adaptive means for network scalability and flexibility. The number of the 5G radio frequency bands is targeted to be higher than in previous generations of cellular networks, more specifically multiple mmWave bands. Also, massive Multiple Input Multiple Output (MIMO) and hybrid beam forming are core techniques to achieve the targeted high data rates and the large number of devices

I.5 Conclusion

In this first chapter, I have presented general radio network planning processes, the basic notions concerning radio network planning for different generations (GSM, GPRS, LTE). Network planning is one of the most important tasks of the network operator, which determines, significantly, the quality of service offered to the users. After planning, optimization must be taken into consideration. This task will be the subject of the next chapter.

Chapter II

Mobile network optimization

II.1 Introduction:

Radio optimization starts after planning and is a crucial step in making telecommunication networks work better. Radio optimization helps fix different problems that come up after a network is started. It helps to manage, check, and make the network work better. It starts after the plan is made. A cell phone network goes over a big area and can give its users good communication. In order to make sure the network works properly, some settings need to be adjusted all the time for the radio connection. In this chapter, we will talk about making things better, how we do it, and what's important in the different kinds of mobile networks.

II.2 Objective of radio optimization

Radio network optimization is performed to improve the performance of the network with existing resources. The goal is to better utilize existing network resources, to solve existing and potential problems and to identify possible solutions for future planning. Through Radio Network Optimization, the service quality and resources usage of the network are greatly improved to achieve a balance between coverage, capacity and quality[15]. In general, the following steps are followed during the Radio Network Optimization process:

- Data Collection and Verification
- Data Analysis

- Parameter and Hardware Adjustment
- Parameter and Hardware Adjustment

Due to the mobility of subscribers and the complexity of radio propagation, most of network problems are caused by increasing subscribers and the changing radio environment. Radio Network Optimization is a continuous process that is required as the network evolves.

II.3 Basics of radio network optimization

Radio Network Optimization is a important step in planning the network. The main aim of this process is to check, confirm, and make the radio network work better. Because a lot of people use the cellular network, there are many things that need to be checked and fixed regularly to make sure the network works well for everyone. Furthermore, the network is always growing because more people are signing up as subscribers, there is more internet traffic, and new retail centers are being opened, which means more demand for internet capacity in those areas. This means that the network should be checked regularly to make it work better and earn more money. Planning for radio networks involves three main areas: coverage, capacity, and frequency. They move on to do other activities like choosing a place, making a plan, and so on. We focus on the same things when we try to make something better: how much it covers, how much it can hold, and how often it happens. The only change now is that we have decided where to put the sites and antennas, but the people using the service can still move around as much as they want, and the service is getting bigger.

It's getting harder to optimize the radio network because the time between the launch and optimization is getting longer. After the radio network is set up, it is checked to see how well it works. This is done by watching the network and comparing it to the key performance metrics established. Figure 2.1 shows how optimization can be thought of as a distinct process or as part of the network planning process. Power control, quality, handovers, subscriber traffic, and resource availability (and access) measures are all areas where radio network optimization is focused.

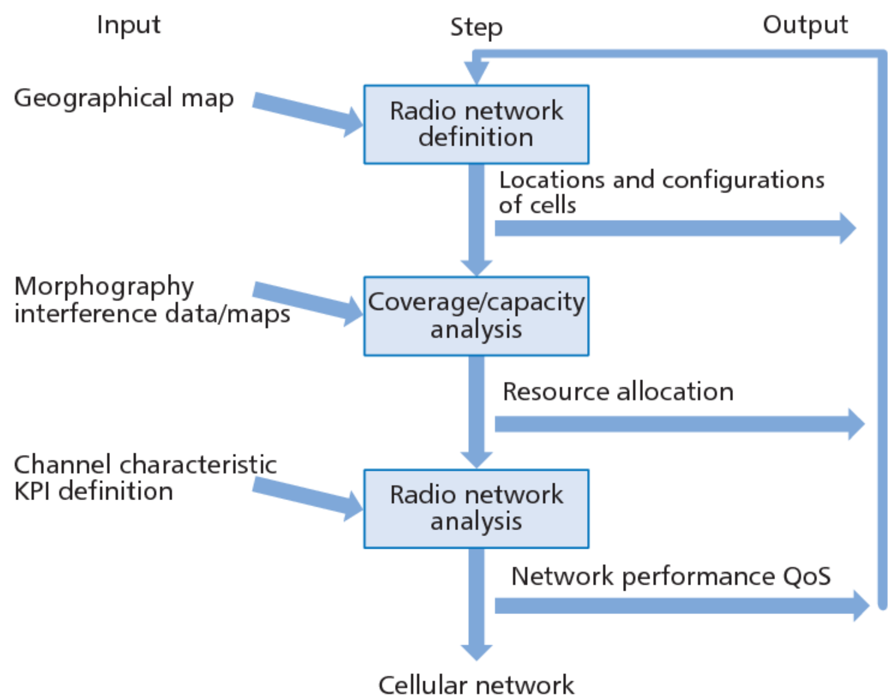


Figure II.1: Network Planning Process.

II.4 Radio Network Optimization Process

Optimizing the radio network is an important part of planning the network. This process is meant to check and make better the performance of the radio network. It starts at the end of planning the radio network, when the parameters are being set. The cellular network is a big system that can handle a lot of people at once. There are many things that affect how well it works, and they need to be watched and fixed to keep the network working well. Also, the network is still growing. ie. by always increasing the number of subscribers, the increase in traffic, the creation of new shopping centers means that the capacity needs in these "hot spots" increase, etc. This means that the optimization process should be conducted in the network at regular intervals, which increases the efficiency of the network and generates revenue from the network.

In planning, engineers focus on three main things: making sure there is enough coverage, enough space, and planning how often things happen. In the optimization process, we focus on the same points. The difference is that we already chose the sites and the antenna locations are fixed. However, the number of subscribers keeps increasing and they remain as mobile as before.

The main focus of radio network optimization is on areas such as power contrai, quality, handovers, subscriber traffic, and resource availability (and access) measurements.

The optimization process uses two types of measurements: statistics from the network and measurements from drive tests. Based on these measurements, an engineer can find and study possible problems. Customer complaints can help make the network work better by adjusting some settings.

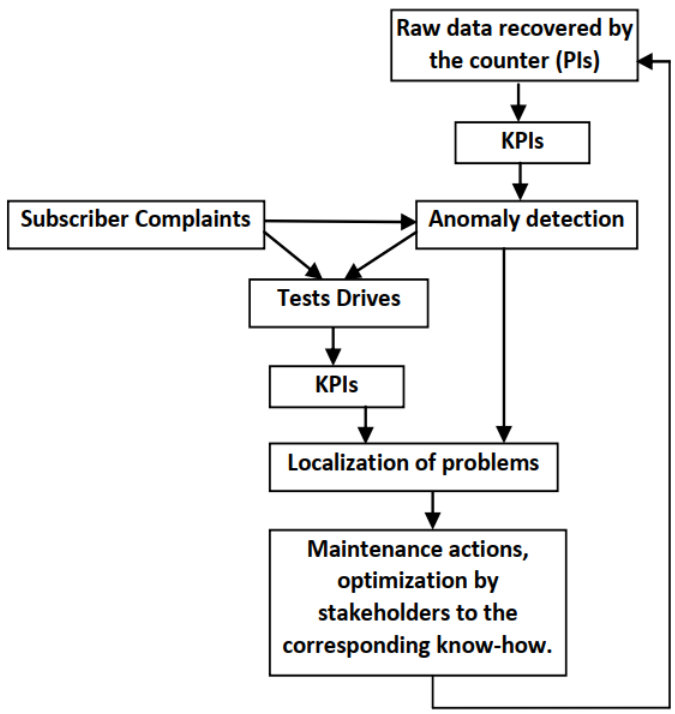


Fig. 2. General diagram of the optimization process.

Figure II.2: General diagram of the optimization process.

II.5 Key Performance Indicators

Key Performance Indicators (KPI) are a measure of successful network performance and its Quality. With growing customer base and continuous addition of capacity and coverage sites, operators need to continuously monitor the KPIs of their network to assess service quality.

Figure II.3: Importance of KPIs.

II.5.1 Indicators KPI

In order to optimize a radio network, key performance indicators must be determined.

- Accessibility
- Retainability
- Mobility
- Service integrity
- Availability
- Utilization
- Traffic

II.5.1.1 Accessibility

The accessibility performance indicator is defined as the ability of mobile stations to get access to the network (requested service) in a given operation conditions. For GSM, lt can be found as a percentage of how a user can/cannot access to the network:

- SDCCH congestion/blocking
- SDCCH drop

- Mobility
- TCH blocking/congestion
- TCH assignment success rate (eTASR)

These KPls are used to measure the probability whether services requested by a user can be accessed within specified tolerance in the given conditions.

- **RRC Setup Success Rate (service)**
  This KPI is calculated based on the counters measured at eNodeB when the eNodeB receives an RCC connection Request from the UE, as shown in Figure 2.4. To illustrate the KPI calculation procedures, we briefly discuss how the related counters (number of RCC Connection setup attempts (service) and number of successful RCC setup (service)) are collected. The number of RCC connection attempts is collected by the eNodeB at measurement point A and the number of successful RCC connection is counted at measurement point C.

  The RRCSSR evaluates service-related causes in an involved cell or cluster and is based on the meters measured at eNB upon receipt of the RRC connection EU request as indicated in the relationship below.

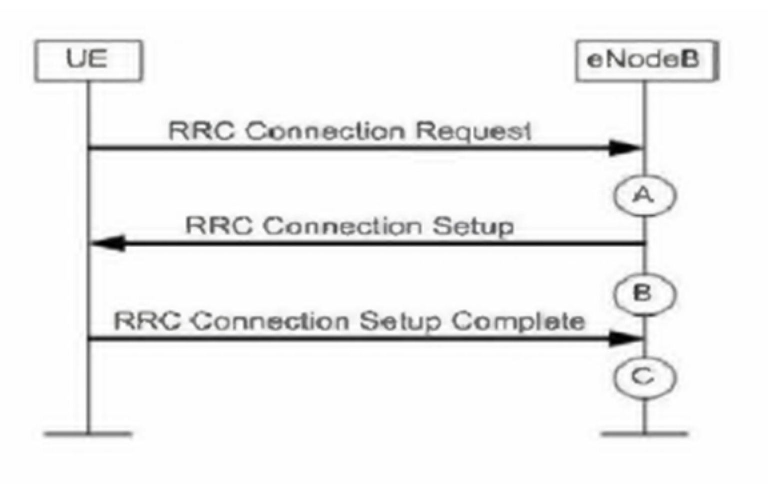


Figure II.4: Measurement point for RRC connection setup.

The RRC setup success rate (service) KPI is defined as the number of RRC connection setup successful times over the number of RRC connection attempts, which can be calculated based on the following formula:

$$\text{Service\_CDR} = \frac{\text{ERABAbnormalRelease}}{\text{ERABRelease}} \cdot 100\% \tag{II.1}$$

- **RRC Setup Success Rate (signaling)**

This KPI evaluates the RRC setup success rate of the signaling-related cause (mo-signaling) in a given cell or cluster.

The present KPI is defined as the RCC connection setup attempts (signaling) and the RCC connection setup success rate (only when the "establishment-Cause" is set to mo-signaling) in a cell or cluster. lts formula is given by

$$\text{RRCS\_SR}_{(\text{other})} = \frac{\text{RRCCnnectionSucces}_{(\text{other})}}{\text{RRCConnectionAttempt}_{(\text{other})}} \cdot 100\% \tag{II.2}$$

- **ERAB Setup Success Rate (VolP)**

The counters related to this KPI are measured when the eNodeB receives an ERAB setup Request message or an initial Context setup request from the MME, as shown in Figure 2.5

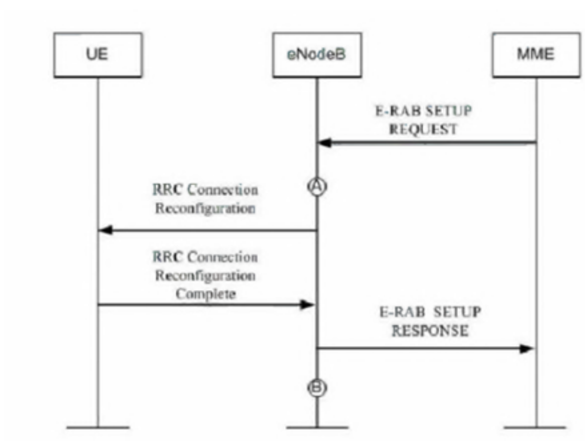


Figure II.5: Measurement point for MME-initiated ERAB setup.

The ERAB is part of the evolved Packet Service (EPS) bearer. An ERAB is one or more Service Data Flows between UE and EPC. The ERAB identity remains unique for the UE even if the UE -associated logical S1-connection (S1 Bearer) is released during periods of user inactivity. The ERAB consists of both ERAB radio bearer (between eNodeB and UE, same as the radio bearer defined in the EPS bearer) and corresponding S1 bearer (between eNodeB and MME).

There are two scenarios can be shown in Figure 2.5and 2.6. MME-initiated ERAB setup (scenario A) and UE-triggered ERAB setup (scenario B). Scenario B is triggered by the radio bearer setup. Initial context setup request messages are exchanged between eNodeB and MME. If the ERAB setup Request message or initial Context Setup request message requires multiple ERAB setups at the same time, specific counters are incremented for each ERAB.

The ERAB setup success rate (VolP) KPI can be calculated as follow:

$$\text{VOIPERABS\_SR} = \frac{\text{VoIPERABSetupSucces}}{\text{VoIPERABSetupAttempt}} \cdot 100\% \qquad \text{(II.3)}$$

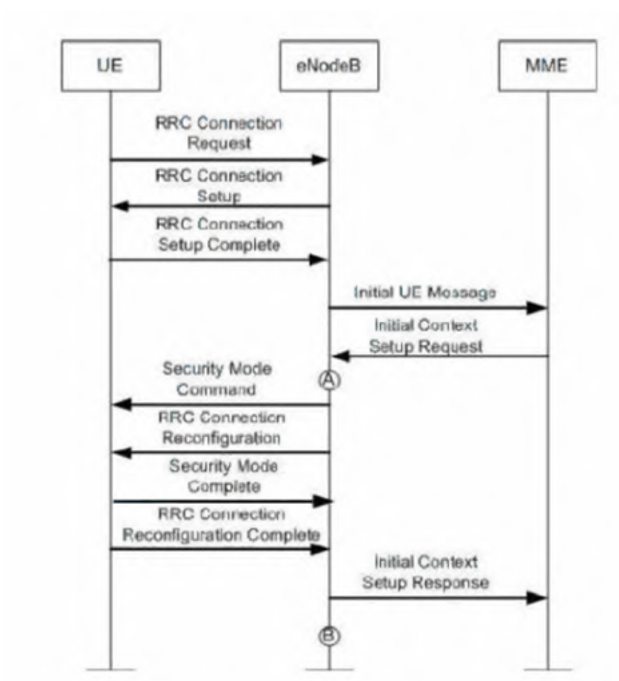


Figure II.6: Measurement point for UE-triggred ERAB setup.

- **ERAB Setup Success Rate (All)**

This KPI can be used to evaluate the ERAB setup success rate of all services including the VolP service in a cell or a cluster. The ERAB setup success rate

(All) KPI can be calculated as follow:

$$\text{ERABS\_SR} = \frac{\text{ERABSetupSuccess}}{\text{ERABSetupAttempt}} \cdot 100\% \qquad \text{(II.4)}$$

- **Call Setup Success Rate**

  This KPI can be used to evaluate the call setup success rate of all services including the VolP service in a cell or cluster. This KPI is calculated based on the KPI of RRC setup success rate (service) and the KPI of ERAB setup success rate (All). The Cali setup success rate is calculated based on multiplying the KPI of RRC Setup success rate (service) and the KPI of ERAB setup success rate (All). The Call Setup Success Rate cabe defined as:

$$\text{CSSR} = \frac{\text{RRCConnectionSuccess}_{\text{service}}}{\text{RRCConnectionAttempt}_{\text{service}}} \cdot \frac{\text{EFABSetuoSuccess}}{\text{ERABSetupAttempt}} \cdot 100\% \qquad \text{(II.5)}$$

II.5.1.2 Retainability KPI

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

- **Call Drop Rate (VolP)**

  This KPI can be used to evaluate the call drop rate of the VolP services in a cell or cluster. The call drop rate is calculated by monitoring the VolP ERAB abnormal release rate. Each ERAB is associated with the QoS information. The voice service can be distinguished by the specific QCl=l. ERAB includes both ERAB radio bearer and the corresponding S1 Bearer. Any abnormal release on either bearer causes call drop and therefore is counted in call drop rate. The abnormal release is identified by the CauselE. The call drop rate (CDR) is defined as Abnormal ERAB release/AII released ERAB.

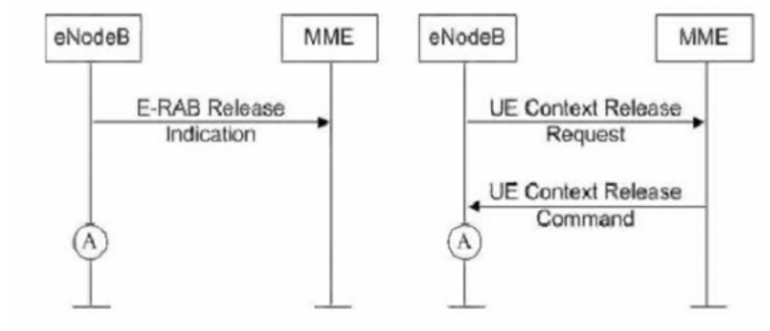


Figure II.7: Abnormal ERAB release.

As shown in Figure 2.7, the abnormal ERAB release counter is incremented when the eNodeB sends an ERAB release Indication to the MME or receives an UE Context Release Command message from the MME and the release causes are not Normal Release, User lnactivity, Partial Handover, or Handover triggered. If the message contains several ERAB ID IEs (in the ERAB to be release List IE), the counter will be incremented for each individual ERAB. For the eNodeB initiated abnormal ERAB release, the eNodeB knows whether it is a normal or abnormal ERAB release. The call Drop Rate (VolP) isdefined as :

$$\text{VoIP\_CDR} = \frac{\text{VoIPERABAbnormal Release}}{\text{VOIPERAB Release}} \cdot 100\% \tag{II.6}$$

- **Service Drop Rate (All)**

  This KPI can be used to evaluate the call drop rate of all services in a cell or cluster, including VolP service. The service Drop Rate (All) is defined as:

$$\text{Service\_CDR} = \frac{\text{ERABAbnormal Release}}{\text{FRAB Release}} \cdot 100\% \tag{II.7}$$

II.5.1.3 Mobility KPI

Mobility KPls are used to evaluate the performance of E-UTRAN mobility, which is critical to the customer experience. Many categories of Mobility KPls are defined based on the following handover types: intra-frequency, inter-frequency, and inter-Radio Access Technology (RAT).

- **Intra-frequency transfer success rate**

  KPI is used to evaluate the success rate of HO outputs at the cell or cluster level

$$\text{IntraHOOutSR} = \frac{\text{IntraFHOOutSuccess}}{\text{IntraHOOutAttempt}} \cdot 100\% \qquad (II.8)$$

- **Inter-frequency transfer success rate**

  This KPI is used to evaluate the transfer success rate at the cell or cluster level

$$\text{IntrerHOOutSR} = \frac{\text{IntrerFHOOutSuccess}}{\text{IntrerHOOutAttempt}} \cdot 100\% \qquad (II.9)$$

- **Inter-RAT Transfer Success Rate (LTE to WCDMA)**

  The KPI is used to evaluate the success of the HO rate of LTE to WCDMA in a cluster

$$\text{IRATHO\_L2W\_SR}_{(\text{out})} = \frac{\text{IRATHO\_L2W\_SuccessOut}}{\text{IRTHO\_L2W\_Attempt}} \times 100\% \qquad (II.10)$$

- **Inter-RAT transfer success rate (LTE to GERAN)**

  The KPI is used to evaluate HO success rate from LTE to GERAN

$$\text{IRATHO\_L2G\_SR}_{(\text{out})} = \frac{\text{IRATHO\_L2G\_SuccessOut}}{\text{IRTHO\_L2G\_Attempt}} \times 100\% \qquad (II.11)$$

II.5.1.4 Service integrity KPI

The service integrity KPls indicate the E-UTRAN impacts on the service quality provided to the end-user. The service integrity KPls can be calculated per cell or per cluster. The KPls at the cluster level can be calculated by aggregating all the cell counters.

- **Service Downlink Average Throughput**

  This KPI consists of nine sub-KPIs that are mapped to nine QCIs. These sub-KPIs can be used to evaluate the busy-hour downlink (DL) throughput of a service with a specific QCI per user in each cell. It reflects the end-user experience.

  The service downlink average throughput is defined by the following formulas. There are nine different sub-KPIs for each QCI. The formulas for each KPI are mapped to corresponding counters.

- DLAverage Throughput_QCI_1
- DLAverage Throughput_QCI_2
- DLAverage Throughput_QCI_3
- DLAverage Throughput_QCI_4
- DLAverage Throughput_QCI_5
- DLAverage Throughput_QCI_6
- DLAverage Throughput_QCI_7
- DLAverage Throughput_QCI_8
- DLAverage Throughput_QCI_9

- **Service Uplink Average Throughput**

  This KPI consists of nine sub-KPIs that are mapped to nine QCIs. These sub-KPIs can be used to evaluate the busy hour uplink (UL) throughput of a service (with a specific QCI) per user in each cell. It reflects the end-user experience.

  The service uplink average throughput is defined by the following formulas. There are nine sub-KPIs for each QCI. The formula for each KPI is mapped to its corresponding counter.

  - ULAverage Throughput_QCI_1
  - ULAverage Throughput_QCI_2
  - ULAverage Throughput_QCI_3
  - ULAverage Throughput_QCI_4
  - ULAverage Throughput_QCI_5
  - ULAverage Throughput_QCI_6
  - ULAverage Throughput_QCI_7
  - ULAverage Throughput_QCI_8
  - ULAverage Throughput_QCI_9

- **Cell Downlink Average Throughput**

This KPI evaluates the cell downlink average throughput when there is data transferring at downlink.

$$\text{CellDLAveThp} = \frac{\text{CellDLTraffic Volume}}{\text{CellDLTransfer Time}} \text{ in Kbit/s} \tag{II.12}$$

- **Cell Uplink Average Throughput**

  This KPI evaluates the cell uplink average throughput when there is data transferring at uplink.

$$\text{CellULAveThp} = \frac{\text{CellULTraffic Volume}}{\text{CellULTransfer Time}} \text{ in Kbit/s} \tag{II.13}$$

- **Cell Downlink Maximum Throughput**

  This KPI evaluates the cell downlink maximum throughput when there is data transferring at downlink.

$$\text{CellDLMaxThp} = \frac{\text{CellDLTraffic Volume For Each ls(bit)}}{\text{1000 (ms)}} \text{ in kbit/s} \tag{II.14}$$

- **Cell Uplink Maximum Throughput**

  This KPI evaluates the cell uplink maximum throughput when there is data transferring at uplink.

$$\text{CellULMaxThp} = \frac{\text{CellULTraffic Volume For Each ls(bit)}}{\text{1000 (ms)}} \text{ in kbit/s} \tag{II.15}$$

II.5.1.5 Availability KPI

Availability is the percentage of time that a cell is available. A cell is available when the eNodeB can provide EPS bearer services. Availability can be measured at the cell level for a variety of hardware/software faults.

- **Radio Network Unavailability Rate**

  This KPI is calculated based on the time of all cell service unavailability on the radio network (cluster)

$$\text{RAN\_Unavail\_Rate} = \frac{\sum_{\text{cluster}} \text{CellUnavailTime}}{\text{TheTotalNumberOfCellsInCluster} \times \text{SP} \times 60} \cdot 100\% \tag{II.16}$$

II.5.1.6 Utilization KPI

Utilization KPIs are used to evaluate the capability to meet the traffic demand and other characteristics in specific internai conditions.

- **Resource Black Utilizing Rate**

  This KPI consists of two sub-KPlsThese two sub-KPls can be used to evaluate the busy-hour DL and UL RB utilizing rate in each cell or cluster. The UL and DL RB utilizing rate KPls are defined by the following formulas. These two KPls are calculated by dividing the total number of used RBs by the number of available RBs.

$$\text{RB\_UR}_{(\text{DL})} = \frac{\text{RB\_Used}_{(\text{DL})}}{\text{RB\_Available}_{(\text{DL})}} \cdot 100\% \tag{II.17}$$

$$\text{RB\_UR}_{(\text{UL})} = \frac{\text{RB\_Used}_{(\text{UL})}}{\text{RB\_Available}_{(\text{UL})}} \cdot 100\% \tag{II.18}$$

II.5.1.7 Traffic KPI

KPIs based on several types of traffic: radio bearer, downstream and upstream. They are primarily used to measure traffic at the LTE Access Network (RAN) level. The fundamental KPIs used for traffic:

- Radio Bearers
- Average of Traffic User
- Average of Downlink /Uplink traffic volume
- Maximum User Number

II.5.2 Drive test

Drive test is a step as important as the study of traffic is the drive test, it is an operation that aims to measure the level and quality of the signals broadcast by the BTS.

The drive test is done by a car using three specific mobiles in different modes, three external antennas placed on the roof of the car, a Global Positioning System (GPS) to localize the position of quality degradation precisely, and also a special software TEMS Investigation installed on a laptop computer for the acquisition, recording and processing of recovered measurements. In the drive test operation, each mobile can be in one of three modes:

- **Idle mode:** established during the drive test process, the Mobile Station (MS) is on, but no calls were made during this period.
- **Dedicated mode / long call:**make continuous calls during the drive test process, and the call will not end until the end of the route.
- **Dedicated mode / short call:**make short calls during the drive test process.

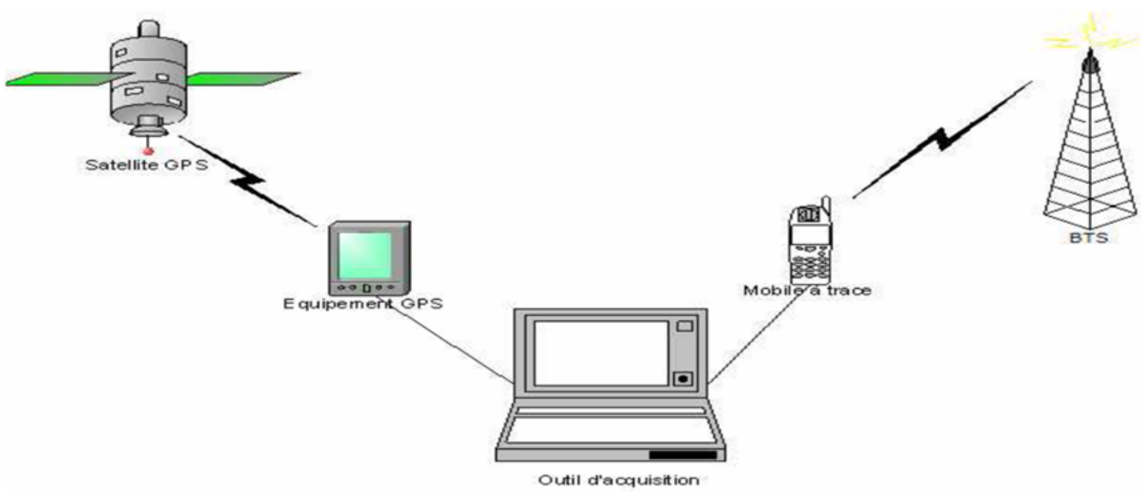


Figure II.8: Drive-Test measurement chain.

Objective of drive test is to monitor and perform network communication. The objectives of drive test are classified as network bencmarking, optimization & troubleshooting, service quality monitoring. Drive test is the activity data collection mobile telecommunications system performance. Drive test data results are used for materials analysis and optimization of telecommunications networks.

II.6 Conclusion

In this chapter, we have discussed the optimization process, we believe that radio optimization is a crucial step in improving radio networks. It starts after the planning phase and is the most important and challenging part. It involves monitoring, verifying, and improving the performance of the radio network.

Chapter III

Drive test Analysis of mobile network using TEMS Discovery

III.1 Introduction

Drive testing is a process for measuring and evaluating the coverage, capacity and quality of service (QoS) of a mobile radio network, in this chapter I present the drive test operation for a mobile network.

III.2 Drive test

Drive testing is a process for measuring and evaluating the coverage, capacity and quality of service (QoS) of a mobile radio network. The technique involves using a motor vehicle containing a mobile radio measuring device, which can detect and record a wide variety of physical and virtual parameters of mobile cellular service in a given geographic area.

By measuring what a wireless network subscriber would experience in a specific area, wireless carriers can make changes to their networks that provide better coverage and service to their customers. These tests require a mobile vehicle equipped with drive test devices. This equipment is generally highly specialized electronic devices that interface with telephonesMobiles. This ensures measurements are realistic and comparable to the user's actual experience.

During the measurement campaigns, the technician tests:

- The establishment of the call (absence of failure).
- Maintaining communication for a certain period of time (absence of cut).
- The quality of communication.

III.2.1 Data collected during a Drive Test:

The drive test equipment generally collects data relating to the network

Same, services running over the network such as voice or data services and GPS information to provide location recording. The data set collected during training test field measurements may include information such as:

- Signal intensity (RxLEV)
- Signal quality (RxQual)
- Interference (C/I)
- Dropped calls
- Blocked calls
- Call statistics
- QoS information
- Neighbours cell information
- GPS coordinates location
- Voice and DATA network performance
- Handover information

III.2.2 Types of Drive Test

- **Network Benchmarking:**

  Sophisticated multi-channel tools are used to measure several network technologies and service types simultaneously to very high accuracy and collect accurate competitive data on the true level of their own and their competitor's technical performance and quality levels.

- **Optimization and Troubleshooting:**

  Optimization and troubleshooting information is more typically used to aid in finding specific problems during the rollout phases of new networks or to observe specific problems reported by consumers during the operational phase of the network lifecycle.

- **Service Quality Monitoring:**

  Service quality monitoring typically involves making test calls across the network to a fixed test unit to assess the relative quality of various services using mean opinion score (MOS).Service quality monitoring is typically carried out in an automated fashion.

III.2.3 Equipment used in Drive test:

The drive test will be carried out with mobiles: mobiles by operator to test voice quality (CS) and data network quality (PS).

- A laptop computer or other similar device.
- Data collecting software installed in the laptop.
- A security Key -Dongle- common to these types of software.
- One mobile phone for each mobile network that is being tested.
- One GPS antenna.

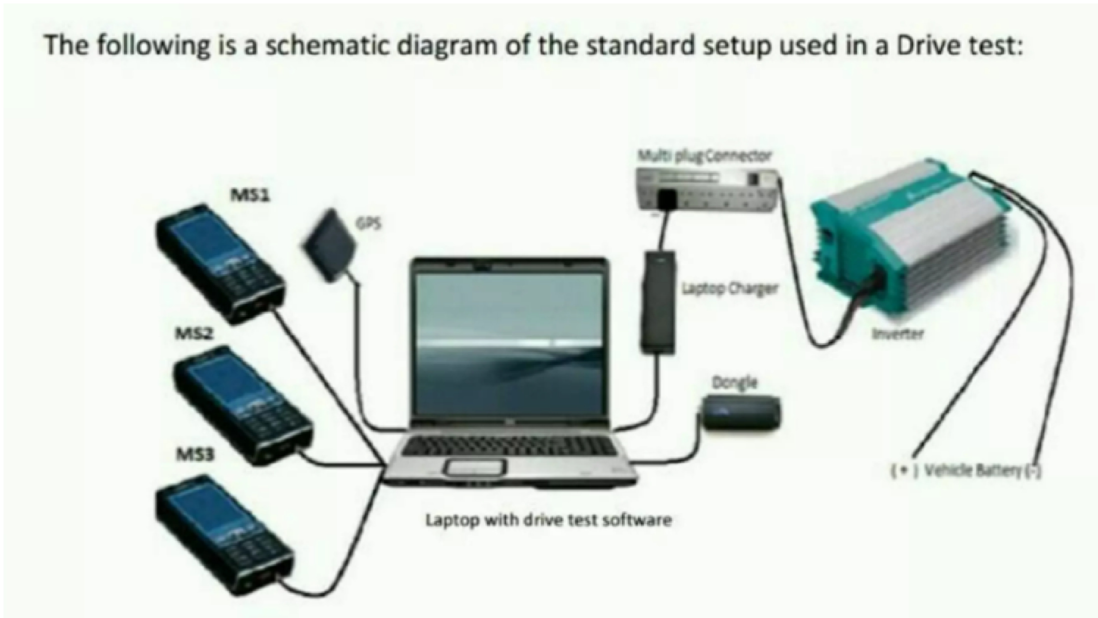


Figure III.1: Drive Test Measurement Chain.

III.2.4 Why Drive Test?

- To check deployement of new network sites in order to meet coverage, capacity and quality requirement.
- Optimization of the network.
- Benchmarking of performance.
- Trouble shooting.
- To verify the performance after an upgrade or reconfiguration of the network.

III.3 Radio engineering rules for a drive tester

A high level block diagram of the steps to be followed on thisDrive Test Process is shown in Figure 3.2:

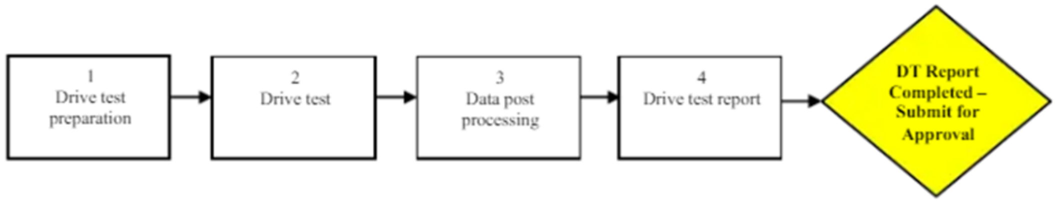


Figure III.2: Test Process – Steps Overview

The steps defined for this process are described below:

- Drive test preparation
  - Prepare the test equipment (hardware and software) for the measurements.
- Drive test
  - Actual drive test.
- Data post processing
  - Post processing activities (logs post-processing, compile, filter, export to Mapinfotables, etc).
- Drive test report
  - Drive Test Report production for the site.

The steps for the completion of each phase will be described in the sections below:

III.3.1 Drive test preparation

Some preparation activities must be initially performed in order to set up the testingequipment. This step will prepare the test equipment and set the software and hardwaredetails for the measurements. The DT check list must be completed during this DT stageand delivered with the drive test report

- **Expected results:**

  The measurement system is set and all test cases are set/

- **Procedure:**

  The drive test engineer shall use a map of the areato be driven with a “marked” route. He shall then make sure that all equipment are ready.

- **Deliverables:**

  To consider this activity completed the following deliverables must be produced:

  - Ist of constrains related to this activity (if any).
  - The DT check list must be completed.

III.3.2 Drive test

This step will perform the actual drive test defined for the site under test. Each drive test must be clearly documented. Additionally,so that each drive test data set collected can be correlated with the OMC statistics in order to produceKPI snapshots.

- **Expected results:**
  - The drive test has been completed as planned
  - Any issues have been documented and reported
- **Procedure:**
  - All test calls should be terminated to a test number. Test number should be of Warid.
  - The drive testing scripts should be configured to provide the following test sequences:
    1. **MS1:**configured to run on **dedicated mode** one continuous test call (Short callsof duration of 120 seconds. Establish the short calls as per the DT route; mean DTengineer will establish the new short call after every 120 seconds). If the call isdropped during 120 seconds the DT engineer should re-establish a new callimmediately.
    2. **MS2:**configured to run on **idle mode** throughout the drive test.
       * Each drive test should be clearly documented (duration, major events, issues etc).

III.3.3 Data post processing

Drive Test Types & Acceptance Details:

- Sites with Urban Objective:

Radius of area to collect data for acceptance procedure: 1 km

- Sites with Rural Objective:

Radius of area to collect data for acceptance procedure: 4 km

- Sites with Highway Objective:

Linear Area to collect data for acceptance procedure: 7 km on eachDirection of the road of the target (highway).
Note: The radius of area depends upon the height of the Antenna. As the heightincrease the radius area also increase.

- **Sites with Urban Objective:**
  RX Level Threshold:85% of the samples shall have greater and equal to -75dbm.
  RxQual Threshold:80 % of the values shall be between 0-4.
  where samples of value 4 shall be less than and equal to 20%.
  Values 6 and 7 shall be _ 10% of the total samples.
  C/I Threshold:90% of the samples less are in between 12 to 30.

- **Sites with Rural Objective:**
  RX Level Threshold:70% of the samples shall have greater and equal to -75dbm.
  RxQual Threshold:80% of the values shall be between 0-4.
  where samples of value 4 shall be less than and equal to 20%.
  Values 6 and 7 shall be _ 10% of the total samples.
  C/I Threshold:90% of the samples less are in between 12 to 30.

- **Sites with Highways and Roads Objective:**
  RX Level Threshold:85% of the samples shall have greater and equal to -80dbm.
  RxQual Threshold:80% of the values shall be between 0-4.
  where samples of value 4 shall be less than and equal to 20%.
  Values 6 and 7 shall be _ 10% of the total samples.
  C/I Threshold:90% of the samples less are in between 12 to 30.
  To consider this activity completed the following deliverables must be produced:

  - List of constrains related to this activity (if any)
  - Log files delivered
  - Site Integration Report.

III.3.4 Drive test report

This step will produce the final DT report which shall contain all RF indicators.

III.4 Software tools for Drive test

Generally, there are several alternative software tools that can be used by a drive tester. One can cite: TEMS investigation, Ellipse, some other complementary tools such as ATTOL, MCOM, and MapInfo.

In our case, we will use the TEMS Discovery software to read our collected logfiles. These last logfiles are collected to prepare SSV reports. For that a detailed description of TEMS Discovery will be given in the next subsection.

III.5 TEMS Discovery

Test Mobile System (TEMS) is a technology used by telecom operators to measure, analyze and optimize their mobile networks. It is considered as the basic tool to perform wireless network drive testing, benchmarking, monitoring and analysis. Originally, part of Field Measurement Systems and Network Planning Software divisions of Virginia, US-based LCC International Inc., it was acquired by Ericsson in 1999. The TEMS Products business was divested from Ericsson to Ascom on June 2, 2009. The TEMS Products business has been then divested to Infovista, effectively on October 3, 2016

TEMS Discovery Device is highly configurable and extremely user friendly. It allows engineers to assess wireless performance and pinpoint network problems.

Figure III.3: TEMS™ Discovery 23.4.2 software.

III.5.1 TEMS Overview

- **The Workspace**

The TEMS software is equipped with different windows and task bars like any other software. We find the **workspace** (work area),**worksheets** (worksheets) and **toolbars** (task bars). The workspace is the environment that stores all windows and arrangements necessary for a function. The arrangements include information related to external devices. This area is configured where we find all the sectors and reliefs of a territory .An update of this map is established each time a new site is deployed. By default a work area is opened for each data collection by the TEMS. The Figure III.4 following represents a Workspace.

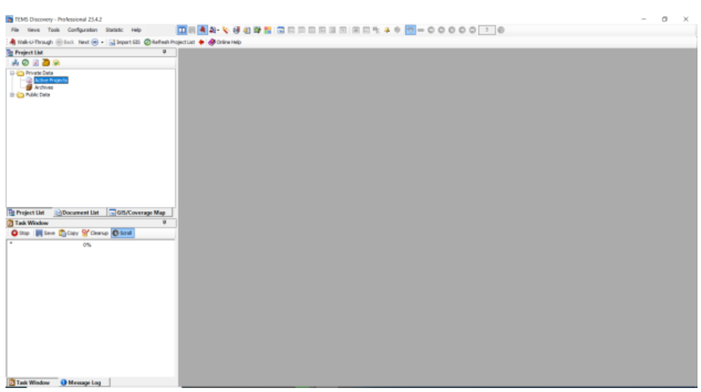


Figure III.4: Workspace of TEMS investigation.

- **Worksheets**

  The work area is divided into several parts called worksheets. They are used for different functions. They are manipulated by the menu of worksheets; an example of worksheets is given in Figure III.5.

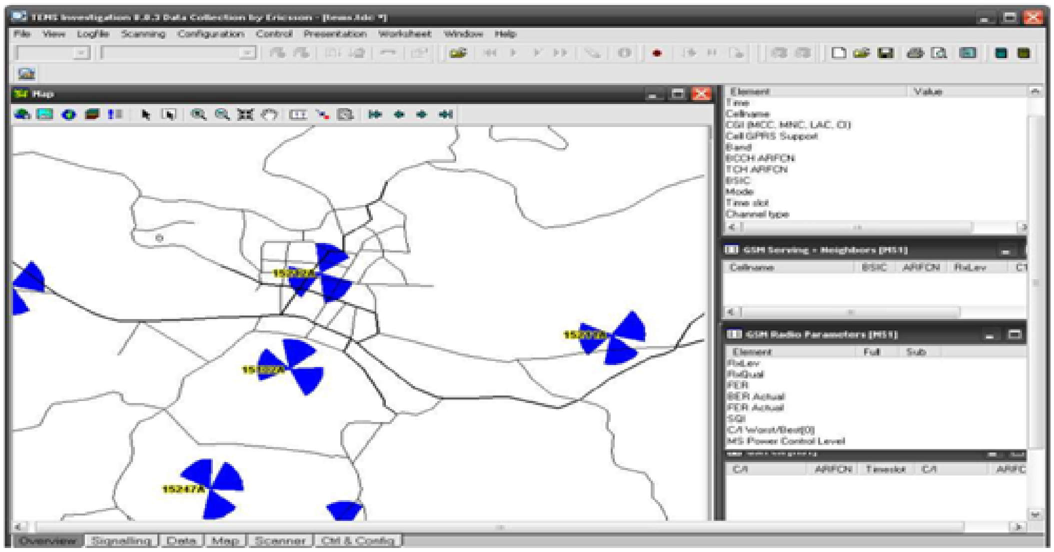


Figure III.5: Worksheet of TEMS.

- **The Toolbar**

  The task bar of the main window leads to quick access to the main functions of the TEMS data collection. This bar has different icons necessary for the drive test.

III.5.2 TEMS collected data

During drive test using TEMS, data can be collected. the equipment of drive test collects data relating to the mobile network. Also, services running over the network such as voice, data

- **RxLev**

  RxLev is the reception signal strength which states the magnitude of the signal received at the receiving side (Mobile Station). The RxLev value is a value indicating the signal strength level, which is expressed in the minus dBm range.

The smaller the RxLev value (the greater the minus dBm at RxLev), the weaker the received signal strength at MS. The TEMS classifies the received signal level according to the following color code:

Table III.1: Color code for RxLevel.

Color	Value ranges	Signal level
Green ●	-75 down to 0dBm	Good
Yellow●	-90 Up to -75dBm	Average
Orange●	-96 Up to -90dBm	Acceptable
Red ●	-110 Up to -96dBm	Bad

- **RxQual**

RxQual is the quality of the voice signal (voice) measured in BER. This RxQual value serves as a marker of signal quality, whether it is good or not. The range of RxQual values is between 0 to 7, where the value is affected by the number of BERs that occur. The greater the RxQual value, the worse the signal quality.

RxQual measurement can be used for the illustration of how good coverage is provided from BS sites and how much interference is generated. There is no set standard for the RxQual value, and each operator has a different threshold. However, because RxQual is used as a measure of the performance between MS and BS, it is necessary to determine the minimum RxQual to obtain adequate system performance. RxQual values are color-coded as shown in the table below:

Table III.2: Color code for RxQual.

Color	Value ranges	Signal level
Green ●	0 up to 4	Good
Yellow●	4 up to 6	Mean
Red ●	6 up to 8	Bad

- **Interference (C/I)**

TEMS monitors interference between TCH traffic channels and BCCH broadcast. Note that the higher the level of interference, the better the call quality decreases until cut.

Table III.3: Coding for C/I (TCH).

Color	**Value ranges**	**Interpretation**
Red •	0 up to 9	Strong interference
Yellow•	9 up to 12	Average interference
Green •	12 up to 100	Low interference

For BCCH, the color code is given in the following table:

Table III.4: Coding for C/I (TCH).

Color	**Value ranges**	**Interpretation**
Red •	0 up to 9	Strong interference
Yellow•	9 up to 12	Average interference
Green •	12 up to 30	Low interference

- **speech quality (SQI)**

SQI can be interpreted as an indicator of voice quality in a calling state (dedicated mode). This SQI value ranges from -20 to 30. The higher the SQI value, the better the sound quality. The SQI value is calculated by TEMS automatically which is updated every 0.5 seconds. SQI is calculated based on FER and BER. The SQI score standard for each provider is different.

The TEMS also controls the quality of speech during a call; the software classifies the Speech quality according to the color code given by the table.

Table III.5: Color Code for speech.

Color	**Value ranges**	**Speech quaity**
Red ●	0 up to 16	Bad
yellow ●	16 up to 22	Mean
green ●	22 up to 31	Good

- **Timeadvance (TA)**

  This parameter is used to calculate the distance between the mobile terminal and the BTS, this distance is between:

$$T_A \times 554 \text{ m} \quad \text{et} \quad (T_A + 1) \times 554 \text{ m} \tag{III.1}$$

  The TA parameter takes values in a scale from 0 to 62 (62 is the maximum value, it corresponds to 35 Km).

  Example: for TA = 5, the distance between the MS and the BTS is between 2.770Km and 3.324Km. We notice that the TA parameter increases as the mobile moves away from the BTS.

  The distance between the BTS and the mobile is given by a color code as shown in the following table:

Table III.6: Color Code for speech.

Color	**Value ranges**	**Distance MS-BTS**
Red ●	0 up to 4	Between 0 and =3 km
yellow ●	4 up to 6	Between 3 km and 5 km
green ●	6 up to 62	Between 5 km and 35 km

For more details, in LTE the TA can be explained using this following Figure.

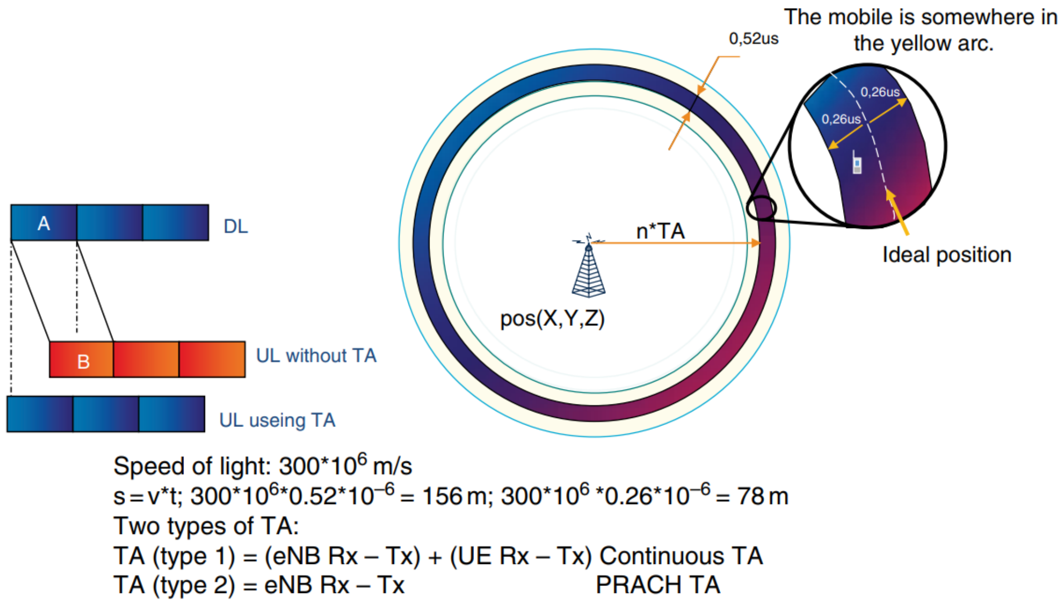


Figure III.6: Timing Advance in LTE[21].

- **Cell Signal strength: RSRP (Reference Signal Received Power)**

In LTE and 5G, cell signal strength is measured by RSRP in dBm. The greater the RSRP value, the stronger the cellular signal. RSRP is usually a negative number, so −90 dBm RSRP is stronger than −100 dBm RSRP.

Signal strength is important, but it's only as good as the quality of the signal itself. Increasing the strength of a poor-quality signal is like turning up the volume on a television that's only producing noise—all you get is louder noise.

≥ −89 dBm	Excellent
−90 to −104 dBm	Good
−105 to −114 dBm	Fair
−115 to −124 dBm	Poor
≤ −125 dBm	No signal (effectively)

Figure III.7: RSRP distribution Values.

- **Cell Signal quality: RSRQ (Reference Signal Received Quality)**

As mentioned previously for RSRP, the cell signal quality (RSRQ) in 4G LTE and 5G is measured in dB. The greater the RSRQ value, the less interference the signal is getting from other cells operating at or near the same channel. Like RSRP, RSRQ is a negative number; therefore, -8 dB RSRQ is a higher-quality signal than -12dBRSRQ.

Cell signal boosters amplify the strength (RSRP) of the ambient cell signal available at the outside antenna. A cell signal booster can't improve the quality (RSRQ) of the signal, but an outside directional antenna (an LPDA or a Yagi) can isolate a specific cell tower and help reduce interference from other nearby towers. Even a small increase in RSRQ can result in a significant improvement in cellular data rates.

≥ −9 dB	Excellent
−10 to −14 dB	Good
−15 to −19 dB	Fair
≤ −20 dB	Poor

Figure III.8: RSRQ Values.

- **Cell signal quality: SINR (Signal to Interference-plus-Noise Ratio)**

  Although SINR is not included in the 3GPP mobile broadband specifications, some equipment manufacturers use this traditional way of measuring the ratio of signal to noise:

  – Signal (S) refers to the desired signal coming from the cellular tower. It carries the data and information that the device is trying to receive.

  – Interference (I) consists of unwanted signals from sources other than the serving cell tower, including neighboring cell towers, adjacent bands of frequency, or other electronic devices operating in the vicinity. Interference can degrade the quality of the desired signal and cause data errors or dropped connections.

  – Noise (N) refers to random electrical signals that can come from electronic components, atmospheric conditions, thermal effects, and other sources. Noise adds an additional layer of unwanted information that can negatively affect the quality of the received signal.

– Ratio (R) is the mathematical relationship between the signal (S) and the combined strength of interference (I) and noise (N):

$$R = \frac{S}{(I + N)} \tag{III.2}$$

SINR is a positive number; the greater the value, the better quality the signal.

≥ 11	Excellent
6 to 10	Good
0 to 5	Fair
< 0	Poor

Figure III.9: SINR Values.

III.6 Drive test and analyze of logfiles

Through the drive test carried out by the Novatel It team, the engineers scanned all frequencies and took all measurements of the radio signal through several phases. The first phase is collecting data in special log files.

It is sent to the company headquarters to begin the second phase, which is processing the data and results obtained.

Below is an applied study I conducted with Novatel It engineers on the O13X061 site.

III.6.1 The steps to get the log file distribution graphs

- Open the TEMS Discovery 23.4.2 software on the PC.
- We click File.
- We click Import.
- We click Import Drive Test Data.

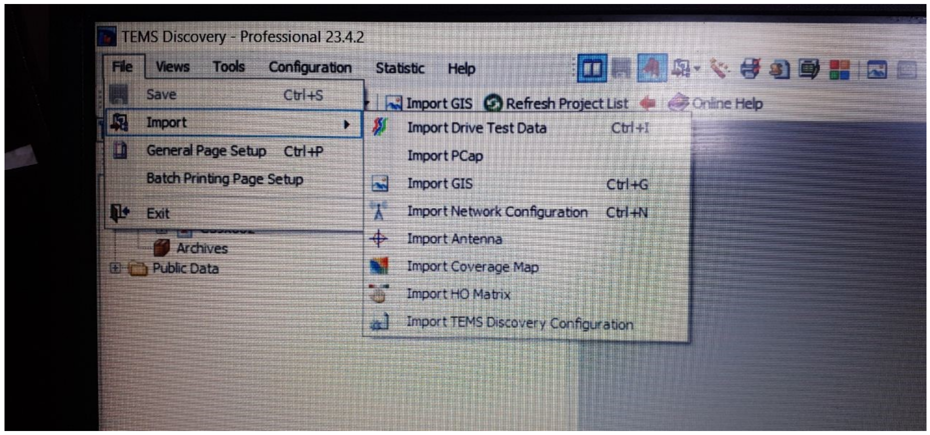


Figure III.10: Steps to get the log file distribution graphs.

III.6.2 The steps to get the network configuration

- We click File.
- We click Import.
- We click Import Network Configuration.
- The configuration of parameters.

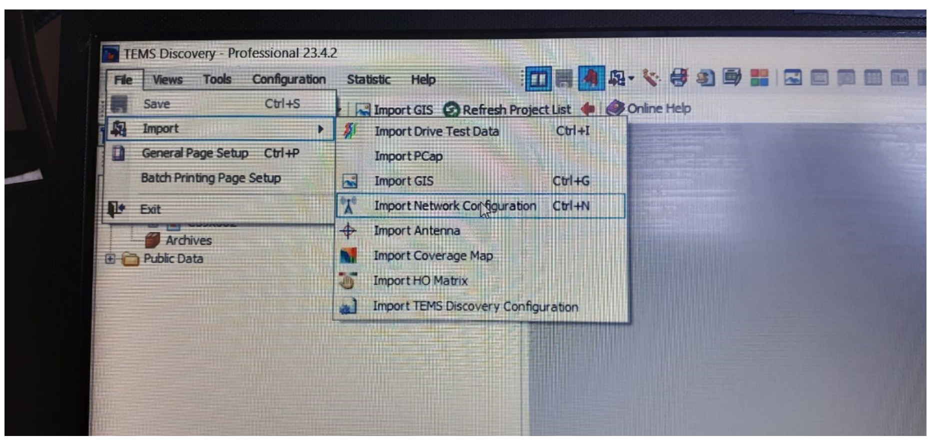


Figure III.11: Steps to get the network configuration.

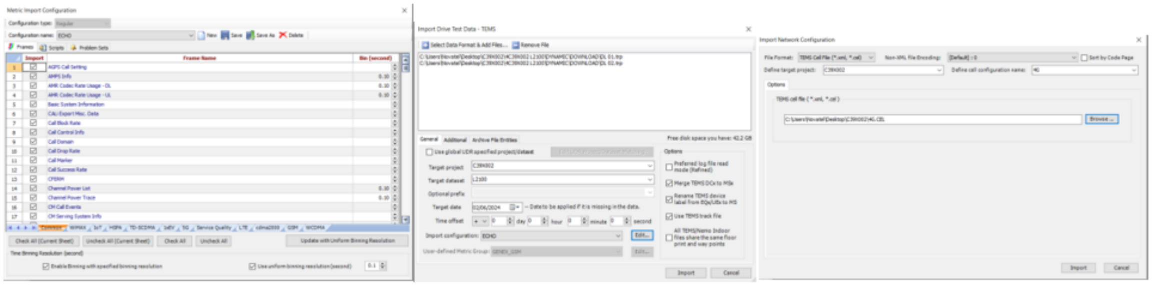


Figure III.12: Configuration of parameters in TEMS.

III.6.3 SSV Measurements

After DT, an SSV report can be delivered, the most important results are reported in the following table.

Table III.7: SSV reported parameters

Classes	Indicator	Test Method	attempt	success/ drop	Target	Test	Result	Remark
Accessibility	Call Setup Success Rate(PS)	SSV DT	1	1/0	98.00%	100.00%	pass	
	RRC Setup Success Rate	SSV DT	18	18/0	99.00%	100.00%	pass	
	E-RAB Establishment Success Rate	SSV DT	0	0/0	99.00%	0.00%	pass	
Retainability	Call Drop Rate_PS	SSV DT	0	0/0	1.00%	0.00%	pass	
CSFB	LTE to 2G/3G CSFB Success Rate	SSV DT	10	10/0	98.00%	100.00%	pass	
IRAT Mobility	LTE to 2G/3G Handover Success Rate	SSV DT	2	2/0	98.00%	100.00%	pass	
Mobility	Intra-system Handover Success Rate	SSV DT	4	4/0	98.50%	100.00%	pass	
Throughput	Single User DL Average Throughput (APP)	SSV DT	-	-	21Mbps	32.63	pass	Cat3/Cat4
	Single User UL Average Throughput (APP)	SSV DT	-	-	15Mbps	30.24	pass	Cat3/Cat4

We will convert these results into graphs for analysis. The results obtained are shown below:

III.6.3.1 PCI Distribution

PCI is one of the most important cell identifiers in LTE network. Therefore, it is one of the most important steps in planning and optimizing the air interface. Using PCI can reasonably reduce interference and increase resource utilization and QoS service quality.

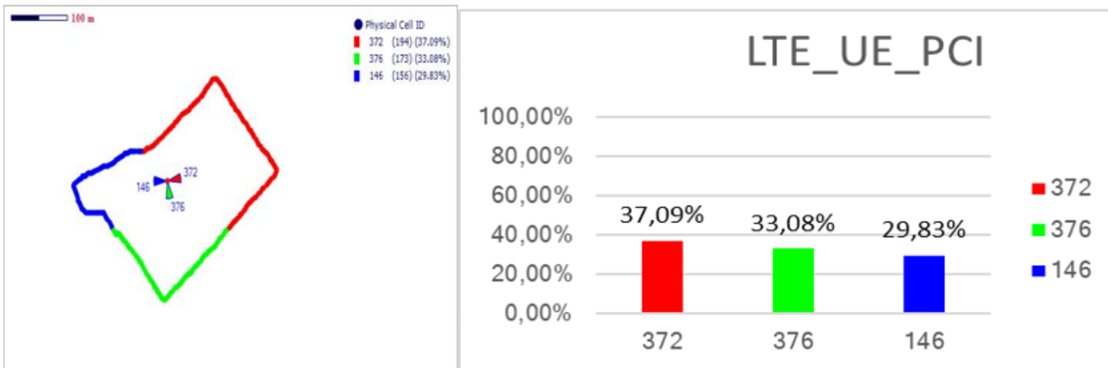


Figure III.13: PCI Distribution result and histogram.

Interpretation of the Histogram:

- 37.09% of samples for 372 cells
- 33.08% of samples for 376 cells
- 29.83% of samples for 146 cells

III.6.3.2 DL RSRP Distribution

As the SINR, the RSRP distribution is used to analyze the LTE network coverage.

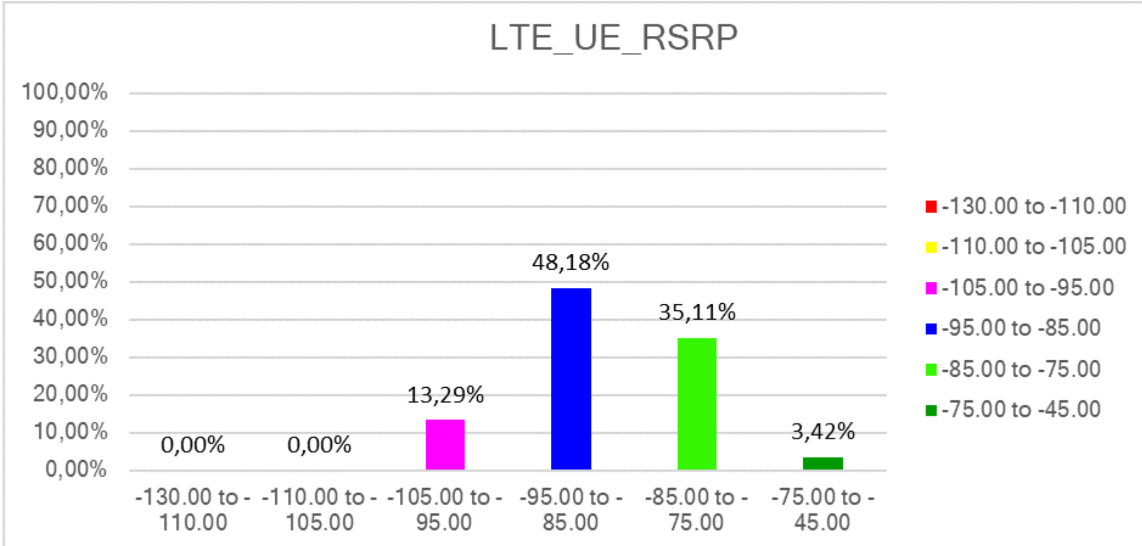


Figure III.14: Histogram of RSRP.

Interpretation of the Histogram:

- 0 % of the samples have values between [-130; -110] dBm. This corresponds to a no signal (effectively).
- 0 % of the samples have values between [-110; -105] dBm. This corresponds to a poor signal.
- 13.29 % of the samples have values between [-105; -95] dBm. This corresponds to an acceptable signal.
- 48.18 % of the samples have values between [-95; -85] dBm. This corresponds to a good signal.
- 35.11 % of the samples have values between [-85; -75] dBm. This corresponds to a very good signal.
- 3.42 % of the samples have values between [-75; -45] dBm. This corresponds to a excellent signal.

III.6.3.3 DL SINR Distribution

It is the indicator of the quality of the transmission of information.

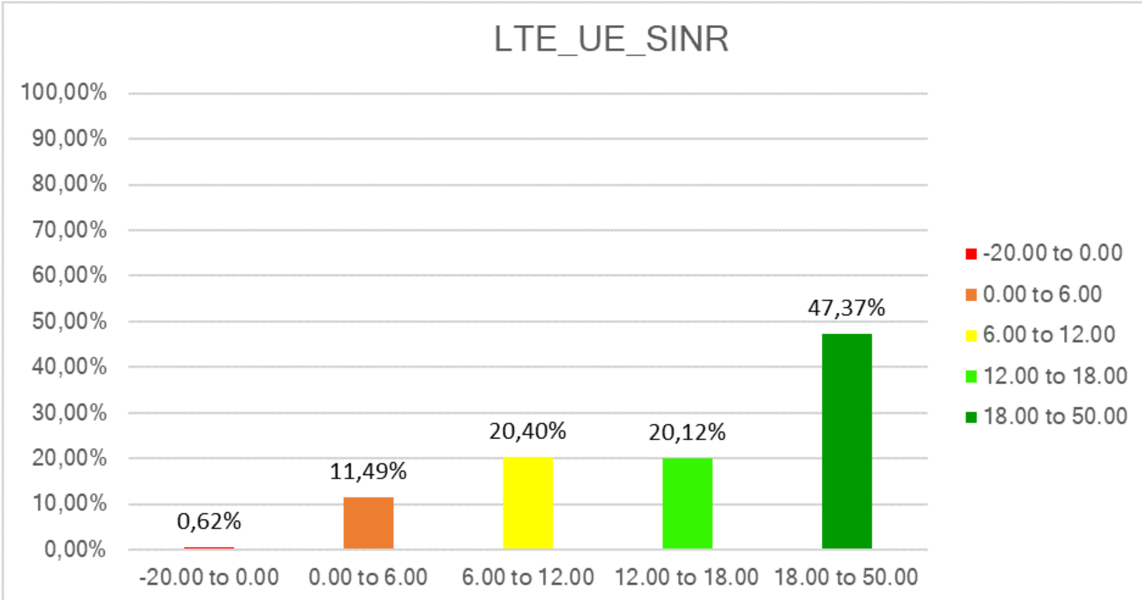


Figure III.15: Histogram of SINR.

Interpretation of the Histogram

- 0.62 % of the samples have values between [-20; 0] dBm. This corresponds to a poor signal.
- 11.49 % of the samples have values between [0; 6] dBm. This corresponds to a fair signal.
- 20.40 % of the samples have values between [6; 12] dBm. This corresponds to a good quality of signal.
- 20.12 % of the samples have values between [12; 18] dBm. This corresponds to a very good signal.
- 47.37 % of the samples have values between [18; 50] dBm. This corresponds to an excellent quality of signal.

III.6.3.4 DL Throughput

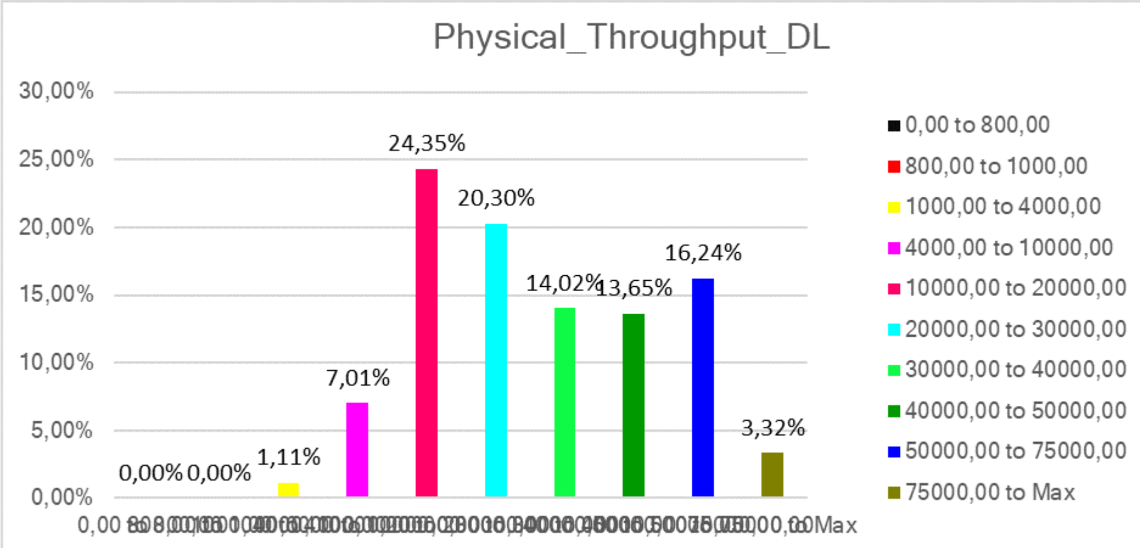


Figure III.16: Histogram of DL Throughput (Kbps).

Interpretation of the Histogram:

- 1.11 % of the samples have values between [1; 4] Mbps.
- 7.01 % of the samples have values between [4; 10] Mbps.
- 24.35 % of the samples have values between [10; 20] Mbps.
- 20.30 % of the samples have values between [20; 30] Mbps.
- 14.02 % of the samples have values between [30; 40] Mbps.
- 13.65 % of the samples have values between [40; 50] Mbps.
- 16.24 % of the samples have values between [50; 75] Mbps.
- 3.32 % of the samples have values between [75; Max] Mbps.

III.6.3.5 UL Throughput

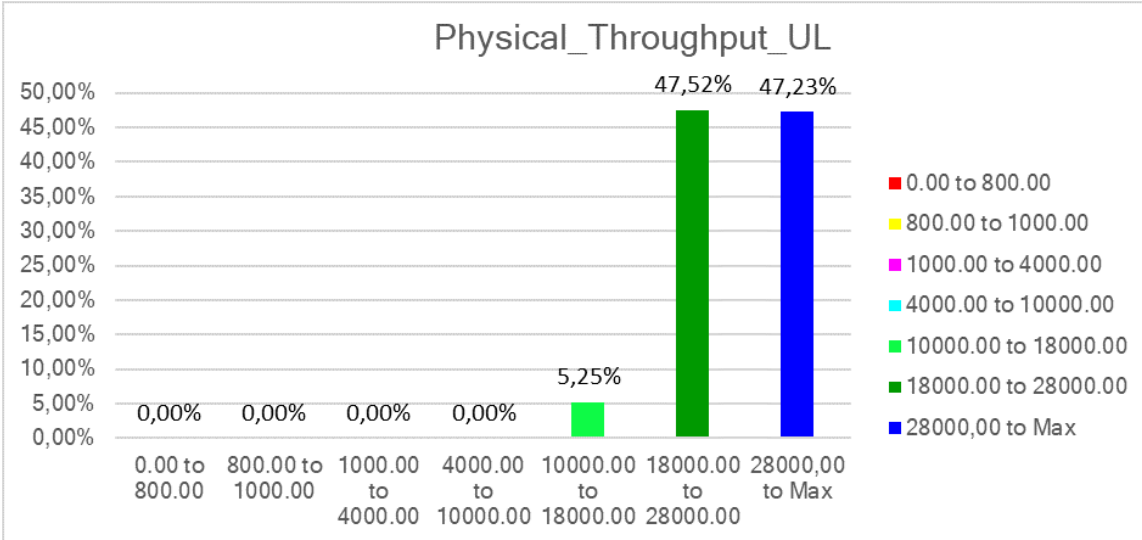


Figure III.17: Histogram of UL Throughput (Kbps).

Interpretation of the Histogram

- 5.25 % of the samples have values between [10; 18] Mbps.
- 47.52 % of the samples have values between [18; 28] Mbps.
- 47.23 % of the samples have values between [28; Max] Mbps.

III.6.3.6 Number of PDSCH Resource Blocked (RB)

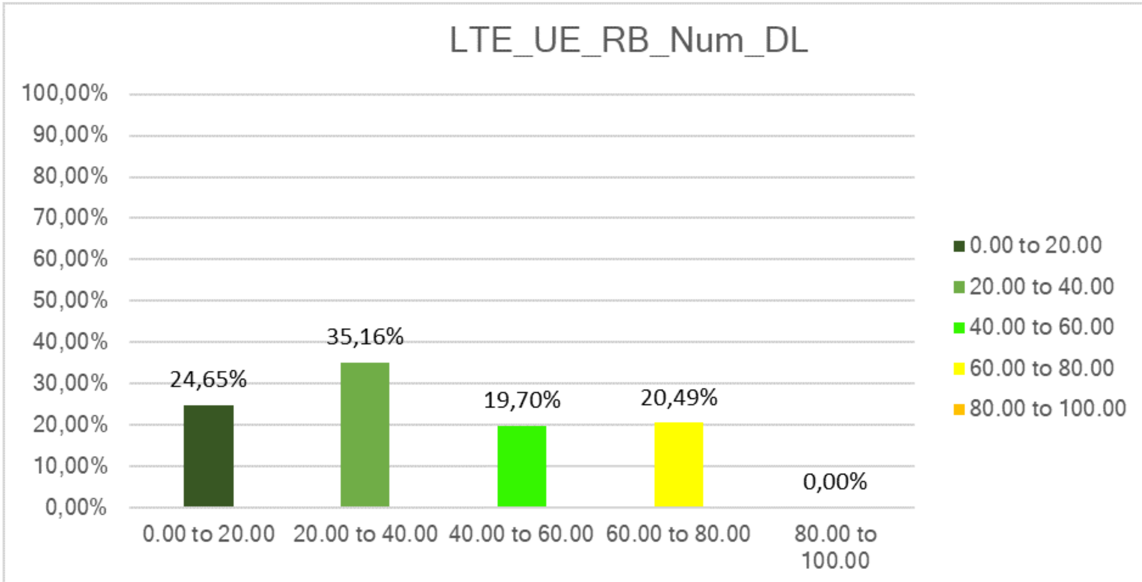


Figure III.18: Histogram of RB.

Interpretation of the Histogram

- 24.65 % of the samples have values between [0; 20] resource blocked
- 35.16 % of the samples have values between [20; 40] resource blocked
- 19.70 % of the samples have values between [40; 60] resource blocked
- 20.49 % of the samples have values between [60; 80] resource blocked
- 0.00 % of the samples have values between [80; 100] resource blocked

III.6.3.7 RSRQ

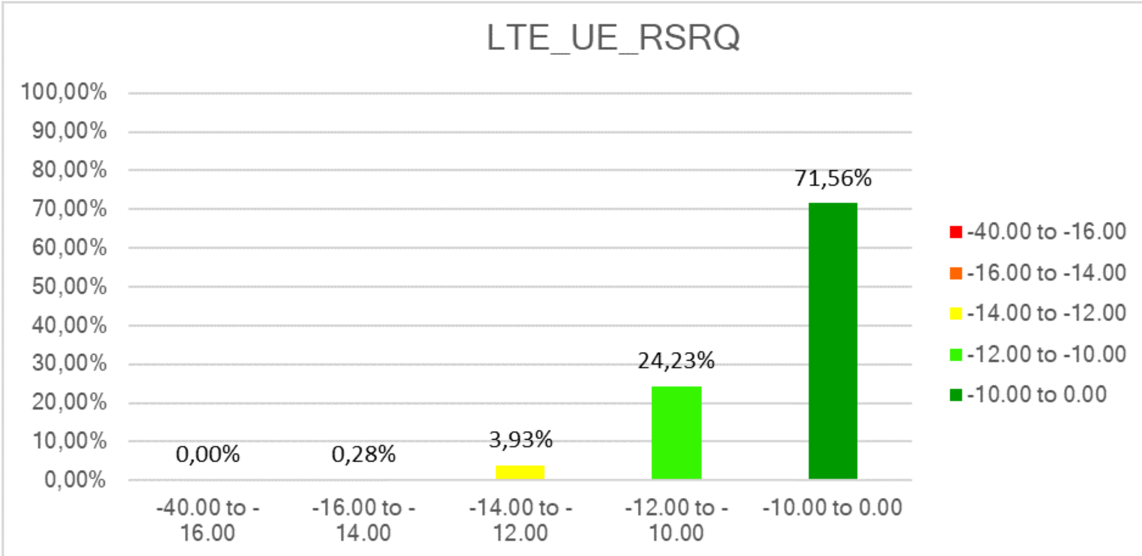


Figure III.19: Histogram of RSRQ.

Interpretation of the Histogram

- 0 % of the samples have values between [-40; -16] dBm. This corresponds to a poor signal.
- 0.28 % of the samples have values between [-16; -14] dBm. This corresponds to a fair signal.
- 3.93 % of the samples have values between [-14; -12] dBm. This corresponds to an acceptable signal.
- 24.23 % of the samples have values between [-12; -10] dBm. This corresponds to a good signal.
- 71.56 % of the samples have values between [-10; -0] dBm. This corresponds to an excellent signal.

III.6.3.8 Spatial Rank

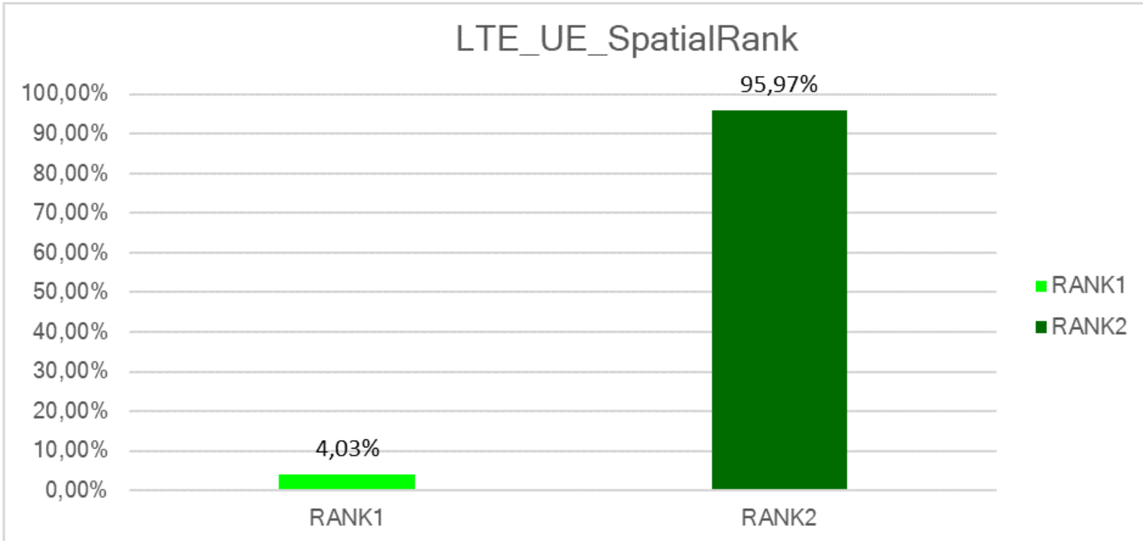


Figure III.20: Histogram of Spatial Rank.

Interpretation of the Histogram

- 4.03% for RANK1
- 95.97% for RANK2

Let's consider the case of two antenna where RI is indicated using one bit, so a bit 0 indicates RANK1 and a bit 1 indicates RANK2. RANK1 means the UE is seeing a good SINR only on one of its receive antenna so asking the eNodeB to bring down the transmission mode to single antenna or transmit diversity. A RANK2 from the UE means good SINR on both the antenna ports and eNodeB can schedule MIMO.

Based on this report, the enodeB will decide a transmission mode (single antenna or MIMO diversity).

III.6.3.9 Transmission mode

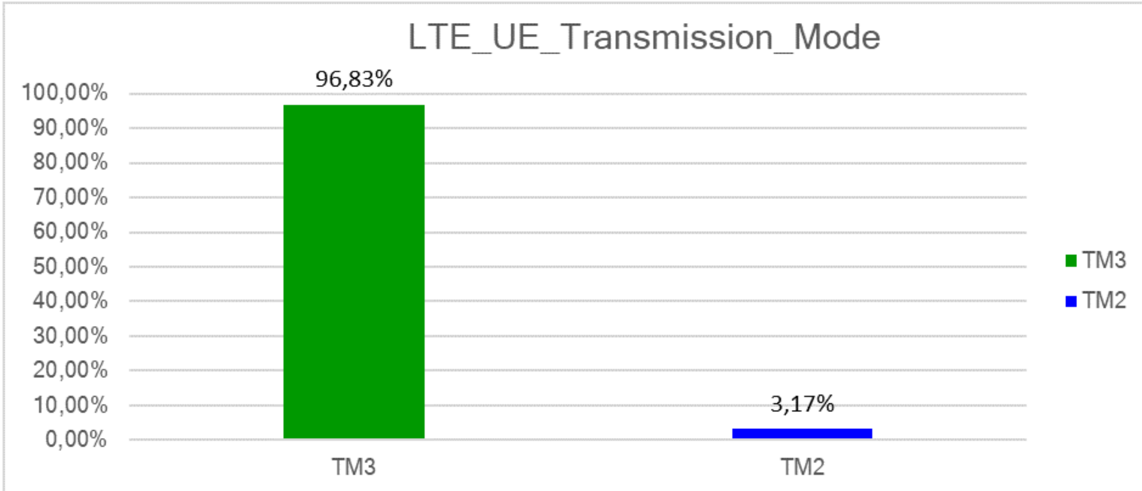


Figure III.21: Histogram of Transmission Mode.

Interpretation of the Histogram

- 96.83 % of the samples for Spatial Multiplexing mode.
- 3.14 % of samples for Transmission Diversity mode.

Transmission diversity (Div): It consists of transmitting the same information from several antennas; diversity increases the robustness of the transmission.

Spatial multiplexing (MS): It consists of transmitting several different information streams, called spatial layers, over the same time-frequency resources.

III.6.3.10 Technology Mode

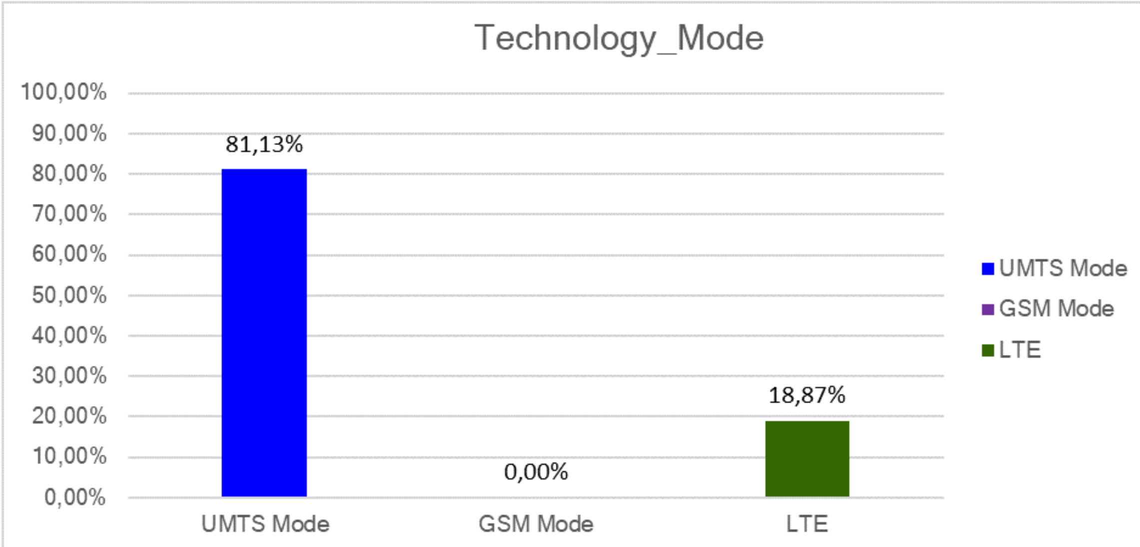


Figure III.22: Histogram of Technology Mode.

Interpretation of the Histogram:

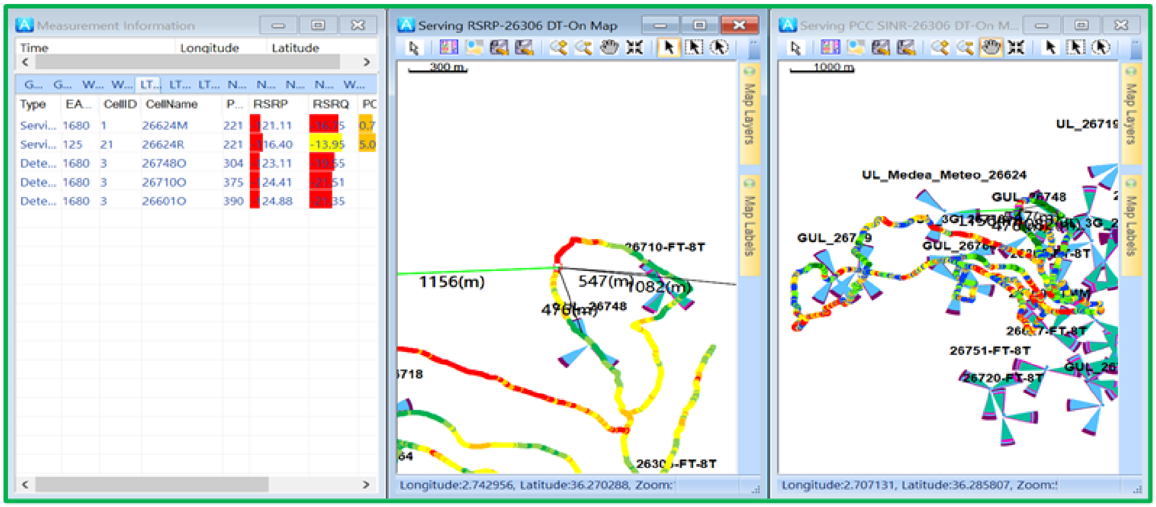
- 81.13 % of the samples for UMTS mode.
- 0.00 % of samples for GSM mode.
- 18.87 % of samples for LTE mode.

III.7 Some DT analysis and optimization cases

In this part, some DT analysis will be presented. The measurement of DT was done on Medea region. The reported cases here touch two important parameters in LTE (RSRP end SINR). As explained previously, these two parameters affect directly to the coverage.

- **Case 01. LTE RSRP analysis and suggestion**
  Description:

  Case 01: Bad coverage due to Bad topology and the concerned area located in hidden area between elevations



Suggestion:

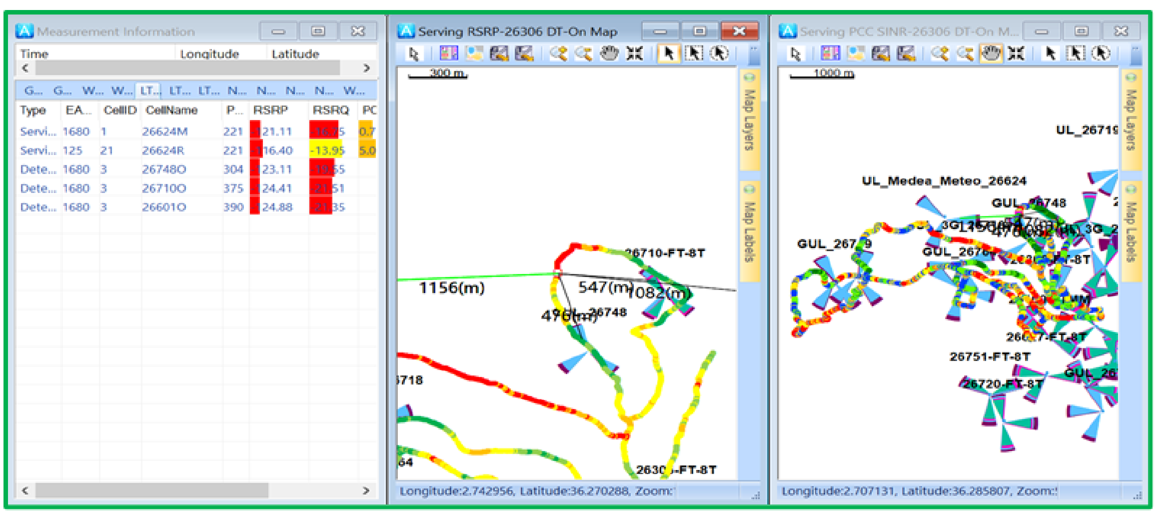
UP Etilt 26624M FROM 100 TO 70.

UP Etilt 267480/T from 60 to 40.

In order to enhance coverage.

- **Case 02. LTE RSRP analysis and suggestion Description:**

  Case02: Bad coverage due to Bad topology with Big Up hills, most of concerned locations are higher than our nearest sites.



Suggestion:

UP Etilt 26306O/T by 20 degrees from 60 to 40.

Adjust Power 26306 already done, it is carrying traffic better than before In order to enhance coverage

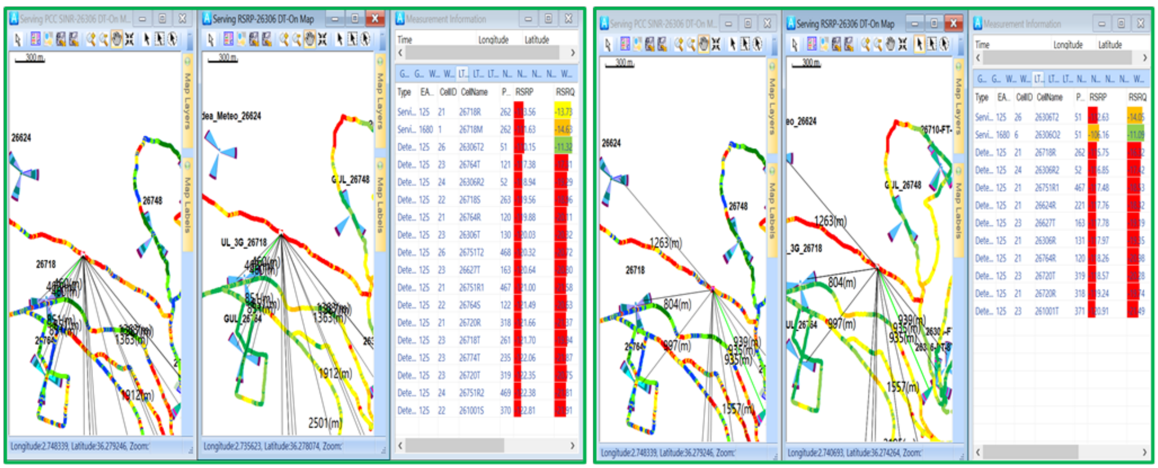
Long Term solution:

Add 4th sector on 26718 with Azimuth =0 degree

New site is needed in this area (36.275762°, 2.738098°) in order to enhance coverage over this road.

- **CASE 03: 4G SINR Analysis and Recommendation Description:**

  Case03: Bad SINR due to Bad coverage

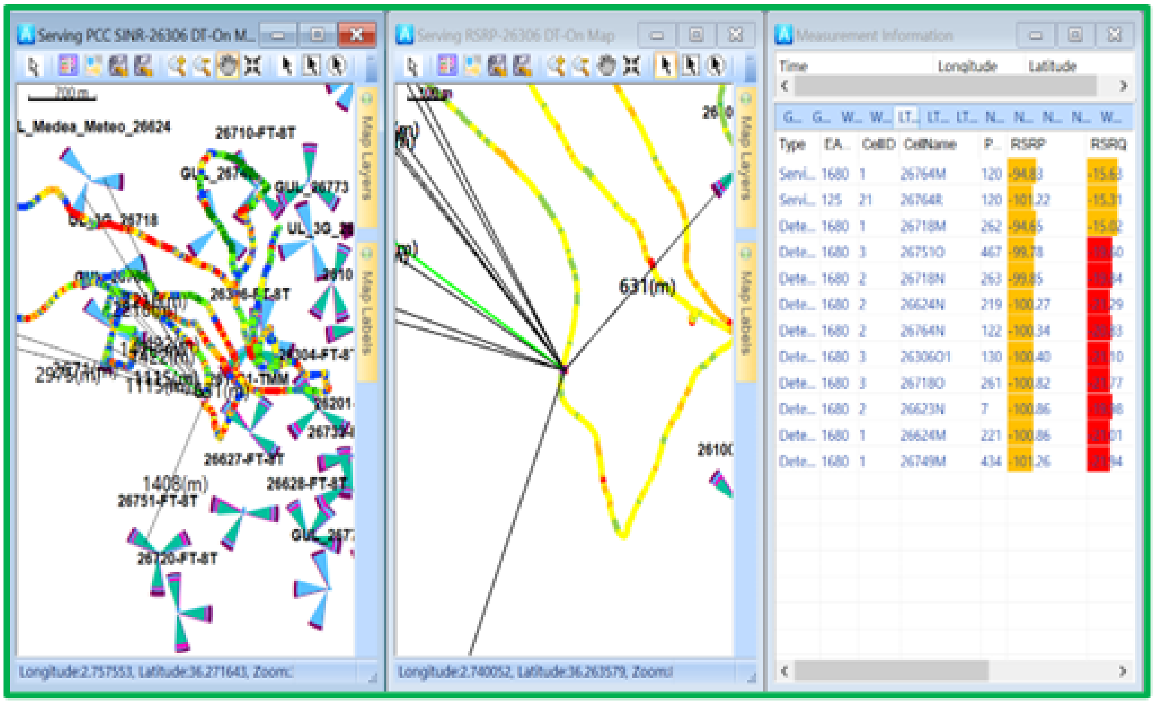


Suggestion:

Same recommendation as in case 02 RSRP Analysis see previous case.

- **CASE 04: 4G SINR Analysis and Recommendation Description:**

  Case 04: Bad SINR due to no best serving site with overshooting cells caused by Bad topology



Suggestion:

Down E-tilt 261001O From 40 to 60 in order to enhance coverage near the site

Down E-tilt the overshooting cells

267510 From 20 to 40 (Already done previously)

26623N From 80 to 100

III.8 Conclusion

In this chapter, DT has been explained. As mentioned previously, two types of DT measurements were done. The first one is SSV reports, which make us show the performance of the mobile network through a good experience with a team of engineers from SARL Novatel. The SSV report helps to improve the quality of service in terms of coverage, quality and capacity. The SSV report was done using TEMS Discovery, which is used for data collection (log files). The second part concerning drive test tasks at the light of some complains on the region of Media, when a problem description was given with some suggestions.

Chapter IV

KPIs optimization of LTE Mobilis network: Wilaya of M'sila as a study case

IV.1 Introduction

Optimization engineers analyse measurements collected by KPIs to identify potential arrange issues. At that point they distinguish the causes of these issues and give fitting remedial activities. In this chapter, we are going portray all the optimization stages of a few KPIs and will survey the quality of service of the LTE arrange within the wilaya of M'sila.

IV.2 KPIs statistics:

During the period 29-05-2023 to 05-06-2023, we were able to get some KPI statistics for different cells in the LTE Mobilis network in M'sila. These KPIs are listed below:

- E-RAB Setup Success Rate (All)(%)
- Handover preparation success rate
- Handover execution success rate
- L.UL.Interference.Avg(dBm)

- Call Drop Rate (All)(%)
- RRC Setup Success Rate(%)
- Downlink Traffic Volume(Gbyte)
- Uplink Traffic Volume(Gbyte)
- L.Traffic.User.Avg
- L.Traffic.User.Max
- Cell DL Average Throughput(Mbps)
- Cell UL Average Throughput(Mbps)
- LTE_Incoming_HHO_Success_Rate
- LTE_RRC_Congestion_Rate

IV.3 Statistics of ARPT agency

The number of mobile phone subscribers had amounted to 49 million till December 31, 2022 in Algeria, compared to 47 million subscribers in the same period of 2021, an increase of 4.26%, according to the latest report from the Post and Electronic Communications Regulatory Authority (ARPCE).

According to the same data, of the 49 million active subscribers to mobile telephony (GSM, 3G and 4G), 4.26 million were subscribers to the GSM network, i.e. 8.6%, against 44.75 million subscribers to the 3G/4G network, i.e. 91.31%.

The mobile telephone network penetration rate recorded a net change of 4.34% in one year, from 106.71% till December 31, 2021 to 111.05% till December 31, 2022.

"This development is due to the slight increase in the mobile phone market on the one hand and the Algerian population on the other hand," explained the same source.

This report has been drawn up according to an Algerian population estimated at 44.14 million inhabitants and a number of households estimated at 7.35 million till December 31, 2022.

IV.3.1 Traffic stats of consumption in the wilaya of M'sila

In this part, the traffic of voice and data for the wilaya of M'sila will be delivered for the period May 16th to 28th May 2023. (See the following table).

Table IV.1: M'sila traffic 4G (Ps) in the period 15May-28May 2023.

PS Volume (Gbyte)	**15-May**	**16-May**	**17-May**	**18-May**	**19-May**	**20-May**	**21-May**
Msila	112572	112775	116872	118092	123421	120418	122014
22-May	18-May	23-May	24-May	25-May	26-May	27-May	28-May
121950	122053	121479	123723	125784	124222	122227	122521

According to the reported stats in Table 4.1, M'sila has a huge consumption in data as well as in traffic voice, the evolution of traffic PS illustrated in Figures 4.1.

This exponential growing in traffic makes M'sila among the highest traffic areas in Algeria.

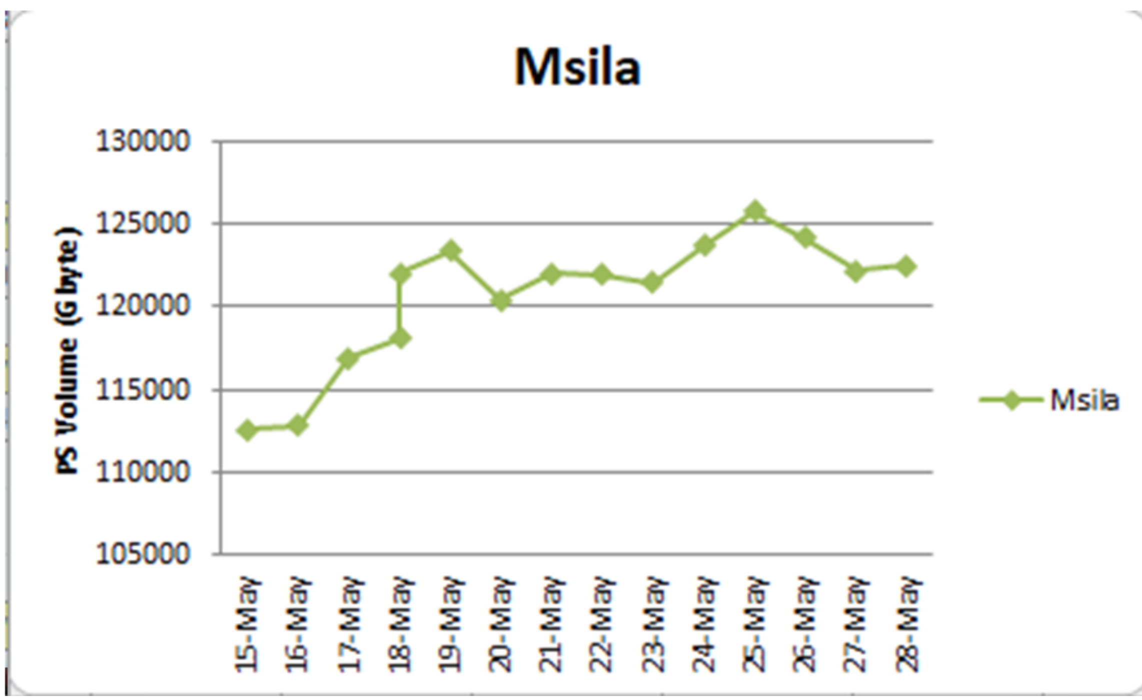


Figure IV.1: M'sila 4G PS volume in the period 15May-28May 2023 (in Gbytes).

IV.4 Optimization process

After network planning, an optimization process must be mandatory. To do this important task, each mobile company must offer a given process. There are many steps of the optimization process such as data collection, analysis reports, detection of problems, and the preposition of solutions.

Data collection: For AlgérieTélécom, there are many collect KPI data tools are used following to the company and the corresponding operator. For example, one can cite U2000, imanager, NetAct, NetNumen, OSS_RC. In our case, the U2000 was used.

Time	RRC Setup Success Rate(%)	E-RAB Setup Success Rate (All)(%)	Call Drop Rate (All)(%)	LTE_RRC_Congestion_Rate	Handover preparation success rate	Handover execution success rate	Incoming HO Attempt(times)	LTE_Incoming_HHO_Success_Rate	Downlink Traffic Volume(Gbyte)	Uplink Traffic Volume(Gbyte)	L.Traffic.User.Avg	L.Traffic.User.Max	Cell DL Average Throughput(Mbps)	Cell UL Average Throughput(Mbps)	L.UL.Interference.Avg(dBm)
2023-05-29 00:00	100	99.8145	0	0	99.1935	98.374	141	96.4539	0.431	0.0567	9.4597	17	6.5034	0.9355	-116
2023-05-29 00:00	100	99.7675	0.2406	0	99.6473	100	483	99.1718	4.6702	0.9525	66.1725	92	13.9831	4.0109	-114
2023-05-29 00:00	99.9395	99.7292	0.6358	0	100	99.2857	109	97.2477	1.8122	0.3474	27.3931	49	11.2706	1.8292	-114
2023-05-29 00:00	99.8524	99.3803	0.2869	0	100	99.7365	824	98.4223	5.2427	1.4026	102.7342	130	13.1853	3.44	-116
2023-05-29 00:00	99.9426	99.9225	0	0	100	99.7992	530	98.8679	3.0173	0.4618	35.7136	57	12.587	1.786	-115
2023-05-29 00:00	99.8077	100	0	0	100	100	141	95.0355	0.9073	0.087	10.0722	18	10.2911	1.0937	-116
2023-05-29 01:00	100	99.5726	0.2242	0	100	100	88	93.1818	0.083	0.0228	6.0167	13	6.9278	1.7213	-117
2023-05-29 01:00	100	99.9444	0.1708	0	99.6835	100	257	98.4436	3.2208	0.574	43.4888	61	14.0304	3.0667	-116
2023-05-29 01:00	100	99.7735	0	0	100	100	72	100	1.3345	0.1215	17.0231	27	13.3813	1.5076	-116
2023-05-29 01:00	99.9187	99.8243	0.1689	0	100	99.1453	394	98.2234	4.8178	1.2539	66.4337	104	15.0792	3.9751	-117
2023-05-29 01:00	99.9372	99.8298	0.2538	0	100	99.5708	236	96.6102	1.8238	0.2617	24.8063	38	13.2688	1.5877	-116
2023-05-29 01:00	100	99.1736	0.8043	0	100	100	71	91.5493	0.1422	0.0331	6.5046	13	8.7101	1.1612	-118
2023-05-29 02:00	100	100	0	0	100	100	55	98.1818	0.2328	0.0493	5.4547	17	10.6008	1.6163	-118
2023-05-29 02:00	100	100	0.1378	0	100	99.1228	77	100	1.633	0.5272	22.4881	43	14.5338	4.5055	-117
2023-05-29 02:00	100	100	0.1613	0	100	98.0769	46	100	0.5923	0.0579	10.3183	19	15.2397	1.6793	-117
2023-05-29 02:00	99.9365	100	0.0382	0	100	100	203	99.0148	4.1367	0.8739	45.4767	67	15.5152	3.2296	-118
2023-05-29 02:00	100	100	0	0	100	100	562	99.4662	2.6566	0.1157	22.7089	46	19.9169	1.1751	-117
2023-05-29 02:00	100	100	0	0	100	92.8571	54	94.4444	0.2954	0.0315	6.015	23	10.0411	0.7646	-118
2023-05-29 03:00	100	100	0	0	100	100	31	100	0.2145	0.0063	4.2969	13	13.8733	0.8106	-118
2023-05-29 03:00	100	100	0	0	100	100	26	100	0.7428	0.0549	14.0114	27	20.5409	1.7991	-118
2023-05-29 03:00	100	99.8447	0	0	100	98.4375	53	100	0.2602	0.0215	7.1558	15	15.922	1.4589	-118
2023-05-29 03:00	100	100	0	0	100	100	143	100	1.9081	0.3562	36.4279	55	14.9872	2.1123	-118
2023-05-29 03:00	100	100	0	0	100	100	160	99.375	1.26	0.077	19.2108	35	22.8962	1.8117	-117
2023-05-29 03:00	100	100	0.2994	0	100	100	43	95.3488	0.2605	0.0293	7.308	20	13.925	1.119	-118
2023-05-29 04:00	100	100	0	0	100	100	35	97.1429	0.0744	0.0032	4.2492	11	24.7593	1.0691	-118
2023-05-29 04:00	100	100	0	0	100	100	36	100	0.362	0.1532	11.0514	18	10.5503	2.1671	-118
2023-05-29 04:00	100	100	0.1387	0	100	100	53	100	0.6455	0.0475	8.8586	19	11.8646	0.6874	-118
2023-05-29 04:00	100	99.9651	0	0	100	99.0566	168	91.0714	1.9144	0.2038	35.6921	48	15.6954	1.8942	-118
2023-05-29 04:00	100	100	0	0	100	100	116	88.7931	1.8089	0.079	19.0439	29	22.8218	1.5519	-117

Figure IV.2: Report of KPI Data collected as Excel file (M'sila enodeB 283004).

IV.5 study of some KPIs:

IV.5.1 E-RAB Setup Success Rate (All%)

Figure IV.3 Represent the diagram of E-RAB Setup Success Rate (All %) in the cell 283004 this cell covers an area with a high density of subscribers.

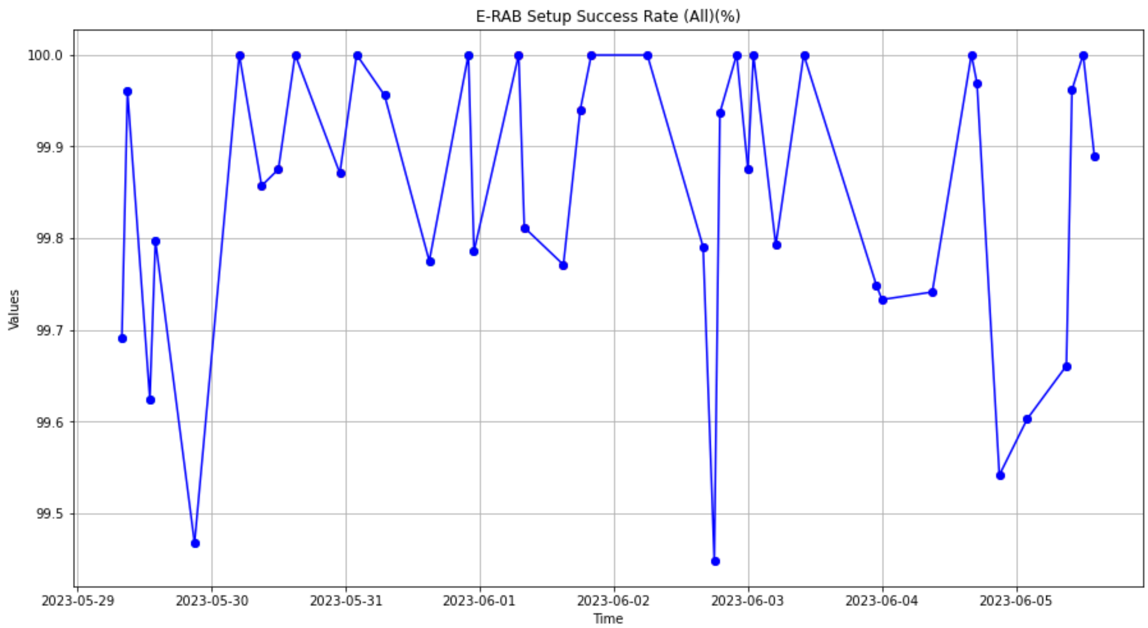


Figure IV.3: KPI E-RAB Setup Success Rate (All %) in the cell 283004.

One of the major KPIs for LTE is the LTE ERAB Success Rate, which is also part of the accessibility. This KPI can be used to evaluate the success rate of ERAB setup for all services, including VoIP service in a cell or cluster. From the chart, a high KPI ERAB Success Rate (%) indicates that the network is able to handle a large number of ERAB Success Rate requests without any issues, which results in better connectivity and user experience for mobile users.

IV.5.2 2 RRC Setup Success Rate (%):

Figure IV.4 represents the diagram of the RRC setup success rate (%) in cell 283004 in the period from 29 May to 05 June.

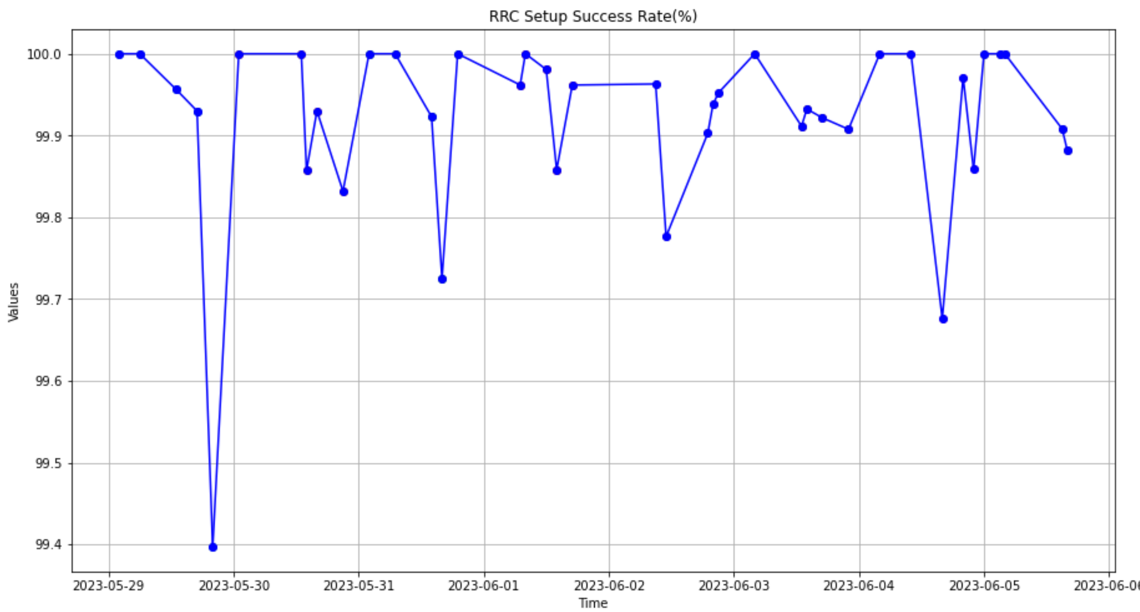


Figure IV.4: KPI RRC Setup success rate (%) in the cell 283004.

A high RRC setup success rate indicates that the network is able to successfully establish and maintain connections with mobile devices, resulting in better call quality, faster data transfer rates, and an overall improved user experience. A low RRC setup success rate can indicate issues with network coverage, capacity, or configuration, which can result in dropped calls, slow data speeds, and poor user experience. Therefore, monitoring and improving this KPI is crucial to ensuring optimal network performance and customer satisfaction.

IV.5.3 Call drop Rate (All %):

The significance of Call Drop Rate (All) Key Performance Indicators (KPIs) lies in their ability to measure the quality and reliability of a telecommunications network. Call drop rate refers to the percentage of calls that are prematurely terminated or dropped before completion.

A high call drop rate implies a poor user experience, as calls are frequently interrupted or abruptly terminated. This can lead to frustration for users and may impact their ability to communicate effectively. A monitoring and minimizing call drop rate is essential for service providers to ensure reliable connectivity and maintain customer satisfaction.

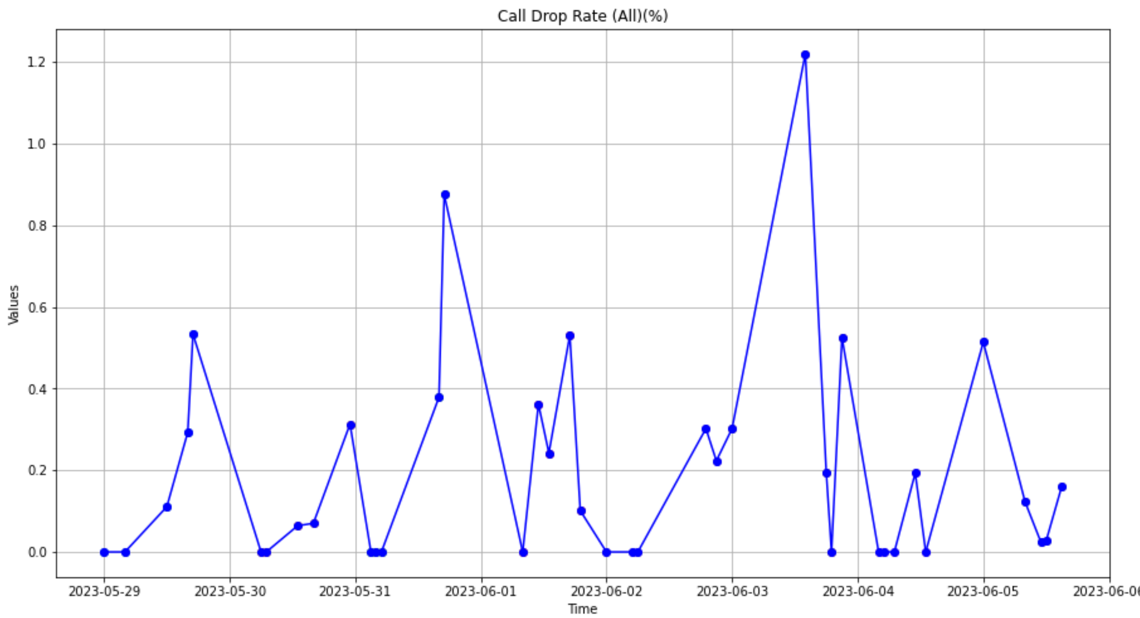


Figure IV.5: KPI Call drop Rate (ALL %) in the cell 283004.

IV.5.4 LTE RRC Congestion Rate:

Figure IV.6 represents the diagram of the LTE RRC Congestion rate (%) in cell 283004 in the period from 29 May to 05 June.

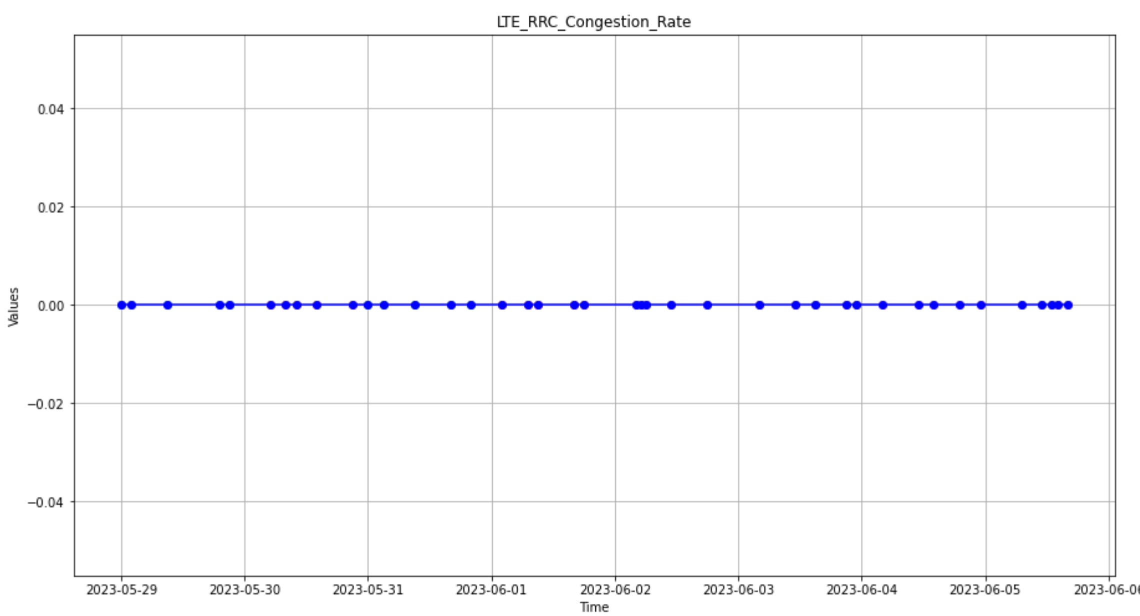


Figure IV.6: KPI LTE Congestion Rate in the cell 283004.

The congestion rate is very low, almost zero. This is a very good indicator. Therefore, the radio resources are available.

IV.5.5 Handover preparation success rate:

As we can see from the figure below, the preparation for the open hand operation is very high, and this is evidence of the seamless transfer of a mobile device's connection from one base station (eNodeB) to another while maintaining an ongoing communication session.

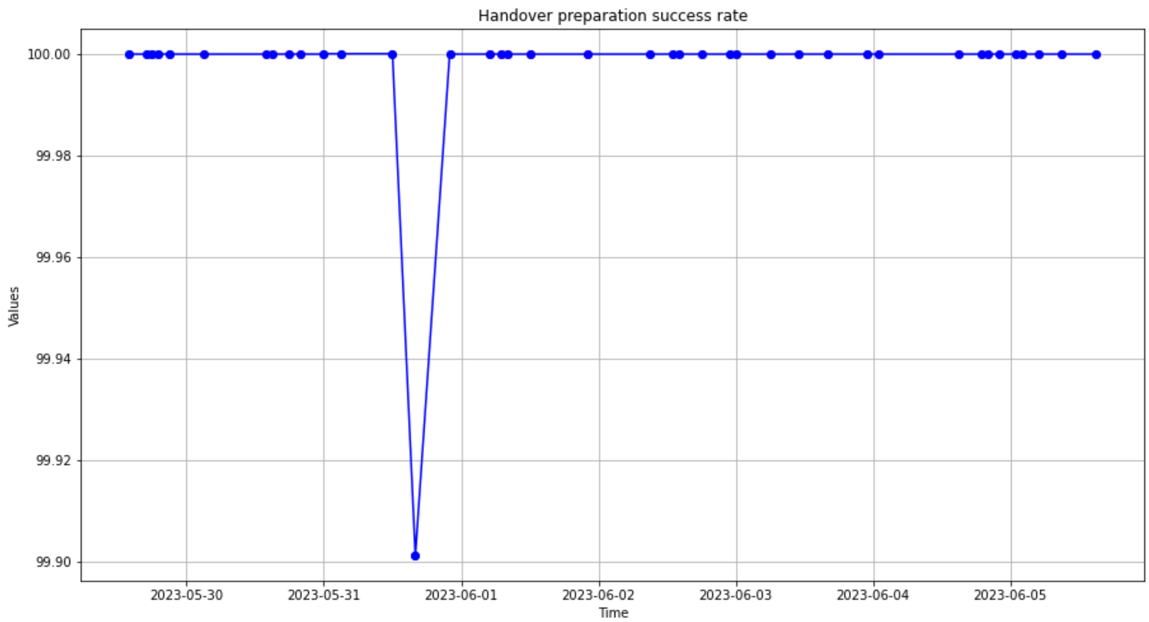


Figure IV.7: KPI Handover preparation success rate in the cell 283004.

IV.5.6 Handover execution success rate:

Figure IV.8 represents the diagram of the handover execution success rate in cell 283004 in the period from 29 May to 05 June.

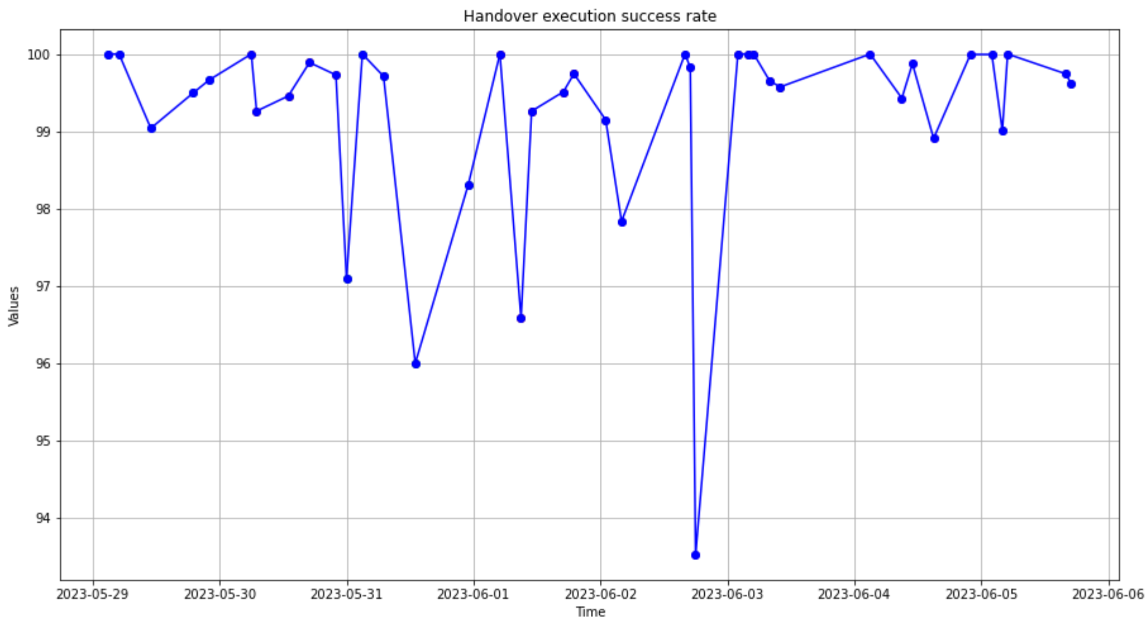


Figure IV.8: KPI handover execution success rate in the cell 283004.

We see in the figure IV.9 the high rate of success of the handover process, which is a result close to what was mentioned in the preparation process above.

IV.5.7 Cell UL Average Throughput (Mbps):

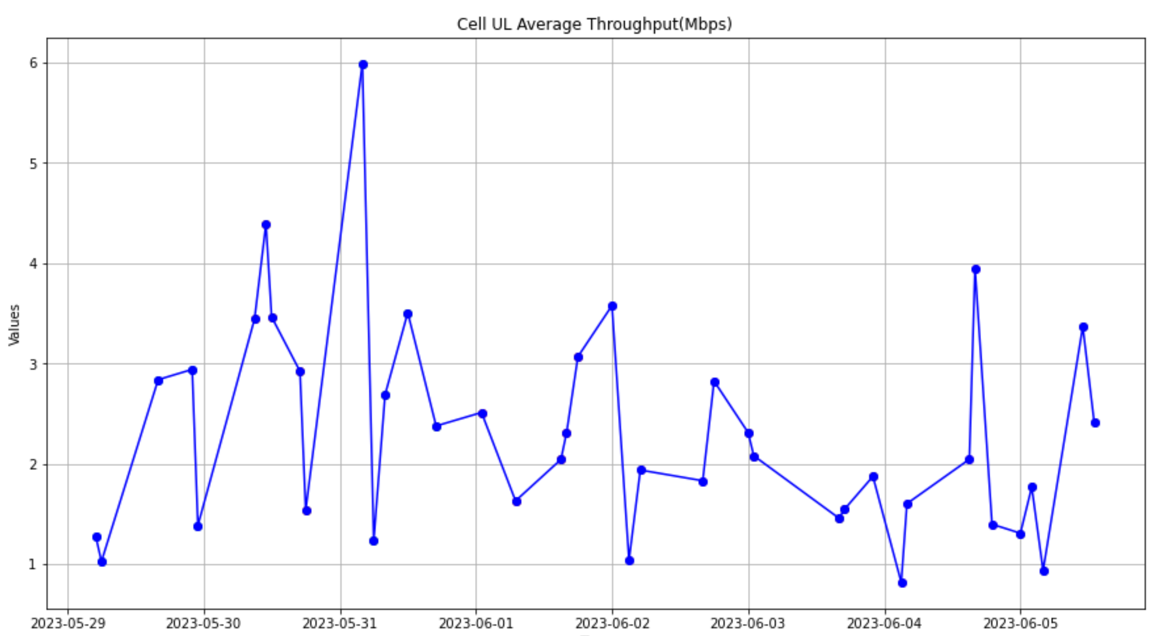


Figure IV.9: KPI Cell UL Average Throughput (Mbps) in the cell 283004.

- **Trends:Fluctuations:** The uplink (UL) average throughput shows significant fluctuations throughout the observed period.
- **Peaks:** The highest throughput peaks at around 6 Mbps on May 31, 2023.
- **Lows:** The lowest throughput drops below 1 Mbps several times, notably on May 31 and June 2, 2023.
- **Pattern:** There is no clear upward or downward trend, indicating variability in UL performance day-to-day.

Comparison with Standards:

- **4G/LTE Standards:** Typical UL throughput for 4G networks ranges from 5 Mbps to 50 Mbps under optimal conditions.
- **5G Standards:** Typical UL throughput for 5G networks ranges from 50 Mbps to 100 Mbps or higher. Evaluation: The observed UL throughput (1 to 6 Mbps) is below typical standards for both 4G and 5G, indicating suboptimal performance.
- **Summary:** The UL average throughput is highly variable, with significant peaks and lows, showing no clear trend. The observed UL throughput is below the typical standards for both 4G and 5G networks.

IV.5.8 Cell DL Average Throughput (Mbps):

According to the figure 4.9 we will analyse of the Graph: Cell DL Average Throughput (Mbps), Observation Period: From May 29, 2023, to June 5, 2023.

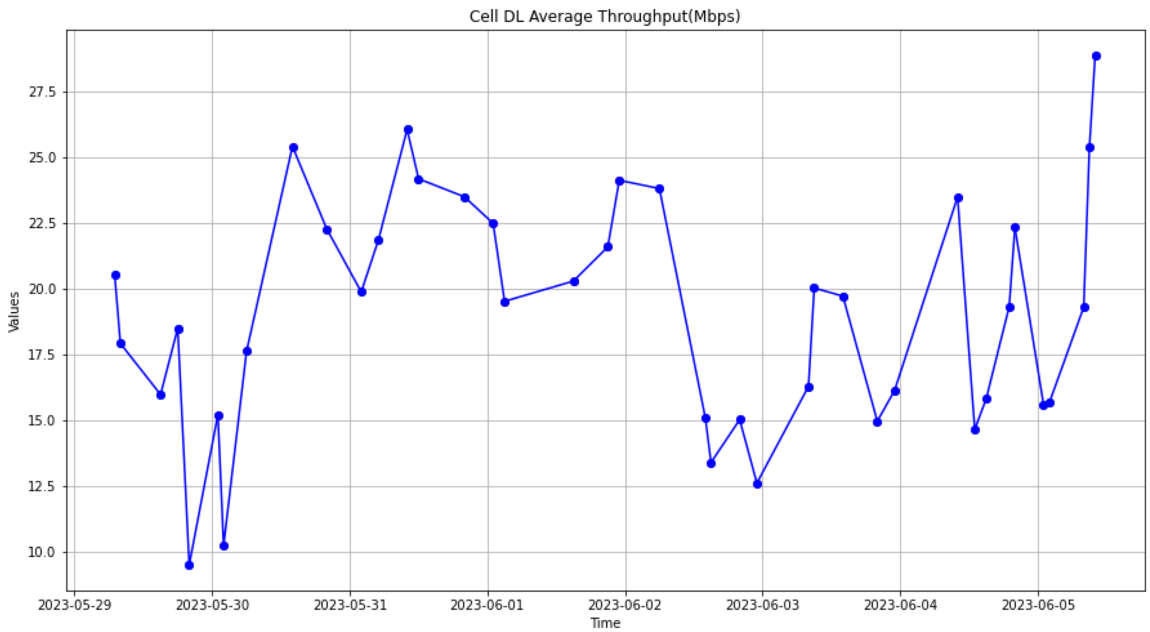


Figure IV.10: KPI Cell DL Average Throughput (Mbps) in the cell 283004.

- **Trends: Fluctuations:** The downlink (DL) average throughput also shows significant variability.
- **Peaks:** The highest throughput reaches around 27.5 Mbps on June 5, 2023.
- **Lows:** The lowest throughput is around 10 Mbps on May 30, 2023.
- **Increase:** There is a noticeable increase towards the end of the observation period, particularly on June 5, 2023.
- **Pattern:** Unlike UL, DL throughput shows a slight upward trend towards the end of the period.

Comparison with Standards:

- **4G/LTE Standards:** Typical DL throughput for 4G networks ranges from 10 Mbps to 100 Mbps under optimal conditions.
- **5G Standards:** Typical DL throughput for 5G networks ranges from 50 Mbps to 1 Gbps or higher. Evaluation: The observed DL throughput (10 to 27.5 Mbps) falls within the lower range of typical 4G standards but is below 5G standards.
- **Summary:** The DL average throughput is highly variable, with a slight upward trend towards the end of the observation period. The observed DL throughput

is within the lower range of 4G standards but below 5G standards. The pattern of fluctuations suggests there may be certain factors or conditions that are impacting the cell's data throughput performance over time, such as network congestion, user demand, or infrastructure changes.

Compared to the previous graph showing the uplink throughput, the uplink throughput exhibits more pronounced spikes and valleys, indicating the uplink may be more sensitive to changes in the network.

IV.5.9 Uplink Traffic Volume (Gbyte):

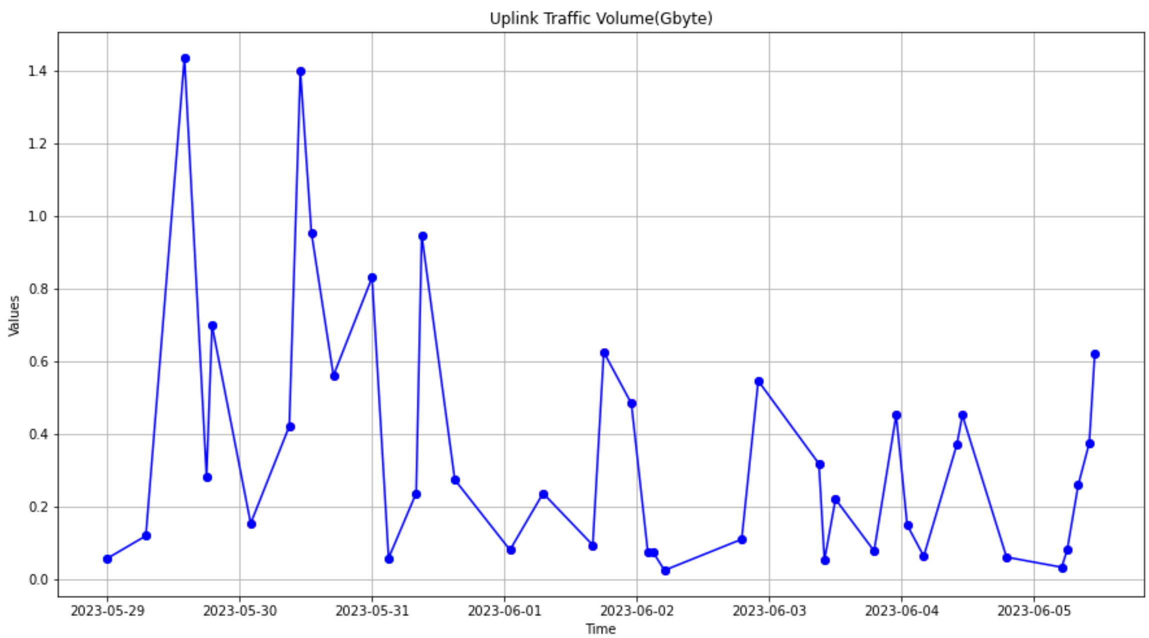


Figure IV.11: KPI Uplink Traffic Volume (Gbyte).

- **Trends: Fluctuations:** The uplink traffic volume fluctuates significantly.
- **Peaks:** The highest traffic volume peaks around 1.4 Gbytes on May 30 and May 31, 2023.
- **Lows:** The traffic volume drops to almost 0 Gbytes multiple times throughout the period.
- **Decrease:** A general decrease in traffic volume can be observed after May 31, with sporadic increases.

- **Pattern:** The volume of uplink traffic decreases after initial peaks, with some intermittent spikes.

- **Summary:** The uplink traffic volume shows a decrease after initial peaks, with significant fluctuations throughout the period. While the traffic volume itself is not directly compared to standards, the patterns suggest variability in network usage or performance.

IV.5.10 Downlink Traffic Volume (Gbyte):

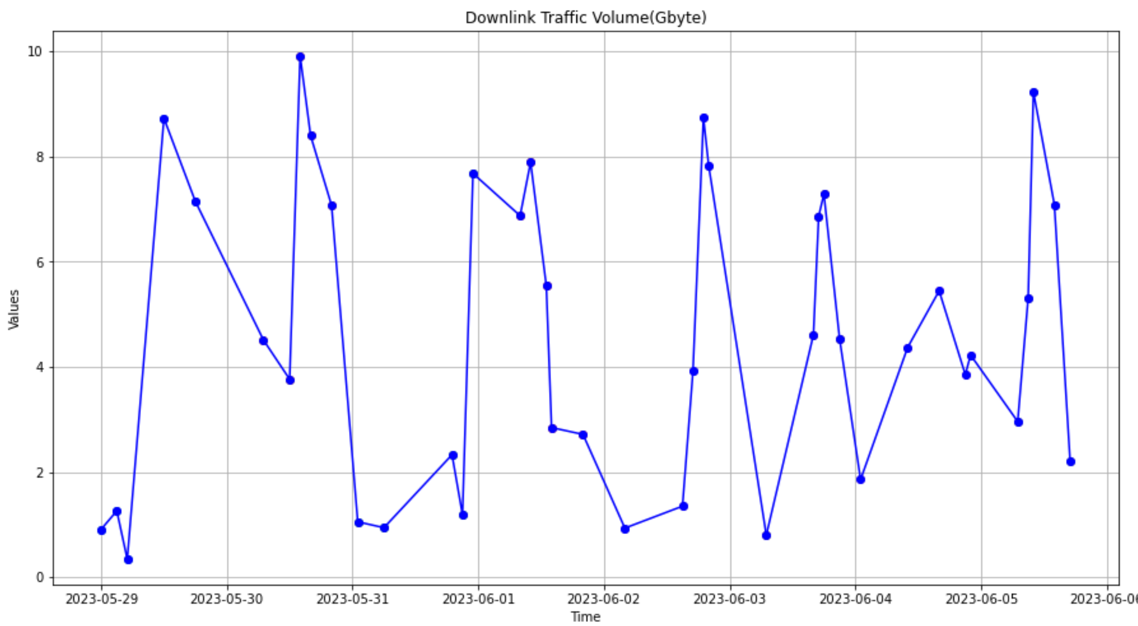


Figure IV.12: KPI Downlink Traffic Volume (Gbyte).

- **Peaks:** The highest traffic volume peaks around 10 Gbytes on May 30, 2023.

- **Lows:** The traffic volume drops to almost 0 and 1 Gbytes multiple times throughout the period.

- **Summary:** The volume of downlink movement shows significant fluctuations throughout the period. Although the traffic volume itself is not directly compared to benchmarks, patterns indicate variation in network usage or performance.

IV.5.11 Traffic User Average:

The figure IV.13 represents the chart of Traffic User Average in the cell 283004:

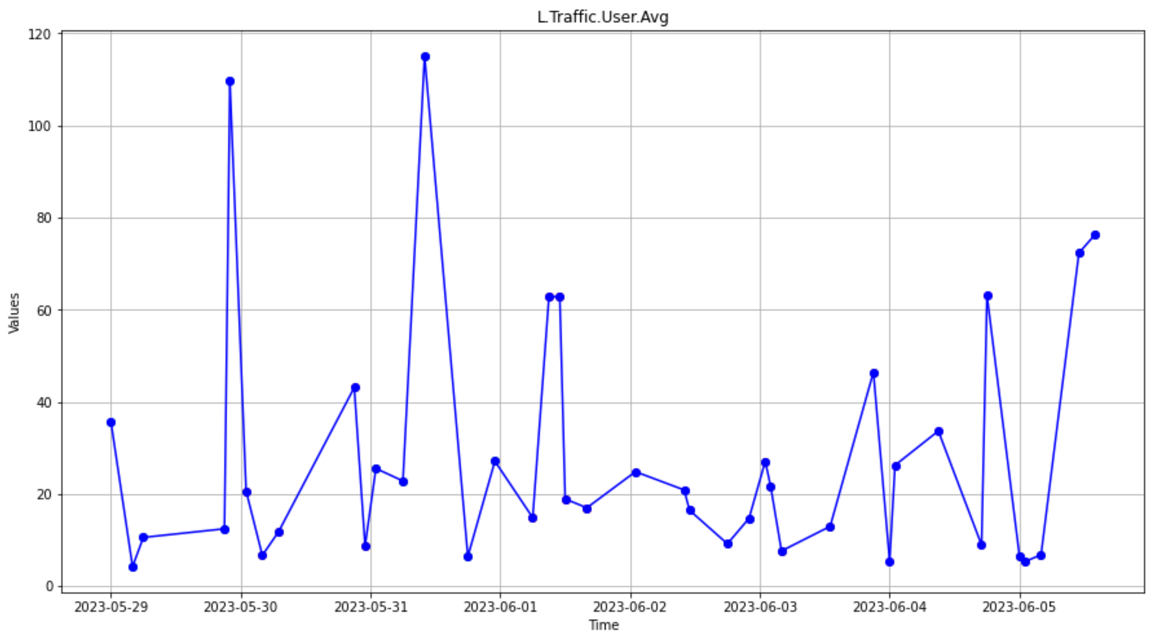


Figure IV.13: KPI Downlink Traffic Volume (Gbyte).

- The traffic user average exhibits significant fluctuations, with sharp spikes and valleys throughout the time period.
- The highest peak in traffic user average occurs around 115 on 2023-06-01.
- There are a few other notable peaks, such as around 80-90 on 2023-05-31 and 2023-06-05.
- The traffic user average generally ranges between 20-60, with some dips below 20.
- The pattern of these fluctuations suggests that the network is experiencing variable levels of user traffic and activity over time. This could be influenced by factors like time of day, user demand, network conditions, etc.
- The sharp spikes and valleys indicate the network is experiencing significant changes in user traffic, which could impact overall network performance and user experience.
- Without additional context about the network, location, or other relevant information, it's difficult to pinpoint the exact reasons for these traffic variations. However, the graph provides a clear visual representation of the dynamic nature of the LTE traffic user average over the given time period.

IV.5.12 Traffic User Max:

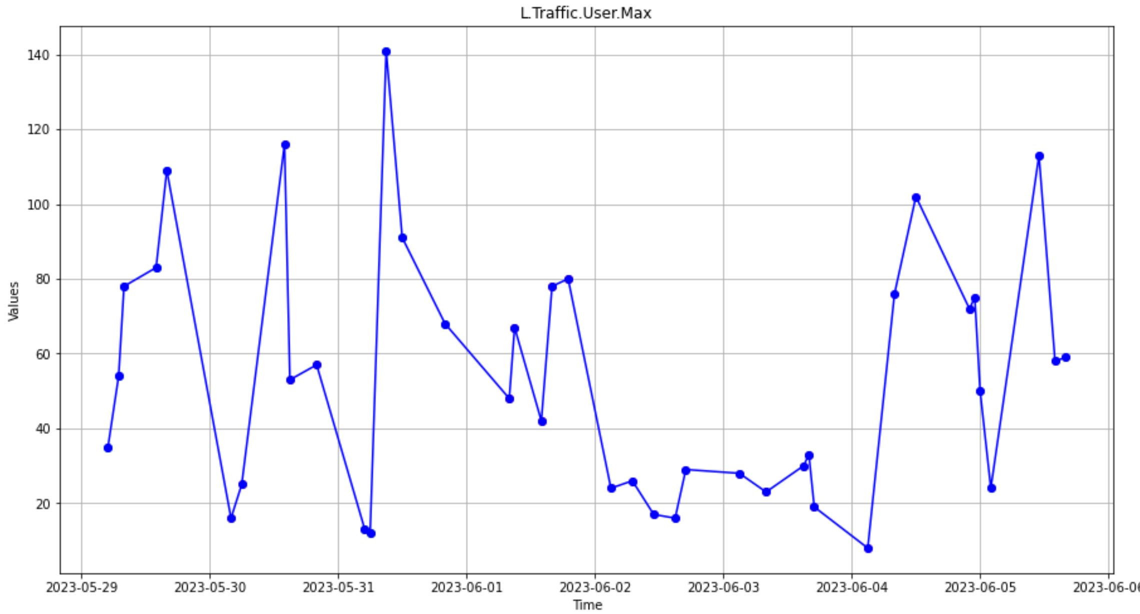


Figure IV.14: KPI Traffic Use Max in the cell 283004.

- The graph exhibits significant fluctuations, with sharp spikes and valleys in the user traffic max values throughout the time period.
- The highest peak in user traffic max occurs around 136 on 2023-06-01.
- There are a few other notable peaks, such as around 100-120 on 2023-05-31 and 2023-06-05.
- The user traffic max generally ranges between 20-80, with some dips below 20.
- The pattern of these fluctuations suggests that the network is experiencing variable levels of maximum user traffic, which could be influenced by factors like time of day, sudden increases in user demand, network conditions, or other external factors.
- The sharp spikes and valleys indicate the network is handling significant changes in maximum user traffic, which could impact overall network performance, resource utilization, and user experience.

IV.5.13 UL Interference Average (dbm):

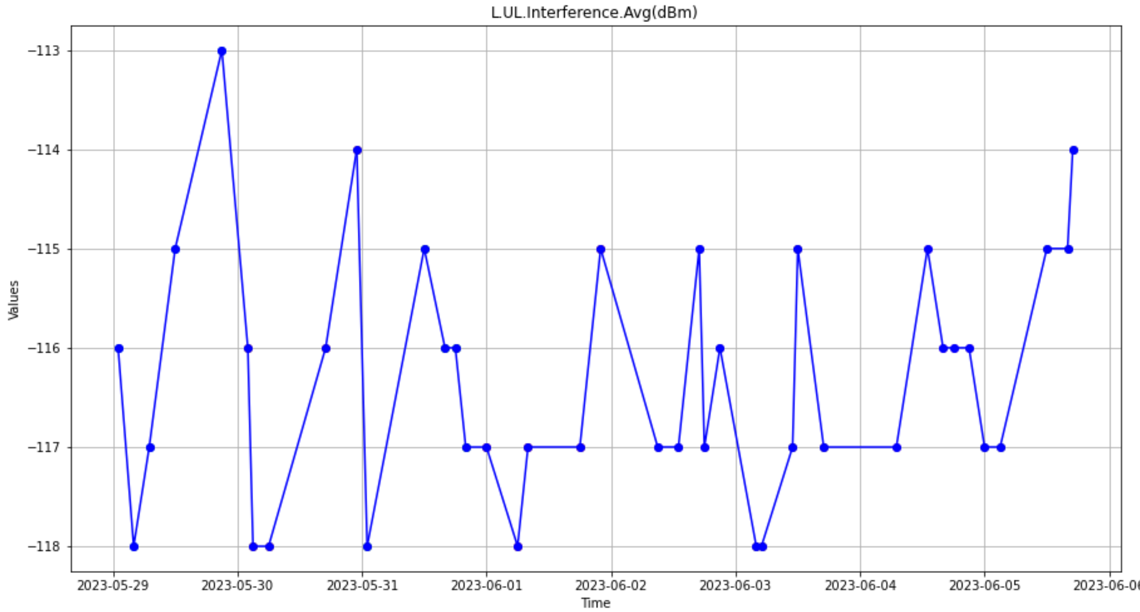


Figure IV.15: KPI UL Interference Avg (dbm) in the cell 283004.

- The graph exhibits significant fluctuations in the interference average values, ranging from approximately -113 dBm to -115 dBm.
- There are multiple sharp spikes and valleys throughout the time period, indicating the interference levels are constantly changing.
- The highest interference average peak occurs around -113 dBm on 2023-06-05.
- There are a few other notable peaks, such as around -113.5 dBm on 2023-06-01 and 2023-06-06.
- The interference average generally hovers around -114 dBm to -115 dBm, with occasional deviations above and below this range.

IV.5.14 LTE Incoming HHO success rate:

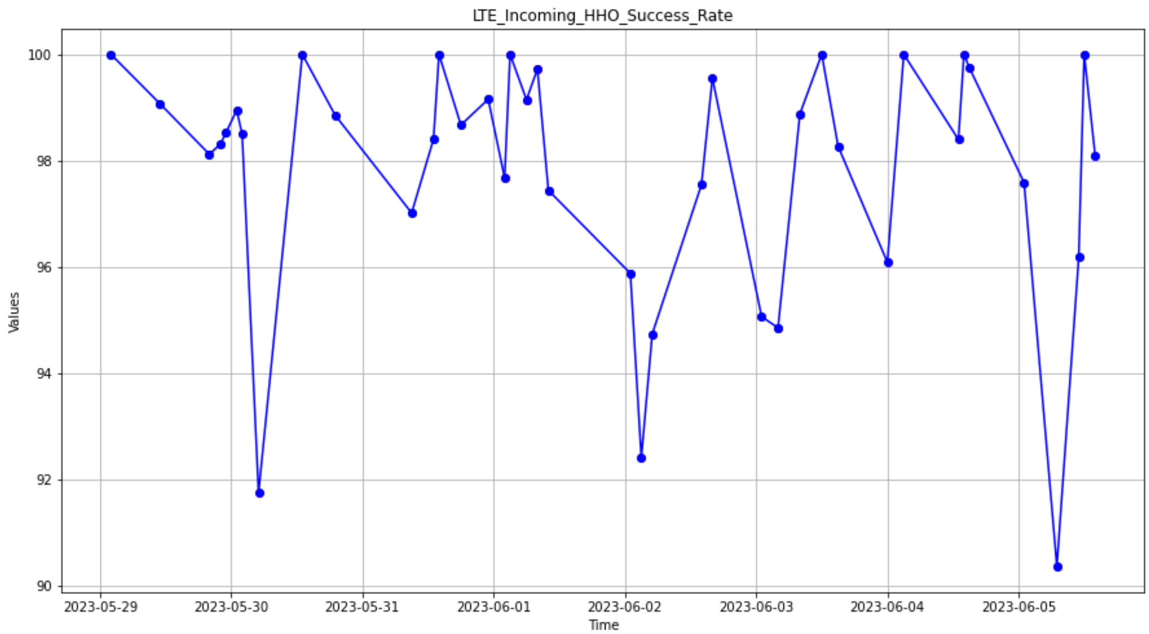


Figure IV.16: KPI LTE Incoming HHO success rate in the cell 283004.

Based on the graph showing the LTE Incoming_HHO_Success_Rate over time, here is an analysis of the key observations:

- The graph exhibits significant fluctuations in the success rate, with values ranging from around 90% to 100%.
- There are multiple sharp spikes and valleys throughout the time period, indicating the success rate is constantly changing.
- The highest peak in success rate occurs around 99.5% on 2023-06-02.
- There are a few other notable peaks, such as around 99% on 2023-06-01 and 2023-06-05.
- The success rate generally hovers around 95-97%, with occasional deviations above and below this range.
- The pattern of these fluctuations suggests the network is experiencing variable levels of handover success.

IV.6 Conclusion

In this chapter we analysed a few KPIs of 283004 cells of the Mobilis in M'sila, we were able to recognize the causes of the irregularities, and at long last accumulate a few arrangements to cure them. From the comes about of our examination, we will say that the Mobilis network is within the measures and reacts well and well to the necessities of their subscribers. The examination of KPIs is never-ending within the optimization benefit to keep the organize in great working arrange to offer a great quality of benefit to endorsers.

Conclusion

This thesis is the result of planning and optimizing the mobile network in the wilaya of M'sila.

The main objective of this project is to plan and optimize the mobile network. This study allowed us to learn about the work of a radio engineer within the team and take advantage of the software tools available.

In the first two chapters we made a general theoretical study on planning and improvement.

In collaboration with the operator MOBILIS, a series of tests and practical measurements of various data and parameters (RxLev, RxQual, SQI, etc.) were carried out with the aim of finding solutions to problems that lead to weak networks and then we did

In the last two classes, in the third trimester we did the driving test

In the fourth chapter improve network performance by analyzing the collected KPIs

Finally, it can be said that the planning and optimization phases are important for operators to avoid additional optimization costs that may arise during network operation.

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